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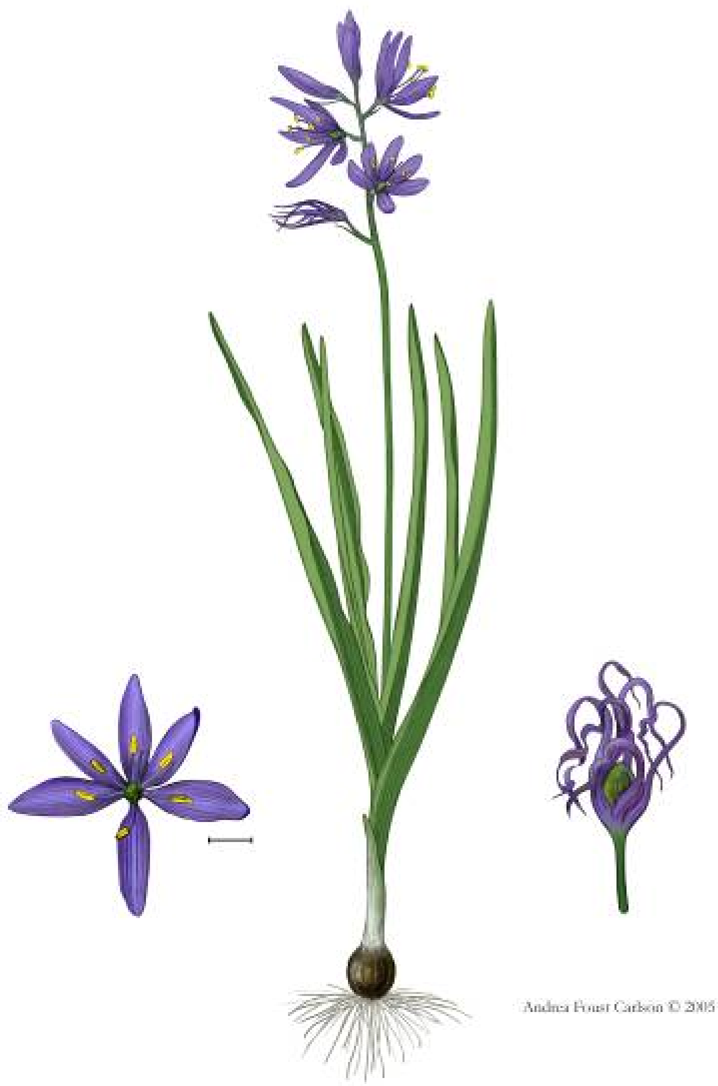
Camas Monitoring at Nez Perce National Historical Park and Big Hole National Battlefield

2010 Annual Report

Natural Resource Technical Report NPS/UCBN/NRTR—2011/430



ON THE COVER
Illustration of *Camassia quamash* (Pursh) Greene.
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Camas Monitoring at Nez Perce National Historical Park and Big Hole National Battlefield

2010 Annual Report

Natural Resource Technical Report NPS/UCBN/NRTR—2011/430

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

This report is also available from the Upper Columbia Basin Network (http://www.nature.nps.gov/im/units/UCBN) and the Natural Resource Publication Management website (http://www.nature.nps.gov/publications/NRPM) on the internet.

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Abstract

As part of the Upper Columbia Basin Network's effort to conduct vital signs monitoring, we completed monitoring of camas (*Camassia quamash*) in Big Hole National Battlefield (BIHO) and Nez Perce National Historical Park (NEPE). Camas is a unique resource for these parks because it is both culturally and ecologically significant. Camas was and remains one of the most widely utilized indigenous foods in the Pacific Northwest and it is strongly associated with the wet prairie ecosystems of the region that have been degraded or lost due to historic land use practices. A long-term citizen science-based monitoring program for detecting status and trends in camas populations at BIHO and Weippe Prairie, a unit of NEPE, serves as a central information source for park adaptive management decision making and will provide essential feedback on any eventual restoration efforts of park wet prairie habitats. The involvement of student citizen scientists in this particular program has been effective both in terms of leveraging resources as well as in engaging communities in park stewardship and science education.

This annual report details the status and trend estimates obtained from the first six years of monitoring, 2005-2010, at Weippe Prairie and BIHO. Overall trends in camas density appear to be stable or slightly increasing, particularly in Weippe Prairie zone C, providing some evidence that the *de facto* passive restoration implemented at Weippe Prairie with the cessation of grazing and mowing following NPS acquisition of the property in 2003 is having a positive effect. Camas populations across the two park units range widely in abundance, with densities of two of the five Weippe Prairie management zones, A and C, estimated at 71 and 45 plants/m^2, respectively. BIHO and Weippe Prairie management zone B exhibited the lowest densities, at 5-6 plants/m^2. Historical densities available from anthropological sources were estimated to be 100 plants/m^2 or more in high-quality sites. The ratio of flowering to total established camas plants has been consistently higher at BIHO than at Weippe Prairie during the study period, although this pattern did not hold in 2010, and flowering ratios at BIHO were lower than all Weippe Prairie zones. Flowering ratio appeared to be most stable over time in zones A, C, and D at Weippe Prairie. Overall invasion by sulfur cinquefoil (*Potentilla recta*) and orange hawkweed (*Hieracium aurantiacum*), as measured by frequency of occurrence in quadrats, has declined on average 21% and 17% per year, respectively. No discernible correlations between annual precipitation and density have emerged as of yet, although this will require several more years to evaluate adequately.

Introduction

Camas (*Camassia quamash* [Pursh] Greene) is a perennial bulb-producing lily (Family Liliaceae; alternatively Agavaceae, APG 2003) that was and remains one of the most widely utilized plant foods of the Nez Perce people (Harbinger 1964; Hunn 1981; Turner and Kuhnlein 1983; Thoms 1989; Mastrogiuseppe 2000). Camas was also a focal resource at many of the significant historical events memorialized by Big Hole National Battlefield (BIHO) and Nez Perce National Historical Park (NEPE). It was during the camas harvest at Weippe Prairie, a subunit of NEPE, where the Lewis and Clark Corps of Discovery first encountered the Nez Perce. The battle at Big Hole occurred at a traditional Nez Perce camas harvesting campsite. It is also noteworthy that the botanical "type" specimen for the *Camassia* genus as well as for *C. quamash* itself was collected by the Lewis and Clark expedition returning through the Weippe Prairie during the spring of 1806 (Meehan 1898; Gould 1942).

Camas is considered a facultative wetland species (Reed 1988) that is strongly associated with the seasonal wet prairie ecosystems of the interior Columbia Plateau which are represented at the Weippe Prairie, a subunit of NEPE, and along the North Fork of the Big Hole River, where the Big Hole Battlefield is located. Large expanses of camas in bloom were noted by numerous explorers and botanists that entered the Pacific Northwest in the 19th century, including the Lewis and Clark expedition, and which were frequently described as "blue lakes" when viewed from a distance (Havard 1895; Leiberg 1897; Murphey 1987; Thoms 1989). The extent of the wet prairie ecosystem type has been drastically reduced throughout the Pacific Northwest as a result of agricultural conversion, irrigation and flood control development, and other land use practices (Thoms 1989; Dahl 1990; Taft and Haig 2003). Remaining wet prairies in the region are often structurally altered and compromised by non-native and woody native invasive species. The NPS-owned portions of Weippe Prairie and the Big Hole valley are no exception. Both sites have historic agricultural developments that have altered site hydrology, are impacted by invasive weeds, and Weippe Prairie has also been used for intensive haying and grazing. Orange hawkweed (*Hieracium aurantiacum*) and sulfur cinquefoil (*Potentilla recta*), invasive plants in Idaho, are present at Weippe Prairie and part of the focus of current park weed management. Competition from invasive weed species, including the aforementioned forbs as well as thatch-building grasses such as timothy (*Phleum pratense*), may impact camas populations within the UCBN through competition. Reduced fire frequency has allowed black hawthorn (*Cretaegus douglasii*) to become established in the prairie, and this may eventually cause an undesirable shift in prairie plant vegetation, including a reduction in camas. Park managers at NEPE discontinued grazing in 2008. Herbicide applications at Weippe Prairie, and to a lesser extent at BIHO, continue as part of the parks' integrated weed management programs. The impacts of these activities on camas populations are not well understood at this time but are potential stressors as well.

Despite the continued impacts of modern anthropogenic stressors on what appear to be markedly reduced camas populations, the wet prairies of BIHO and NEPE, like their better studied analogues in Oregon's Willamette Valley, are highly productive ecosystems that exhibit a good potential for restoration (Pendergrass et al. 1998, Taft and Haig 2003). A long-term monitoring program for detecting status and trends in camas populations at BIHO and Weippe Prairie serves as a central information source for park adaptive management decision making and will provide essential feedback on any eventual restoration efforts. Camas monitoring is particularly important at Weippe Prairie because it is the focal resource for the site, and because invasive plant treatment is an ongoing management concern there. The site is also a likely target for park restoration efforts in the future. The National Park Service acquired the Weippe Prairie property in 2003 and does not yet have a developed management plan. The implementation of camas monitoring early in the process of NPS management at Weippe Prairie is timely and is greatly facilitating science-based decision making. Park management has considerable latitude in the strategies and tools employed there. At BIHO, where management is less intense and opportunities for restoration are few, given the cultural sensitivity of the battlefield, camas monitoring still provides a valuable indication of overall status and trend of the camas population and its supporting wetland over time.

It is hoped that the UCBN camas monitoring program will deliver timely and helpful information to park managers. Both park sites are managed to preserve the historic landscapes of which camas is a central component. Camas is a facultative wetland species that should respond conspicuously to perturbations in the wet prairie ecosystems of Weippe Prairie and BIHO, thus making it an effective indicator of overall ecological condition. Restoration of the Weippe Prairie to increase camas populations is emerging as a real interest to park management and therefore makes this monitoring effort a critically important source of information for the park. Camas monitoring results can help in the development of restoration targets and in the evaluation of any eventual site manipulations. The design of the sampling frame at Weippe Prairie included the creation of 5 management zones, setting in motion quasi-experimental opportunities for the future, where management treatments might be applied to some zones, leaving other zones as controls. We have adopted the recommendations made by Bennetts et al. (2007) and begun the identification of early-warning assessment points. Our first assessment point is a 25% decline in mean camas density. A concomitant 25% increase is also an assessment point, but one better described as an initial desired future condition benchmark rather than an early-warning sign (Bennetts et al. 2007). These were arrived at as starting points in the face of considerable uncertainty concerning camas synecology, were logistically and statistically feasible, and inherently conservative. We will look to add new assessment points as our knowledge about camas and the wet prairie ecosystem grows. Annual reports such as this are important elements in this process.

The National Park Service initiated a camas monitoring program at NEPE and BIHO in 2005, assisted in large part by student “citizen scientists” who participate in annual spring field data collection. The field effort involves counting all established camas plants within quadrats, as well as those plants that flower during that growing season. Thatch depth and the presence of target invasive weeds have also been measured in each quadrat, although thatch depth measurements were discontinued in 2010 following recommendations made by Rodhouse and Jocius (2009). Weather is an additional important driver of camas population dynamics, and summaries from weather stations near each of the parks will be used in modeling long-term trends. The monitoring protocol developed by Rodhouse et al. (2007) was reviewed and approved for implementation by the Pacific West Regional I&M Program Coordinator in October 2007.

We report here on the 2010 sampling results from both Weippe Prairie and BIHO, and include data from 2005-2009 to provide context for current estimates of camas density. Changes were made in design and methodology of the sampling protocol during the first three years. We have made some adjustments to the data from these early years, enabling preliminary comparisons among years and identification of baseline patterns of density. Some interesting patterns are emerging in these data, which will serve to stimulate new hypotheses and assessment points. With the protocol complete and the design and methodology stabilized, we have begun to accumulate a robust long-term data set. Given the predictions of climate change in the Pacific Northwest and a considerable land use legacy, monitoring UCBN camas prairies over time is sure to shed new light on the important issues of ecosystem recovery, resistance, and resilience.

Objectives

The monitoring objectives for this program are:

- Estimate mean established plant and flowering stem densities (status) in the camas populations of Weippe Prairie and within the targeted portion of BIHO.
- Determine trends (net trend, as reviewed by MacDonald 2003) in the densities of established camas populations in Weippe Prairie and BIHO.
- Determine trends in the proportion of flowering to non-flowering camas plants in Weippe Prairie and BIHO.
- Determine trends in the frequency of occurrence of targeted invasive plants (currently these are orange hawkweed and sulfur cinquefoil).
- Determine the magnitude and direction of camas density response to measurable explanatory variables such as winter precipitation and specific management activities.

Note: "Established camas plants" are those plants expressing 2 or more leaves and excludes single-leaved seedlings. The significance of this distinction is discussed in greater detail in the UCBN camas monitoring protocol (Rodhouse et al. 2007).

This report summarizes status and trend estimates for camas populations over the period 2005-2010. We consider the trends reported here to be encouraging but preliminary estimates that should be interpreted cautiously. A more in depth trend analysis report will be presented in 2011, five years after completion of the final sampling protocol.

Methods

The UCBN initiated camas monitoring in 2005 at the Weippe Prairie, a NEPE unit, located in Weippe, Idaho. Monitoring was initiated at BIHO, located near Wisdom, Montana, in 2006. Figures 1 and 2 show the sampling frames and 2010 sampling points for each park unit.

Sampling methods followed those detailed by Rodhouse et al. (2007). Students from local high schools conducted the majority of field sampling, under field leadership and supervision from NPS staff. The approach is quadrat-based and involves the measurement of camas plant density, camas flowering stem density, graminoid thatch depth, and the presence of targeted invasive plant species. A systematic sample of one-hundred-seventy-seven 0.5 m^2 quadrats was measured at Weippe Prairie in 2005 and was considered a pilot effort. Management zone D in Weippe Prairie was not sampled in 2005. Weippe Prairie was completely surveyed in 2006 using a simple random sampling design with long, narrow 0.6 m^2 quadrats, and this design was used in all subsequent years at both park units. At BIHO, historical and cultural concerns led to the development of a targeted sampling frame with arbitrary boundaries that encompassed the largest and most abundant portion of the camas population in that park. Sample sizes at Weippe Prairie were 177, 220, 283, 360, 350, and 350 for the years 2005-2010, respectively. At BIHO, sample sizes were 81, 124, 150, 150, and 160 for the years 2006-2010. Sample sizes were increased following power analysis (Rodhouse et al. 2007) and as field capacity increased through the support of park staff and citizen scientist volunteers. All camas plants were included in camas density counts in 2005 and 2006, but a protocol change beginning in 2007 led to the exclusion of single-leaved seedlings. Camas seedlings are ephemeral and highly variable in their germination, and this led us to focus the protocol on *established* camas plants beginning in 2007. This is the most significant methodological change and one that requires careful and cautious consideration of comparisons among the first 2 years.

Camas flowering stem density was measured at each quadrat beginning in 2006. Mature camas plants can produce one conspicuous and persistent inflorescence each year, making flowering stem counts reliable and direct. Not all mature plants flower in a given year, however, and variability in flowering is of interest to the UCBN. Graminoid thatch depth was measured at each quadrat beginning in 2006 as well. Thatch depth was measured in three pre-established locations along the quadrat long axis and averaged. This practice was discontinued in 2010 due to lack of evidence of any relationship between thatch depth and density (Rodhouse and Jocius 2009). The presence or absence of two target weed species, sulfur cinquefoil and orange hawkweed, was noted in each quadrat for use in measures of frequency of occurrence at Weippe Prairie. There currently are no weed species being recorded in quadrats at BIHO, as no high priority weed species have been encountered in the sampling frame there.

Early monitoring results indicated that density counts were extremely skewed and required alternative analytical procedures that did not require assumptions of normality. We used a non-parametric bootstrap computer-intensive method to conduct power analyses with 2006, 2007 and 2008 data following methods outlined by Hamilton and Collings (1991). Ninety percent confidence intervals around means were calculated using the simple bootstrap percentile method described by Efron and Tibshirani (1993) and Manly (2001). Data from 0.5 m^2 quadrats in 2005 were scaled by 1.2 in order to make them comparable with 0.6 m^2 quadrats in subsequent years.

We scaled all years by 1.66 in order to report estimates per m^2. We fit models of linear trend using ordinary least squares regression and non-parametric permutation methods to test the significance of and to estimate 90% confidence intervals around the regression slope coefficient β_1, following methods outlined by Manly (2001). Data were log transformed for this procedure, requiring interpretation of back-transformed estimates to be made in terms of a percent change in the median rather than the mean. Homogeneity of variances, an important assumption for ordinary least squares regression, was evaluated for each sampling frame (management zone) using the Fligner-Killeen test and the Bartlett test. According to these tests, log transformation was effective in establishing variance homogeneity in all frames except Weippe Prairie zone E.

We summarized all six years of data graphically using a control or "conformance" chart approach following recommendations by Beauregard et al. (1992) and Morrison (2008). Because of our initial interest in "assessment points" $\pm$ 25% of a baseline mean value, the charts displayed here are a-statistical in the sense that control or "action" limits are not based on an underlying probability distribution but arbitrarily established at assessment point values. We used the mean of 2007 and 2008 mean values as a preliminary baseline, but note that baseline decisions will be updated as additional years of data become available. We conducted a fixed-effect meta-analysis of all 5 management zones for Weippe Prairie to provide an overall estimate of trend across the park unit for NEPE's annual resource stewardship summary reporting. This procedure provides a weighted average of reported effects (trend estimates, in this case) using the reciprocal of the variance for weights. No meta-analysis was required for BIHO reporting, as there is only one sampling frame.

We used ordinary kriging (Fortin and Dale 2009) to produce interpolated density maps for both Weippe Prairie and BIHO using 2005-2010 data. These maps provide useful interpretive tools to illustrate density patterns across the parks. More involved interpolation using regression kriging will be generated for the 2011 trend report, using a newly acquired digital elevation model for the site.

Finally, we evaluated the presence of trend in sulphur cinquefoil and orange hawkweed occurrence (frequency) using logistic regression models. These weeds have been targeted for eradication by park management using herbicides, and this analysis provides a measure of the effectiveness of that effort. All analyses and preparation for graphics were conducted in R software and computing environment (R version 2.7.2, http://www.r-project.org/) and ArcGIS (ESRI, Inc., Redlands, California).

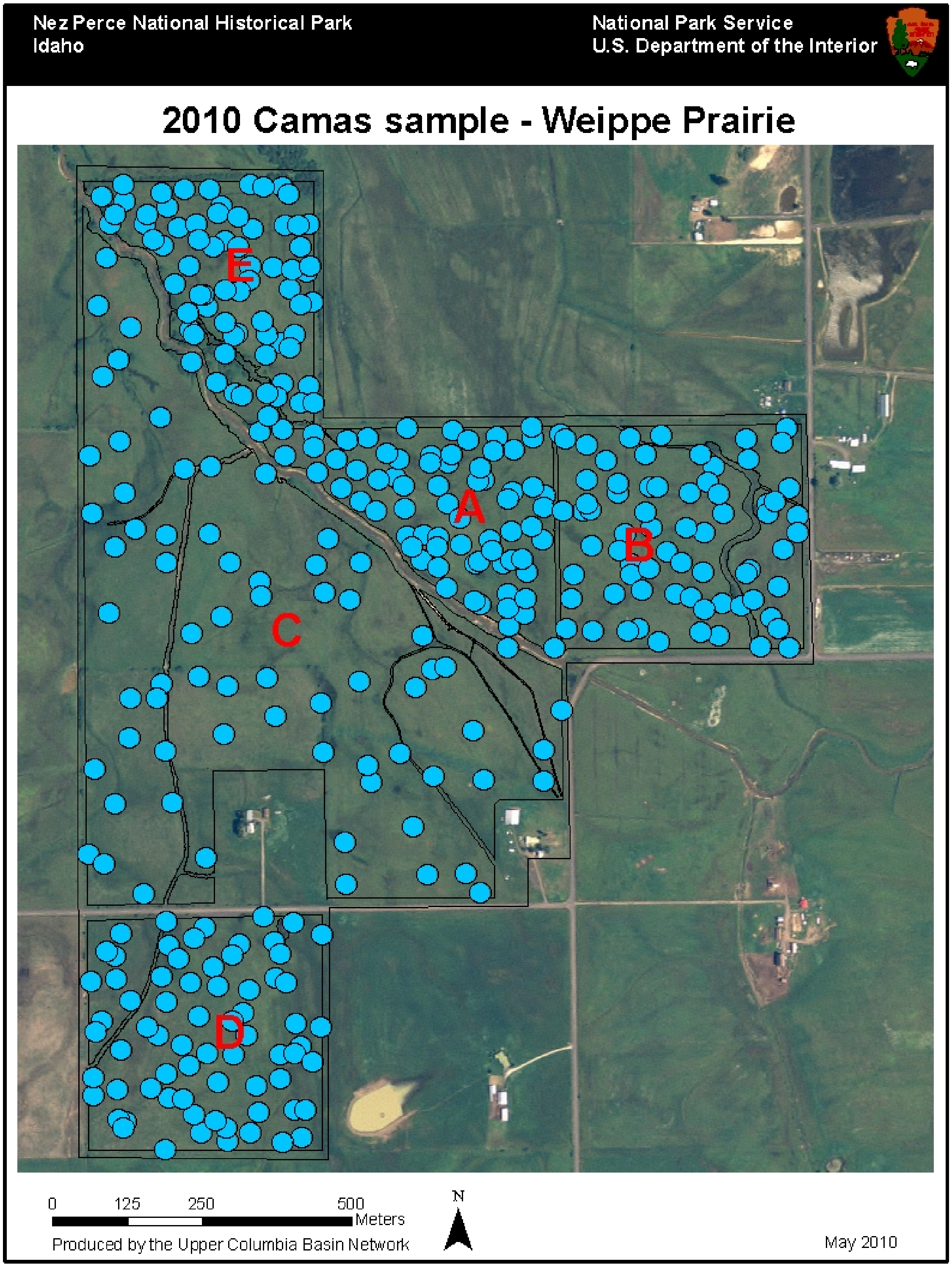


Figure 1. The camas monitoring sampling frame at Weippe Prairie, Nez Perce National Historical Park, including all 5 management zones (red letters A-E) and 2010 sampling locations (blue points). Details of sampling frame development are available in the UCBN camas monitoring protocol (Rodhouse et al. 2007).

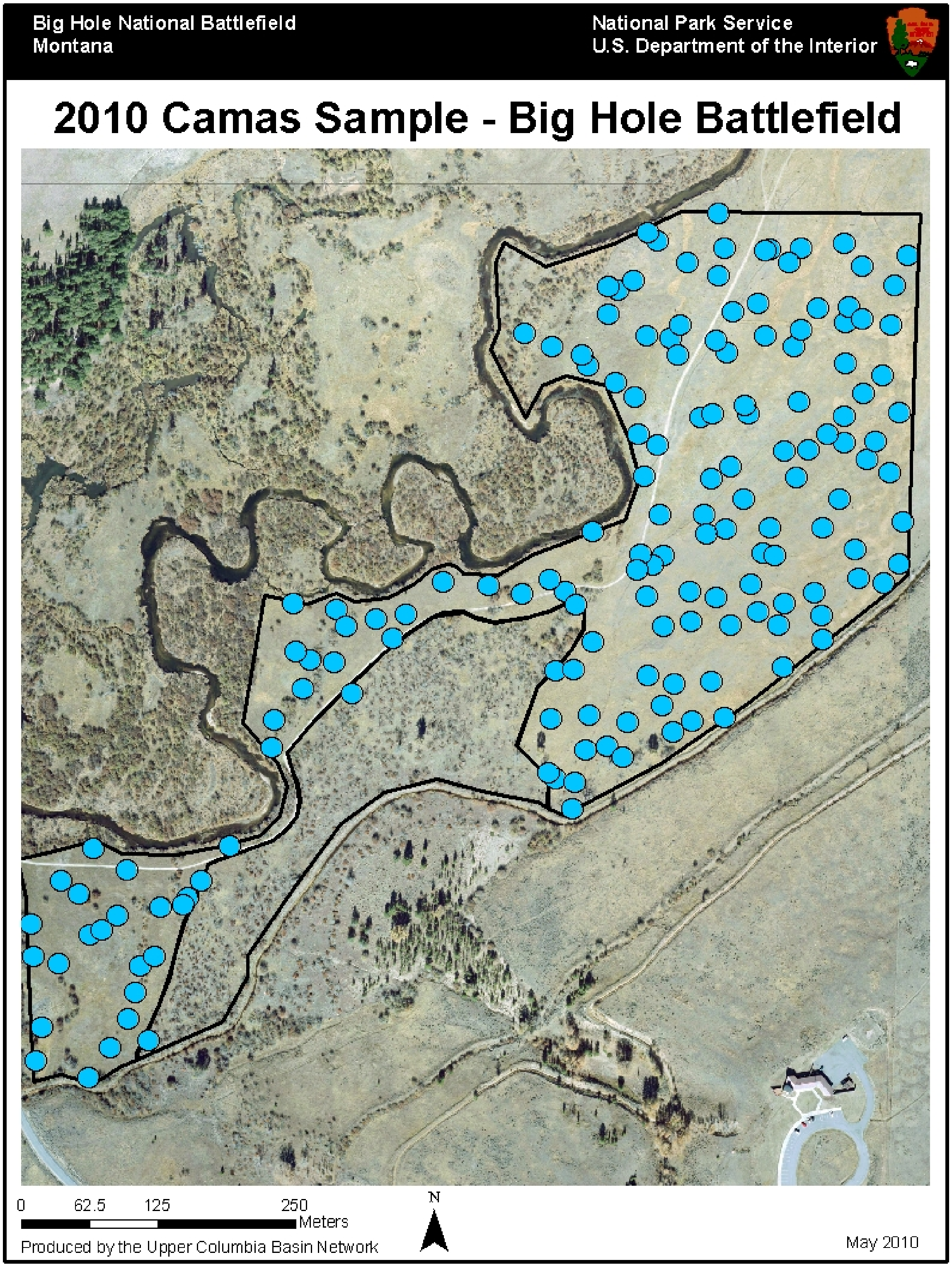


Figure 2. The camas monitoring sampling frame (black polygon) and 2010 sampling locations (blue points) at Big Hole National Battlefield. Details of the sampling frame and how boundaries were determined are available in the UCBN camas monitoring protocol (Rodhouse et al. 2007).

Results

Point estimates of means, confidence intervals, and flowering ratios for Weippe Prairie and BIHO are presented in tables 1 and 2. Management zones A and D at Weippe Prairie have been consistently the largest populations among the 6 sampling frames (including BIHO), although zone C was considerably higher in 2010, exceeding the estimate for zone D. Zone E has been the smallest population, but these results may have been biased low because of early livestock turnout into that area in 2007 before sampling had been completed. In 2010, zone E density was estimated higher than density in zone B. Figure 3 presents control charts for each sampling frame. All populations fall within or above the conformance range during 2010 except zone D, which dipped below the conformance range for the second year in a row. Zone E, which has been above the conformance range since the low of 2007, has exhibited extreme fluctuations over the 5 year period and the baseline range for this population is not well characterized by the existing data. A new baseline from 2008-2009 might be more appropriate for future analyses. Flowering ratios were similar across all zones except for BIHO, which was higher than Weippe Prairie ratios over 2007-2009, but which dipped below observed ratios in Weippe Prairie in 2010. Note that all zones in Weippe Prairie have exhibited increasing flowering ratios since last year.

Table 3 presents preliminary trend estimates for each of the 6 populations. All zones showed a weak positive trend, but only zones C and E were statistically significant at the α=0.10 level (Note this 90% α level was established by Rodhouse et al. 2007). Figure 4 presents the meta-analysis results for Weippe Prairie. The summary effect estimate for Weippe Prairie was 1.08 (i.e., an 8% annual rate of change in median density over all zones; 90% confidence interval 1.04-1.13). Note that the slope value 1.0 represents no trend for these back-transformed estimates, and confidence intervals include 1.0 (no trend or "0") for all zones except C and E that have a significant positive trend.

Figures 5 and 6 illustrate interpolated camas density maps for both Weippe Prairie and BIHO, showing the patchy distribution of camas density patterns in both parks. Tables 4 and 5 present the estimates of current condition for the three camas vital sign measures for each management unit. These current condition estimates are the point estimates, rounded to the nearest integer, and are packaged for inclusion in park resource stewardship strategy reporting and vital signs summary tables.

Finally, figure 7 illustrates the location of 2010 plots in Weippe Prairie where the invasive weeds sulfur cinquefoil and orange hawkweed were encountered. Logistic regression models provided evidence of sustained downward trend in the occurrence of both species, although only the trend in sulphur cinquefoil was statistically significant at the α=0.5 level. Based on observed data, the estimated decline in cinquefoil was approximately 21% per year (90% CI = 35% - 3% decline), and the estimated decline in hawkweed was approximately 19% per year (90% CI = 35% decline – 5% increase, covering 0% no trend).

Table 1. Means, 90% confidence intervals, and flowering ratios for Weippe Prairie camas populations, 2005-2010. Data are presented separately for each management zone. Confidence intervals were computed with the percentile bootstrap method outlined by Manly (2001).

			Plants/m2	90% percentile CI		Stems/m2	90% Percentile CI		Flowering
Zone	Year	n	Density	lower	upper	Flowers	lower	upper	Ratio
A	2010	70	71.40	57.96	86.01	13.87	11.24	16.58	0.19
B	2010	70	5.74	2.94	9.06	1.64	0.81	2.68	0.29
C	2010	70	45.74	34.81	57.27	8.94	6.19	12.17	0.20
D	2010	70	30.07	21.03	39.86	5.53	3.98	7.23	0.18
E	2010	70	6.40	4.39	8.58	1.57	0.95	2.25	0.24
A	2009	70	75.71	61.27	90.5	12.9	10.23	15.84	0.17
B	2009	70	16.38	11.5	21.7	3.12	2.27	4.05	0.19
C	2009	70	27.66	19.14	38.13	5.59	3.92	7.32	0.2
D	2009	70	44.22	30.78	59	5.66	3.92	7.59	0.13
E	2009	70	5.03	3.17	7.09	0.5	0.32	0.68	0.1
A	2008	60	57.65	46.48	69.31	9.32	7.25	11.56	0.16
B	2008	80	7.14	4.13	10.54	1.22	0.64	1.97	0.17
C	2008	80	35.46	27.47	43.74	9.52	7.1	12.14	0.27
D	2008	60	56.94	37.02	79.18	9.43	6.45	12.81	0.17
E	2008	80	5.94	4.09	8.01	0.17	0.06	0.29	0.03
A	2007	65	61.65	48.96	74.93	7.81	6	9.76	0.13
B	2007	88	6.76	4.26	9.6	0.82	0.38	1.15	0.12
C	2007	60	29.63	20.28	39.92	6.03	3.9	8.52	0.2
D	2007	40	64.16	40.63	89.31	8.3	5.4	11.54	0.13
E	2007	30	0.44	0.11	0.83	0.17	0.06	0.33	0.37
A	2006	43	61.73	49.22	74.58	2.55	1.66	3.51	0.04
B	2006	17	2.64	0.39	5.27	0.68	0	1.46	0.26
C	2006	115	17.44	13.16	22.06	1.88	1.41	2.38	0.11
D	2006	30	33.31	17.76	51.68	3.65	2.05	5.42	0.11
E	2006	15	2.77	1.22	4.76	0.11	0	0.33	0.04
A	2005	25	48.67	32.93	65.87	NA	NA	NA	NA
B	2005	40	4.48	1.66	6.39	NA	NA	NA	NA
C	2005	87	20.78	14.18	28.07	NA	NA	NA	NA
D	2005	0	NA	NA	NA	NA	NA	NA	NA
E	2005	25	5.51	2.32	9.3	NA	NA	NA	NA

Table 2. Means, 90% confidence intervals, and flowering ratios for the BIHO camas population, 2006-2010. Confidence intervals were computed with the percentile bootstrap method outlined by Manly (2001).

		Plants/m^2	90% percentile		Stems/m^2	90% Percentile		Flowering
Year	n	Density	lower	upper	Flowers	lower	upper	Ratio
2010	160	5.40	3.82	7.14	0.56	0.38	0.76	0.1
2009	150	5.78	4.18	7.52	1.58	1.06	2.16	0.27
2008	150	5.71	3.97	7.67	2.69	1.83	3.69	0.47
2007	124	3.86	2.53	5.52	1.90	1.25	2.68	0.49
2006	81	4.22	2.19	6.58	0.68	0.37	1.02	0.16

Table 3. Trend results for the period 2005-2010 using a randomization approach to linear regression to assess the null hypothesis of no trend (β_1=0) over time in log-transformed camas density counts. Coefficients (for β_1) are back-transformed and should be interpreted as a multiplicative (percent) change in the median density of camas. For example, based on the observed data, zone C has increased at an annual rate of 13% in the median number of established camas plants over 2005-2010. 90% confidence intervals, also back transformed, were computed using a randomization approach described by Manly (2001). These results are preliminary and should be interpreted with caution. Count data from 2005 and 2006 included seedlings as well as established plants. Variances for zone E were not homogeneous. Spatial effects of microtopography and dispersal-induced autocorrelation have not been accounted for. A more thorough trend analysis is forthcoming in 2011.

Zone	β_1(Year)	90%lower	90%upper	Direction	P
A	1.06	0.96	1.17	up	0.31
B	1.06	0.96	1.15	up	0.32
C	1.13	1.03	1.23	up	0.02
D	1.00	0.88	1.14	u	0.99
E	1.11	1.02	1.22	up	0.04
BIHO	1.05	1.00	1.10	up	0.06

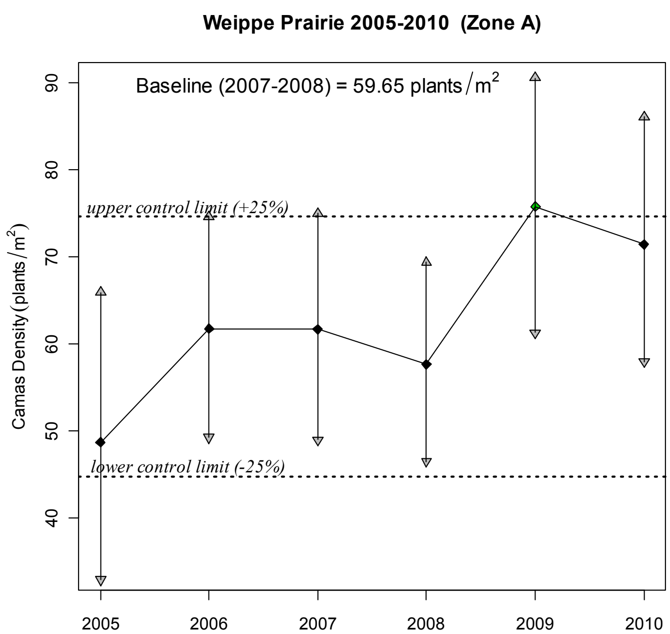
Table 4. Vital sign summary information for the camas lily vital sign, Big Hole National Battlefield, 2010. Current condition values are estimates from 2010 samples.

UCBN Vital Sign	Measure	Management Zone	Current Condition
Camas Lily			
	Established stem density (established plants/m^2)	BIHO	5.5
	Flowering stem density (flowering stems/m^2)	BIHO	0.5
	Flowering ratio (flowering stems:established plants)	BIHO	0.1

Table 5. Vital sign summary information for the camas lily vital sign, Nez Perce National Historical Park, 2010. Current condition values are estimates from 2010 samples.

UCBN Vital Sign	Measure	Management Zone	Current Condition
Camas Lily			
	Established stem density (established plants/m^2)	Weippe Prairie A	71
		Weippe Prairie B	6
		Weippe Prairie C	46
		Weippe Prairie D	30
		Weippe Prairie E	6
	Flowering stem density (flowering stems/m^2)	Weippe Prairie A	14
		Weippe Prairie B	2
		Weippe Prairie C	9
		Weippe Prairie D	6
		Weippe Prairie E	2
	Flowering ratio (flowering stems: established plants)	Weippe Prairie A	0.19
		Weippe Prairie B	0.29
		Weippe Prairie C	0.20
		Weippe Prairie D	0.18
		Weippe Prairie E	0.24
	Orange hawkweed invasion (% frequency)	Weippe Prairie A	0
		Weippe Prairie B	4
		Weippe Prairie C	6
		Weippe Prairie D	3
		Weippe Prairie E	4
	Sulphur cinquefoil invasion (% frequency)	Weippe Prairie A	4
		Weippe Prairie B	9
		Weippe Prairie C	1
		Weippe Prairie D	0
		Weippe Prairie E	1

A.



B.

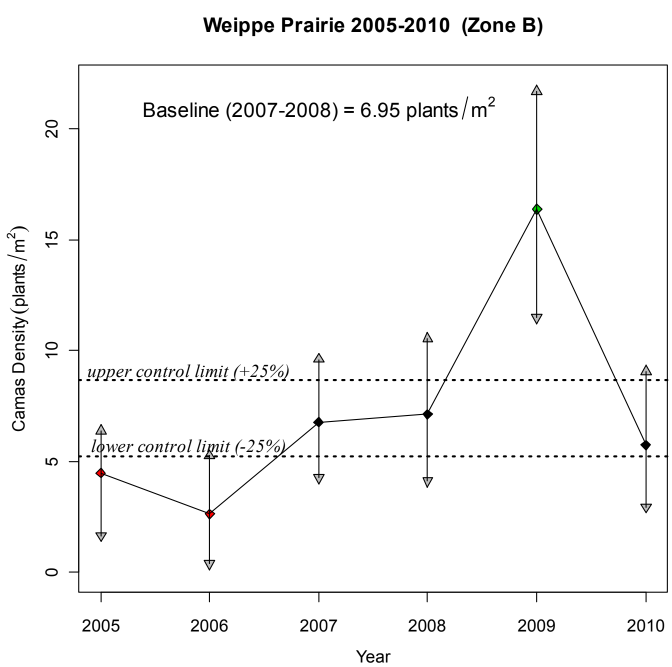
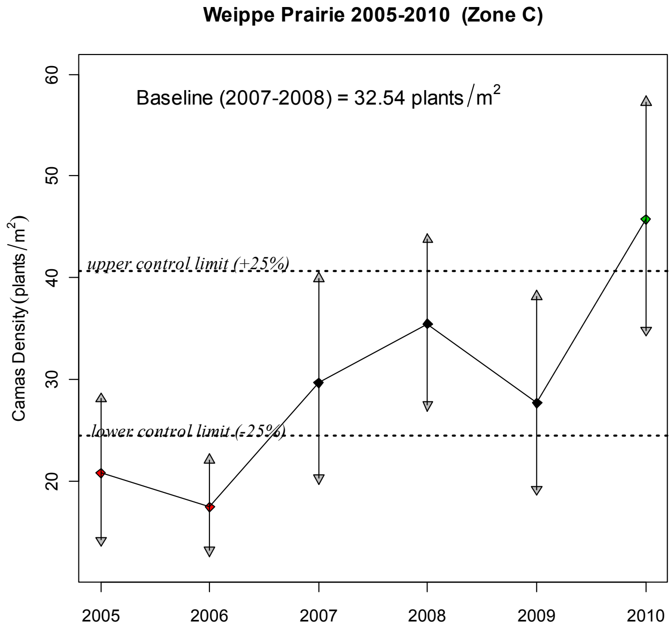


Figure 3. Control or "conformance" charts for each UCBN camas monitoring sampling frame for samples obtained during 2005-2010. We used $\bar{x} \pm 25\%$ from baseline mean values computed with 2007 and 2008 data to establish upper and lower control limits or "conformance bounds" (horizontal lines). Means are center points with 90% confidence intervals as vertical arrows. Charts A-E illustrates respective Weippe Prairie management zones A-E. Chart F illustrates BIHO data.

C.



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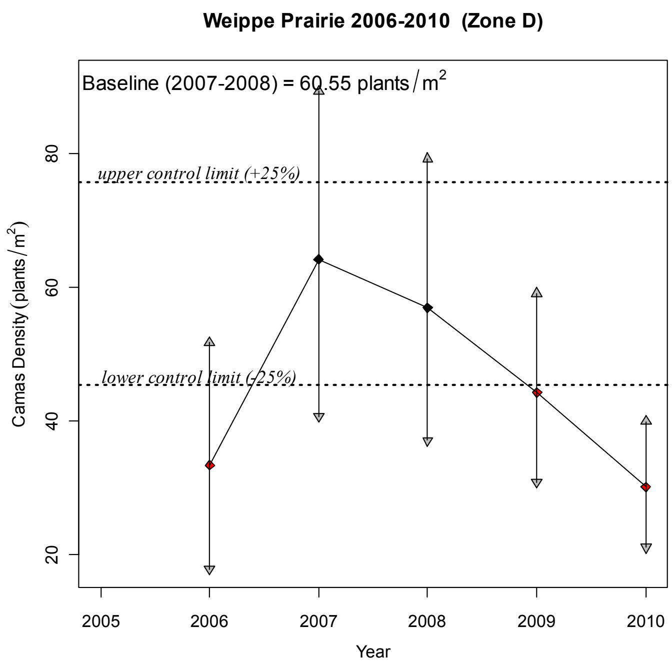
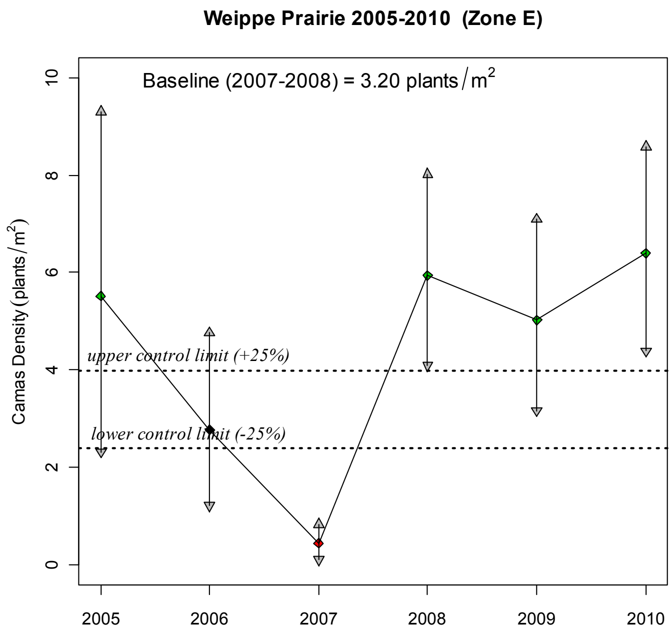


Figure 3. Control or "conformance" charts for each UCBN camas monitoring sampling frame for samples obtained during 2005-2010. We used $\bar{x}$ $\underline{+}$ 25% from baseline mean values computed with 2007 and 2008 data to establish upper and lower control limits or "conformance bounds" (horizontal lines). Means are center points with 90% confidence intervals as vertical arrows. Charts A-E illustrates respective Weippe Prairie management zones A-E. Chart F illustrates BIHO data (continued).

E.



F.

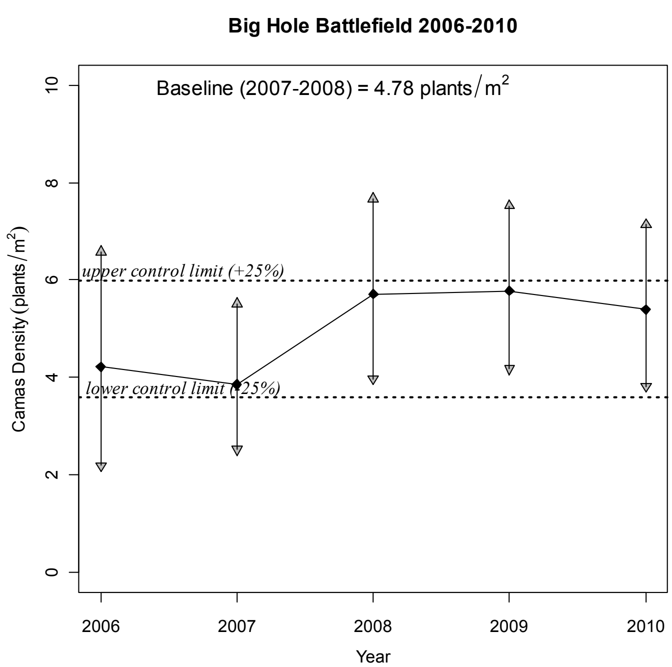


Figure 3. Control or "conformance" charts for each UCBN camas monitoring sampling frame for samples obtained during 2005-2010. We used $\bar{x}$ $\underline{+}$ 25% from baseline mean values computed with 2007 and 2008 data to establish upper and lower control limits or "conformance bounds" (horizontal lines). Means are center points with 90% confidence intervals as vertical arrows. Charts A-E illustrates respective Weippe Prairie management zones A-E. Chart F illustrates BIHO data (continued).

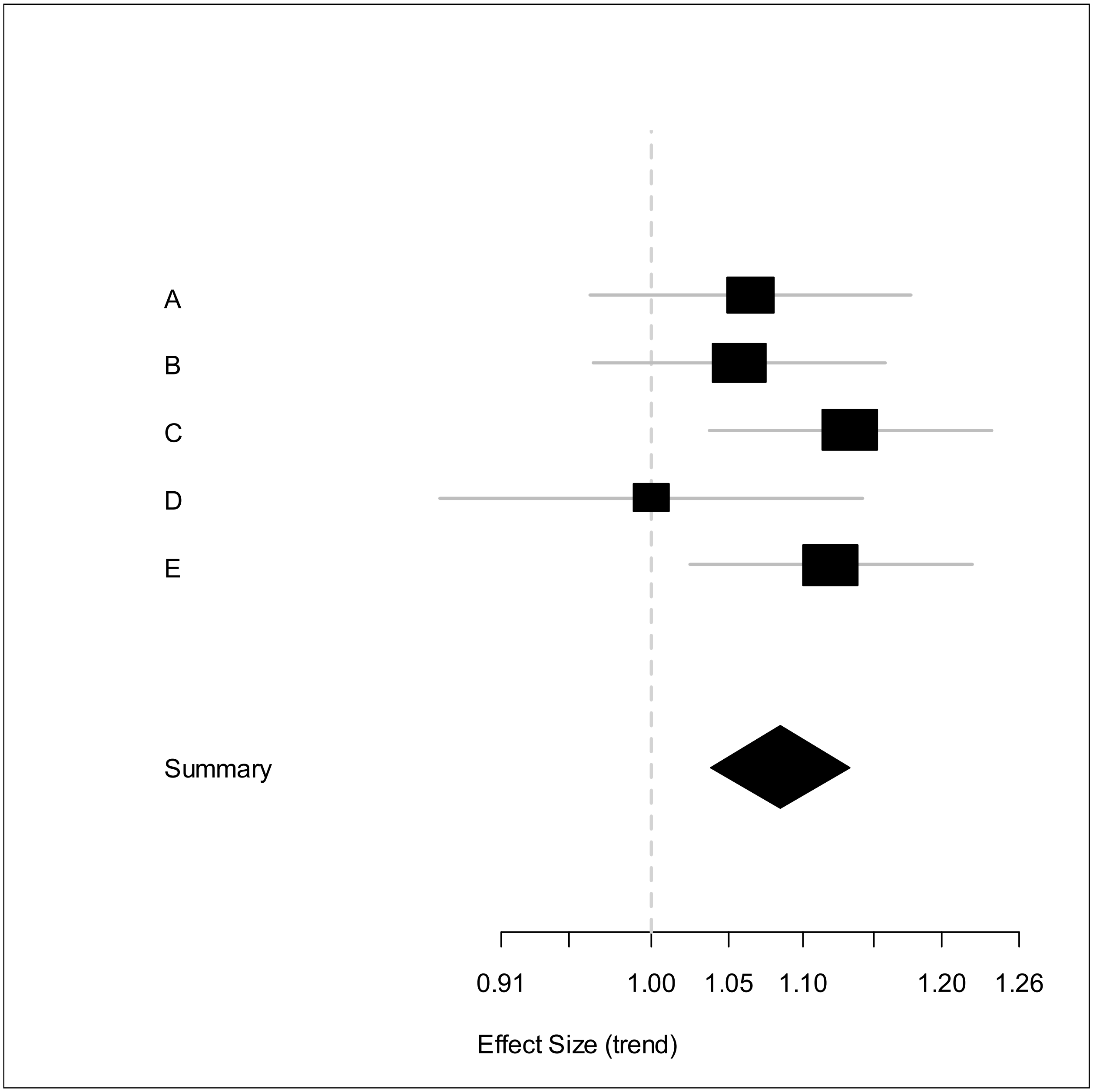


Figure 4. Meta-analysis plot for the estimates of trend in camas established plant density from each of the five Weippe Prairie management zones. The effect sizes (trend estimates) are back-transformed and represented in solid boxes scaled by the reciprocal of their variance. 90% confidence intervals are shown as horizontal lines. The estimated summary effect (1.08) is represented by the solid diamond. Note that zones C and E have significant positive trend. We note however that considerable spatial heterogeneity exists within and among zones and forthcoming 2011 trend analyses that account for this will provide more reliable trend estimates.

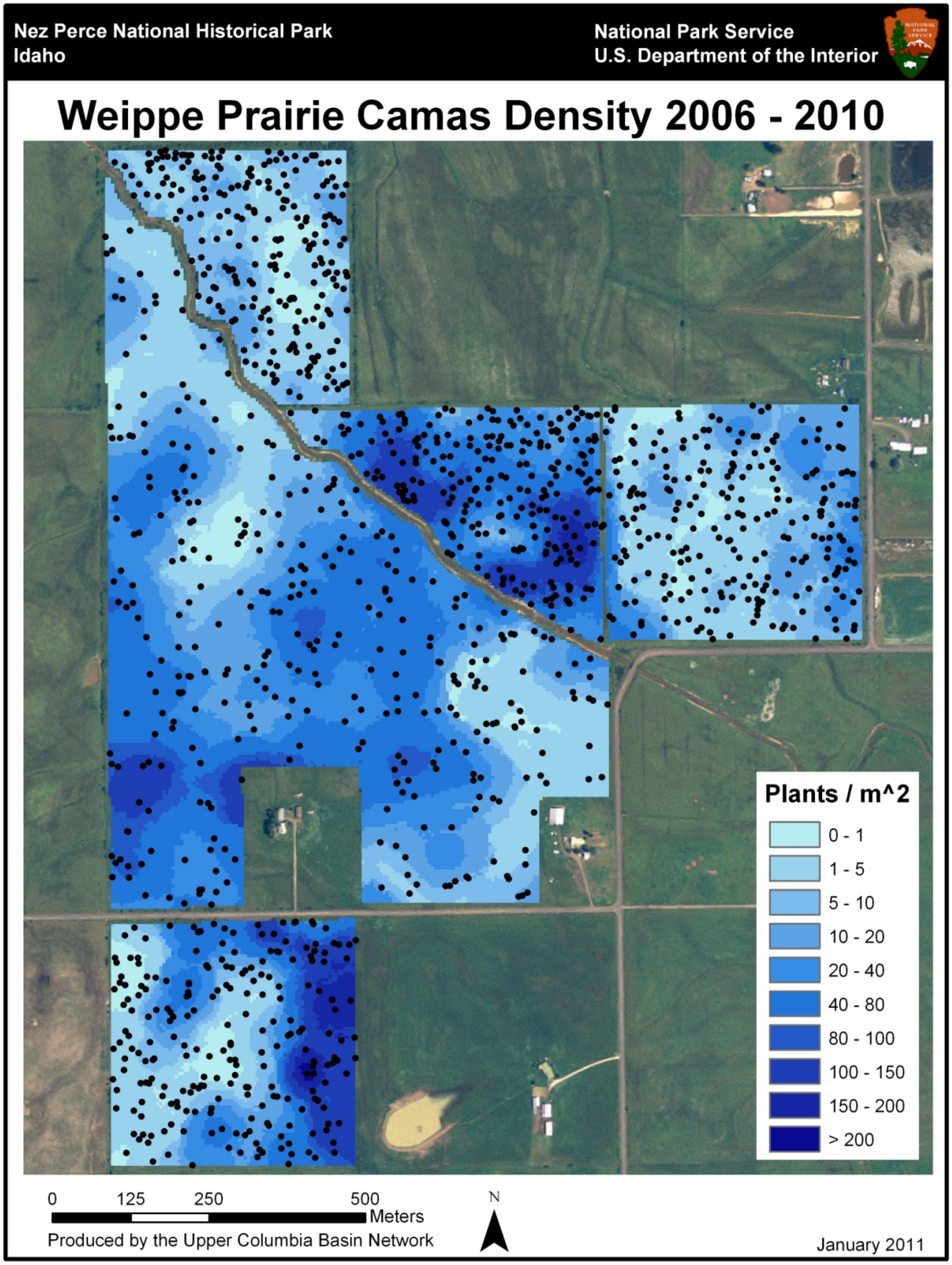


Figure 5. Interpolated camas density patterns at Weippe Prairie, 2006-2010. Interpolation was accomplished in ArcGIS using ordinary kriging.

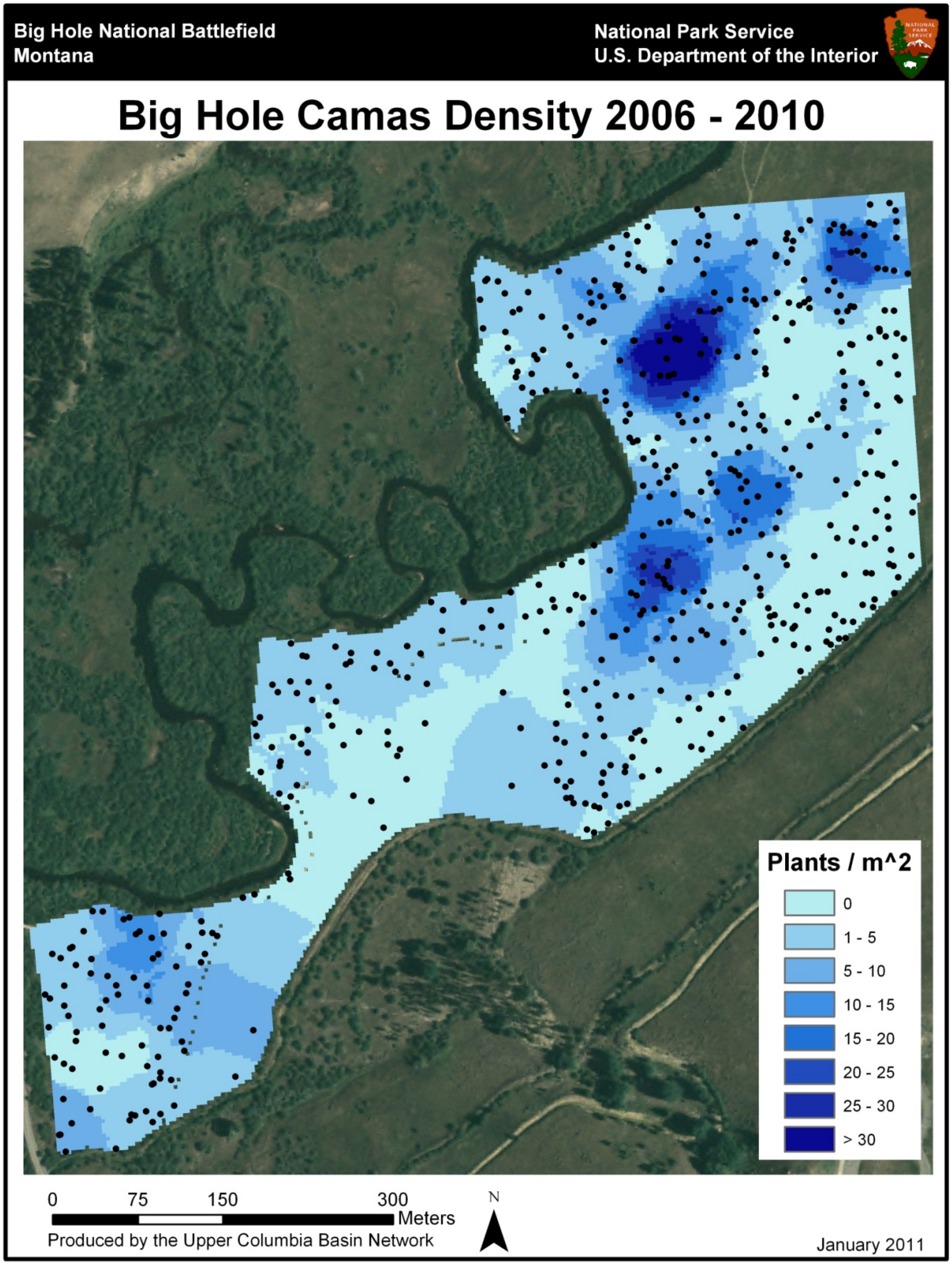


Figure 6. Interpolated camas density patterns at Big Hole National Battlefield, 2006-2010. Interpolation was accomplished in ArcGIS using ordinary kriging.

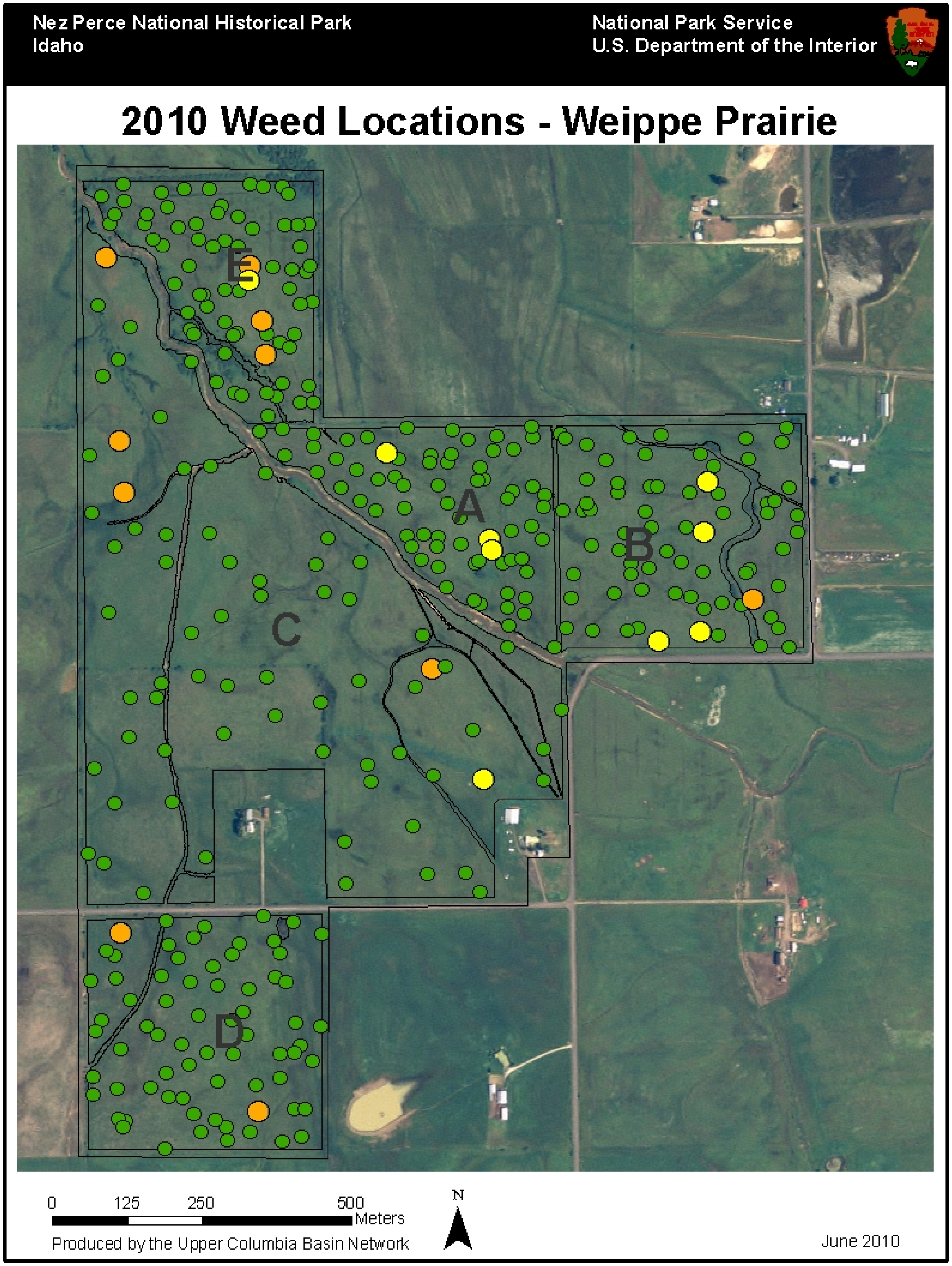


Figure 7. 2010 locations of plots containing orange hawkweed (*Hieracium aurantiacum*; orange dots) and sulphur cinquefoil (*Potentilla recta*; yellow dots) at Weippe Prairie.

Discussion

The UCBN camas monitoring program has begun to characterize both the baseline central tendency of camas abundance as well as the variability in that abundance across six NPS management zones in two parks, NEPE and BIHO. Each of these zones appear to have unique populations (in terms of both baseline levels of camas density as well as in the variation in trends over time), and they are being treated independently for analytical and reporting purposes. These zones represent a broad range in overall density and in flowering ratios. Zones A, D, and C at Weippe Prairie have the largest populations, although these are still well below historic estimates available from the ethnobotanical and archaeological literature (Thoms 1989). Zones B and E have the smallest populations, and zone E was most heavily impacted by permitted grazing during the start-up years of monitoring. Sampling error resulting from a simple inability to see plant leaves clipped down by livestock during sampling may have explained the dramatic drop in the 2007 density estimate in zone E. However, there appears to be an overall positive trend among the five Weippe Prairie management zones (Figure 4), which may be the result of "passive" restoration related to cessation of intensive land use practices. BIHO appears to be exhibiting a stable trend in camas density.

We did not include information on precipitation patterns during the period of study this year because there was no clear evidence of a relationship with camas density or flowering reported by Rodhouse and Garrett (2008). However, there is considerable variability in both precipitation and density, and any relationship will require additional years of sampling before becoming apparent. Also, temperature may be important, and may interact with precipitation and site hydrology in complex ways to influence available soil moisture during critical periods such as spring germination. A study of soil moisture patterns has been initiated at Weippe Prairie by University of Idaho collaborators and may shed light on this important question. Preliminary results indicate that soil chemical properties at Weippe Prairie do not differ appreciably among zones, and are not likely factors in variation in camas density (McDaniel 2008).

Finally, frequencies of the two target weeds at Weippe Prairie are showing evidence of decline. This is significant because Weippe Prairie was only acquired by NPS in 2003 and the potential for dramatic weed invasion accompanying land use changes associated with ownership was of concern to park managers, and efforts to control or possibly eradicate both species from the site has been an important goal for management.

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