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Natural Resource Stewardship and Science

Forest Structure and Fuel Loads at Wind Cave National Park

2017 Status Report

Natural Resource Report NPS/NGPN/NRR—2019/1950

ON THE COVER
Long-term forest monitoring plot PCM_0008 in Wind Cave National Park, 2017.
Image courtesy the NPS.

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Natural Resource Report NPS/NGPN/NRR—2019/1950

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Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols. This report also received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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Executive Summary

The Northern Great Plains Inventory & Monitoring Network and the Northern Great Plains Fire Ecology Program surveyed 90 forested plots in Wind Cave National Park (WICA) in 2017. The survey effort began in 2012, and is repeated every 5 years thereafter to better understand status and trends in forest vegetation. The 2017 survey was the second year of forest data collection. Tree stem density, tree diameter, live and dead tree condition, fire fuel loads, cover of exotic species, and disturbance were measured in all plots. Ten plots were within the boundary of Casey Addition that was acquired by the park in 2011 and the remaining 80 were in the main portion of the park. In this report, we provide a summary of our results from sampling in 2017.

The density of ponderosa pine forests and woodlands that cover WICA are similar to densities in pre-settlement era, although there are some high density stands. There are slight differences in forest structure between the Casey Addition and the main portion of the park. For instance, the ponderosa pine seedlings are found in higher densities in the main portion of the park. Exotic species were generally more common in the main portion of the park, although Japanese brome was widespread in both areas. We found very little change in forest structure between 2012 and 2017, but in 2017 we found higher frequencies of exotic target species such as Japanese brome and Canada thistle. The Legion Lake wildfire occurred after this survey, and we expect to see larger changes in forest densities and seedling recruitment the future.

Acknowledgments

We thank all the authors of the NGPN Plant Community Monitoring Protocol, particularly A. Symstad, for outstanding guidance on data collection and reporting. Thank you to the staff at WICA for providing logistical support and safety checks, particularly G. Schroeder and T. Richardson. We also thank the WICA and EPMT biological technicians that assisted with fieldwork. We thank T. Phillipi for assisting with statistical analyses and data checks. We also thank B. Burkhart and M. Hendrix for providing comments on a draft of this manuscript. The NGPN and NGP Fire Ecology field crews collected all of the data included in this report.

Introduction

Wind Cave National Park (WICA) protects a 13,699 ha mosaic of ponderosa pine (*Pinus ponderosa*) woodlands and mixed-grass prairie located in the southeastern foothills of the Black Hills of South Dakota. The park purpose is to protect the unique Wind Cave resources and preserve and enhance the native plants and wildlife, while providing for the enjoyment of the public. Roughly 30% of the park is comprised of ponderosa pine forest and woodlands with the largest contiguous forested area concentrated in the west and northwest of the park (Cogan et al. 1999). Historically, smaller fires have maintained a relatively stable amount of prairie and woodland in this area of the southern Black Hills (Shinneman and Baker 1997) but after the early 1900s, fires were much less common, and when they did occur they were smaller in area (Brown and Sieg 1999). More recently, prescribed fires and wildfires have restored a fire regime more typical of historical conditions. In 2011, WICA acquired the 2,246 ha Casey property which contains a greater proportion of mountain mahogany shrublands than the main portion of the park (Cogan et al. 1999). This property is fenced off from the majority of the park, excluding large densities of elk and bison from the area. In 2011, the park completed a natural resource assessment for the main portion of the park and classified the natural vegetation communities as in relatively good condition. However, the increase in invasive species and the increasing density of ponderosa pine poles and seedlings were of a moderate concern to managers (Komp et al. 2011).

In 2012, the National Park Service Northern Great Plains Inventory & Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology Program (FireEP) began monitoring 90 forested sites in WICA to better understand the condition of forest structure and health, surface fuel loads, and exotic plant prevalence (Symstad et al. 2012). Ten of these sites were in the Casey Addition and the remaining 80 were in the main portion of the park (Figure 1). We found that the WICA forests were in good condition with a low prevalence of exotics specie and surface fuels were at or below the management target (Ashton et al. 2013). Compared to the main portion of the park, the Casey Addition had more Rocky Mountain juniper, thinner forests, less grazing pressure, and fewer exotic species (Ashton et al. 2013). In the summer and fall of 2017, we revisited the same 90 sites to explore the following questions:

1. What is the current status of the forest structure in WICA, how has it changed since 2012, and how does it compare to historic conditions?

2. What is the current status of the surface fuels and how has it changed since 2012?
3. What is the distribution and abundance of exotic plant species of concern and how have these patterns changed since 2012?

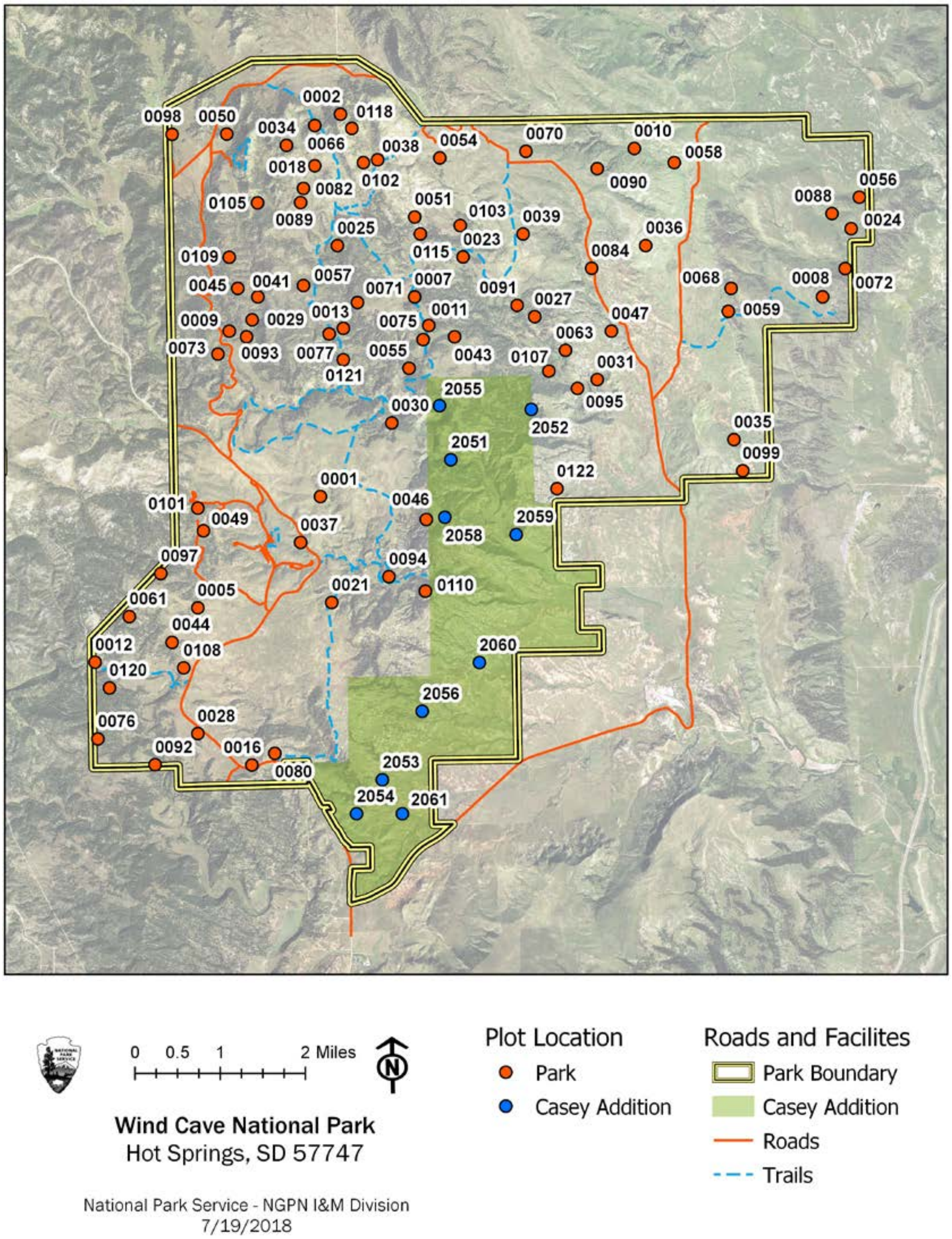


Figure 1. Map of Wind Cave National Park and the location of 90 forest monitoring plots sampled in 2012 and 2017. Ten plots are in the Casey Addition (green shading), and 80 plots fall within the 2010 Boundary (unshaded).

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2012) describes in detail the methods used for sampling long-term plots in WICA forests. Below, we briefly describe the general approach, sample frame, plot locations, and sampling methods. For more detail, please see Symstad et al. 2012, available at: http://science.nature.nps.gov/im/units/ngpn/monitor/plants.cfm.

Sample design

We implemented a protocol to monitor forest structure and fuel loads in WICA using a spatially balanced probability survey design (Generalized Random Tessellation Stratified (GRTS); Stevens and Olsen 2003, 2004). A grid of 54 x 54 m cells was overlaid on the park to create the sample frame with sampling locations at the center of a random subset of grid cells. We excluded the following areas from the sample frame: administrative areas, bison holding areas, roads, utility lines and an appropriate buffer, areas within 10 m of a park boundary, paved trails, and areas with little to no potential for terrestrial vegetation (e.g., large areas of bare rock). The final design included 80 randomly located sites (Figure 1). We applied the same process as above in the Casey Addition to select 10 additional randomly located sites.

The sample frame for the woody plots in WICA included the whole park because most of the park provides suitable habitat for tree growth, particularly in the absence of fire. However, trees and tall shrubs currently do not occur or are very sparse in a substantial portion of the park. When we visited the randomly located plots, the first step was to determine whether it was appropriate to conduct forest sampling in that selected location. If we found trees, tall shrubs, or woody fuels within 38 m of the plot center, we established the plot in 2012. In 2017, we resampled all 90 plots, regardless of whether there was currently a tree or fuel within 38 m (although in almost all cases there still was). Over time this means that some plots could be converted from forest to grassland (e.g. after a high severity fire). In this case, the loss of forest would be reflected in decreased tree density over time and/or a decrease in the proportion of plots with trees present.

The GRTS sample design was developed to better understand and monitor forests in WICA. We recognize that within the broader class of ponderosa forest and deciduous forests there are numerous alliances and community types represented. For instance, the WICA vegetation map included 28 distinct community types with eight forest and woodland types and five shrubland types (Cogan et al. 1999). The dynamic nature of these community types and the large variety makes it difficult to compare data among them. Moreover, park management actions (e.g. fire plans, exotic control) rarely are considered on the scale of community type. Therefore, we report data summarized across the park and the Casey Addition rather than for each community type.

Plot layout and sampling

At each of 90 sites, we sampled tree regeneration and density in a 10-m radius permanent plot (0.03 ha; Figure 2). All sites were visited in June - October of 2017. Tree and targeted tall shrub species with diameter at breast height (DBH, where breast height = 137 cm) < 2.54 cm were tallied by species and classified as seedlings. Trees were classified as poles (2.54 cm > DBH < 15.0 cm) or adult trees (DBH > 15 cm). Juniper trees (*Juniperus scopulorum*) and tall shrubs were commonly encountered and these were measured at root collar rather than DBH. For each tree, the species, DBH, status (live or dead), and condition (e.g., leaf-discoloration, insect-damaged, etc.) were recorded.

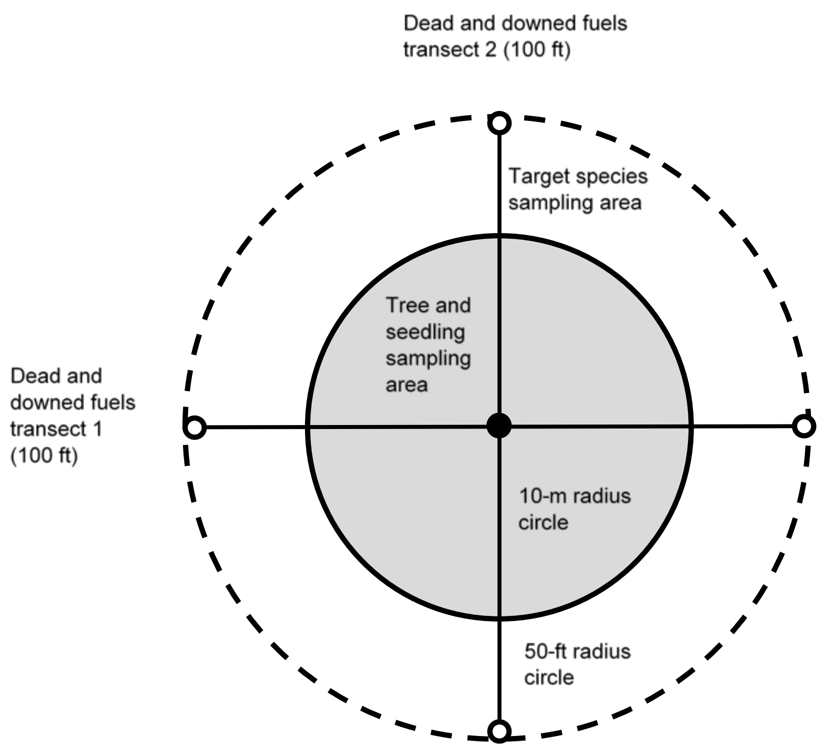


Figure 2. Long-term monitoring plot used for sampling forest structure and fuels in Wind Cave National Park.

Dead and downed woody fuel load data were collected along two perpendicular, 100 foot (30.49 m) transects with midpoints at the center of the plot (Figure 2), following Brown's Line methods (Brown 1974, Brown et al. 1982), when fuels were present. Photographs were taken at the beginning and end of dead and downed fuels transects using standardized methods (e.g., height, distance, camera settings), and the same set of photographs are repeated at each visit.

In cases where we found fewer than 5 trees or poles within the sampling area, we extended the radius to 20 m and recorded all trees within the larger area. This was done to increase the number of individual trees within the forest survey dataset. However, during data analyses we realized this practice increased variability and made it difficult to discern changes in tree density over time. Therefore, in this report we included only the trees measured within the smaller 10 m radius. We also revised the protocol so that all future forest structure surveys will only use a 10 m radius for tree data collection.

At all plots, we surveyed the plot for common disturbances and target species of interest to the park. Common disturbance categories included prescribed fire and wildfire, mountain pine beetle activity, animal trails, erosion, and herbivore browsing. The type and approximate area of the disturbances were recorded. This method was meant as a quick assessment of disturbance and typically took no more than 15 minutes in the field. Thus, the dataset focuses on large-scale and obvious disturbances such as wildfires. The Rankin Ridge wildfire burned 2000 acres of WICA on September 11th during the 2017 forest survey. The burn perimeter included one plot that was sampled prior to the fire (PCM_0002) but the remaining 7 were sampled after the fire burned over the plots (see Appendix A). The Legion Lake Fire started on December 11th 2017, which was after all forest plots had been surveyed. Therefore, since the 2012 forest survey a number of plots monitored in 2017 were affected by either prescribed fire or wildfire, including the Cold Brook North Prescribed Fire (2014), Cold Brook South Prescribed Fire (2015), Cold Brook Wildfire (2015), and Rankin Ridge Wildfire (2017). When these plots are resampled in 2022 we will likely observe the effects of the larger Legion Lake Fire.

We also surveyed the plot for new or recent exotic species that have the potential to spread into the park and cause significant ecological impacts (early detection) and more widespread exotic species that were identified as management concerns (Table 1). These species were chosen with assistance from Midwest Invasive Plant Network staff (a non-profit organization with a mission to reduce the impact of invasive plant species in the Midwest, https://www.mipn.org/), the Northern Great Plains Exotic Plant Management Team, park managers, and local weed experts. Each target species that was present at a site was assigned an abundance class on a scale from 1-5, where 1 = one individual, 2 = few individuals, 3 = cover of 1–5%, 4 = cover of 5–25%, and 5 = cover > 25% of the plot. This set of early detection species were developed for the whole NGPN region and as a result some species may already be present in WICA.

Table 1. Target exotic species of management concern at Wind Cave National Park included in forest structure surveys in 2017. In the Notes column “Noxious” indicates the species is on South Dakota’s state list of noxious weeds (SD Department of Agriculture 2017), and “Noxious: Custer” indicates species classified as noxious only in Custer County, SD. Early detection indicates it is a new invader or a species that has the potential to spread into the park.

Family	Scientific Name	Common Name	Notes
Apiaceae	*Heracleum mantegazzianum*	giant hogweed	Early detection
Apiaceae	*Pastinaca sativa*	wild parsnip	Early detection
Asteraceae	*Carduus nutans*	musk thistle	–
Asteraceae	*Centaurea diffusa*	diffuse knapweed	Early detection
Asteraceae	*Centaurea solstitialis*	yellow star thistle	Early detection
Asteraceae	*Centaurea stoebe*	spotted knapweed	Noxious: Custer
Asteraceae	*Centaurea virgata*	squarrose knapweed	Early detection
Asteraceae	*Chondrilla juncea*	rush skeletonweed	Early detection

*Previously reported in WICA, but an early detection species for the NGP region.

Table 1 (continued). Target exotic species of management concern at Wind Cave National Park included in forest structure surveys in 2017. In the Notes column “Noxious” indicates the species is on South Dakota’s state list of noxious weeds (SD Department of Agriculture 2017), and “Noxious: Custer” indicates species classified as noxious only in Custer County, SD. Early detection indicates it is a new invader or a species that has the potential to spread into the park.

Family	Scientific Name	Common Name	Notes
Asteraceae	*Cirsium arvense*	Canada thistle	Noxious
Asteraceae	*Cirsium vulgare*	bull thistle	–
Asteraceae	*Hieracium aurantiacum*	orange hawkweed	Early detection
Asteraceae	*Hieracium caespitosum*	meadow hawkweed	Early detection
Asteraceae	*Leucanthemum vulgare*	oxeye daisy	–
Asteraceae	*Onopordum acanthium*	Scotch thistle	–
Asteraceae	*Rhaponticum repens*	Russian knapweed/hardheads	Noxious
Asteraceae	*Sonchus arvensis*	perennial sowthistle	Noxious
Asteraceae	*Tanacetum vulgare*	common tansy	Noxious: Custer
Boraginaceae	*Cynoglossum officinale*	houndstongue	–
Brassicaceae	*Alliaria petiolata*	garlic mustard	Early detection
Brassicaceae	*Isatis tinctoria*	Dyer's woad	Early detection
Brassicaceae	*Lepidium latifolium*	perennial pepperweed	Early detection
Caryophyllaceae	*Gypsophila paniculata*	baby's breath	Early detection
Chenopodiaceae	*Salsola tragus*	Russian thistle	–
Clusiaceae	*Hypericum perforatum*	common St Johnswort	Noxious: Custer
Convolvulaceae	*Convolvulus arvensis*	field bindweed	–
Dipsacaceae	*Dipsacus fullonum*	common teasel	Early detection
Dipsacaceae	*Dipsacus laciniatus*	cutleaf teasel	Early detection
Eleagnaceae	*Elaeagnus angustifolia*	Russian olive	–
Euphorbiaceae	*Euphorbia cyparissias*	cypress spurge	Early detection
Euphorbiaceae	*Euphorbia esula*	leafy spurge	Noxious
Euphorbiaceae	*Euphorbia myrsinites*	myrtle spurge	Early detection
Fabaceae	*Pueraria montana var. lobata*	kudzu	Early detection
Fabaceae	*Securigera varia*	crown vetch	Early detection*

*Previously reported in WICA, but an early detection species for the NGP region.

Table 1 (continued). Target exotic species of management concern at Wind Cave National Park included in forest structure surveys in 2017. In the Notes column "Noxious" indicates the species is on South Dakota's state list of noxious weeds (SD Department of Agriculture 2017), and "Noxious: Custer" indicates species classified as noxious only in Custer County, SD. Early detection indicates it is a new invader or a species that has the potential to spread into the park.

Family	Scientific Name	Common Name	Notes
Iridaceae	*Iris pseudacorus*	yellow iris	Early detection
Lamiaceae	*Marrubium vulgare*	horehound	Noxious: Custer
Lamiaceae	*Salvia aethiopis*	Mediterranean sage	Early detection
Poaceae	*Agropyron cristatum*	crested wheatgrass	–
Poaceae	*Arundo donax*	giant reed	Early detection
Poaceae	*Bromus inermis*	smooth brome	–
Poaceae	*Bromus japonicus*	Japanese brome	–
Poaceae	*Bromus tectorum*	cheatgrass	–
Poaceae	*Taeniatherum caput-medusae*	medusahead	Early detection
Poaceae	*Ventenata dubia*	African wiregrass	–
Polygonaceae	*Fallopia japonica var. japonica*	Japanese knotweed	Early detection
Polygonaceae	*Fallopia sachalinense*	giant knotweed	Early detection
Polygonaceae	*Fallopia X bohemica*	Bohemian knotweed	Early detection
Rhamnaceae	*Rhamnus cathartica*	common buckthorn	Early detection*
Rosaceae	*Potentilla recta*	sulpher cinquefoil	–
Scrophulariaceae	*Linaria dalmatica*	Dalmatian toadflax	Early detection
Scrophulariaceae	*Linaria vulgaris*	yellow toadflax	Early detection; Noxious: Custer
Scrophulariaceae	*Verbascum blattaria*	moth mullein	Early detection
Scrophulariaceae	*Verbascum thapsus*	common mullein	Noxious: Custer
Simaroubaceae	*Ailanthus altissima*	tree of heaven	Early detection
Solanaceae	*Hyoscyamus niger*	black henbane	Noxious: Custer
Tamariaceae	*Tamarix ssp.*	salt cedar	Noxious

*Previously reported in WICA, but an early detection species for the NGP region.

Data Management and Analysis

We used FFI (FEAT/FIREMON Integrated; http://frames.gov/ffi/) as the primary software environment for managing our sampling data. FFI is used by a variety of agencies (e.g., NPS, USDA

Forest Service, U.S. Fish and Wildlife Service), has a national-level support system, and generally conforms to the Natural Resource Database Template standards established by the NPS Inventory and Monitoring Program.

Species scientific names, codes, and common names were taken from the USDA Plants Database (USDA-NRCS 2018). This report uses common names after the first occurrence in the text.

After data were entered, 100% of records were verified to the original data sheet to minimize transcription errors, and 10% of those records were reviewed a second time. After all data were entered and verified, automated queries were used as a final check for errors. When errors were identified by the crew or automated queries, changes were made to the original datasheets and/or the FFI database as needed. Data summaries were produced using the FFI reporting and query tools. Through this process, we were also able to find and correct errors in our historic monitoring data, some of which is included in the 2012 forest report (Ashton et al. 2013). The data in this report are the most accurate to date. The data are available to the public at: https://irma.nps.gov/DataStore/Reference/Profile/2251881.

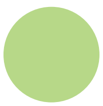
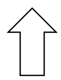
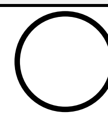
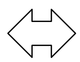
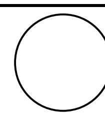
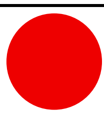
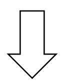
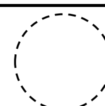
Forest structure metrics include measures of density and basal area. Only trees and poles measured within a 10 m radius of plot center for all plots were included in analyses (0.0314 ha). Basal area is the area that is occupied by the cross-section of tree trunks and reported as square meter per hectare. For our calculations of basal area, we included all live trees greater than 2.54 cm DBH. Densities were calculated separately for each tree size class (pole, tree, and seedling). Snag density was calculated as the number of standing dead trees per unit area (poles are not included). Seedlings were only counted when they were at least one season old (indicated by hardened off stems), and small stump resprouts were included in the seedling category. Seedlings were typically counted in a 0.0314 ha area, but when densities were very high (> 100 individuals) a smaller area was searched (0.0079 ha, 0.0157 ha, or 0.02355 ha). For analyses we used these counts to develop estimated densities for the 0.014 ha area. Target exotic species cover values were calculated using midpoint values of each cover class (e.g., 1-5% = 3%, 5-25% = 15%, etc.), and the smallest cover class of a single plant was calculated using 0.1%.

Metric calculations, statistical summaries, and graphics were generated using the R statistics software package (R Core Team 2017, version 3.4.3). Trends in plant community plots were tested using generalized or linear mixed model with plots and years as random factors using R software. Models were compared with and without factors to compare likelihood, and effects were considered significant P value was < 0.05. When initial likelihood tests were significant, models were compared using parametric bootstrap methods to improve the accuracy of the P value estimate. See Supplementary Material for R code.

Reporting on Natural Resource Condition

Results were summarized in a Natural Resource Condition Table based on the style of State of the Park report series (https://www.nps.gov/stateoftheparks/). The goal is to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way. By focusing on specific indicators, such as basal area, it will also be possible and straightforward to revisit the metric in subsequent years. The status and trend of each indicator is scored and assigned a corresponding symbol based on the key found in Table 2. Reference values were based on descriptions of historic forest condition, the 2012 forest survey, or management targets. Historic conditions are not necessarily ‘desired conditions’ or management targets, but they can provide a benchmark of comparison for park managers.

Table 1. Key to the symbols used in the Natural Resource Condition Table. The background color represents the current status, the arrow summarizes the trend, and the thickness of the outside line represents the degree of confidence in the assessment.

Condition Status		**Trend in Condition**		**Confidence in Assessment**	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Results

Forest structure

WICA forests include open ponderosa woodlands with few trees, dense ponderosa forest, juniper woodlands, and woody draws with a high density of deciduous shrubs. Ponderosa pine can be found in most of these forest types, and mature trees were observed in 50 of the 90 monitoring plots in 2017 (Table 3). The remaining plots had no mature trees (40 plots), but these were included in the forest survey because they were close to forest edges and had trees, seedlings, or fuels within 38 m of the center. Rocky Mountain juniper woodlands were common in the Casey Addition, occurring in 40% of plots, but fairly rare in the main portion of the park, where they were observed in only 5% of the plots (Table 3). There was also a greater percentage of plots with seedlings in the Casey Addition than in the main portion of the park (Table 3). Chokecherry and American elm were the most common deciduous tree species we encountered in the park and Casey Addition.

Table 3. Tree and tall shrub frequency in Wind Cave National Park in 2017 at 80 monitoring plots in the main portion of the park and 10 plots in the Casey Addition. Seedlings have a DBH <2.54 cm, poles are > 2.54 cm and <15.0 cm DBH. The percent of plots is indicated in the parentheses.

	Park			Casey Addition		
Common Name	**Trees (# of plots)**	**Poles (# of plots)**	**Seedlings (# of plots)**	**Trees (# of plots)**	**Poles (# of plots)**	**Seedlings (# of plots)**
ponderosa pine	45 (56%)	33 (41%)	46 (58%)	4 (40%)	5 (50%)	7 (70%)
Rocky Mountain juniper	4 (5%)	5 (6%)	10 (13%)	4 (40%)	4 (40%)	5 (50%)
chokecherry	–	1 (1%)	12 (15%)	–	1 (10%)	4 (40%)
American elm	0	0	7 (9%)	1 (10%)	1 (10%)	2 (20%)
All deciduous species	0	1 (1%)	16 (20%)	1 (10%)	1 (10%)	4 (40%)
Total	45 (56%)	35 (44%)	53 (66%)	5 (50%)	6 (60%)	8 (80%)

Ponderosa pine basal areas and mature tree density in the two WICA properties were similar to one another (Table 4; $F_{1,176}$= 0.1, P=0.7349 and $F_{1,176}$= 1.9, P=0.1744, respectively). The forests in the park averaged 10 m^2 ha^{-1} and 133 stems ha^{-1} while those in the Casey Addition averaged 9.6 m^2 ha^{-1} and 83 stems ha^{-1} (Table 4). While ponderosa pine density appears lower in the Casey Addition, the variability in density is large, so it is not statistically significant. The frequency of plots with ponderosa, juniper, and deciduous species showed little change from the 2012 values (Appendix B). Basal area, ponderosa tree, and ponderosa pole densities did not significantly change since 2012 ($F_{1,176}$= 0.1, P=0.7117; $F_{1,176}$= 0.1, P=0.7539; $F_{1,176}$= 0.12, P=0.6633). Nor were there significant interactions between time and property, meaning the park and the Casey Addition responded to time similarly (neither changed).

While the ponderosa pine densities are similar across the properties, densities of other species are not (Table 4). The Casey Addition has a higher density of juniper trees and poles than the main portion of the park ($F_{1,176}$= 26.8, *P*<0.0001and $F_{1,176}$= 26.9, *P*<0.0001, respectively). The Casey property also has a significantly larger density of deciduous trees and poles ($F_{1,176}$= 17.3, *P*<0.0001and $F_{1,176}$= 12.8, *P*=0.0004, respectively). Again, there were no significant differences between the 2017 and 2012 sampling.

Table 4. Tree basal area and density by size class for ponderosa pine, Rocky Mountain juniper, and deciduous trees in Wind Cave National Park in 2017. Values are the mean across 80 (park) or 10 (Casey Addition) forest monitoring sites ± standard error of the mean.

Species	Indicator	Park	Casey Addition
Ponderosa Pine	Basal Area (m^2/ ha)	10.0 ± 1.4	9.6 ± 4.4
	Tree Density (stems/ha)	133 ± 24.1	83 ± 49.3
	Pole Density (stems/ha)	297 ± 65.4	755 ± 670.1
	Seedling Density (stems/ha)	2474 ± 663.4	210 ± 161.4
	Snag Density (stems/ha)	14 ± 6.4	10 ± 9.5
Rocky Mountain Juniper	Tree Density (stems/ha)	5 ± 2.8	29 ±13.8
	Pole Density (stems/ha)	20 ± 12.4	220 ± 119.7
	Seedling Density (stems/ha)	83 ± 45.4	591 ± 456.2
Deciduous Tree and Tall Shrubs	Tree Density (stems/ha)	0	3 ± 3.2
	Pole Density (stems/ha)	0.4 ± 0.4	29 ± 28.7
	Seedling Density (stems/ha)	801 ± 379.7	3218 ± 1659.1

Ponderosa pine seedlings were significantly more abundant in the main portion of the park than in the Casey Addition (Table 4; *P*=0.0108). While the Casey Addition tended to have more juniper and deciduous seedlings, the large variation among plots meant this difference was not statistically significant. As with all the other metrics we examined, there was no significant difference between the 2017 and the 2012 surveys (Appendix B). Plot PCM_0058 and PCM_2061 (Figure 3) had the greatest density of deciduous seedlings, both of these plots were small draws where chokecherry was abundant.

Figure 3. Two sites in Wind Cave National Park with a high density of deciduous tree seedlings. Both PCM_2061 (left) and PCM_0058 (right) are in small draws with an abundance of chokecherry.

Surface fuels

Total fuel loads were similar in the park and the Casey property (Table 5) at 7.5 and 9.5 tons per acre, respectively (note that standard practice for fire management is to report fuels data in English units). There were no significant changes in fuel loads since 2012 (data in Appendix B), nor were there significant differences between the two properties. In both areas, duff and litter made up the majority of total surface fuels (Table 5).

Table 5. The average surface fuel loadings in 80 forested plots in the main area of the park (Park) and 10 plots in the Casey Addition of Wind Cave National Park. Means are given by class and standard errors are in parentheses

Surface Fuel Type	Park	Casey Addition
Fine woody debris (tons acre^{-1})	0.4 (0.1)	1.5 (0.9)
Sound thousand hour fuels (tons acre^{-1})	0.9 (0.3)	0
Rotten thousand hour fuels (tons acre^{-1})	0.8 (0.2)	1.4 (1.1)
Duff (tons acre^{-1})	3.3 (0.5)	4.5 (2.1)
Litter (tons acre^{-1})	1.4 (0.2)	2.0 (0.6)
Total surface fuels (tons acre^{-1})	7.5 (1.0)	9.5 (3.7)

The Rankin wildfire started on September 11, 2017, due to a lightning event the previous day and burned 2,132 acres within the park over the next five days. Seven forest structure & fuel plots were burned and these plots were read for burn severity and changes in fuel loading in late September. Significant reductions occurred within the 1000-hr, litter, duff, and total fuel loading classes following the wildfire (Figure 4).

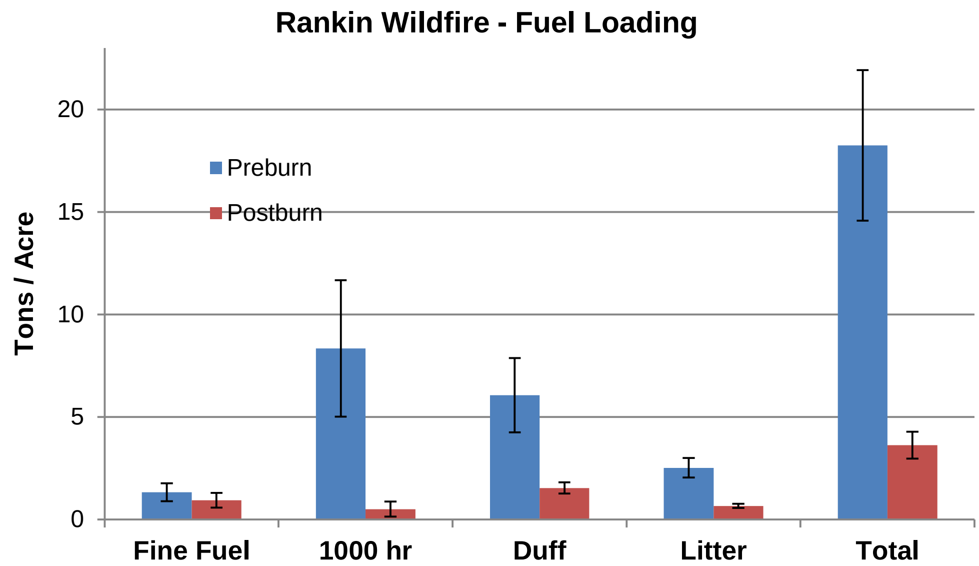


Figure 4. Changes in average surface fuel loading by size class for seven forested plots after the September 11-15, 2017 Rankin wildfire. Values represent means + standard errors.

The Legion lake wildfire started on December 11, 2017 and burned approximately 7,000 acres within the park and a total of 53,875 acres in multiple jurisdictions over the next five days. Six forest structure & fuel plots were burned and these plots were read for burn severity and changes in fuel loading from December 2017 to April 2018. Significant fuel load reductions occurred within the 1000-hr, litter, duff, and total fuel loading classes following the wildfire (Figure 5).

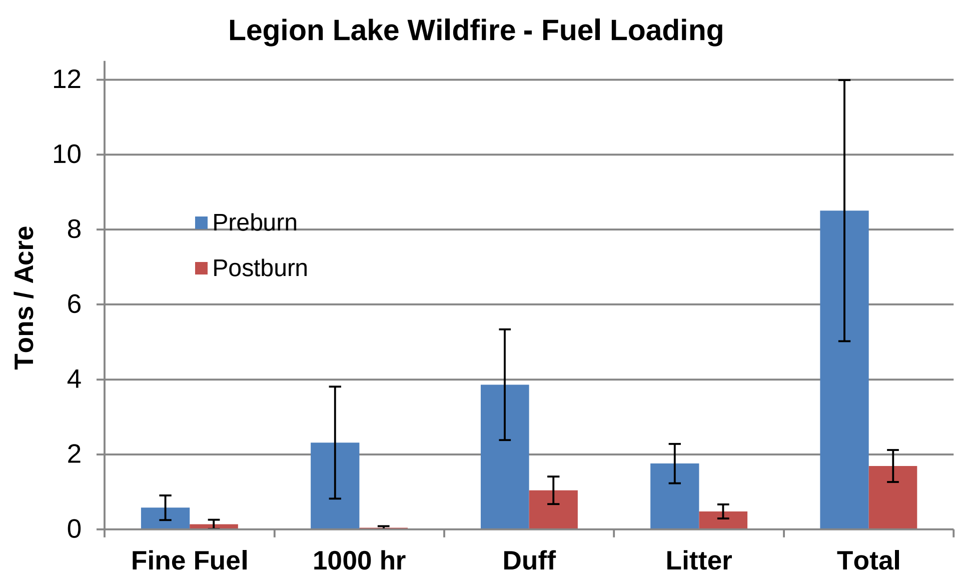


Figure 5. Changes in average surface fuel loading by size class for six forested plots after the December 11-15, 2017 Legion Lake wildfire. Values represent means + standard errors.

Disturbance and Exotic species

We observed 12 of the 55 potential target exotic species in WICA in 2017 (Tables 6-7). Common mullein, Japanese brome, Canada thistle, and houndstongue were the most commonly observed species and were each present in more than 25% of the 90 forest plots visited in 2017 (Table 6). Target exotic plant species richness was greater in plots within the park compared with the Casey Addition (12 and 4 species, respectively) and exotic plant cover also tended to be greater (Table 7). The plants with the greatest cover values were also the most commonly observed, including common mullein, Japanese brome, Canada thistle, and houndstongue (Table 6). Smooth brome, which was only observed in seven plots, occupied more than 3% of the plot area where it was observed. At the whole-park scale, common mullein was the most frequently observed target species (Table 6) and occupied the greatest average cover (Table 7) over all 90 forested plots. Across the whole park, cover of exotic species was generally low, with maximum cover values averaging less than 1% for all species in 2017, which is similar to average cover of target exotic species observed during 2012 monitoring efforts.

Table 6. Target exotic species cover in forest plots in Wind Cave National Park in 2017 where observed. These cover values are calculated only across plots where the species was observed. Values are reported as means ± standard error of the mean, values in parentheses are the number of plots where a species was observed. The most commonly encountered species appear at the top of the list.

Scientific Name	Common Name	Park	Casey Addition
Verbascum thapsus	common mullein	1.73 ± 0.60 (41)	3.00 (1)
Bromus japonicus	Japanese brome	1.11 ± 0.18 (37)	0.92 ± 0.47 (5)
Cirsium arvense	Canada thistle	1.88 ± 0.57 (26)	0
Cynoglossum officinale	houndstongue	0.64 ± 0.15 (24)	3.00 ± 0.00 (2)
Marrubium vulgare	horehound	0.71 ± 0.24 (10)	0.50 (1)
Bromus tectorum	cheatgrass	0.76 ± 0.30 (8)	0
Bromus inermis	smooth brome	3.29 ± 1.85 (7)	0
Cirsium vulgare	bull thistle	0.44 ± 0.05 (7)	0
Convolvulus arvensis	bindweed	0.50 ± 0 (2)	0
Rhamnus cathartica	buckthorn	0.50 ± 0 (2)	0
Agropyron cristatum	crested wheatgrass	0.50 (1)	0
Eleagnus angustifolia	Russian olive	0.10 (1)	0

Table 7. Target exotic species cover in 90 forest plots in Wind Cave National Park in 2017. Cover is calculated as a mean across all 80 plots in the main portion of the park and across 10 plots in the Casey Addtion. Values are reported as means ± standard error of the mean.

Scientific Name	Common Name	Park	Casey Addition
Verbascum thapsus	common mullein	0.89 ± 0.32	0.30 ± 0.28
Cirsium arvense	Canada thistle	0.61 ± 0.21	0
Bromus japonicus	Japanese brome	0.51 ± 0.1	0.46 ± 0.28
Bromus inermis	smooth brome	0.29 ± 0.19	0
Cynoglossum officinale	houndstongue	0.19 ± 0.06	0.60 ± 0.38
Marrubium vulgare	horehound	0.09 ± 0.04	0.05 ± 0.05
Bromus tectorum	cheatgrass	0.08 ± 0.04	0
Cirsium vulgare	bull thistle	0.04 ± 0.01	0
Agropyron cristatum	crested wheatgrass	0.01 ± 0.01	0
Convolvulus arvensis	bindweed	0.01 ± 0.01	0
Rhamnus cathartica	buckthorn	0.01 ± 0.01	0
Eleagnus angustifolia	Russian olive	< 0.01 ± < 0.01	0

However, many species were observed in more plots in 2017 when compared with 2012 (Ashton et al. 2013). Japanese brome doubled in frequency between 2012 and 2017, with the number of observations increasing from 21 to 42 in five years. Other species that experienced substantial increases in plot frequency between 2012 and 2017 included houndstongue and common mullein which increased by 16 observations; and Canada thistle, which increased by nine observations. Detailed maps including plot locations and cover values for target species at each plot can be found in Appendix C. These maps are not a survey of the whole park acreage but rather, highlight the plots where target species occur.

In addition to target exotic species, the field crews surveyed the plots for signs of natural and anthropogenic disturbance. Evidence of fire and animal trails were the most common disturbance recorded. Forty percent of plots in the park and Casey Addition had animal trails through them, but plots in the main part of the park were more likely to have grazing impacts (18 plots in the park compared to 0 in the Casey Addition. Four plots had prairie dogs present and six had bison wallows within the area. There were a few plots that showed signs of mountain pine beetle, wind damage, and erosion. Plots with prairie dog towns tended to have a greater number of exotic target species present, but there was too small a sample size to determine if the pattern was statistically significant.

Discussion

The forests in WICA are dominated by ponderosa pine, as is typical of the Black Hills region. Average stand density and basal areas were similar in 2017 to the reconstructed historic forest density and basal area for the southern Black Hills in 1900 (Table 7; Brown and Cook 2006). However, the park-wide estimates include forested areas and more open grassland sites on the edge of woodlands. Only 50 of the 80 monitoring plots in the park and 3 of the 10 plots in the Casey Addition had large ponderosa pines present (≥30 cm DBH). Accounting for this in the analysis and using only the plots with the larger trees provides a more direct comparison to the Brown and Cook (2006) historic density estimates. We found the plots with the larger trees had an average density of 176 ± 32 stems ha^{-1} and an average basal area of 14.2 ± 1.8 m^2 ha^{-1} in the park. This suggests that the few areas with older trees in WICA are denser than forests during the pre-settlement period which averaged 131 stems ha^{-1}. High ponderosa stand density and basal area can increase susceptibility to attack by mountain pine beetles (Negrón et al. 2008). However, the recent mountain pine beetle epidemic in the Black Hills did not adversely affect WICA, and as of 2016 the mountain pine beetle densities went back to endemic levels (Black Hills National Forest 2017).

In the five years between the 2012 and 2017 forest surveys, there was very little change in forest structure and this stability was consistent across both the Casey Addition and the main portion of the park. The Cold Brook North RX fire, Cold Brook South RX fire, Cold Brook WF, and Rankin WF occurred during this time period, but affected a small number of plots (Appendix A) and caused limited tree mortality. As a result, it was difficult to discern an effect on tree densities. The Legion Lake Wildfire in December 2017 affected a large number of plots and caused significant tree mortality in some areas, so we expect it to reduce forest densities, but the magnitude of these affects will not be known until the 2022 survey. The NGP Fire Ecology Program revisited 6 forest plots that burned in the Legion Lake Wildfire during the 2018 field season and will provide a summary of the changes to forest structure in their 2018 annual report. Moreover, recent elk management efforts have reduced the population of elk. There was some concern that high elk populations in the past have reduced recruitment and survival of deciduous trees. It will be interesting to see if there is a corresponding increase in the deciduous tree and tall shrub species they browse on over the next 5 years.

The most noticeable change in WICA between the 2012 and 2017 survey was the increasing prevalence of exotic species. Japanese brome, in particular, doubled in frequency and was found in almost 50% of the plots we visited (Table 8). Canada thistle also increased in frequency and was found in a third of all plots. It is not clear whether the increase is due to changes in vegetation management strategies, or if rather it is an effect of weather. The last survey was done in a drought year and 2017 had more rain in comparison, although it was also a dry year (Figure 6). This moisture likely contributed to an increase in exotic species. Future monitoring may help discern whether this change is a longer trend of increasing prevalence of invasive species. Regardless, the park should continue efforts to manage these species.

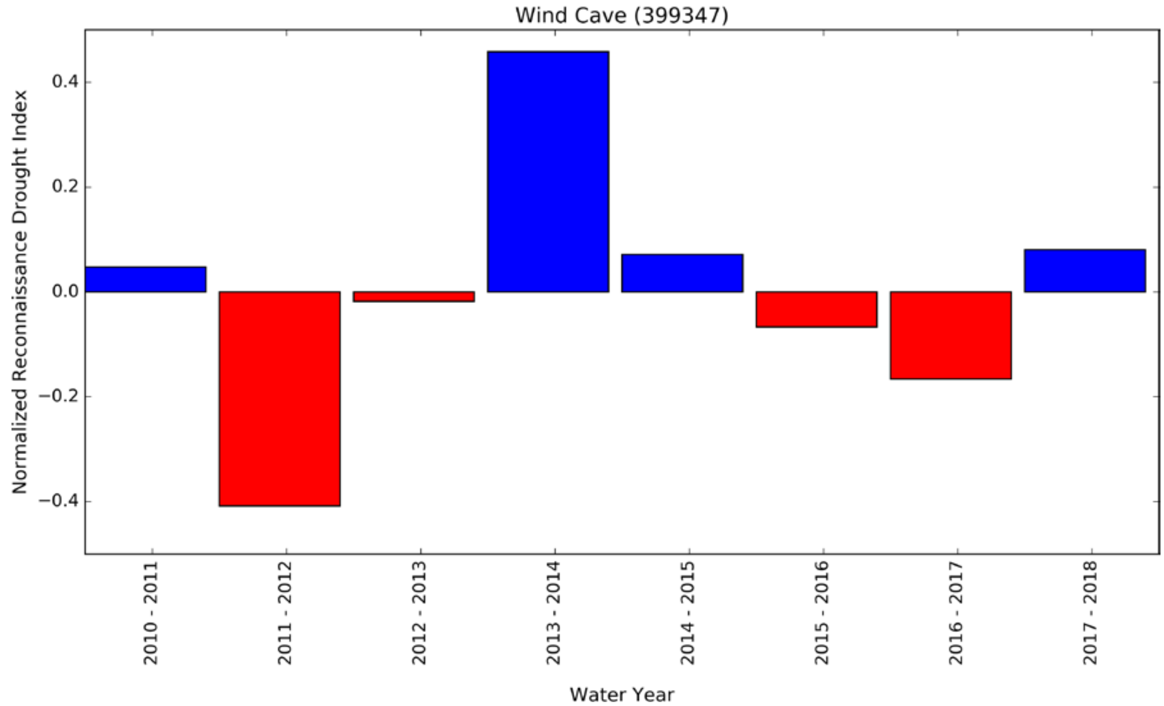
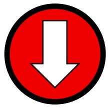
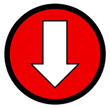
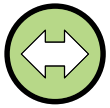
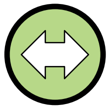
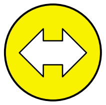
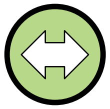


Figure 6. Normalized Reconnaissance Drought Index (RDI) for water years from 2010 – 2018. The data are based on climate records from the Wind Cave COOP weather station (399347) and summarized using tools in the Climate Analyzer (Tercek 2019). RDI is calculated using precipitation and evapotranspiration, where negative numbers are droughts (red) and positive values are wet periods (blue).

In conclusion, the forests in WICA are in good condition and densities resemble historic conditions. Surface fuel loads are within fire management targets and while deciduous tree seedlings are not abundant, they are still found throughout the park suggesting there is some recruitment and potential for recovery in the absence of herbivory. The largest threat to forests in WICA is the increasing prevalence of exotic species. Another concern is continued warming temperatures and the potential for more frequent wildfires. Future climate projections and modelling predict that by the end of the next century forests may reduce in extent in WICA and may convert from forest to woodland (Bachelet et al. 2000). Moreover, there may be an expansion of woody shrubs, particularly Rocky Mountain juniper, where fires are suppressed (King et al. 2015). Continued monitoring and assessment of WICA forests should provide an early warning to park managers, if and when these changes appear.

Table 8. Natural resource condition summary table for forest structure and fuels in WICA in 2017.

Indicators of Condition	Specific Measures	Park (mean ± SE)	Casey Addition (mean ± SE)	Reference Value	Condition Status/ Trend	Rationale
Exotic Plant Early Detection	Canada thistle frequency (Number of plots with *C.arvense)*	33%	0	<10% of plots		The Casey Addition typically has a lower cover of exotic species than the main portion of the park. We found no plots in 2017 with Canada thistle present in the Casey Addition. Compared to 2012, there was a large increase in the number of plots with Canada thistle present.
	Japanese brome frequency (Number of plots with *B.japonicus)*	46%	50%	<10% of plots		Japanese brome is common in the WICA occurring in close to half the plots. It is found in both the main portion of the park and the Casey Addition. Japanese brome doubled in frequency between 2012 and 2017.
Upland Plant Communities	Ponderosa pine basal area	10.0 ± 1.4 $m^2\ ha^{-1}$	9.6 ± 4.4 $m^2\ ha^{-1}$	15.3 ± 2.7 $m^2\ ha^{-1}$		As of 2012, overall condition of the forest community was good and basal areas and tree densities are similar to historic conditions (Brown and Cook 2006).
	Ponderosa pine density	133 ± 24.1 stems ha^{-1}	83 ± 49.3 stems ha^{-1}	131 ± 24.7 stems ha^{-1}		There was no significant difference in densities across the two sections of the park.
	Proportion of plots with deciduous seedlings*	20%	40%	40%[1]		Seedlings of deciduous trees were more commonly found in the Casey addition.
Fire and Fuel Dynamics	Total fuel loads	7.5 ± 1.0 tons per acre	9.5 ± 3.7 tons per acre	Between 2 and 10		The current fire ecology program aims to maintain fuel loads of less than 10 tons per acre. Both WICA properties have fuel loads below this management threshold.

*We use the frequency of seedlings in the Casey addition as the reference condition because this area is fenced and elk and bison are excluded.

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Appendix A: Wind Cave National Park Forest Structure Survey Plots

Plot Name	Plot Type	Park Area	Recent Fires
WICA_PCM_0001	Plant Community	2010 Boundary	–
WICA_PCM_0002	Plant Community	2010 Boundary	Rankin (2017), 2017 read was completed before the fire
WICA_PCM_0005	Plant Community	2010 Boundary	Cold Brook North RX fire (2014)
WICA_PCM_0007	Plant Community	2010 Boundary	–
WICA_PCM_0008	Plant Community	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0009	Plant Community	2010 Boundary	–
WICA_PCM_0010	Plant Community	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0011	Plant Community	2010 Boundary	–
WICA_PCM_0012	Plant Community	2010 Boundary	Cold Brook North RX fire (2014)
WICA_PCM_0013	Plant Community	2010 Boundary	–
WICA_PCM_0016	Plant Community	2010 Boundary	Cold Brook WF (2015)
WICA_PCM_0018	Plant Community	2010 Boundary	–
WICA_PCM_0021	Plant Community	2010 Boundary	Cold Brook (2015)
WICA_PCM_0023	Plant Community	2010 Boundary	–
WICA_PCM_0024	Plant Community	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0025	Plant Community	2010 Boundary	–
WICA_PCM_0027	Plant Community	2010 Boundary	–
WICA_PCM_0028	Plant Community	2010 Boundary	Cold Brook South RX fire (2015)
WICA_PCM_0029	Plant Community	2010 Boundary	–
WICA_PCM_0030	Plant Community	2010 Boundary	–
WICA_PCM_0031	Plant Community	2010 Boundary	–
WICA_PCM_0034	Plant Community	2010 Boundary	–
WICA_PCM_0035	Plant Community	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0036	Plant Community	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0037	Forest Structure	2010 Boundary	–
WICA_PCM_0038	Forest Structure	2010 Boundary	Rankin (2017)

Appendix A (continued): Wind Cave National Park Forest Structure Survey Plots

Plot Name	Plot Type	Park Area	Recent Fires
WICA_PCM_0039	Forest Structure	2010 Boundary	–
WICA_PCM_0041	Forest Structure	2010 Boundary	–
WICA_PCM_0043	Forest Structure	2010 Boundary	–
WICA_PCM_0044	Forest Structure	2010 Boundary	Cold Brook North RX fire (2014)
WICA_PCM_0045	Forest Structure	2010 Boundary	–
WICA_PCM_0046	Forest Structure	2010 Boundary	Cold Brook WF (2015)
WICA_PCM_0047	Forest Structure	2010 Boundary	–
WICA_PCM_0049	Forest Structure	2010 Boundary	–
WICA_PCM_0050	Forest Structure	2010 Boundary	–
WICA_PCM_0051	Forest Structure	2010 Boundary	Rankin (2017)
WICA_PCM_0054	Forest Structure	2010 Boundary	Rankin (2017)
WICA_PCM_0055	Forest Structure	2010 Boundary	–
WICA_PCM_0056	Forest Structure	2010 Boundary	–
WICA_PCM_0057	Forest Structure	2010 Boundary	–
WICA_PCM_0058	Forest Structure	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0059	Forest Structure	2010 Boundary	–
WICA_PCM_0061	Forest Structure	2010 Boundary	–
WICA_PCM_0063	Forest Structure	2010 Boundary	–
WICA_PCM_0066	Forest Structure	2010 Boundary	–
WICA_PCM_0068	Forest Structure	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0070	Forest Structure	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0071	Forest Structure	2010 Boundary	–
WICA_PCM_0072	Forest Structure	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0073	Forest Structure	2010 Boundary	–
WICA_PCM_0075	Forest Structure	2010 Boundary	–
WICA_PCM_0076	Forest Structure	2010 Boundary	Cold Brook South RX fire (2015)
WICA_PCM_0077	Forest Structure	2010 Boundary	–
WICA_PCM_0080	Forest Structure	2010 Boundary	Cold Brook WF (2015)

Appendix A (continued): Wind Cave National Park Forest Structure Survey Plots

Plot Name	Plot Type	Park Area	Recent Fires
WICA_PCM_0082	Forest Structure	2010 Boundary	–
WICA_PCM_0084	Forest Structure	2010 Boundary	–
WICA_PCM_0088	Forest Structure	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0089	Forest Structure	2010 Boundary	–
WICA_PCM_0090	Forest Structure	2010 Boundary	Legion Lake (2017)*
WICA_PCM_0091	Forest Structure	2010 Boundary	–
WICA_PCM_0092	Forest Structure	2010 Boundary	Cold Brook South RX fire (2015)
WICA_PCM_0093	Forest Structure	2010 Boundary	–
WICA_PCM_0094	Forest Structure	2010 Boundary	Cold Brook (2015)
WICA_PCM_0095	Forest Structure	2010 Boundary	–
WICA_PCM_0097	Forest Structure	2010 Boundary	–
WICA_PCM_0098	Forest Structure	2010 Boundary	–
WICA_PCM_0099	Forest Structure	2010 Boundary	–
WICA_PCM_0101	Forest Structure	2010 Boundary	–
WICA_PCM_0102	Forest Structure	2010 Boundary	Rankin (2017)
WICA_PCM_0103	Forest Structure	2010 Boundary	Rankin (2017)
WICA_PCM_0105	Forest Structure	2010 Boundary	–
WICA_PCM_0107	Forest Structure	2010 Boundary	–
WICA_PCM_0108	Forest Structure	2010 Boundary	Cold Brook North RX fire (2014)
WICA_PCM_0109	Forest Structure	2010 Boundary	–
WICA_PCM_0110	Forest Structure	2010 Boundary	Cold Brook WF (2015)
WICA_PCM_0115	Forest Structure	2010 Boundary	Rankin (2017)
WICA_PCM_0118	Forest Structure	2010 Boundary	Rankin (2017)
WICA_PCM_0120	Forest Structure	2010 Boundary	Cold Brook South RX fire (2015)
WICA_PCM_0121	Forest Structure	2010 Boundary	–
WICA_PCM_0122	Forest Structure	2010 Boundary	–
WICA_PCM_2051	Plant Community	2011 Addition	–
WICA_PCM_2052	Plant Community	2011 Addition	–

Appendix A (continued): Wind Cave National Park Forest Structure Survey Plots

Plot Name	Plot Type	Park Area	Recent Fires
WICA_PCM_2053	Plant Community	2011 Addition	Cold Brook WF (2015)
WICA_PCM_2054	Plant Community	2011 Addition	–
WICA_PCM_2055	Plant Community	2011 Addition	–
WICA_PCM_2056	Plant Community	2011 Addition	Cold Brook WF (2015)
WICA_PCM_2058	Plant Community	2011 Addition	–
WICA_PCM_2059	Plant Community	2011 Addition	–
WICA_PCM_2060	Forest Structure	2011 Addition	–
WICA_PCM_2061	Forest Structure	2011 Addition	–

Appendix B: Forest Structure Metrics from 2012 in Wind Cave National Park

Table B-1. Tree and tall shrub frequency in Wind Cave National Park in 2012 at 80 monitoring plots in the main portion of the park and 10 plots in the Casey Addition. Seedlings have a DBH <2.54 cm, poles are > 2.54 cm and <15.0 cm DBH. The percent of plots is indicated in the parentheses.

	Park			Casey Addition		
Common Name	**Trees (# of plots)**	**Poles (# of plots)**	**Seedlings (# of plots)**	**Trees (# of plots)**	**Poles (# of plots)**	**Seedlings (# of plots)**
ponderosa pine	44 (55%)	36 (45%)	53 (66%)	4 (40%)	6 (60%)	6 (60%)
Rocky Mtn. juniper	4 (5%)	5 (6%)	10 (13%)	4 (40%)	4 (40%)	5 (50%)
chokecherry	–	0	10 (13%)	–	0	4 (40%)
American elm	0	0	3 (4%)	1 (10%)	1 (10%)	3 (30%)
All deciduous species	0	0	11 (14%)	1 (10%)	1 (10%)	4 (40%)
Total	44 (55%)	36 (45%)	56 (70%)	6 (60%)	6 (60%)	8 (80%)

Table B-2. Tree basal area and density by size class for ponderosa pine, Rocky Mountain juniper, and deciduous trees in Wind Cave National Park in 2012. Values are the mean across 80 (park) and 10 (addition) forest monitoring sites ± standard error of the mean. Asterisks indicate significant differences.

Species	Indicator	Park	Casey Addition
Ponderosa Pine	Basal Area (m^2/ ha)	9.4 ± 1.4	7.9 ± 3.5
	Tree Density (stems/ha)	118 ± 21.9	70 ± 47.1
	Pole Density (stems/ha)	313 ± 74.6	348 ± 93.1
	Seedling Density (stems/ha)	3882 ± 916.3	2223 ± 594.3
	Snag Density (stems/ha)	19 ± 9.1	6 ± 6.3
Rocky Mountain Juniper	Tree Density (stems/ha)	4 ± 2.5	22 ± 10.7
	Pole Density (stems/ha)	19 ± 11.8	150 ± 82.4
	Seedling Density (stems/ha)	58 ± 290	280 ± 216.7
Deciduous Tree and Tall Shrubs	Tree Density (stems/ha)	0	3 ± 3.2
	Pole Density (stems/ha)	0	13 ± 12.7
	Seedling Density (stems/ha)	1312 ± 953.2	1993 ± 1004

Table B-3. The average surface fuel loadings in 80 forested plots in the main portion and 10 plots in the Casey Addition of Wind Cave National Park in 2012. Means are given by class and standard errors are in parentheses

Surface Fuel Type	Park	Casey Addition
Fine woody debris (tons $acre^{-1}$)	0.9 (0.2)	1.9 (1.2)
Sound thousand hour fuels (tons $acre^{-1}$)	1.1 (0.3)	0.3 (0.2)
Rotten thousand hour fuels (tons $acre^{-1}$)	1.3 (0.6)	0.6 (0.4)
Duff (tons $acre^{-1}$)	4.3 (0.6)	2.7 (1.2)
Litter (tons $acre^{-1}$)	1.7 (0.2)	1.3 (0.4)
Total surface fuels (tons $acre^{-1}$)	9.3 (1.2)	6.9 (2.8)

Appendix C: Maps of Exotic Species Abundance in Wind Cave National Park

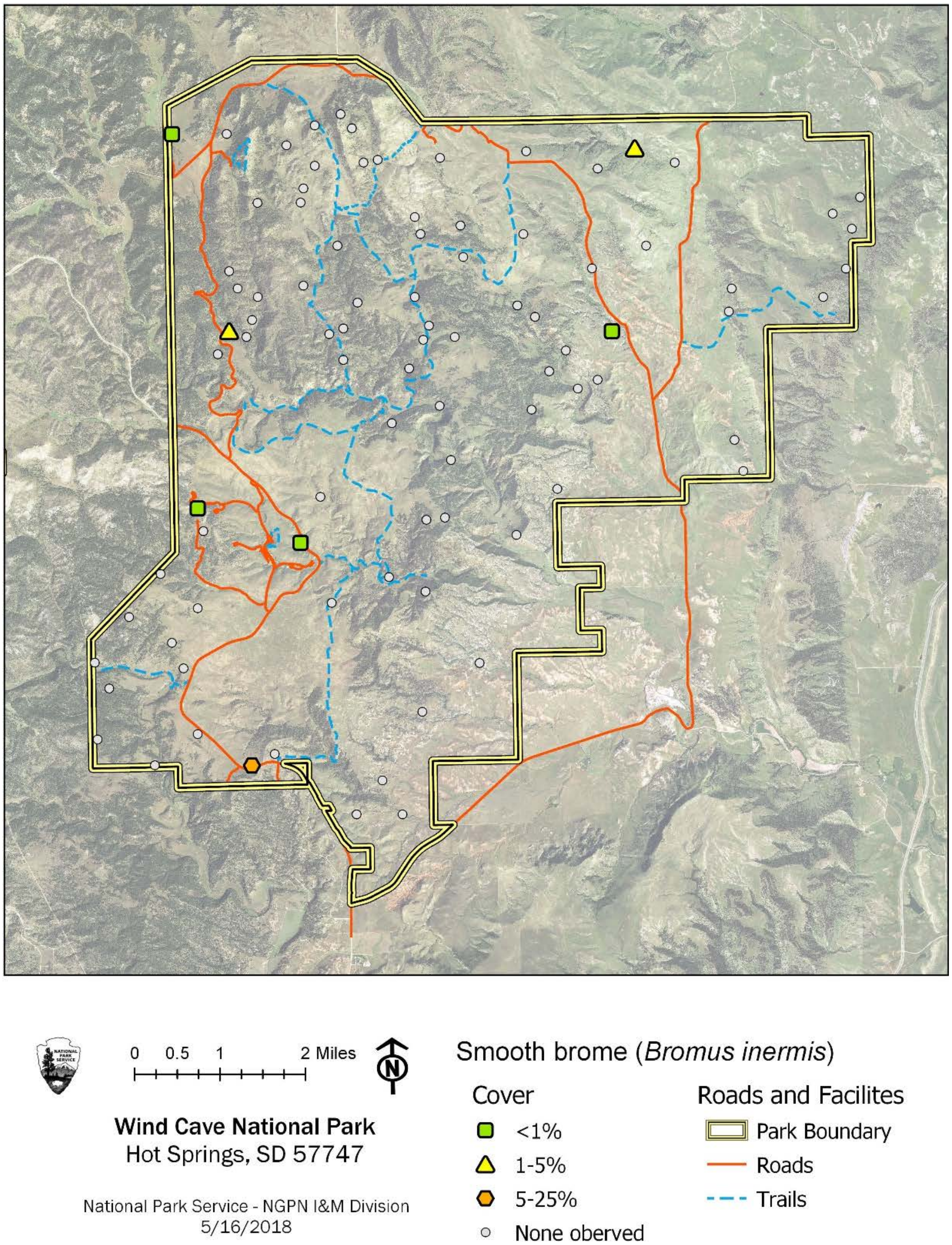

Figure C-1. Map showing smooth brome sampling plots at Wind Cave National Park.

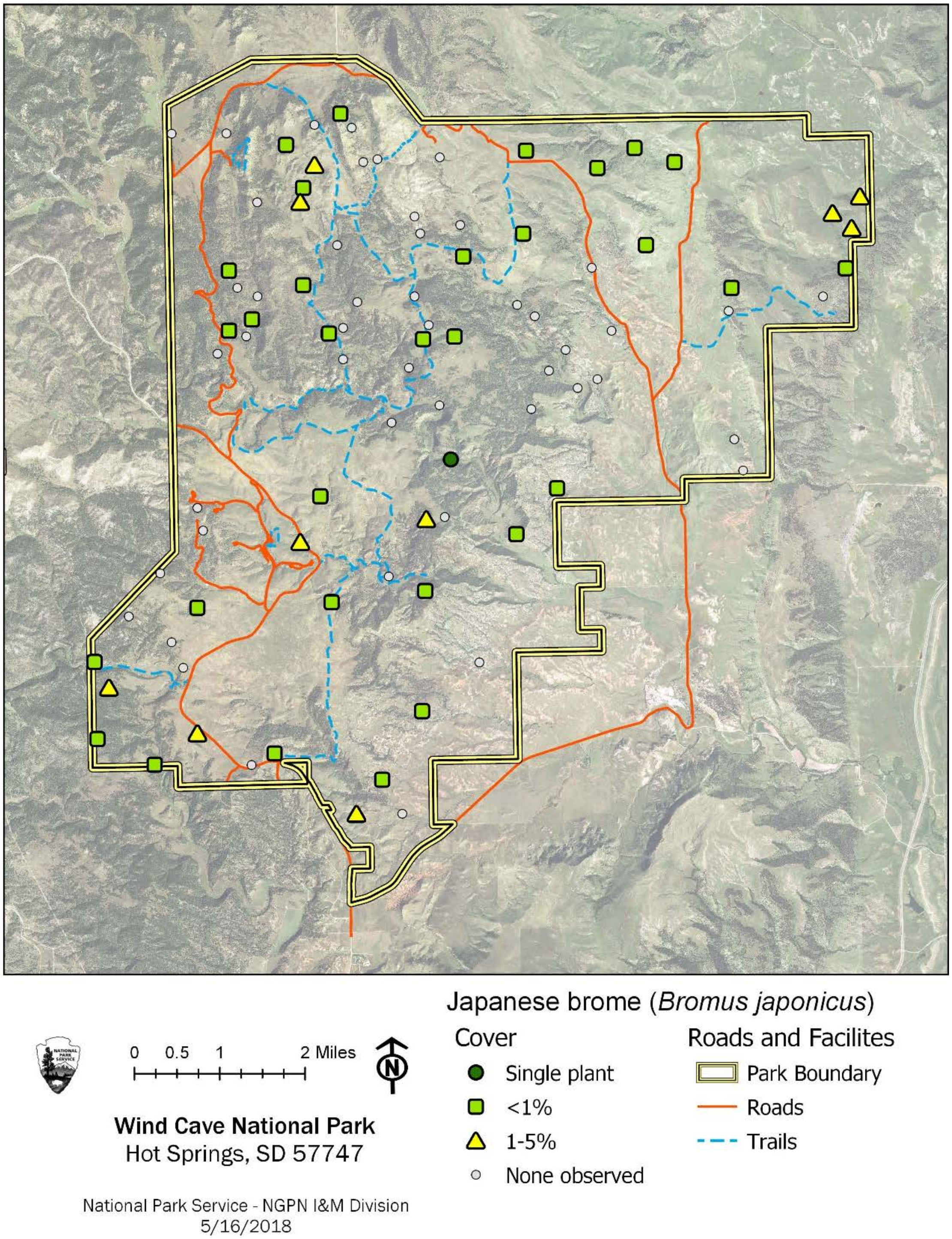

Figure C-2. Map showing Japanese brome sampling plots at Wind Cave National Park.

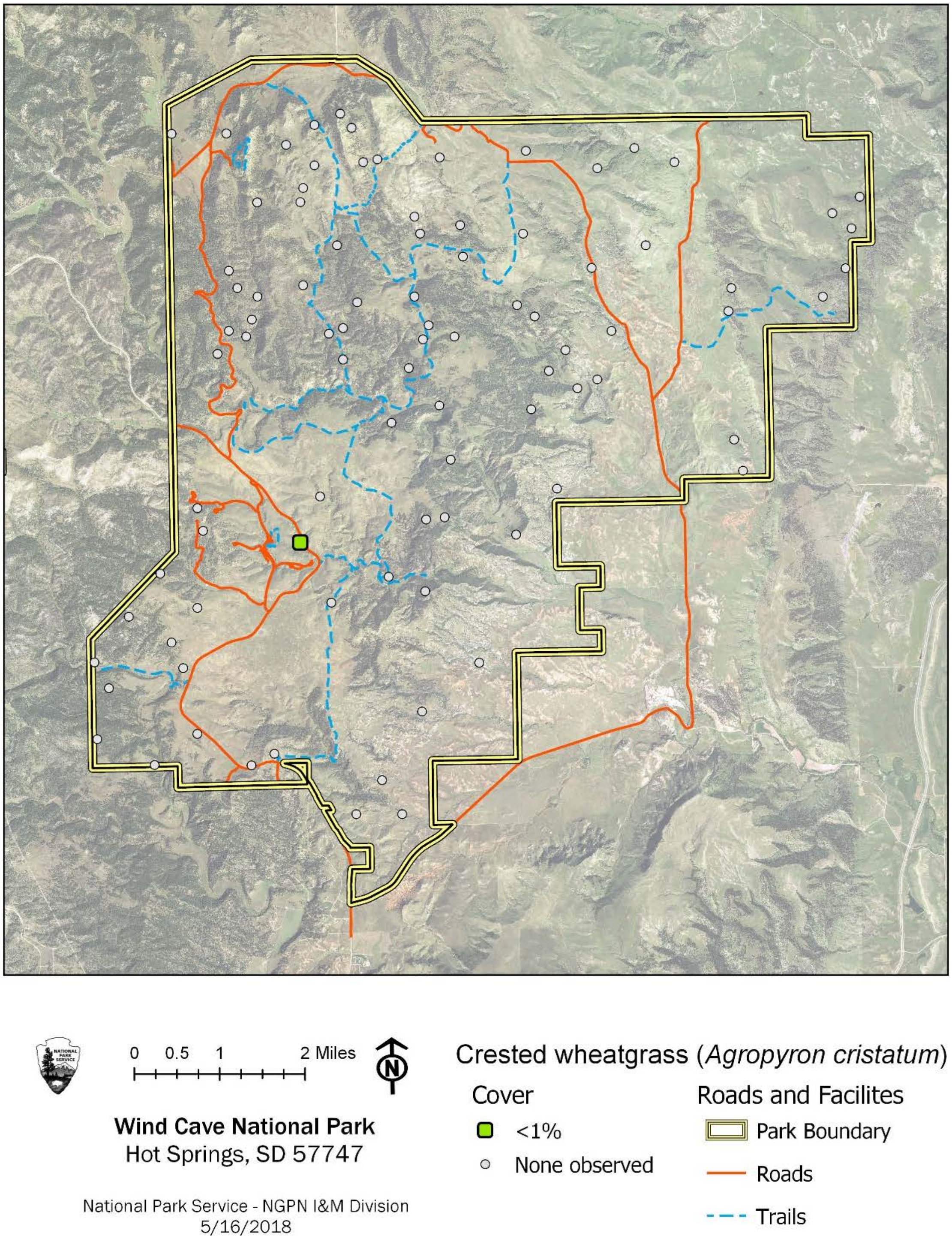

Figure C-3. Map showing crested wheatgrass sampling plots at Wind Cave National Park.

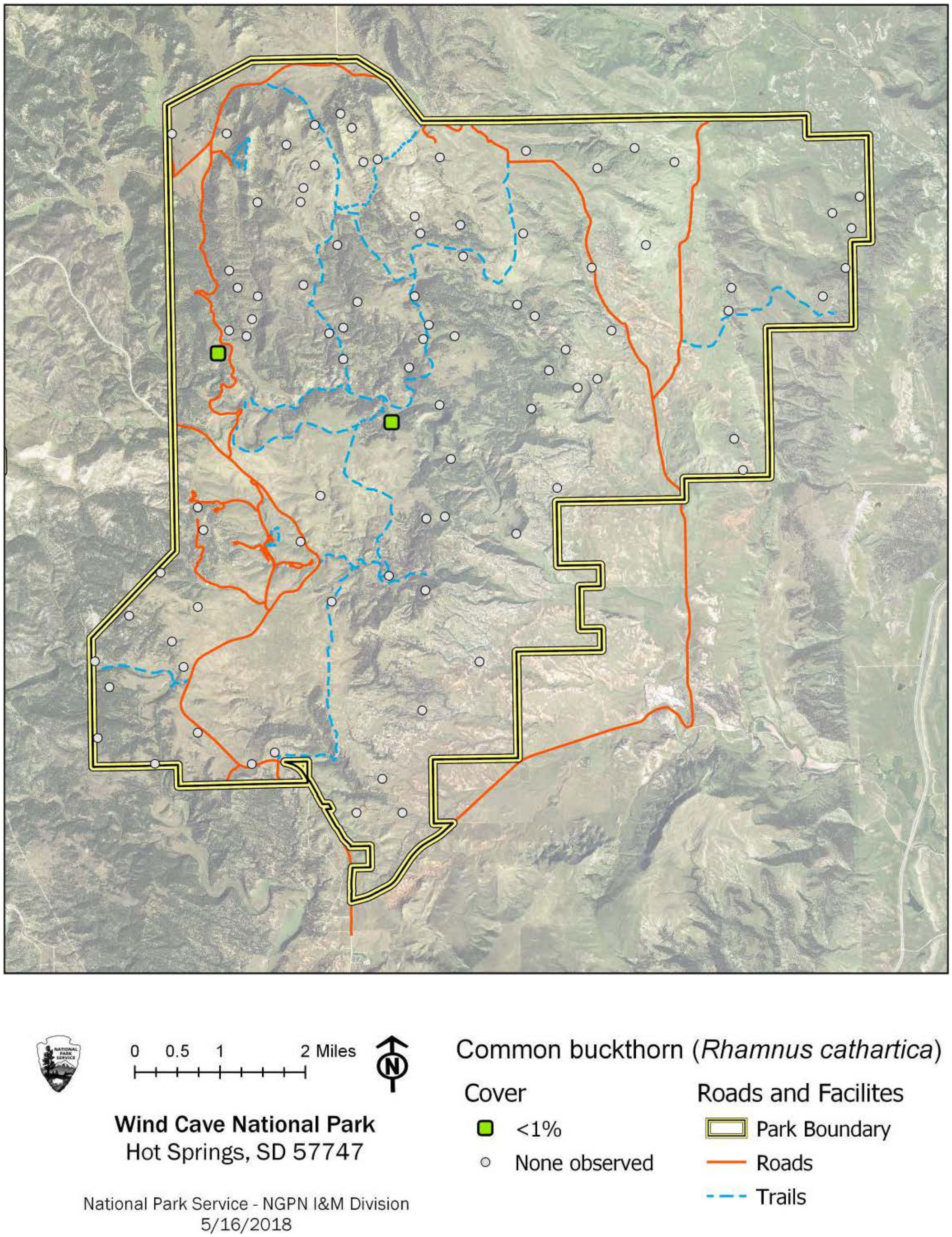

Figure C-4. Map showing common buckthorn sampling plots at Wind Cave National Park.

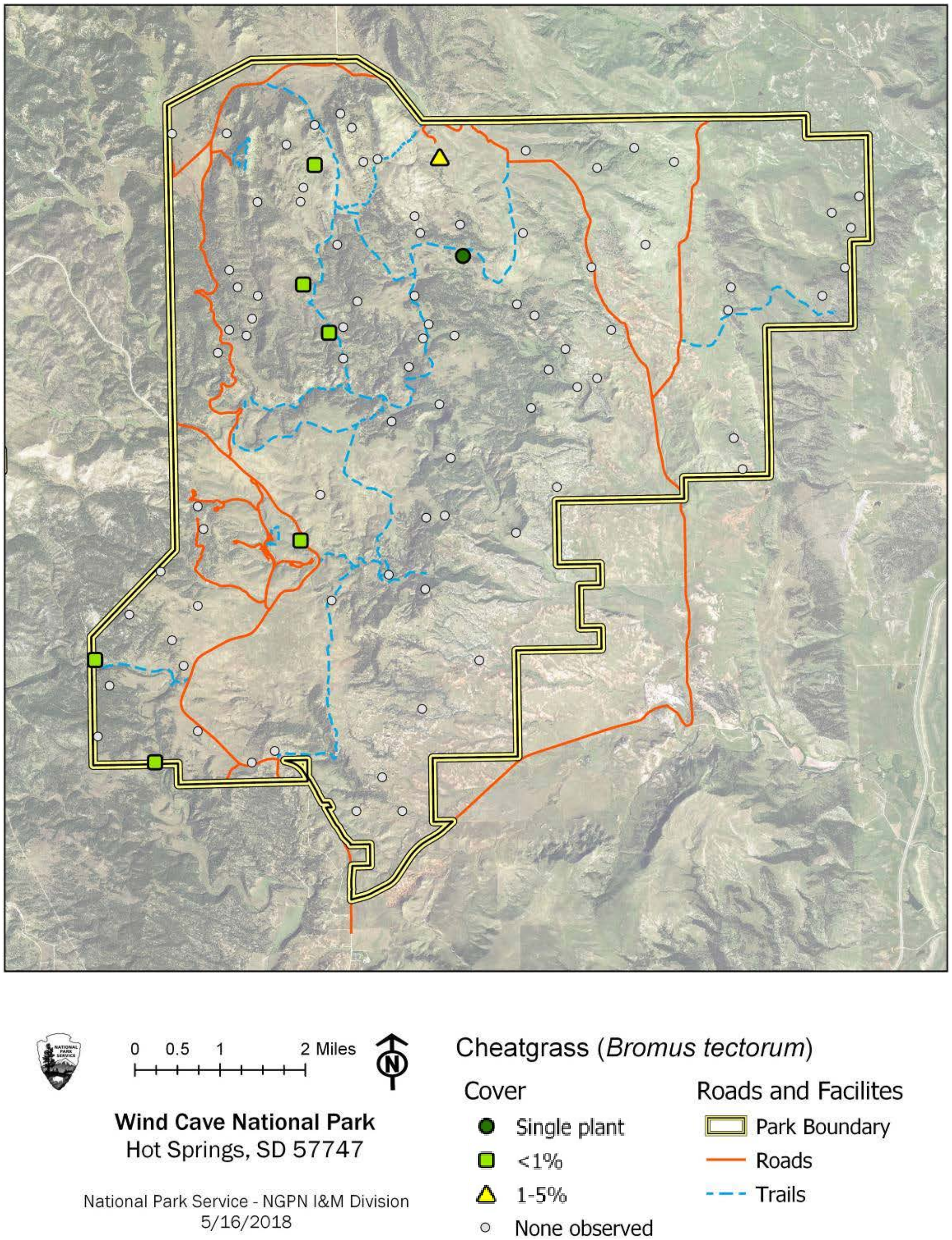

Figure C-5. Map showing cheatgrass sampling plots at Wind Cave National Park.

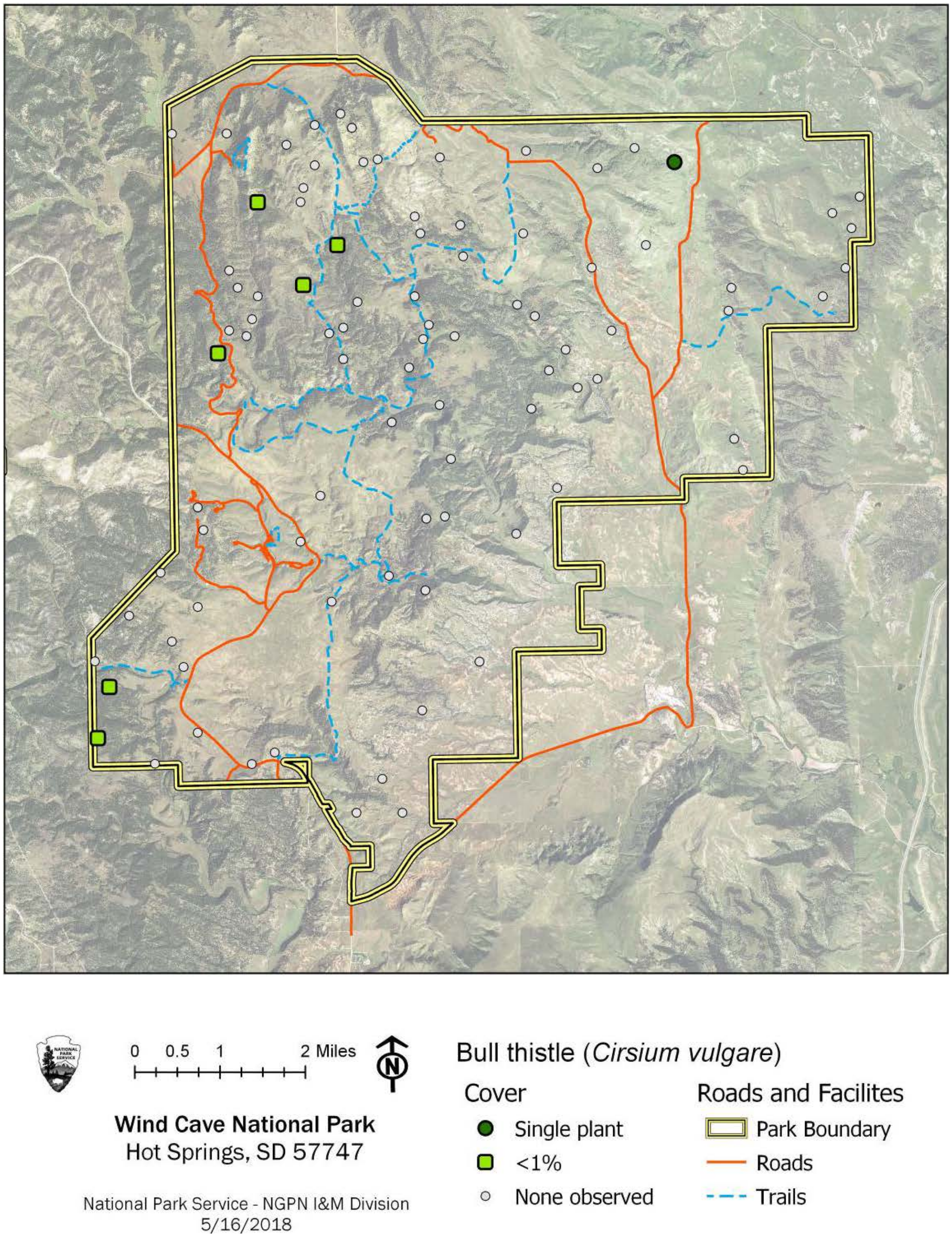

Figure C-6. Map showing bull thistle sampling plots at Wind Cave National Park.

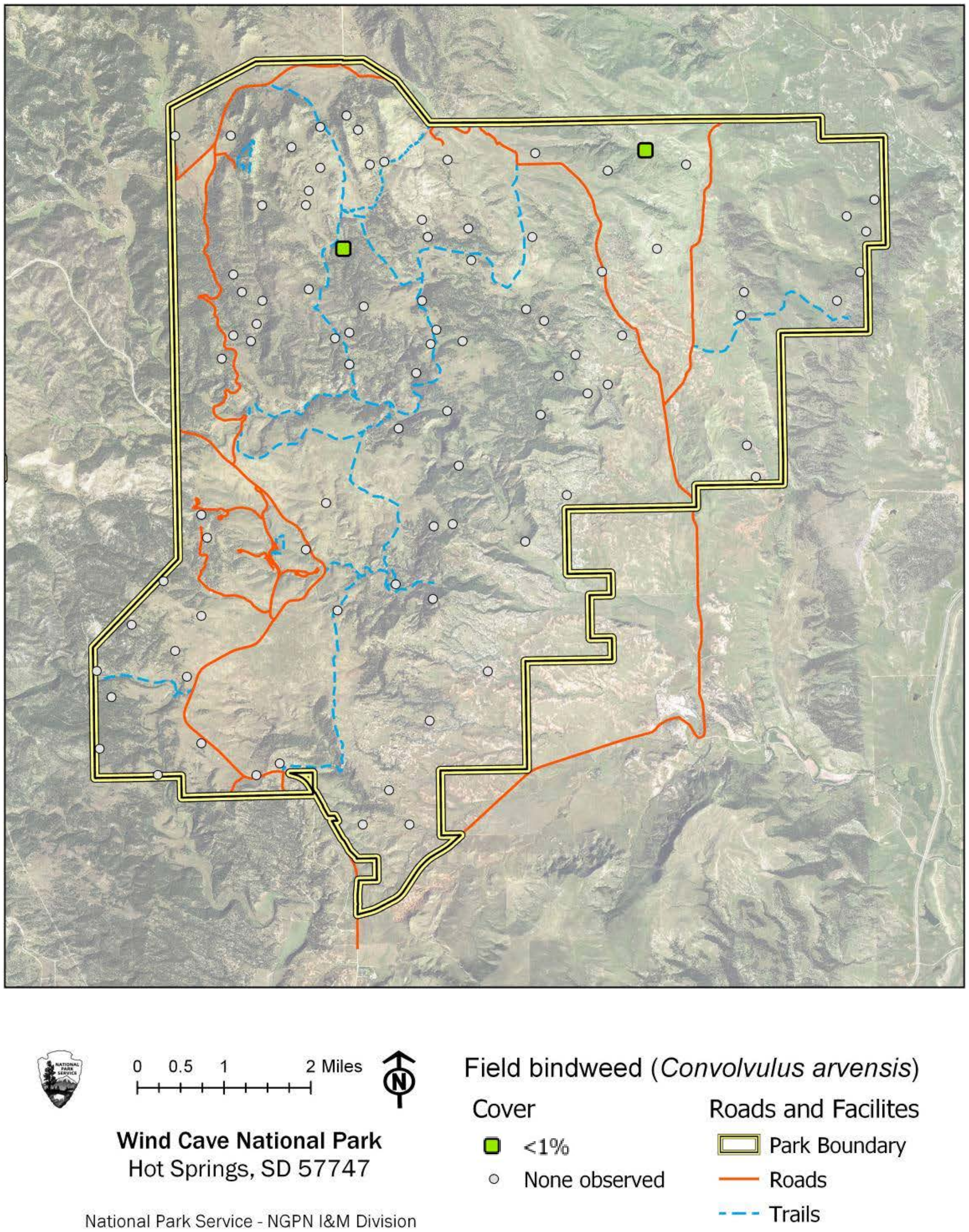

Figure C-7. Map showing field bindweed sampling plots at Wind Cave National Park.

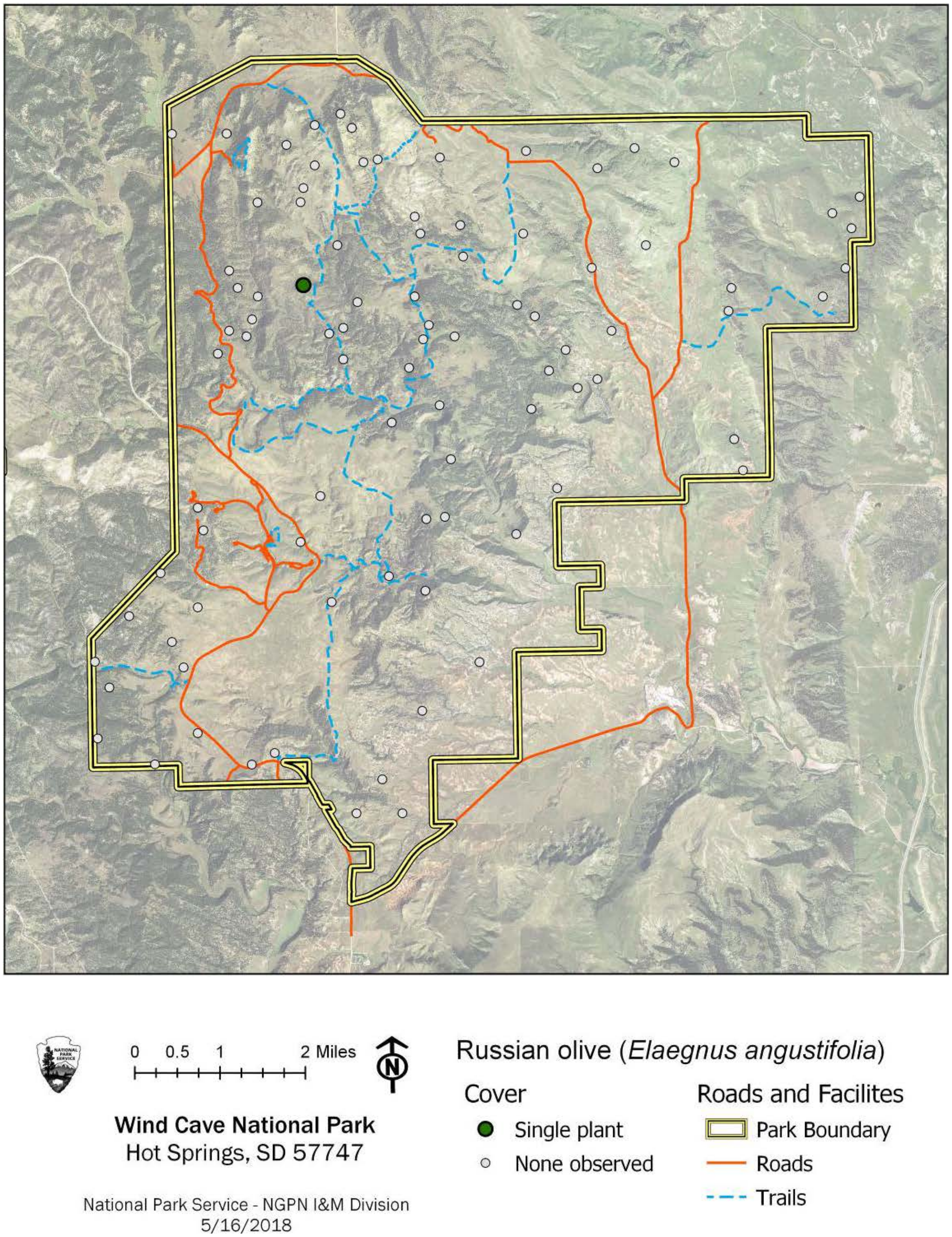

Figure C-8. Map showing Russian olive sampling plots at Wind Cave National Park.

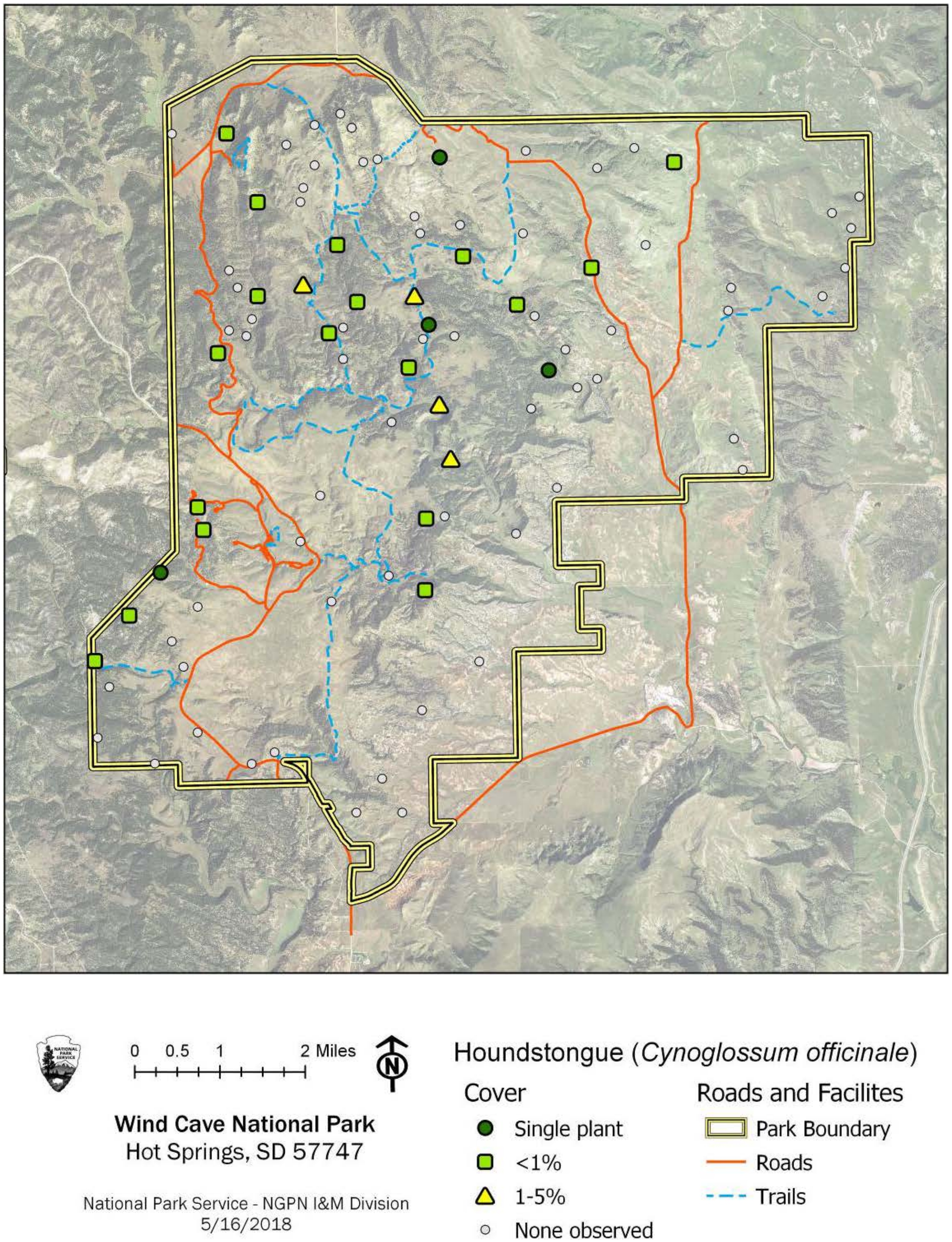

Figure C-9. Map showing houndstongue sampling plots at Wind Cave National Park.

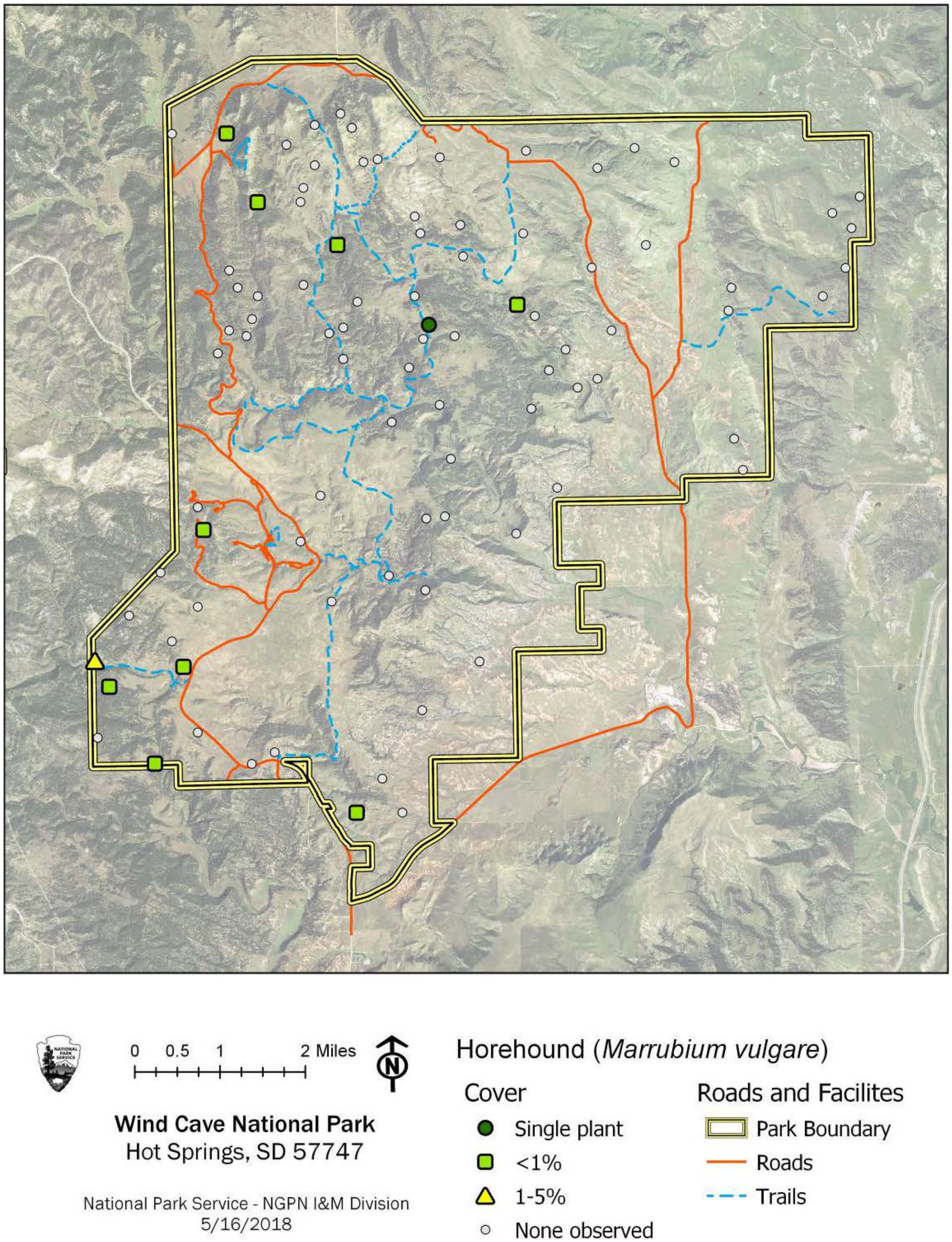

Figure C-10. Map showing horehound sampling plots at Wind Cave National Park.

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