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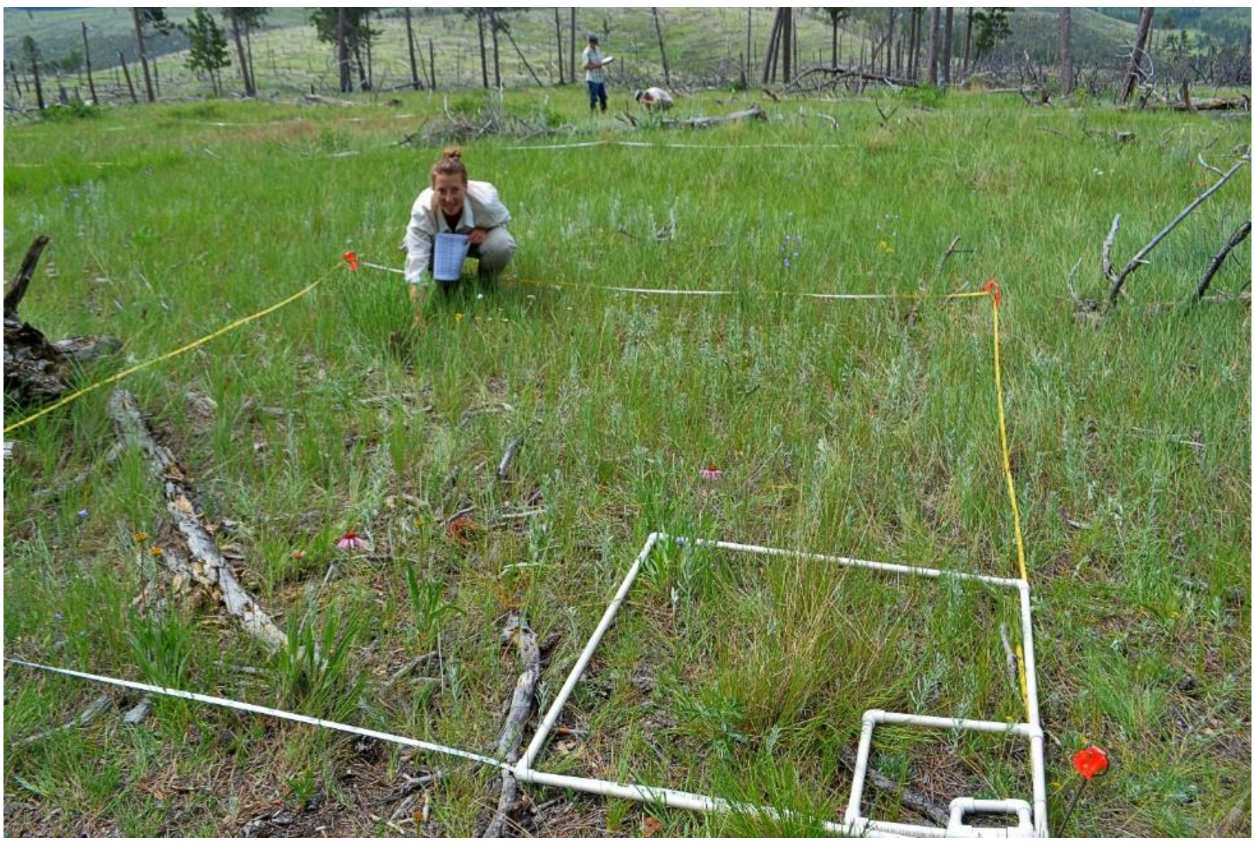
Plant Community Composition and Structure at Jewel Cave National Monument

2011–2017 Summary Report

Natural Resource Report NPS/NGPN/NRR—2018/1642



ON THIS PAGE
A view of the forests in Jewel Cave National Monument, 2015
Photo credit: NPS

ON THE COVER
A member of the Northern Great Plains Inventory & Monitoring Network, Stephanie Rockwood, searches for plant species in a long-term monitoring plot at Jewel Cave National Monument, 2015
Photo credit: NPS

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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

This report presents the results of vegetation monitoring efforts at Jewel Cave National Monument (JECA) by the Northern Great Plains Inventory and Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology Group from 1998-2017. Field crews collected data relating to species richness, herb-layer height, and abundance of individual native and non-native species, ground cover, seedling and tree densities, and site disturbance at 27 plots and across 97 plot visits. We compared our findings to the range of natural variability seen in other grasslands and management targets to develop summaries of natural resource condition (Appendix C). We also explored how key metrics have changed over time from 1998 to 2017. In addition to annual monitoring, we also surveyed forest condition in 2011 and 2016 at 60 randomly located plots. We collected data on tree and seedling density, tree condition, disturbance, and the presence of exotic species of management concern, such as smooth brome and Canada thistle.

Our findings can be summarized as follows: Monitoring crews identified 274 vascular plant species, and overall native plant diversity was in good condition, with an average of 12 native species occurring within any given 1 m^2 quadrat sampled. Grasses and sedges make up the majority of plant cover, and non-native species comprise about 14% of total plant cover. Grasses and sedges were the most commonly observed plants, and slender wheatgrass (*Elymus trachycaulus*), a native species, was the most abundant plant observed with more than 25% absolute cover. Exotic species comprise 14% of total vegetation cover, which exceeds the management target level of 10% or less. The majority of this cover (8.9%) is comprised of Kentucky bluegrass (*Poa pratensis*), a common non-native species in the Black Hills. Species cover and diversity of both native and non-native plants was relatively stable from 2013–2017 with no significant increases or decreases detected.

Forests are dominated by ponderosa pine (*Pinus ponderosa*) trees, which were observed in 77% of forest monitoring plots. Ponderosa pine density in JECA is similar to that of historic forest records, though on average, trees are smaller now than those observed in in the past, likely the result of the Jasper wildfire in 2000 which resulted in the death of approximately 50% of the park's trees. Encouragingly, between 2011 and 2016 we observed an increase in the frequency of plots with ponderosa pine seedlings present as well as an increase in the number of pine seedlings observed in each plot, suggesting that pine forest regeneration is slowly progressing after the fire. The most frequently observed exotic species of management concern in forest plots was Canada thistle (*Cirsium arvense*), occurring in 72% of plots in 2016. Woody fuel loads in the park are high, averaging about 21 tons per acre, which exceeds the fire management program's target range of 2–12 tons per acre. Overall, the park's vegetation seems to be in good condition, though exotic plants pose a significant challenge to park management.

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 JECA for providing logistical support and safety checks, particularly M. Wiles. We thank all the seasonal staff and SCA volunteers at JECA for their help with field work. We also thank H. Baldwin and M. Davis for providing comments on a draft of this manuscript and T. Phillipi for advice on seedling analyses. The NGPN and NGP Fire Ecology field crews collected all of the data included in this report

Introduction

Jewel Cave National Monument (JECA) is located in the southwestern Black Hills and has a mission to preserve Jewel Cave through management of surface and subsurface ecosystems while providing opportunities for the pursuit of scientific interests and public enjoyment (National Park Service 2016). While JECA occupies a relatively small surface area (516 ha, 1274 ac), that land protects diverse native forest and grassland communities (Marriot and Hartment 1986, Ashton et al. 2012b) with ponderosa pine (*Pinus ponderosa*) forests dominating the landscape (Salas and Pucherelli 1998). In 2000, 95% of the monument was burned in the Jasper Fire (National Park Service 2004) and more than 50% of the trees were lost to fire-injury (Lentile et al. 2005).

The Northern Great Plains Fire Ecology Program (NGPFire) began monitoring plant communities in 1998 to better understand and manage the forest in JECA (NGPFire; Wienk et al. 2010). In 2010 JECA was incorporated into the Northern Great Plains Inventory & Monitoring Network (NGPN). At that time, the vegetation monitoring protocols and plot locations being used at JECA were modified to better represent the entire park and to coordinate efforts between NGPN and NGPFire (Symstad et al. 2011). A total of 62 plots were established in JECA by NGPFire and NGPN, and combined sampling efforts began in 2011 (Ashton et al. 2012b). In 2011, 60 plots were monitored to assess forest condition (Ashton et al. 2012a), and this forest condition assessment was repeated in 2016. A subset of plots have been visited annually to better understand forest and herbaceous plant composition and how they change over time and in response to factors like climate, disturbance, and species invasions. In this report, we use data collected from 2013–2017 to assess the current condition of park vegetation, and we use data from 1998–2017 to look at longer-term trends.

Using plant community monitoring data collected over 19 years in JECA, we explore the following questions:

1. What is the current status of understory plant community composition and structure in JECA?
2. What, if any, rare plants were identified in JECA long-term monitoring plots?
3. How has plant community composition and structure changed from 1998 to 2017?
4. What is the current status of forest structure in JECA and how has it changed since 2011?

Methods

The NGPN monitoring protocol (Symstad et al. 2012b, a) has been used to monitor vegetation plots in JECA since 2010. Our methods are briefly described below, and more detail can be found in the full monitoring protocol (https://irma.nps.gov/DataStore/Reference/Profile/2182479).

NGPN and NGPFire Plant Community Monitoring Plots 2011–2017

The NGPN and NGPFire programs implemented a survey to monitor plant community structure and composition in JECA using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using the GRTS design, NGPN selected 15 randomly located sites within JECA (PCM plots; Figure 1).

The NGPN program is scheduled to visit six plant community monitoring (PCM) plots every year using a rotating sampling scheme where three sites were visited in the previous year and three sites are new visits. In a five year interval (e.g., 2011–2015, 2016–2020) all of the PCM plots are visited twice between late June and July (see Appendix A for a detailed list of which plots were visited in each year). When a PCM plot was located within an active burn unit, NGPFire added additional plot visits to those plots, based on a 1, 2, 5, and 10 year resampling schedule. NGPFire also established and monitored three new sites located in active burn units (Fire Plant Community Monitoring plots, FPCM_038, 102 and 134) using the same GRTS sampling schema. Since 2011, NGPN and NGPFire have collected herbaceous vegetation data from 18 permanent plots throughout the park.

Plant community data were collected in rectangular, 50 m × 20 m (0.1 ha), permanent plots (Figure 2). Data on herbaceous plant height (≤ 2 m), ground cover, and plant cover were collected along two 50 m transects (the long sides of the rectangular plot) using a point-intercept method (Figure 3). At 50 locations along each transect (every 1.0 m) a pole was dropped to the ground and all species that touched the pole were recorded, along with ground cover and the height of the top-most plant intercepted (Figure 3). Using this method, absolute canopy cover can be greater than 100% (particularly in wet years and at productive sites) because we record multiple layers of plants. In plots read by NGPN crews, species richness data from the point-intercept method were supplemented with species presence data collected in five sets of nested square quadrats (0.01 m^2, 0.1 m^2, 1 m^2, and 10 m^2) located systematically along each transect (Figure 3). In 2016 we discontinued the use of all but the 1m^2 quadrats, which is the quadrat size most commonly used by vegetation ecologists. This was done to save time while continuing to collect species richness data at the 1 m^2 scale. In this report, we present only the data from the 1 m^2 quadrats.

When woody species were present anywhere within 38 m of the center of a plot, tree regeneration and tall shrub density data were collected within a 10 m radius subplot centered in the larger 50 m × 20 m plot (Figure 2). Trees with diameter at breast height (DBH) greater than 15 cm, located within the entire 0.1 ha plot, were mapped and tagged. For each tree, the species, DBH, status (live or dead), and condition (e.g., leaf-discoloration, insect-damaged, etc.) were recorded. Juniper trees (*Juniperus scopulorum*) and tall shrubs were measured at root collar rather than DBH. Where they were present, dead and downed woody fuel load data were collected at forested plots 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).

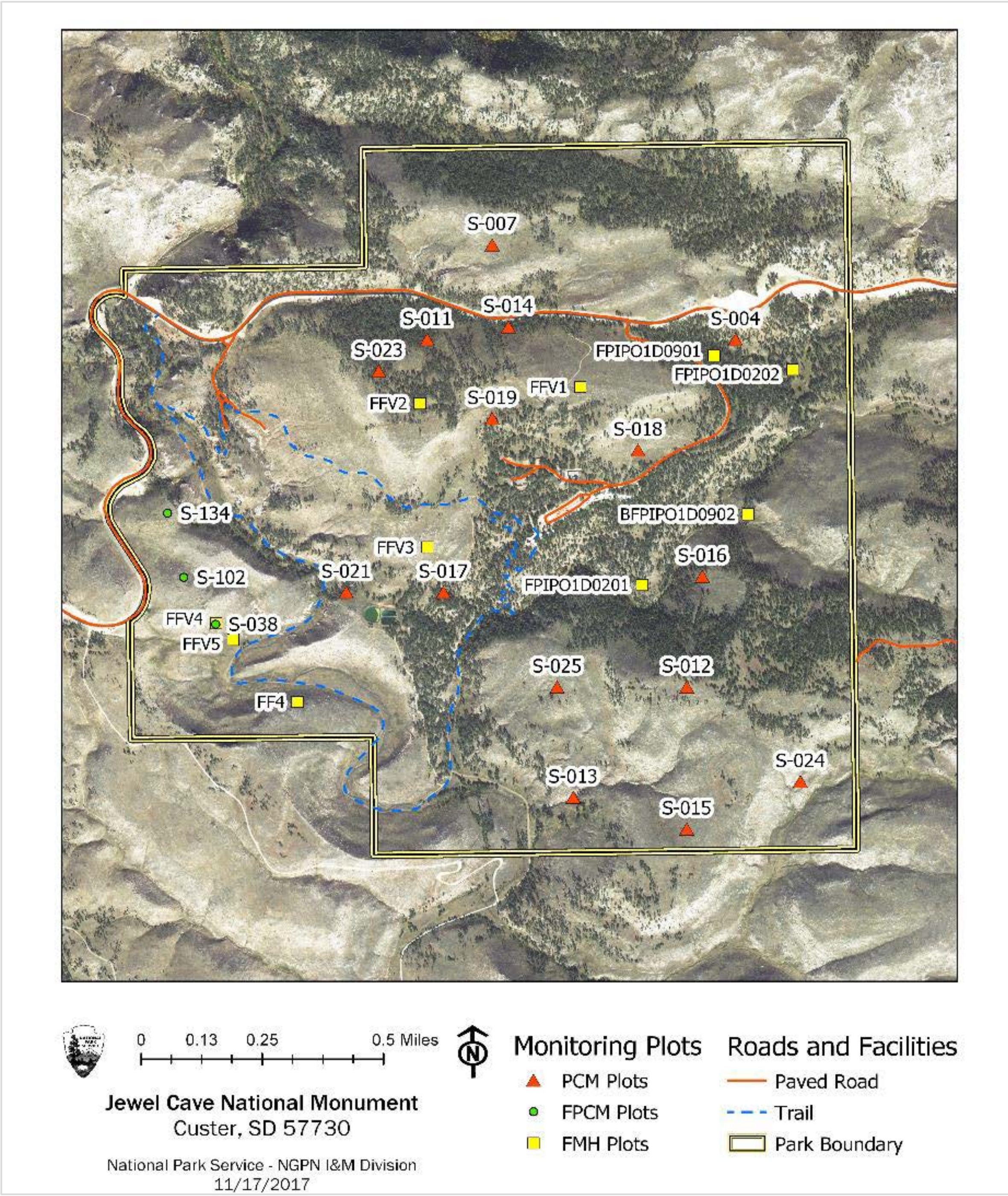


Figure 1. Map of long-term vegetation monitoring plots in Jewel Cave National Monument visited from 1998–2017. Fifteen long-term plots were established by the Northern Great Plains Inventory & Monitoring Program (NGPN) and the Fire Effects Program (NGPFire) between 2011 and 2017 (PCM-orange). Three additional plots were established to better understand the effects of prescribed fire (FPCM-green). Prior to 2011, nine plots were visited as part of fire monitoring efforts (FMH-yellow).

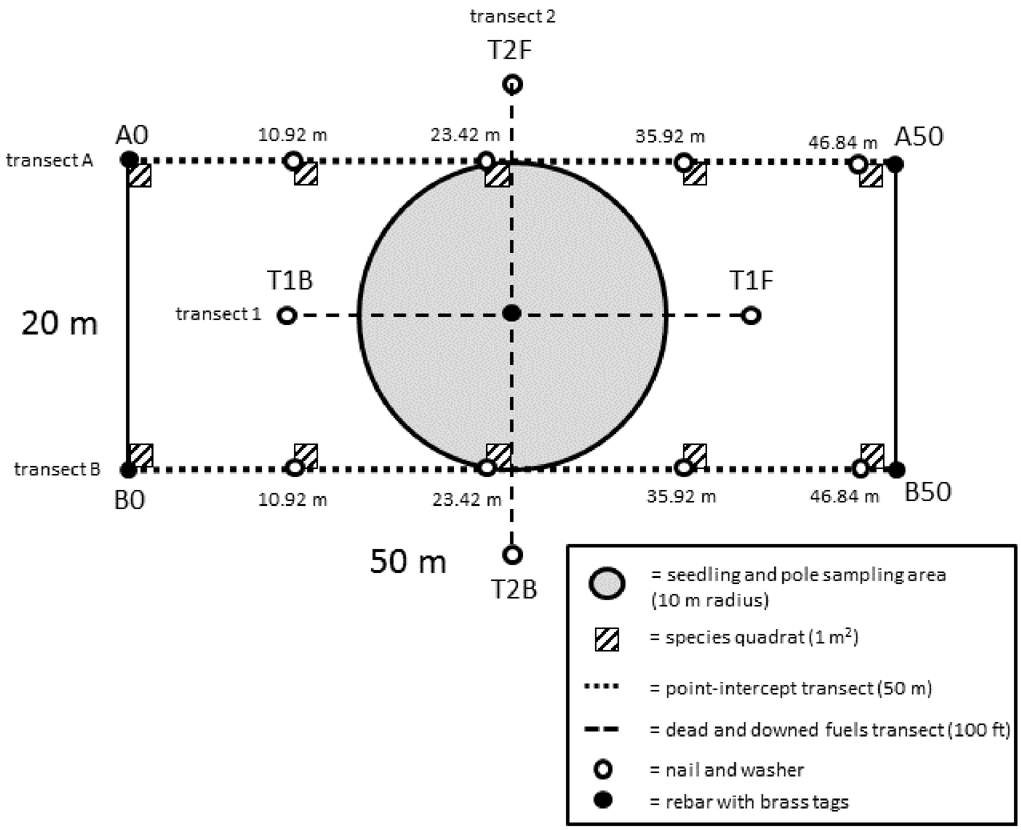


Figure 2. Long-term monitoring plot layout used for sampling vegetation in Jewel Cave National Monument.

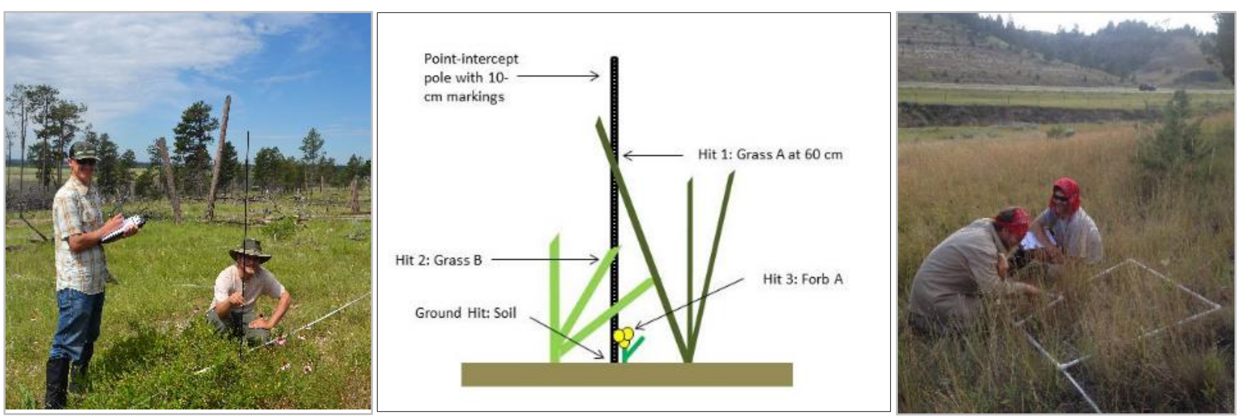


Figure 3. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance.

Photographs of transects were taken from each corner of a plot using standardized methods (e.g., height, distance, camera settings). The same set of photographs are repeated at each visit.

At all PCM plots (not including FPCM plots) we surveyed the area for common disturbances. Common disturbances included rodent mounds, animal trails, erosion, and fire. When disturbances were observed, the type and extent of the disturbances were recorded. We also surveyed all PCM plots for new or recently introduced exotic species that have the potential to spread into the park and cause significant ecological impacts, hereafter referred to as "target species" (Table 1). Target species were chosen with assistance from Midwest Invasive Plant Network (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. The information gathered from this procedure is critical for early detection and rapid response to new or previously undocumented exotic species invasions. However, these data are not sufficient to allow for true mapping of common exotic species in the park.

Table 1. Exotic target species included in surveys at Jewel Cave National Monument as part of the early detection and rapid response program within the Northern Great Plains Network. An asterisk next to a species name indicates the species is on South Dakota's state list of noxious weeds (SD Department of Agriculture 2017).

Scientific Name	Common Name	Habitat
Alliaria petiolata	garlic mustard	Riparian
Polygonum cuspidatum; P. sachalinense; P. × bohemicum	knotweeds	Riparian
Pueraria montana var. *lobata*	kudzu	Riparian
Iris pseudacorus	yellow iris	Riparian
Ailanthus altissima	tree of heaven	Riparian
Lepidium latifolium	perennial pepperweed	Riparian
Arundo donax	giant reed	Riparian
Rhamnus cathartica	common buckthorn	Riparian
Heracleum mantegazzianum	giant hogweed	Riparian
Centaurea solstitialis	yellow star thistle	Upland
Hieracium aurantiacum; H. caespitosum	orange and meadow hawkweed	Upland
Isatis tinctoria	Dyer's woad	Upland
Taeniatherum caput-medusae	medusahead	Upland
Chondrilla juncea	rush skeletonweed	Upland
Gypsophila paniculata	baby's breath	Upland
*Centaurea virgata *; C.diffusa **	Knapweeds*	Upland
Linaria dalmatica; L. vulgaris	toadflax	Upland
Euphorbia myrsinites & *E. cyparissias*	myrtle spurge	Upland
Dipsacus fullonum & *D. laciniatus*	common teasel	Upland
Salvia aethiopis	Mediterranean sage	Upland
Ventenata dubia	African wiregrass	Upland

Other Monitoring Plots (1998–2013)

In 1998, NGPFire began monitoring plots within JECA to evaluate the effectiveness of prescribed burns. Data collection followed the NPS National Fire Ecology Program protocols (National Park Service 2003). In grassland plots, vegetation cover and height data were collected using a point-intercept method, with 100 points evenly distributed along a single 30 m transect. In forested sites, plots were 0.1 ha (20 × 50 m) in size and point-intercept data were collected along the two 50 m sides. For each live tree with a DBH > 15 cm located within the 0.1 ha plot, the species and DBH were recorded. The densities of smaller trees (2.54 cm ≤ DBH ≤ 15 cm) were measured within a subset of the plot area. NGPFire plot locations were located randomly within major vegetation types in areas planned for prescribed burning (burn units) in the near future. The plots were then sampled 1, 2, 5, and 10 years after a prescribed burn. Hereafter, we refer to these plots as Fire Monitoring Handbook (FMH) plots (Figure 1). These FMH plots are being retired after the 10 year visit (permanent markers will be removed) and replaced with the FPCM plots described above.

NGPN and NGPFire Forest Structure Plots 2011 & 2016

In 2011 and 2016, a repeated survey was completed by NGPN and NGPFire using a set of 60 forested sites in JECA (Figure 4). The goal of this survey was to assess status and trends in forest condition. The forest survey will be repeated every five years (e.g., 2016, 2021, 2026, and so on). The site locations were selected from within JECA using the same GRTS sampling scheme described above for plant community monitoring plots and 16 of the plots were used for both plant community monitoring and the forest survey.

The methods used for forest structure surveys were similar to those previously described for plant community monitoring plots. Data were collected for tree density and condition, seedling density, disturbance type and extent, and target species cover. There were some important differences between plant community and forest structure protocols. In forest structure plots (1) the plot size was smaller and tree measurements were only collected within a 10 m radius around plot center (Figure 2; only the seedling and pole sampling area). If there were fewer than 5 trees or poles, the plot radius was extended to 20 m and all trees (but not poles or seedlings) within the larger area were measured; (2) trees were not tagged; (3) neither point-intercept nor 1 m^2 quadrat data were collected; (4) disturbances and target species were measured when they were located within a 50 ft radius of the center (Figure 2; Transect 1 and 2 are the diameters of the circle); and (5) target species included additional early detection species (Table 1) and more widespread exotic species that were identified as management concerns (Table 2).

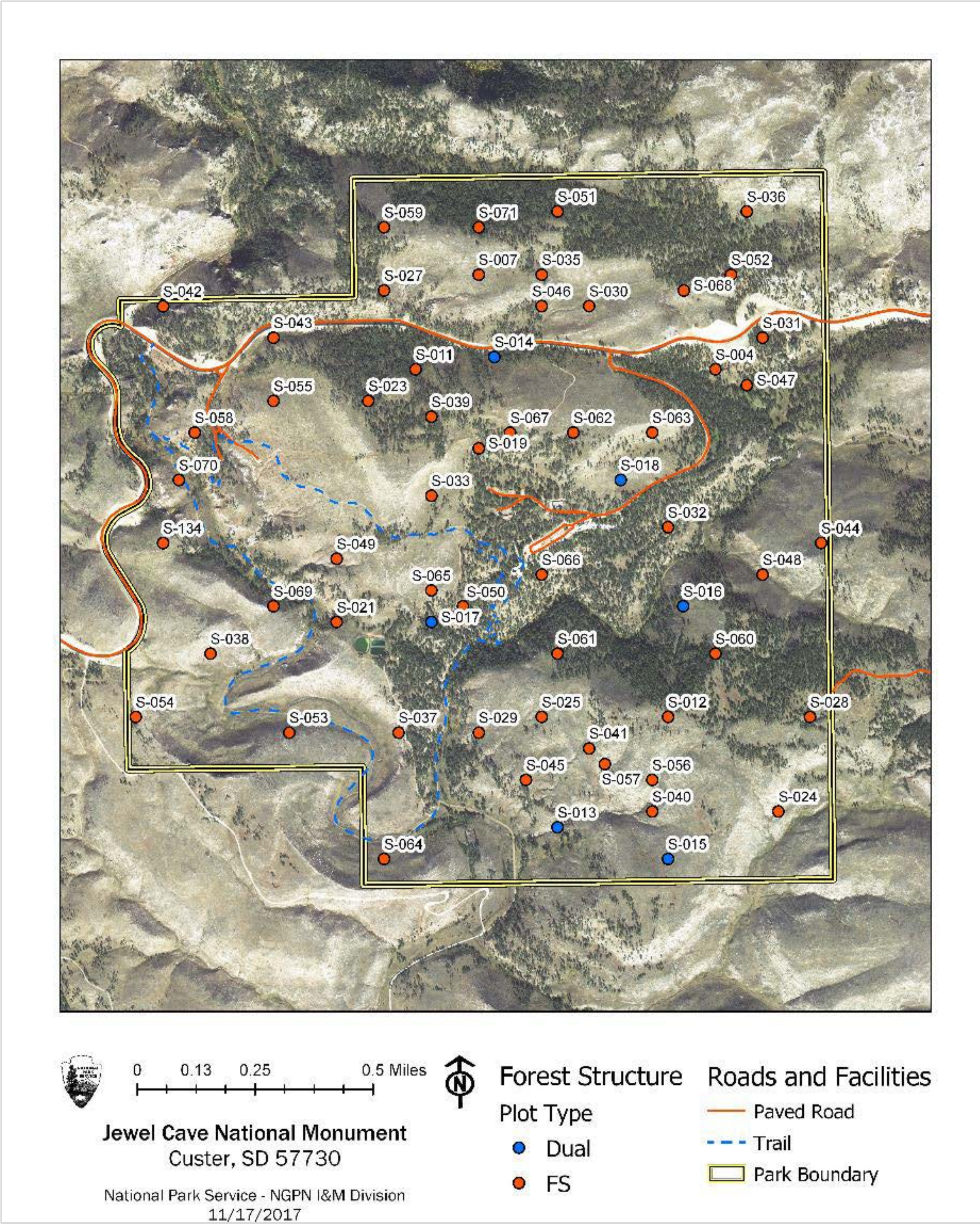


Figure 4. Map of long-term forest structure monitoring plots in Jewel Cave National Monument visited in 2011 and 2016. There are 54 forest structure plots (red) and 6 dual plots (blue). The dual plots are larger (0.1 ha) and both the herbaceous community and forest structure are monitored.

Table 2. Exotic species included in early detection surveys Jewel Cave National Monument during 2016 forest monitoring. In the SD Status 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.

Scientific Name	Common Name	SD Status
Heracleum mantegazzianum	giant hogweed	–
Arctium minus	common burdock	–
Artemisia absinthium	absinth wormwood	–
Carduus nutans	musk thistle	–
Cirsium arvense	Canada thistle	Noxious
Cirsium vulgare	bull thistle	–
Onopordum acanthium	Scotch thistle	–
Rhaponticum repens	Russian knapweed/hardheads	–
Tanacetum vulgare	common tansy	Noxious-Custer
Cynoglossum officinale	Houndstongue	–
Hypericum perforatum	common St Johnswort	Noxious-Custer
Elaeagnus angustifolia	Russian olive	–
Euphorbia esula	leafy spurge	Noxious
Bromus inermis	smooth brome	–
Bromus japonicus	Japanese brome	–
Bromus tectorum	Cheatgrass	–
Verbascum thapsus	common mullein	–
Hyoscyamus niger	black henbane	Noxious-Custer
Tamarix ssp.	salt cedar	Noxious

Canyons Prescribed Fire

The Canyons prescribed fire was completed October 24, 2014 by an interagency effort between the National Park Service and the US Forest Service. Two hundred acres of the unit fell within the west and southwest portion of JECA, and 74 acres were within the Hell Canyon Ranger District, resulting in a total of 274 burned acres (Figure 5). The cooperative effort allowed for simplified logistics, as roads within Forest Service lands could be used as control lines.

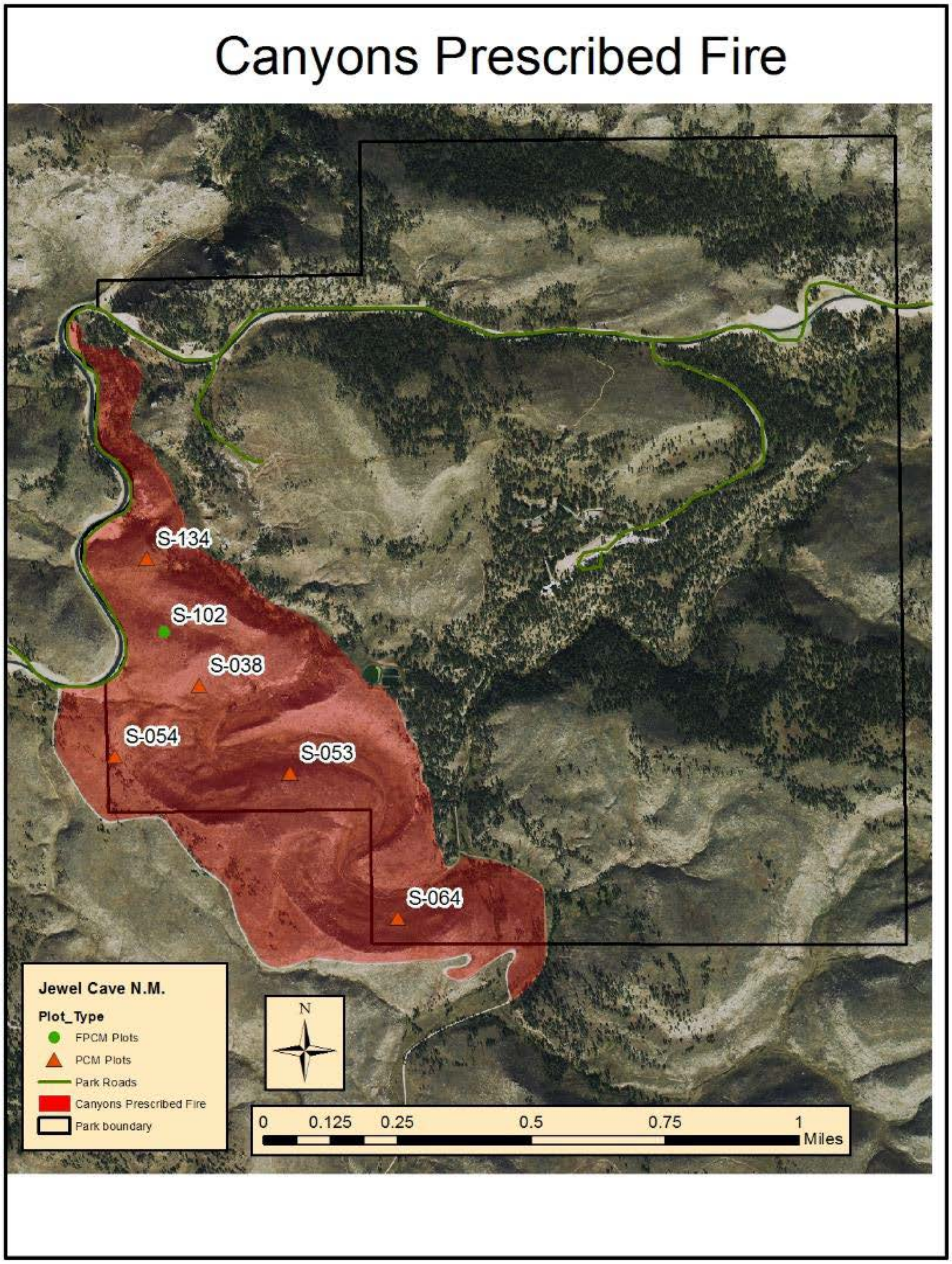


Figure 5. Map of six monitoring plots within the 274 acre Canyons unit in Jewel Cave National Monument and the Black Hills National Forest

Prior to 2000, the unit was dominated by a thick ponderosa pine forest; however, the Jasper wildland fire on August 25 of that year left most of the trees dead. The intervening 14 years have seen most of the snags fall, extremely limited pine regeneration, and the unit now resembles a mixed-grass prairie with a significant slash (woody debris) component. Prior to the prescribed burn, total dead & down fuel loading in the unit averaged over 28 tons per acre, which is approximately 3 times higher than what is expected in a ponderosa pine forest ecosystem that is functioning within its historical fire regime. Approximately 62% of this loading is within the 1000-hr fuel class. Live ponderosa pine forest exists in some areas of the unit, particularly in the bottom of Hell Canyon. These areas also contain heavy fuel loads. The primary objective for the fire was to reduce 1000-hour fuel loading by 40% or greater and total fuel loading by 50% or greater. A secondary objective was to burn at least 70% of the project area to produce a nutrient flush and to encourage growth of native species. Six monitoring plots (five PCM and one FPCM) were read prior to the prescribed fire in 2011 in association with the park-wide forest structure survey. Three monitoring plots (FPCM-102, PCM-038, and PCM-134) were reread in 2014 prior to the anticipated Canyons prescribed fire to gather the most current downed woody fuels data. Following the Canyons prescribed fire (Figure 6), all six monitoring plots had immediate post-burn surveys on October 29 & 30 to assess changes to downed woody fuel loading and burn severity.

Figure 6. Canyons prescribed fire at Jewel Cave National Monument showing heavy fuels burning into the evening hours.

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.

Scientific names, codes, and common names for plant species were obtained from the USDA Plants Database (USDA-NRCS 2017). To ensure the most current nomenclature was being used, scientific names were cross-referenced with the Integrated Taxonomic Information System (ITIS;http://www.itis.gov) (ITIS 2018) database. In the few cases where ITIS recognized a new scientific name that was not in the USDA PLANTS database, the new name was used, and a unique plant code was assigned for that species. This report uses common names after the first occurrence in the text, but scientific names can be found in Appendix B.

After data were entered, 100% of records were verified to the original data sheet to minimize transcription errors, and 10% of 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 historic monitoring data. The data in this report are the most accurate to date. Where there are discrepancies between this report and older data reports (e.g. Ashton et al. 2012a, Ashton et al. 2012b, Ashton et al. 2013, Prowatzke and Wilson 2015, Rockwood 2017), it should be assumed that the data presented in this report are correct. The data are available to the public at: https://irma.nps.gov/DataStore/Reference/Profile/2238101.

The complete list of species that NGPN observed in JECA was cross-referenced with the certified list of plant species known to occur in JECA (https://irma.nps.gov/NPSpecies/Search/SpeciesList/JECA). In the field, when a species identified by NGPN was not on the certified park list and specimen collection was possible, a voucher specimen was sent to botanists for independent verification. In some cases, a mismatch between the certified list and the field data was not found until after the data were collected. In these cases, professional judgement was used to determine whether the species is likely to be a new addition to the park flora or simply a misidentification. In the case of misidentification, the species entry was changed in the database to an unknown species or to a genus-level record.

Plant life forms (e.g., tree, shrub, forb, graminoid) were based on definitions from the USDA Plants Database (USDA-NRCS 2017). The conservation status rank of plant species in South Dakota was determined by cross-referencing the list of species observed by NGPN with conservation status lists for South Dakota (https://gfp.sd.gov/rare-plants/), Wyoming (https://www.uwyo.edu/ wyndd/species-of-concern/plants/), and a list of rare species of the Black Hills compiled by the US Forest Service. For the purpose of this report, a species was considered rare if its conservation status rank was critically imperiled (S1/G1), imperiled (S2/G2), or vulnerable (S3/G3) (Table 3). Noxious weed designations are maintained by the South Dakota Department of Agriculture (https://sdda.sd.gov/ag-services/weed-and-pest-control/weed-pest-control/sd-state-noxious-weed-declared-pest-list-and-distribution-maps/) and are identified in the Appendix B species list.

Table 3. Definitions of state and global species conservation status ranks.

Status Rank*	Category	Definition
S1/G1	Critically imperiled	Due to extreme rarity (5 or fewer occurrences) or other factor(s) making it especially vulnerable to extirpation.
S2/G2	Imperiled	Due to rarity resulting from a very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation.
S3/G3	Vulnerable	Due to a restricted range, relatively few populations (often 80 or fewer), recent widespread declines, or other factors making it vulnerable to extirpation.
S4/G4	Apparently secure	Uncommon but not rare; some cause for concern due to declines or other factors.
S5/G5	Secure	Common, widespread and abundant.
S#S#/ G#G#	Range rank (e.g., S2S3)	Used to indicate uncertainty about the status of the species or community. Ranges cannot skip more than one rank.
SNR/SUR	Rank undetermined	Species either not ranked in this state (SNR) or under review (SUR) for status classification

* Adapted from NatureServe status assessment table (http://www.natureserve.org/conservation-tools/conservation-status-assessment).

A number of vegetation metrics were calculated from our data, including: species richness, absolute herbaceous cover, relative cover, and an index of beta-diversity. Absolute cover was calculated using point-intercept data and was the total number of vegetation intercepts out of 100 possible intercepts. This value is often greater than 100% because more than one species can be intercepted per point due to overlapping vegetation. Relative cover was calculated by dividing the absolute cover of the species or grouping of interest (e.g., native forbs) by the total absolute cover. Relative cover is therefore constrained between 0 and 100%. Species richness is simply a count of the species recorded in an area, and is reported as the number of species (or grouping of interest) intercepted along two 50 m transects or the average number of species observed in ten 1 m^2 quadrats within a plot. Beta-diversity was calculated as the total number of species observed in ten 1 m^2 quadrats divided by the average number of species observed within the quadrats. Larger beta-diversity index values indicate that there is greater heterogeneity among the 1m^2 quadrats.

Forest structure metrics include measures of tree density and basal area. Plot sizes varied across the dataset and were dependent upon visit type and tree size classes being measures as described in the field methods above. Poles were counted and measured in a 0.0314 ha area during all plot visits. Trees were counted and measured in a 0.1 ha, 0.1256 ha, or 0.0314 area depending on the visit type and density of trees. 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). We standardized to the smallest area (0.0314 ha) for analyses to reduce variability from year to year. Basal area is the area that is occupied by the cross-section of tree trunks and reported as square meters per hectare. For our calculations of basal area, we included all live trees greater than 2.4 cm DBH. Densities were calculated separately for each tree size class (pole, tree, and seedling). 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. Snag density was calculated as the number of standing dead trees per unit area (dead poles are not included). 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). For many forest metrics, it was necessary to log-transform (log +1) data prior to analysis to better meet the assumptions of the models. Trends were tested using linear mixed models with plots and years as a random factor using R software. Trends were examined over the period from 2000 to 2017 because there were low samples sizes in the 1998 data and the Jasper fire in 2000 caused large changes in park ecosystems. Model effects were considered significant when the *P* value was <0.05. For forest surveys, models were run to test for differences between 2011 and 2016 data, and the years with reduced sample sizes (all other years) were not included in forest data statistical models. Seedling data were analyzed by species using estimated densities based on raw counts, and only plots with seedlings were included in the model.

Results and Discussion

Status of plant community composition and structure

There are 553 plant species on the JECA species list, and we identified 274 species (42 of these were exotic) in monitoring plots from 1998–2017 (Appendix B). The most commonly observed species in the monitoring plots at JECA were graminoids (grasses, rushes, and sedges). Slender wheatgrass (*Elymus trachycaulus*), Kentucky bluegrass (*Poa pratensis*), prairie Junegrass (*Koeleria macrantha*), and sun sedge (*Carex inops*) were recorded at more than 30 site visits between 2013 and 2017 (Figure 7). The small shrub western snowberry (*Symphoricarpos occidentalis),* and two forbs, American vetch (*Vicia americana*) and common yarrow (*Achillea millefolium*), were also common.

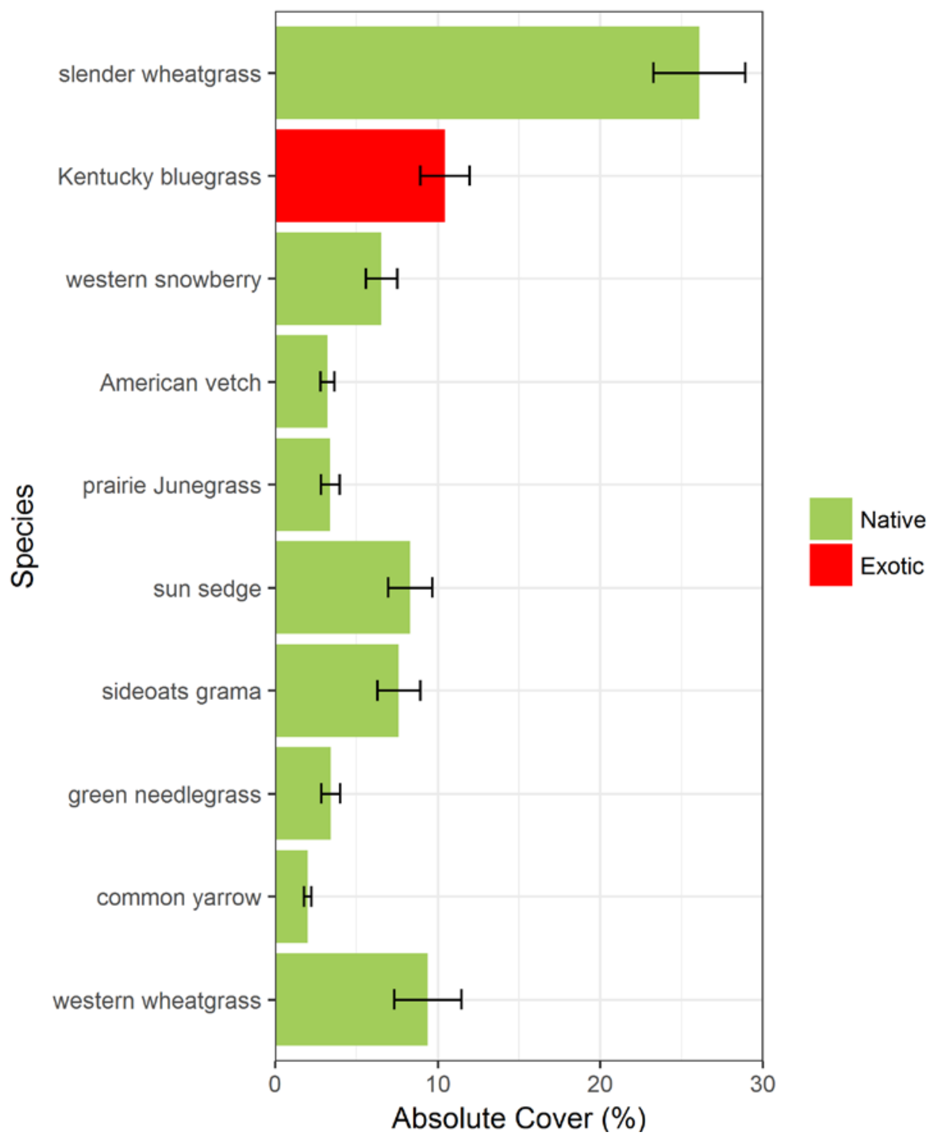


Figure 7. The average absolute cover of the 10 most common native (green) and exotic (red) plants recorded in Jewel Cave National Monument from 2013–2017. The species are in rank order with the most commonly encountered species at the top of the graph. Bars represent mean ± one standard error.

Average relative cover of exotic species at JECA was 14.0 % from 2013–2017 (Table 4), which is greater than the exotic species management target level of 10% or less (Appendix C). Much of this cover was comprised of exotic perennial grasses, which averaged 10.2 % (Table 4). Kentucky bluegrass was particularly abundant (averaging 8.9%), but smooth brome (*Bromus inermis*) also contributed to the perennial exotic grass cover and was observed in 16 plot visits. Other exotic forbs, such as Canada thistle (*Cirsium arvense*) and yellow salsify (*Tragopogon dubius*) were fairly common in the park but made up much less of the total herbaceous cover.

Table 4. Average plant cover by growth form and nativity in long-term monitoring plots at Jewel Cave National Monument 2013–2017. Averages are across 21 plots.

Variable	mean	se	min	Max
Absolute herbaceous cover	105.7	6.10	58	155
Native graminoid relative cover (%)	49.3	4.64	1.3	87.9
Native forb and subshrub relative cover (%)	19.4	2.07	6.0	36.3
Native shrub relative cover (%)	16.7	4.43	0.7	79.8
Total exotic species relative cover (%)	14.0	1.78	4.9	33.5
Exotic perennial graminoid relative cover (%)	10.2	1.61	1.1	24.5
Exotic annual graminoid relative cover (%)	0.6	0.25	0	5.1
Other exotics relative cover (%)	1.5	0.42	0	7.0

Examining the status and trends of a park's native plant diversity and species evenness is one of the ways the NPS measures the effectiveness of management actions directed at achieving the Park Service mission of preserving ecological integrity. Species richness in the mixed-grass prairie is influenced by many factors, including fire regime, grazing, animal-caused disturbances, and weather fluctuations (Symstad and Jonas 2011). Average native species richness has been measured at monitoring plots throughout JECA using species presence observations in 1 m^2 quadrats and point-intercept measurements. In the last 5 years of monitoring, average native species richness was 10 species m^{-2} and on average we identified 19 native species along two 50 m transects at each plot (Table 5). While native graminoids make up most of the total plant cover in plots (49%; Table 4), much of the species richness comes from native forbs and subshrubs (Table 5). One of the plots with the most native species in the park (PCM_014; Figure 1) is located on a north facing slope by US Route 16 (Figure 1), and in 2016 we identified an average of 15.2 native species m^{-2} at this site. Another diverse plot, PCM_013, is in the southern portion of the park (Figure 1). In 2016, 35 native species were identified along point-intercept transects at this plot, and average quadrat richness was 13.8 species m^{-2} (Figure 8).

There are no long-term records of mixed-grass prairie diversity within the Black Hills, but records of species diversity in mostly undisturbed eastern Montana mixed-grass prairie varied between 8 and 18 species per square meter (10–90th percentile range) over the course of 13 years from 1933 to 1945 (Symstad and Jonas 2014). Compared to this nearby mixed-grass prairie, species diversity in JECA is within the historic range (Table 5), suggesting vegetation diversity is in good condition (Appendix C). Future work is needed to develop a robust reference condition for plant communities in the Black Hills.

Table 5. Average species richness in long-term monitoring plots at Jewel Cave National Monument (2013–2017). Richness values are the number of unique species observed along two 50 m transects (Transect Richness) or in ten 1 m^2 quads (Quadrat [1 m^2] Richness) averaged across the number of plots visited ± 1 standard error of the mean.

Unit	Plots	Total Richness	Native Richness	Native Graminoid Richness	Native Forb & Subshrub Richness	All Quads Native Richness	Beta-Richness
Transect Richness	21	22.2 ± 1.24	19.0 ± 1.16	7.1 ± 0.54	9.0 ± 0.66	Na	na
Quadrat (1 m^2) Richness	15	11.6 ± 0.59	10.1 ± 0.49	2.9 ± 0.26	5.7 ± 0.35	38.4 ± 2.19	3.4 ± 0.17

Figure 8. A photograph of the long-term monitoring plot, PCM_013, with the highest average native species diversity in Jewel Cave National Monument. In 2016, we identified 35 native species along the two 50m transects.

Disturbance is often linked to changes in native species richness and exotic species cover, but we did not find any significant relationships between the disturbances we recorded and vegetation condition in our dataset. We performed a brief assessment of disturbance at each plot, and observed a large degree of variation in the extent and type of disturbances across plots. The most common source of disturbance was fire, and evidence from the Jasper fire or more recent prescribed fires was observed in 63 plots. Small mammal activity was the next most commonly observed disturbance, but was only recorded in 15 plots. Other disturbances such as visible animal trails, wind damage, erosion, and roads were recorded in just a handful of plots. Over time, we hope our data can better elucidate patterns between species richness, exotic cover, and disturbance.

Rare Plants

While our monitoring protocol was not specifically designed to survey rare plants or to detect changes in their populations over time, we occasionally identify rare species in our plots. We observed three plant species of conservation concern in long-term monitoring plots in JECA (Table 6). All three of these species are rare in the Black Hills of Wyoming, but not in South Dakota where JECA is located. However, plants generally do not recognize political boundaries so these species are discussed here. Definitions of conservation ranks can be found in Table 3.

Table 6. Rare plant species observed in long-term monitoring plots in Jewel Cave National Monument.

Scientific Name	Common Name	Status	Number of unique plot observations
Pellaea atropurpurea	Purple cliffbrake	WY-S1 / SD-SNR / G5	1
Sporobolus heterolepis	Prairie dropseed	WY-S1 / SD-SUR / G5	6
Carex richardsonii	Richardson's sedge	WY-S2 / SD-S4 / G5	10

Purple cliffbrake (*Pellaea atropurpurea*), a critically imperiled species in Wyoming, was observed at one plot in 2011 and again at the same plot in 2015. Purple cliffbrake is a small perennial evergreen fern that is typically found growing in the cracks of sedimentary rocks (Dorn 2001). This plant is distributed across the southwestern, midwestern, and eastern mountain regions of the US, and reaches the end of its northwestern US extent in the Black Hills (USDA-NRCS 2018). This species is considered globally secure and the most common threat to this plant is habitat alteration resulting from limestone quarrying (NatureServe 2018).

Prairie dropseed (*Sporobolus heterolepis*), another critically imperiled species in Wyoming, was observed at six separate plots from 2012 to 2017. Prairie dropseed is a perennial bunchgrass that can be locally abundant in open pine forests and meadows of the Black Hills (Larson and Johnson 2007). Its main distribution in the United States is across North Dakota, Minnesota, Wisconsin, and Illinois, and reaches the end of its western extent in Wyoming and along the Rocky Mountains (USDA-NRCS 2018). This species is sensitive to grazing (Larson and Johnson 2007), succession, and land-use conversion (NatureServe 2018).

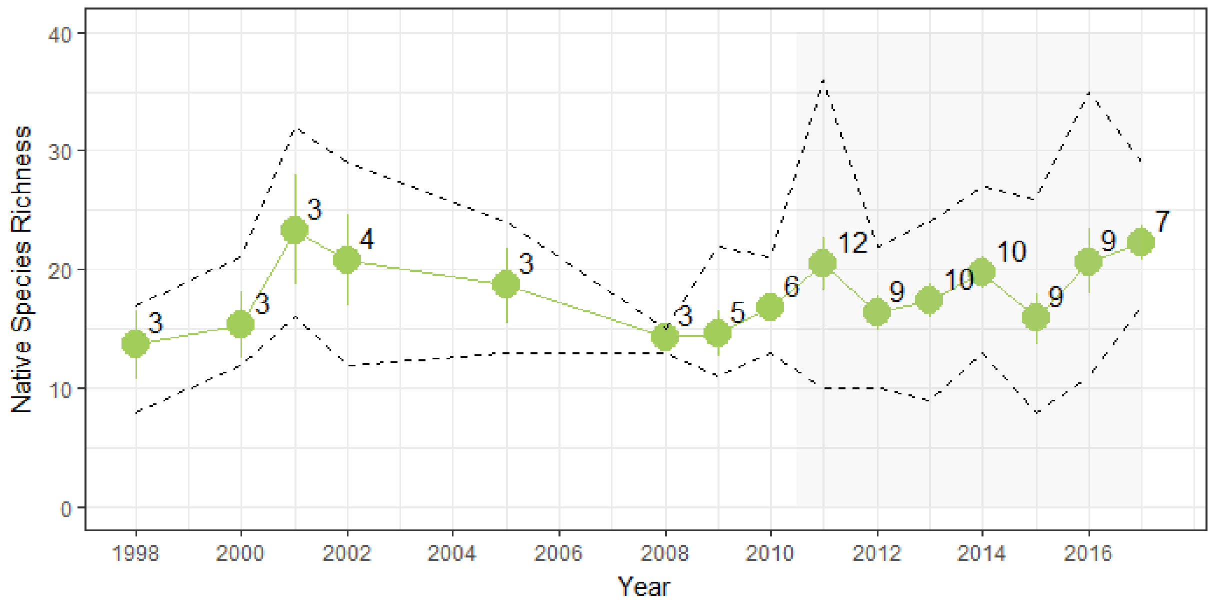
Carex richarsonii (Richardson's sedge) is an imperiled species in Wyoming and was observed at 10 plots from 2011 to 2016. This low-growing perennial sedge is widespread and common in Canadian territories along the US border, and rare in the US (NatureServe 2018, USDA-NRCS 2018), with the exception of populations in the Black Hills where it is relatively common (Larson and Johnson 2007, NatureServe 2018). This species is of conservation concern largely due to the geographic isolation of these Black Hills populations.

Trends in vegetation community composition and structure

Using the 2013–2017 dataset as a baseline for plant community conditions, we found that JECA has high native species richness (Table 5, Appendix C). We were interested in determining whether there have been changes in key metrics since 2000 (1998 and 1999 are included in the graphs, but not in the statistical summaries because of the large changes since the Jasper Fire). While there was annual varibility in native species richness and the relative cover of native graminoids (Figure 9), there was no significant change over time ($F_{1,12}$=0.5, P=0.4763 and $F_{1,12}$=0.6, P=0.4713, respectively). Nor has there been a significant change in the relative cover of exotic perennial graminoids, such as Kentucky bluegrass and smooth brome ($F_{1,12}$=1.0, P=0.3383; Figure 10). This is in contrast to a regional pattern of Kentucky bluegrass increasing in abundance in and around the Northern Great Plains (DeKeyser et al. 2013) where its presence is often correlated with declines in native species richness (Miles and Knops 2009). The U.S. Fish and Wildlife Service has begun an adaptive management program to control Kentucky bluegrass in South Dakota and North Dakota refuges, and their work suggests that Kentucky bluegrass can often spread and become a dominant component in mixed-grass prairie that is rested for long periods (i.e., neither burned nor grazed) (Grant et al. 2009, Gannon et al. 2013).

Cheatgrass (*Bromus tectorum*) and Japanese brome (*B. japonicus*) are Eurasian annual grasses that have been a part of the NGP landscape for more than a century, but their invasion in the region has accelerated since 1950 (Schachner et al. 2008). Recent data suggest these species are increasing in neighboring park units, and that their presence is correlated with decreased native richness (Ashton et al. 2016). Like exotic perennial graminoids, we did not find a statitically significant increase over time in the cover of these exotic annual grasses ($F_{1,12}$=0.8, P=0.4018; Figure 10). These grasses are in low abundance in JECA (Figure 10, Appendix C) and typically observed in only one or two vegetation monitoring plots per year. Continued vegetation monitoring will be critical in determining whether the abundance of exotic grasses remains low in JECA over time or if active management (e.g., herbicide treaments or prescibed fire) may be needed to prevent futher spread.

The diversity and productivity of plant communities in the Northern Great Plains is affected by the dramatically shifting weather patterns of the Great Plains (Jonas et al. 2015). Fluctuations in species abundances due to changes in weather can make detecting long-term trends difficult. For instance, drought conditions in 2012 (Figure 11) likely contributed to the reduction in native species richness (Figure 9) and exotic perennial grasses (Figure 10). Likewise, wet and cool conditions in 2015 (Figure 11) may also have reduced native richness and native graminoid cover (Figure 9). Continued long-term collection of monitoring data will be needed to better understand the complex relationships between climate and vegetation in JECA.



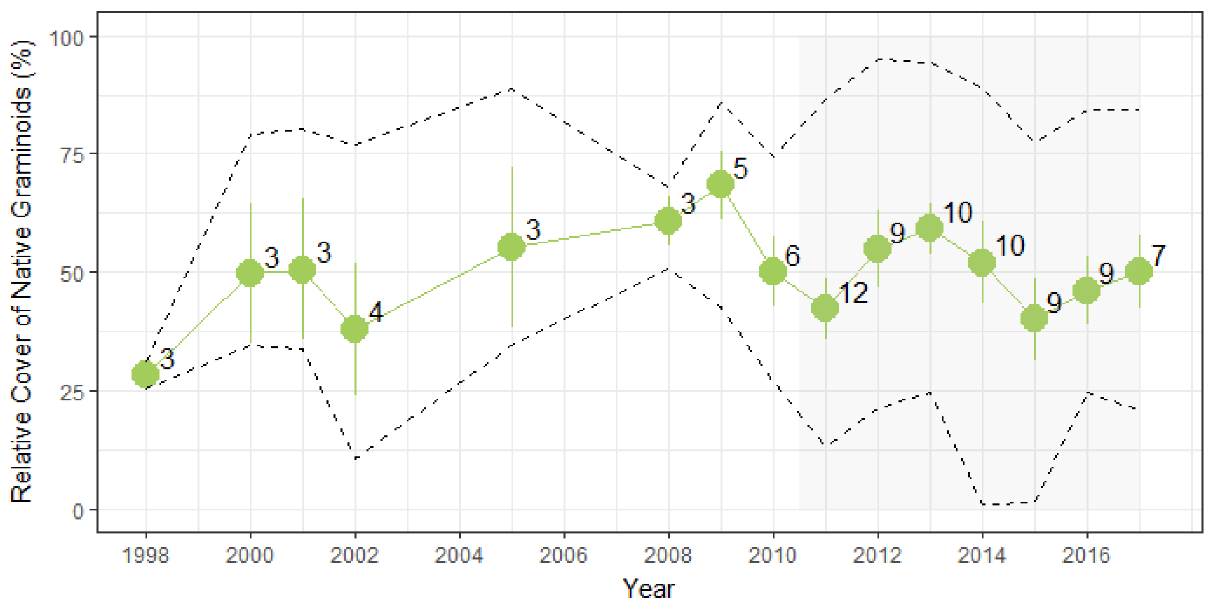


Figure 9. Changes in native species richness (top) and the relative cover of native graminoids (bottom) from 1998 to 2017 at Jewel Cave National Monument. Points represent mean ± one standard error and sample size is to the right of the point. Years with fewer than 3 monitoring plots were excluded from the graph. The shaded area highlights the period from 2011–2015 when sampling methods were consistent and distribution of plots was more even and consistent across years. The dashed line represents the maximum and minimum cover values for each year.

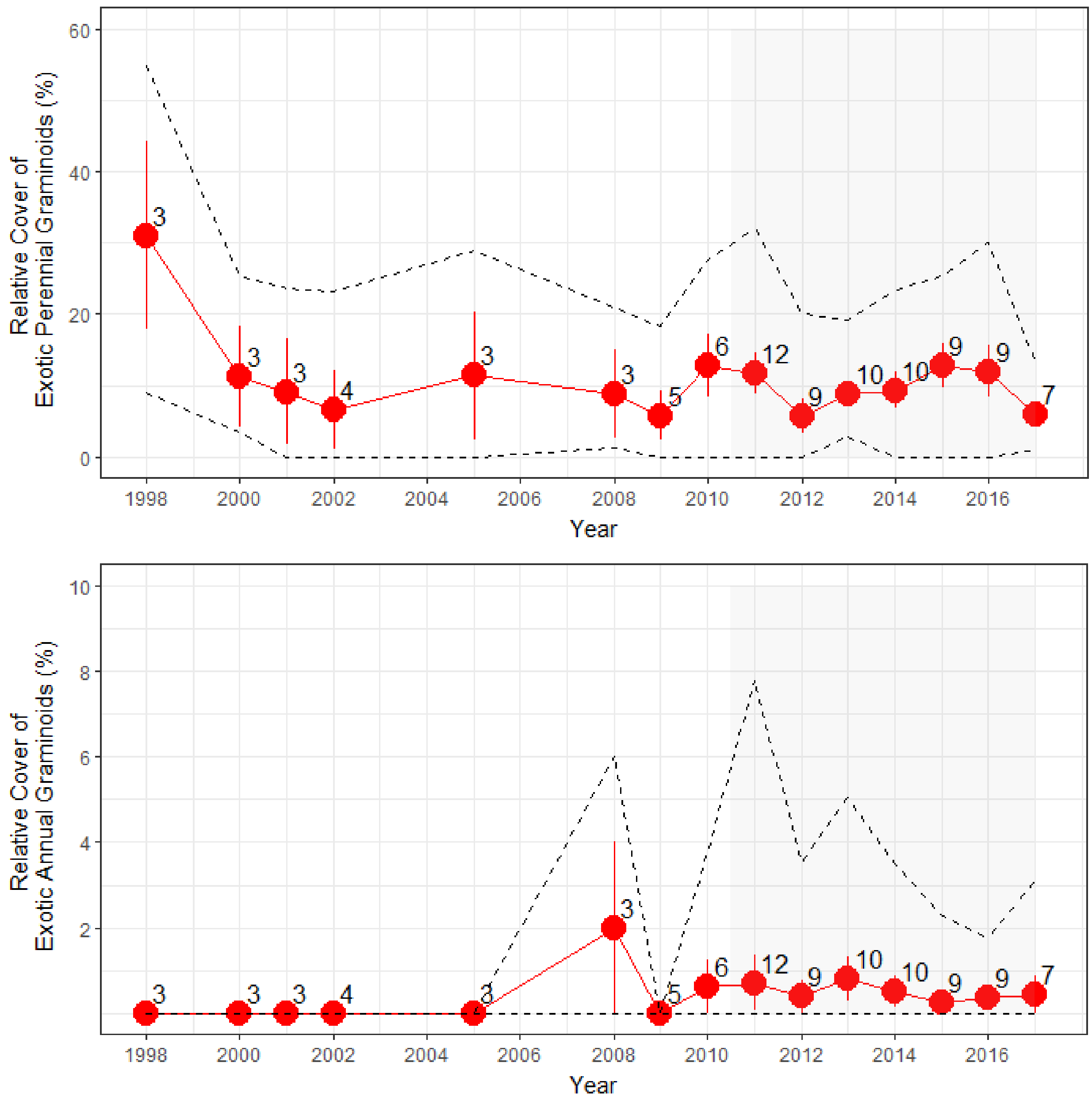
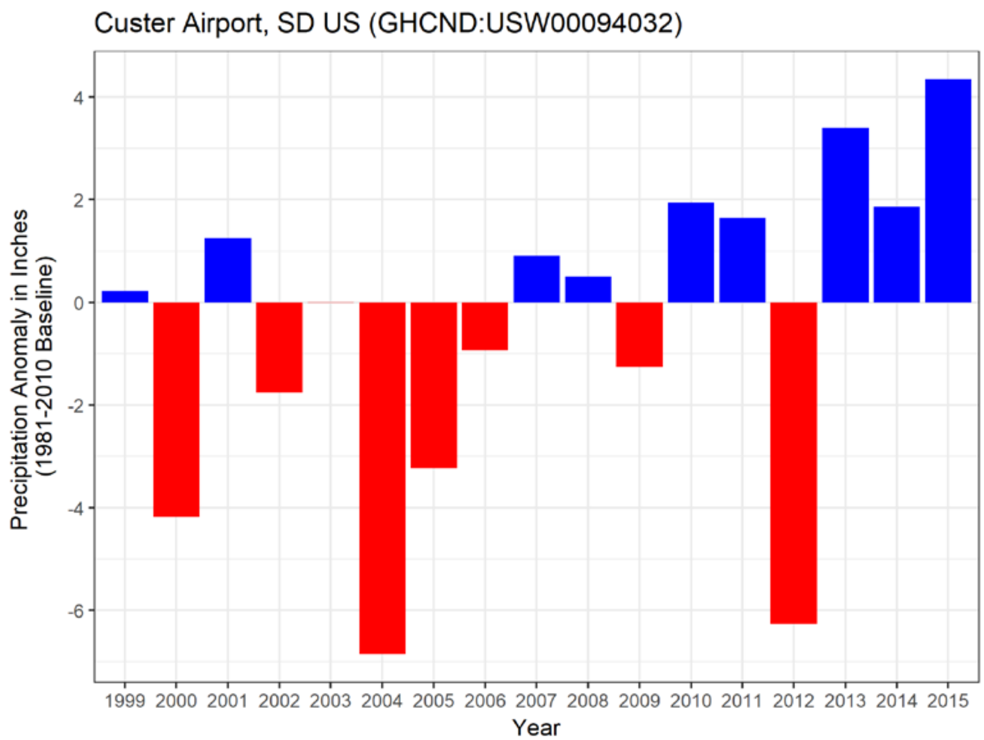


Figure 10. Changes in relative cover of exotic perennial graminoids (top) and the relative cover of exotic annual graminoids (bottom) from 1998 to 2017 at Jewel Cave National Monument. Points represent mean ± one standard error and sample size is to the right of the point. Years with fewer than 3 monitoring plots were excluded from the graph. The shaded area highlights the period from 2011–2015 when sampling methods were consistent and distribution of plots was more even and consistent across years. The dashed line represents the maximum and minimum cover values for each year.



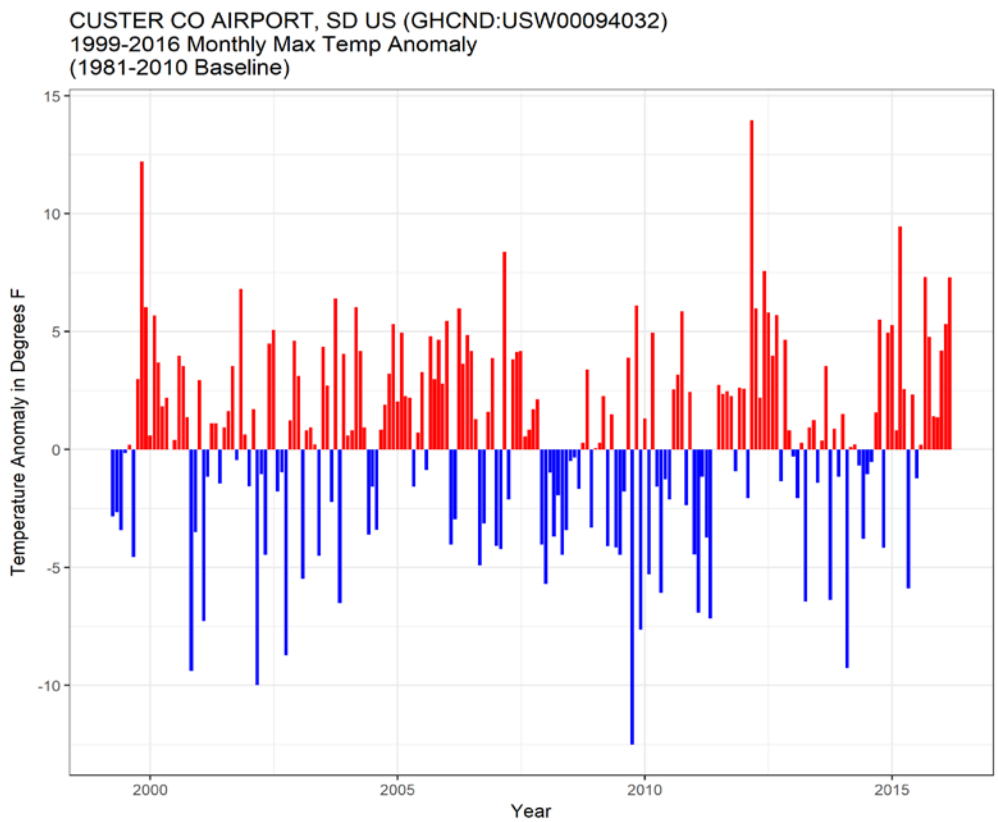


Figure 11. Annual Precipitation anomaly (top) and monthly maximum temperature anomaly 1999 – 2017 (bottom) at Custer County Airport, SD near Jewel Cave National Monument.

Upland Forest Condition

Trees & Seedlings in Forest Survey

We measured tree and seedling densities in 60 monitoring plots that had a tree or tall shrub within 38 m of the plot center in 2011 and 2016. Ponderosa pine was the most common tree we encountered in JECA, and in 2016 a ponderosa tree, pole, or seedling was observed in 77% of monitoring plots (46 of 60 plots). Other species of mature trees or poles were rare and were only observed in a handful of plots. There was a single Rocky Mountain juniper (*Juniperus scopulorum*) in PCM_031, and several dead paper birch (*Betula papyrifera*) and Rocky Mountain juniper trees were found in three other plots.

Reconstructed estimates of forest stand density and tree basal area from Black Hills forests in 1900 were 15.3 m^2 ha^{-1} and 131 stems ha^{-1}, respectively (Brown and Cook 2006). Compared to this reference condition, JECA forests in 2016 had a similar density (125 stems ha^{-1}) but lower basal area (7.4 m^2 ha^{-1}) (Figure 12; Appendix C). This indicates the current forest has fewer large ponderosa pines, which is expected because ~50% of trees were lost during the Jasper Fire (Lentile et al. 2005). Fourteen plots in JECA had tree basal areas larger than 15.3 m^2 ha^{-1}. The largest basal areas were observed at PCM_071, PCM_051, and PCM_011 in the northern portion of the park (Figure 4). There was no significant change between 2011 and 2016 in tree basal area or density ($F_{1,58}$=2.7, P=0.1074 and $F_{1,58}$=0.2, P=0.6373, respectively). There was a significant decline in the density of ponderosa poles, and this reduction could be due to growth out of the pole size class or mortality ($F_{1,58}$=7.6, P=0.0079). A few of the dead trees that were left standing after the Jasper fire have fallen, resulting in a significant reduction in snag density since 2011 (Table 7; $F_{1,58}$=7.9, P=0.0065). Snag longevity is highly variable in the Black Hills and was shown to vary with stand age and can range anywhere from 1 to 57 years (Shepperd and Battaglia 2002).

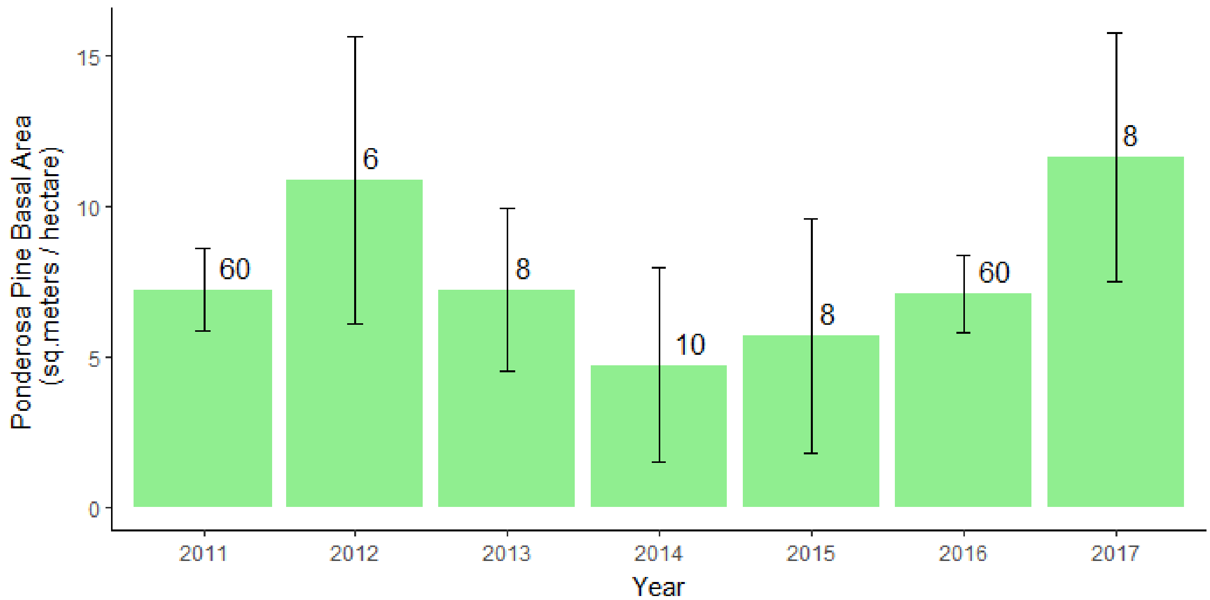


Figure 12. Ponderosa pine basal area at Jewel Cave National Monument from 2011–2017. Bars represent means and lines represent one standard error of the mean. The number of plots monitored each year is shown at the top of the bar.

Table 7. Tree basal area and density by size class for ponderosa pine in Jewel Cave National Monument in 2016. (Values: mean across 60 forest monitoring sites ± standard error of the mean)

Measurement	2011	2016
Basal Area (m^2/ha)	7.2 ± 1.3	7.1 ± 1.3
Tree Density (stems/ha)	122 ± 25.3	122 ± 23.4
Pole Density (stems/ha)	83 ± 30.6	76 ± 28.9
Snag Density (stems/ha)	40 ± 6.5	30 ± 5.6

Serviceberry (*Amelanchier alnifolia*), ponderosa pine, and chokecherry (*Prunus virginiana*) were the most common seedlings encountered at JECA (Table 8). Eighty-two percent of monitoring plots (49 of 60 plots) had at least one species of seedling in 2016. There was a large variation in seedling densities across plots, which is typical of recruitment patterns in Black Hills forests (Lentile et al. 2005). Seedling regeneration was low in high severity fire areas of the Japser fire (Keyser et al. 2009) and is now most prevalent in areas with lower fire severity and adult ponderosa pines nearby (Figure 13). Serviceberry and ponderosa pine were found in significantly greater densities in 2016 than in 2011 (Table 8, P=0.0001 and P<0.001, respectively) and estimated densities of chokecherry declined (Table 8, P<0.0001). The frequency of plots with seedlings increased for serviceberry, ponderosa, and chokecherry. Wet years in 2013, 2014, and 2015 (Figure 11) likely contributed to germination and survival of these seedlings.

Table 8. Tree and tall shrub seedling density and frequency in Jewel Cave National Monument in 2011 and 2016 at 60 monitoring plots. Seedlings have a DBH <2.54 cm. Asterisks indicate a significant increase in density between 2011 and 2016.

Species	Common Name	2011 Seedling Density (stems/ha)	2016 Seedling Density (stems/ha)	2011 Number of plots with seedlings	2016 Number of plots with seedlings
*Amelanchier alnifolia**	serviceberry	3679 ± 862	4079 ± 1066	31	39
*Pinus ponderosa**	ponderosa pine	1392 ± 691	1617 ± 656	26	36
*Prunus virginana**	chokecherry	2097 ± 1044	1868 ± 946	16	20
Juniperus scopulorum	Rocky Mountain juniper	na	na	1	2
Other deciduous trees	–	na	na	3	2
All species*	–	7183 ± 1475	7704 ± 1605	43	49

Figure 13. Long-term monitoring plot PCM_061 in Jewel Cave National Monument had a large number of ponderosa pine seedlings in 2016.

Surface Fuels in Forest Survey

Woody fuels are abundant in Jewel Cave National Monument (Table 9). The Jasper Fire caused widespread tree mortality, and as the trees and snags fall, they become coarse woody debris. While coarse woody debris increases total fuel loads, it can also play a vital role in providing wildlife habitat, decreasing soil erosion, and stimulating new forest growth (Shepperd and Battaglia 2002). Total fuel loads have not changed significantly over time ($F_{1,5}$=1.2, P=0.3096), but there has been a decrease in sound coarse woody fuels ($F_{1,5}$=26.1, P=0.0037) and a corresponding increase in rotten woody fuels ($F_{1,5}$=10.4, P=0.0230). This pattern is expected as logs decay over time. The total fuel loads were higher than the management target of the fire program (2-12 tons per acre) in all years of monitoring (Appendix C).

Table 9. Surface fuels loads in Jewel Cave National Monument Surface by size class from 2011 to 2017. Values represent means ± one standard error.

Year	Number of plots	Total fuel loads (tons acre^{-1})	Total fine woody fuels (tons acre^{-1})	Rotten coarse woody fuels (tons acre^{-1})*	Sound coarse woody fuels (tons acre^{-1})*	Duff (tons acre^{-1})	Litter (tons acre^{-1})
2011	62	25 ± 2.7	4.7 ± 0.5	4.4 ± 1.6	12 ± 1.4	1.9 ± 0.3	2 ± 0.2
2012	7	21.2 ± 5.7	3.4 ± 1.6	3.2 ± 2.1	9.8 ± 3.6	3.2 ± 1.9	1.7 ± 0.3
2013	8	22.1 ± 3.4	4.3 ± 1.4	3.7 ± 2.1	7.6 ± 2	4.3 ± 1.3	2.2 ± 0.6
2014	14	21.8 ± 3.6	4.6 ± 0.8	6.8 ± 1.8	6.7 ± 1.5	2.7 ± 0.9	0.9 ± 0.2
2015	9	18.6 ± 3.7	4.3 ± 1	4.5 ± 1.9	6.3 ± 2.2	2.3 ± 0.7	1.3 ± 0.3
2016	61	21.8 ± 1.5	4.4 ± 0.4	6.8 ± 0.9	5.3 ± 0.6	4.3 ± 0.5	1.1 ± 0.1
2017	8	17.1 ± 5.1	3.4 ± 1	6.9 ± 4.2	4.3 ± 1.7	1.1 ± 0.4	1.4 ± 0.3

Target Exotic Species in Forest Survey

Nine target exotic species were identified during forest structure monitoring in 2016. The most commonly observed target species was Canada thistle (*Cirsium arvense*), which was identified in 72% of the plots visited (Table 10). Canada thistle cover was approximately 1% in plots where it was observed. Smooth brome (*Bromus inermis*) was observed in 33% of plots and occupied the most plot area, with 5.5% average cover in the plots where it was observed. Wooly mullein was also somewhat common, being identified in 61% of plots, but with relatively low cover of 0.7% in plots where it was observed. Henbane (*Hyoscyamus niger*) was only observed in two plots, but with almost 2% cover in those plots it had the third highest cover value of the nine species we identified. Henbane is also included on South Dakota’s list of noxious exotic species. These baseline data will be compared to future data that will be collected in 2021 and every five years thereafter to determine how these target species populations are changing over time. See appendix D for maps of target species observation locations and cover values in the park.

Table 10. Target exotic species identified in 60 forest structure plots in Jewel Cave National Monument in 2016. Species marked with (*) are also on South Dakota's noxious exotic species list and those with (**) are noxious only in Custer County. "Mean cover across all forest plots" is the average cover across all 60 plots, while "mean cover in invaded forest plots" is the average cover across only the plots where that species was observed. Mean values are percent cover ± one standard error of the mean.

Species	Common Name	Mean Cover Across all Forest Plots (%)	Number of Invaded Plots	Mean Cover in Invaded Forest Plots (%)
Bromus inermis	Smooth brome	1.8 ± 1.1	20	5.5 ± 3.3
Cirsium arvense	Canada thistle	0.9 ± 0.2	43	1.3 ± 0.2
*Verbascum thapsis***	Wooly mullein	0.4 ± 0.1	37	0.7 ± 0.1
*Cynoglossum officinale***	Houndstongue	0.2 ± 0.1	14	0.8 ± 0.3
Bromus japonicus	Japanese brome	0.2 ± 0.1	9	1.1 ± 0.4
Euphorbia esula	Leafy spurge	0.1 ± 0.1	4	1.1 ± 0.6
*Hyoscyamus niger**	Henbane	0.1 ± 0.1	2	1.8 ± 1.3
*Cirsium vulgare**	Bull thistle	<0.1 ± <0.1	3	0.4 ± 0.1
Bromus tectorum	Cheatgrass	<0.1 ± <0.1	2	0.5 ± 0.0

Canyons Prescribed Fire

On October 29–30, 2014, post-burn data from six plots were collected. Analyses indicated that 1000-hour fuels decreased from 15.6 to 5.3 tons/acre; a reduction of 66% (Figure 14). Total fuel loads decreased from 23.5 to 9.5 tons/acre; a reduction of 59%. Eighty-one percent of the project area was burned.

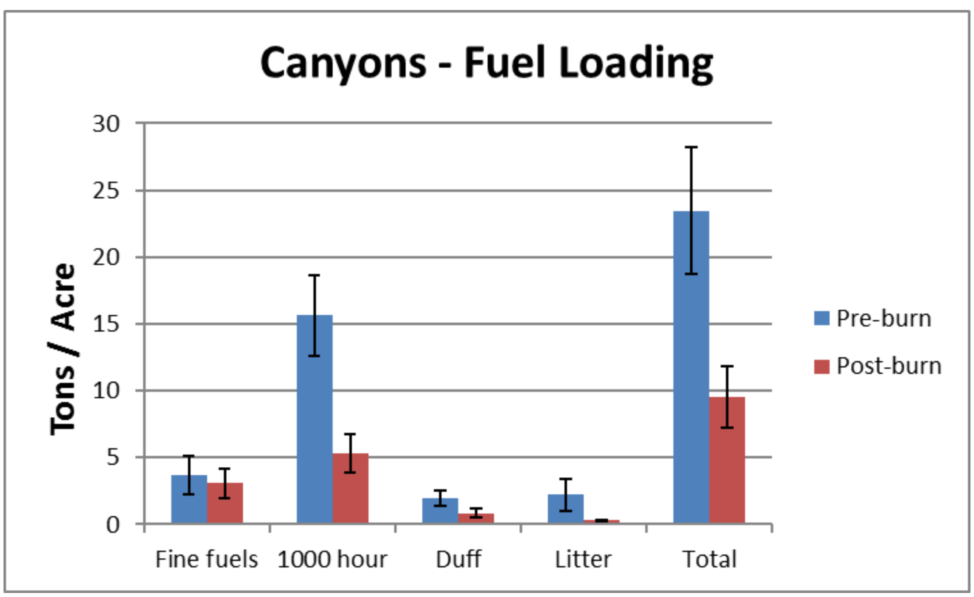


Figure 14. Canyons unit fuel loading pre and post-burn following the prescribed fire on October 24, 2014

Severity measurements on these plots indicated the substrate burn severity was primarily light to moderate indicating that the litter was partially to entirely consumed and duff partially to deeply charred. Vegetation burn severity was nearly evenly split across the unit, with 29% experiencing light severity, 26% experiencing moderate severity, and 26% experiencing heavy severity, while 19% was either unburned or only scorched (Figure 15).

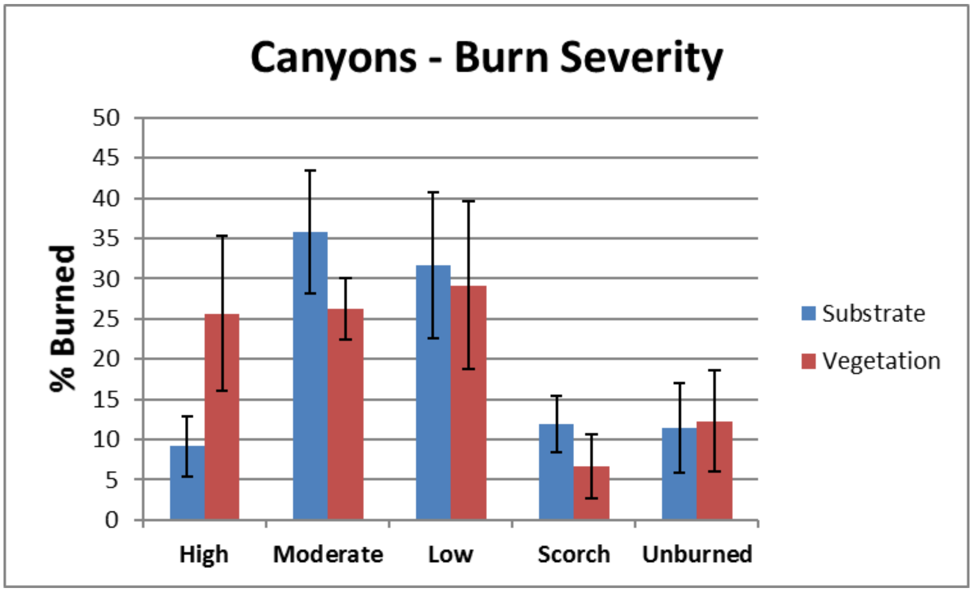


Figure 15. Canyons unit burn severity following the prescribed fire on October 24, 2014

The Canyons prescribed burn successfully accomplished the primary objective of fuel reduction (Figure 16). It was also successful in the secondary objective of burning 70% of the project area. Total and woody debris fuel loads in this unit are now at a level consistent with historical values within the southern Black Hills. In the future, the Northern Great Plains Fire Management program will implement more prescribed burns throughout the monument to restore and maintain Black Hills ponderosa pine forest ecosystems.

Figure 16. (a) Pre- and (b) post-treatment photos from plot FPCM_134 within the Canyons prescribed fire unit at Jewel Cave National Monument. Pre-treatment photo taken July 2, 2014, and post-treatment photo taken June 29, 2015.

Conclusions

This report presents the results of vegetation monitoring efforts at Jewel Cave National Monument (JECA) by the Northern Great Plains Inventory and Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology Group from 1998-2017. We visited 27 plots to monitor forest structure and the understory plant community (Figure 1) and 60 plots were visited in 2011 and 2016 to better understand forest condition (Figure 4). We compared our findings to the range of natural variability seen in other forests and grasslands and management targets to develop summaries of natural resource condition (Appendix C). We also explored how key metrics have changed over time from 1998 to 2017.

Overall, the vegetation communities in JECA are in good condition and are dominated by native grasses and forbs (Table 4). Slender wheatgrass (*Elymus trachycaulus*), a native species, was the most abundant plant observed with more than 25% absolute cover. Species richness is generally high and within the range of natural variability in nearby grasslands (Appendix C). Most vegetation metrics (e.g. native species richness, % native graminoid cover) changed from year to year but there was not a significant trend since 2000 (Figure 9). Exotic perennial graminoids, and Kentucky bluegrass in particular, are the most abundant exotic species in our monitoring plots, but since 2000 their cover has not changed significantly (Figure 10).

Forests are dominated by ponderosa pine (*Pinus ponderosa*) trees, and the current density (Table 7) and high fuel loads (Table 9) are driven strongly by the Jasper wildfire in 2000. Encouragingly, between 2011 and 2016 we observed an increase in the frequency of plots with ponderosa pine seedlings present as well as an increase in the number of pine seedlings observed in each plot, suggesting that pine forest regeneration is slowly progressing after the fire. The most frequently observed exotic species of management concern in forest plots was Canada thistle occurring in 72% of plots in 2016. Overall, the park's vegetation is in good condition, though exotic plants, such as Canada thistle and Kentucky bluegrass, pose a significant challenge to park management.

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Appendix A: Plot visits at Jewel Cave National Monument

Table A-1. Monitoring activities in Jewel Cave National Monument at Fire Management Handbook (FMH) Monitoring Plots from 1998–2013. Reads are designated as PT= Point-Intercept Method and QD= 1m^2 quadrats

Year	BFPIPO 1D0902	FF4	FFV1	FFV2	FFV3	FFV4	FFV5	FPIPO 1D0201	FPIPO 1D0202	FPIPO 1D0901
1998	–	–	–	–	–	–	–	PT	PT	PT
1999	–	–	–	–	–	–	–	–	PT	–
2000	–	–	–	–	–	–	–	PT	PT	PT
2001	–	–	–	–	–	–	–	PT	PT	PT
2002	PT	–	–	–	–	–	–	PT	PT	PT
2003	–	–	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	–	–	–	–
2005	–	–	–	–	–	–	–	PT	PT	PT
2006	–	–	–	–	–	–	–	–	–	–
2007	–	–	–	–	–	–	–	–	–	–
2008	–	–	PT, QD	PT, QD	PT, QD	–	–	–	–	–
2009	–	–	PT, QD	PT, QD	PT, QD	PT, QD	PT, QD	–	–	–
2010	–	–	PT, QD	PT, QD	PT, QD	–	–	PT	PT	PT
2011	–	PT	–	–	–	–	–	PT	PT	PT
2012	–	–	–	–	–	–	–	PT	PT	PT
2013	–	–	PT	PT	PT	–	–	–	–	–

Table A-2. Monitoring activities in Jewel Cave National Monument at Plant Community Monitoring Plots from 2011–2017. Reads are designated as FS= Forest Structure, PC= Plant Community, FX= Fire Effects, Dual=Plant community and forest data collected from that plot in same year.

Plot	2011	2012	2013	2014	2015	2016	2017
JECA_PCM_004	FS	PC	PC	–	–	FS	PC
JECA_PCM_007	FS	–	PC	PC	–	FS	–
JECA_PCM_011	FS	–	–	PC	PC	FS	–
JECA_PCM_012	FS	–	–	PC	PC	FS	–
JECA_PCM_013	DUAL	–	–	–	PC	DUAL	–
JECA_PCM_014	DUAL	–	–	–	PC	DUAL	–
JECA_PCM_015	DUAL	–	–	–	PC	DUAL	–
JECA_PCM_016	DUAL	PC	–	–	–	DUAL	PC
JECA_PCM_017	DUAL	PC	–	–	–	DUAL	PC
JECA_PCM_018	DUAL	PC	FX	FX	–	DUAL	PC
JECA_PCM_019	FS	PC	PC	–	–	FS	PC
JECA_PCM_021	FS	PC	PC	–	–	FS	PC
JECA_PCM_023	FS	FX	PC	PC	–	FS	FX
JECA_PCM_024	FS	–	PC	PC	–	FS	–
JECA_PCM_025	FS	FX		PC	PC	FS	–
JECA_PCM_026	FS	–	–	–	rejected	–	–
JECA_PCM_027	FS	–	–	–	–	FS	–
JECA_PCM_028	FS	–	–	–	–	FS	–
JECA_PCM_029	FS	–	–	–	–	FS	–
JECA_PCM_030	FS	–	–	–	–	FS	–
JECA_PCM_031	FS	–	–	–	–	FS	–
JECA_PCM_032	FS	–	–	–	–	FS	–
JECA_PCM_033	FS	–	–	–	–	FS	–
JECA_PCM_035	FS	–	–	–	–	FS	–
JECA_PCM_036	FS	–	–	–	–	FS	–
JECA_PCM_037	FS	–	–	–	–	FS	–
JECA_PCM_038	FS	–	–	FX	FX	FX, FS	–
JECA_PCM_039	FS	–	–	–	–	FS	–
JECA_PCM_040	FS	–	–	–	–	FS	–
JECA_PCM_041	FS	–	–	–	–	FS	–
JECA_PCM_042	FS	–	–	–	–	FS	–
JECA_PCM_043	FS	–	–	–	–	FS	–
JECA_PCM_044	FS	–	–	–	–	FS	–
JECA_PCM_045	FS	–	–	–	–	FS	–
JECA_PCM_046	FS	–	–	–	–	FS	–
JECA_PCM_047	FS	–	–	–	–	FS	–

Plot	2011	2012	2013	2014	2015	2016	2017
JECA_PCM_048	FS	–	–	–	–	FS	–
JECA_PCM_049	FS	–	–	–	–	FS	–
JECA_PCM_050	FS	–	–	–	–	FS	–
JECA_PCM_051	FS	–	–	–	–	FS	–
JECA_PCM_052	FS	–	–	–	–	FS	–
JECA_PCM_053	FS	–	–	FX	–	FS	–
JECA_PCM_054	FS	–	–	FX	–	FS	–
JECA_PCM_055	FS	–	–	–	–	FS	–
JECA_PCM_056	FS	–	–	–	–	FS	–
JECA_PCM_057	FS	–	–	–	–	FS	–
JECA_PCM_058	FS	–	–	–	–	FS	–
JECA_PCM_059	FS	–	–	–	–	FS	–
JECA_PCM_060	FS	–	–	–	–	FS	–
JECA_PCM_061	FS	–	–	–	–	FS	–
JECA_PCM_062	FS	–	–	–	–	FS	–
JECA_PCM_063	FS	FX	FX	FX	–	FS	FX
JECA_PCM_064	FS	–	–	FX	–	FS	–
JECA_PCM_065	FS	–	–	–	–	FS	–
JECA_PCM_066	FS	–	–	–	–	FS	–
JECA_PCM_067	FS	–	–	–	–	FS	–
JECA_PCM_068	FS	–	–	–	–	FS	–
JECA_PCM_069	FS	–	–	–	–	FS	–
JECA_PCM_070	FS	–	–	–	–	FS	–
JECA_PCM_071	FS	–	–	–	–	FS	–
JECA_FPCM_102	FX,FS	–	–	–	–	FS	–
JECA_FPCM_134	FS	–	–	–	–	FS	–

Appendix B: List of vascular plant species found at Jewel Cave National Monument 1998–2017

Table B-1. This table lists all species identified by NGPN staff during monitoring activities in Jewel Cave National Monument. In the *Notes* column: “Exotic” indicates non-native species; “Target” indicates an exotic species identified as having the potential to cause negative ecological impacts; “Noxious” indicates an exotic species declared a noxious pest by the state of South Dakota; “WY-S#” and “SD-S#” indicate the state conservation status for a species of conservation concern due to rarity, habitat alteration, or distribution in that respective state. “New” indicates a species that was identified by NGPN staff but is not on the verified species list maintained by the park.

Family	Scientific Name	Common Name	Notes
Anacardiaceae	*Rhus trilobata*	skunkbush sumac	–
Anacardiaceae	*Toxicodendron rydbergii*	western poison ivy	–
Apiaceae	*Lomatium foeniculaceum*	desert biscuitroot	–
Apiaceae	*Lomatium orientale*	Northern Idaho biscuitroot	–
Apiaceae	*Musineon tenuifolium*	slender wildparsley	–
Apiaceae	*Zizia aptera*	meadow zizia	–
Apocynaceae	*Apocynum × floribundum*	hybrid dogbane	–
Apocynaceae	*Apocynum androsaemifolium*	spreading dogbane	–
Asclepiadaceae	*Asclepias ovalifolia*	oval-leaf milkweed	–
Asclepiadaceae	*Asclepias pumila*	plains milkweed	–
Asclepiadaceae	*Asclepias speciosa*	showy milkweed	–
Asclepiadaceae	*Asclepias verticillata*	whorled milkweed	–
Asclepiadaceae	*Asclepias viridiflora*	green comet milkweed	–
Asteraceae	*Achillea millefolium*	common yarrow	–
Asteraceae	*Agoseris glauca*	pale agoseris	–
Asteraceae	*Ambrosia artemisiifolia*	common ragweed	–
Asteraceae	*Ambrosia psilostachya*	Cuman ragweed	–
Asteraceae	*Antennaria*	pussytoes	–
Asteraceae	*Antennaria microphylla*	littleleaf pussytoes	–
Asteraceae	*Antennaria neglecta*	field pussytoes	–
Asteraceae	*Antennaria parvifolia*	small-leaf pussytoes	–
Asteraceae	*Artemisia campestris*	field sagewort	New
Asteraceae	*Artemisia dracunculus*	tarragon	–
Asteraceae	*Artemisia frigida*	fringed sagewort	–
Asteraceae	*Artemisia ludoviciana*	white sagebrush	–
Asteraceae	*Aster*	aster	Exotic
Asteraceae	*Cirsium*	thistle	Exotic
Asteraceae	*Cirsium arvense*	Canada thistle	Exotic Target & Noxious
Asteraceae	*Cirsium flodmanii*	Flodman's thistle	New
Asteraceae	*Cirsium undulatum*	wavyleaf thistle	–
Asteraceae	*Cirsium vulgare*	bull thistle	Exotic Target
Asteraceae	*Conyza canadensis*	horseweed	–

Family	Scientific Name	Common Name	Notes
Asteraceae	*Dieteria canescens*	hoary tansyaster	–
Asteraceae	*Echinacea angustifolia*	blacksamson echinacea	–
Asteraceae	*Ericameria nauseosa*	rubber rabbitbrush	–
Asteraceae	*Erigeron*	fleabane	–
Asteraceae	*Erigeron flagellaris*	trailing fleabane	–
Asteraceae	*Erigeron formosissimus*	beautiful fleabane	–
Asteraceae	*Erigeron strigosus*	prairie fleabane	–
Asteraceae	*Erigeron subtrinervis*	threenerve fleabane	–
Asteraceae	*Eurybia merita*	subalpine aster	–
Asteraceae	*Grindelia squarrosa*	curlycup gumweed	–
Asteraceae	*Gutierrezia sarothrae*	broom snakeweed	–
Asteraceae	*Helianthus annuus*	common sunflower	–
Asteraceae	*Helianthus pauciflorus*	stiff sunflower	–
Asteraceae	*Helianthus*	sunflower	–
Asteraceae	*Heterotheca villosa*	hairy false goldenaster	–
Asteraceae	*Lactuca serriola*	prickly lettuce	Exotic
Asteraceae	*Liatris punctata*	dotted blazing star	–
Asteraceae	*Logfia arvensis*	field cottonrose	New, Exotic
Asteraceae	*Lygodesmia juncea*	rush skeletonplant	–
Asteraceae	*Machaeranthera*	tansyaster	–
Asteraceae	*Mulgedium oblongifolium*	blue lettuce	–
Asteraceae	*Packera cana*	woolly groundsel	–
Asteraceae	*Packera paupercula*	balsam groundsel	–
Asteraceae	*Packera plattensis*	prairie groundsel	–
Asteraceae	*Ratibida columnifera*	upright prairie coneflower	–
Asteraceae	*Rudbeckia hirta*	blackeyed Susan	–
Asteraceae	*Senecio integerrimus*	lambstongue ragwort	–
Asteraceae	*Solidago*	goldenrod	–
Asteraceae	*Solidago canadensis*	Canada goldenrod	–
Asteraceae	*Solidago missouriensis*	Missouri goldenrod	–
Asteraceae	*Solidago mollis*	velvety goldenrod	–
Asteraceae	*Solidago nemoralis*	gray goldenrod	–
Asteraceae	*Solidago ptarmicoides*	prairie goldenrod	–
Asteraceae	*Solidago rigida*	stiff goldenrod	–
Asteraceae	*Solidago speciosa*	showy goldenrod	New
Asteraceae	*Symphyotrichum*	aster	–
Asteraceae	*Symphyotrichum ericoides*	white heath aster	–
Asteraceae	*Symphyotrichum falcatum*	white prairie aster	–
Asteraceae	*Symphyotrichum laeve*	smooth blue aster	–
Asteraceae	*Symphyotrichum oblongifolium*	aromatic aster	–
Asteraceae	*Taraxacum officinale*	common dandelion	Exotic
Asteraceae	*Tetraneuris acaulis*	stemless four-nerve daisy	–
Asteraceae	*Tragopogon dubius*	yellow salsify	Exotic

Family	Scientific Name	Common Name	Notes
Berberidaceae	*Berberis repens*	Oregon grape	–
Betulaceae	*Betula papyrifera*	paper birch	–
Boraginaceae	*Cynoglossum officinale*	houndstongue	Exotic Target & Noxious
Boraginaceae	*Lappula occidentalis*	flatspine stickseed	New
Boraginaceae	*Lithospermum incisum*	narrowleaf stoneseed	–
Boraginaceae	*Mertensia lanceolata*	prairie bluebells	–
Boraginaceae	*Onosmodium bejariense*	soft-hair marbleseed	–
Brassicaceae	*Arabis*	rockcress	–
Brassicaceae	*Arabis pycnocarpa*	creamflower rockcress	–
Brassicaceae	*Boechera holboellii*	Holboell's rockcress	–
Brassicaceae	*Boechera pinetorum*	Holboell's rockcress	–
Brassicaceae	*Camelina microcarpa*	littlepod false flax	Exotic
Brassicaceae	*Descurainia pinnata*	western tansymustard	–
Brassicaceae	*Descurainia sophia*	herb sophia	Exotic
Brassicaceae	*Draba*	draba	–
Brassicaceae	*Draba reptans*	Carolina draba	–
Brassicaceae	*Erysimum*	wallflower	Exotic
Brassicaceae	*Erysimum asperum*	western wallflower	New
Brassicaceae	*Erysimum capitatum*	sanddune wallflower	–
Brassicaceae	*Erysimum cheiranthoides*	wormseed wallflower	Exotic
Brassicaceae	*Erysimum inconspicuum*	shy wallflower	–
Brassicaceae	*Physaria arenosa*	Great Plains bladderpod	–
Brassicaceae	*Sisymbrium altissimum*	tall tumblemustard	Exotic
Brassicaceae	*Thlaspi arvense*	field pennycress	Exotic
Campanulaceae	*Campanula rotundifolia*	bluebell bellflower	–
Caprifoliaceae	*Symphoricarpos albus*	common snowberry	–
Caprifoliaceae	*Symphoricarpos occidentalis*	western snowberry	–
Caryophyllaceae	*Cerastium arvense*	field chickweed	–
Caryophyllaceae	*Paronychia sessiliflora*	creeping nailwort	–
Caryophyllaceae	*Silene drummondii*	Drummond's campion	–
Caryophyllaceae	*Silene noctiflora*	nightflowering silene	Exotic
Chenopodiaceae	*Chenopodium*	goosefoot	Exotic
Chenopodiaceae	*Chenopodium album*	lambsquarters	Exotic
Chenopodiaceae	*Chenopodium berlandieri*	pitseed goosefoot	–
Chenopodiaceae	*Chenopodium pratericola*	desert goosefoot	–
Chenopodiaceae	*Chenopodium simplex*	mapleleaf goosefoot	–
Commelinaceae	*Tradescantia occidentalis*	prairie spiderwort	–
Convolvulaceae	*Convolvulus arvensis*	field bindweed	Exotic Noxious
Cupressaceae	*Juniperus communis*	common juniper	–
Cupressaceae	*Juniperus scopulorum*	Rocky Mountain juniper	–
Cyperaceae	*Carex*	sedge	–
Cyperaceae	*Carex backii*	Back's sedge	–
Cyperaceae	*Carex duriuscula*	needleleaf sedge	–

Family	Scientific Name	Common Name	Notes
Cyperaceae	*Carex filifolia*	threadleaf sedge	–
Cyperaceae	*Carex inops*	sun sedge	–
Cyperaceae	*Carex interior*	inland sedge	–
Cyperaceae	*Carex richardsonii*	Richardson's sedge	WY-S2
Cyperaceae	*Carex rossii*	Ross' sedge	–
Elaeagnaceae	*Shepherdia canadensis*	russet buffaloberry	–
Ericaceae	*Arctostaphylos uva-ursi*	kinnikinnick	–
Euphorbiaceae	*Euphorbia*	spurge	Exotic
Euphorbiaceae	*Euphorbia brachycera*	horned spurge	–
Euphorbiaceae	*Euphorbia esula*	leafy spurge	Exotic Target
Euphorbiaceae	*Euphorbia glyptosperma*	ribseed sandmat	–
Fabaceae	*Astragalus*	milkvetch	–
Fabaceae	*Astragalus agrestis*	purple milkvetch	–
Fabaceae	*Astragalus crassicarpus*	groundplum milkvetch	–
Fabaceae	*Astragalus drummondii*	Drummond's milkvetch	–
Fabaceae	*Astragalus flexuosus*	flexile milkvetch	–
Fabaceae	*Astragalus gilviflorus*	plains milkvetch	–
Fabaceae	*Astragalus gracilis*	slender milkvetch	–
Fabaceae	*Astragalus laxmannii*	Laxmann's milkvetch	–
Fabaceae	*Astragalus lotiflorus*	lotus milkvetch	New
Fabaceae	*Astragalus miser*	timber milkvetch	–
Fabaceae	*Astragalus missouriensis*	Missouri milkvetch	–
Fabaceae	*Astragalus racemosus*	cream milkvetch	–
Fabaceae	*Astragalus spatulatus*	tufted milkvetch	–
Fabaceae	*Dalea candida*	white prairie clover	–
Fabaceae	*Dalea purpurea*	purple prairie clover	–
Fabaceae	*Glycyrrhiza lepidota*	American licorice	–
Fabaceae	*Hedysarum alpinum*	alpine sweetvetch	–
Fabaceae	*Lathyrus ochroleucus*	cream pea	–
Fabaceae	*Lathyrus polymorphus*	manystem pea	New
Fabaceae	*Lupinus argenteus*	silvery lupine	–
Fabaceae	*Medicago lupulina*	black medick	Exotic
Fabaceae	*Melilotus officinalis*	yellow sweetclover	Exotic
Fabaceae	*Oxytropis campestris*	field locoweed	–
Fabaceae	*Oxytropis lambertii*	purple locoweed	–
Fabaceae	*Oxytropis sericea*	white locoweed	–
Fabaceae	*Pediomelum argophyllum*	silverleaf Indian breadroot	–
Fabaceae	*Pediomelum esculentum*	large Indian breadroot	–
Fabaceae	*Psoralidium tenuiflorum*	slimflower scurfpea	–
Fabaceae	*Thermopsis rhombifolia*	golden pea	–
Fabaceae	*Trifolium*	clover	Exotic
Fabaceae	*Vicia americana*	American vetch	–
Gentianaceae	*Frasera speciosa*	elkweed	–

Family	Scientific Name	Common Name	Notes
Geraniaceae	*Geranium richardsonii*	Richardson's geranium	–
Grossulariaceae	*Ribes*	currant	–
Grossulariaceae	*Ribes americanum*	American black currant	–
Grossulariaceae	*Ribes cereum*	wax currant	–
Grossulariaceae	*Ribes hirtellum*	hairystem gooseberry	–
Grossulariaceae	*Ribes oxyacanthoides*	Canadian gooseberry	–
Iridaceae	*Iris missouriensis*	Rocky Mountain iris	–
Iridaceae	*Sisyrinchium montanum*	strict blue-eyed grass	–
Lamiaceae	*Hedeoma drummondii*	Drummond's false pennyroyal	–
Lamiaceae	*Hedeoma hispida*	rough false pennyroyal	New
Lamiaceae	*Monarda fistulosa*	wild bergamot	–
Lamiaceae	*Salvia reflexa*	lanceleaf sage	–
Liliaceae	*Allium*	onion	Exotic
Liliaceae	*Allium cernuum*	nodding onion	–
Liliaceae	*Allium textile*	textile onion	–
Liliaceae	*Anticlea elegans*	mountain deathcamas	–
Liliaceae	*Calochortus*	mariposa lily	–
Liliaceae	*Calochortus gunnisonii*	Gunnison's mariposa lily	–
Liliaceae	*Calochortus nuttallii*	sego lily	–
Liliaceae	*Leucocrinum montanum*	common starlily	–
Liliaceae	*Lilium philadelphicum*	wood lily	–
Liliaceae	*Maianthemum stellatum*	starry false lily of the valley	–
Liliaceae	*Toxicoscordion venenosum*	meadow deathcamas	–
Linaceae	*Linum lewisii*	Lewis flax	–
Linaceae	*Linum rigidum*	stiffstem flax	–
Malvaceae	*Sphaeralcea coccinea*	scarlet globemallow	–
Monotropaceae	*Pterospora andromedea*	woodland pinedrops	–
Nyctaginaceae	*Mirabilis linearis*	narrowleaf four o'clock	–
Onagraceae	*Chamerion angustifolium*	fireweed	–
Onagraceae	*Oenothera coronopifolia*	crownleaf evening-primrose	–
Onagraceae	*Oenothera suffrutescens*	scarlet beeblossom	–
Pinaceae	*Pinus ponderosa*	ponderosa pine	–
Plantaginaceae	*Plantago patagonica*	woolly plantain	–
Plantaginaceae	*Synthyris wyomingensis*	Wyoming kittentails	–
Poaceae	*Achnatherum hymenoides*	Indian ricegrass	–
Poaceae	*Achnatherum nelsonii*	Columbia needlegrass	–
Poaceae	*Achnatherum richardsonii*	Richardson's needlegrass	–
Poaceae	*Andropogon gerardii*	big bluestem	–
Poaceae	*Aristida purpurea*	purple threeawn	–
Poaceae	*Bouteloua curtipendula*	sideoats grama	–
Poaceae	*Bouteloua gracilis*	blue grama	–
Poaceae	*Bouteloua hirsuta*	hairy grama	–
Poaceae	*Bromus*	brome	Exotic

Family	Scientific Name	Common Name	Notes
Poaceae	*Bromus anomalus*	nodding brome	–
Poaceae	*Bromus ciliatus*	fringed brome	–
Poaceae	*Bromus inermis*	smooth brome	Exotic Target
Poaceae	*Bromus japonicus*	Japanese brome	Exotic Target
Poaceae	*Bromus tectorum*	cheatgrass	Exotic Target
Poaceae	*Calamovilfa longifolia*	prairie sandreed	–
Poaceae	*Danthonia intermedia*	timber oatgrass	–
Poaceae	*Danthonia spicata*	poverty oatgrass	–
Poaceae	*Elymus*	wildrye	Exotic
Poaceae	*Elymus canadensis*	Canada wildrye	–
Poaceae	*Elymus elymoides*	squirreltail	–
Poaceae	*Elymus glaucus*	blue wildrye	–
Poaceae	*Elymus lanceolatus*	thickspike wheatgrass	–
Poaceae	*Elymus repens*	quackgrass	Exotic
Poaceae	*Elymus trachycaulus*	slender wheatgrass	–
Poaceae	*Elymus virginicus*	Virginia wildrye	–
Poaceae	*Festuca*	fescue	Exotic
Poaceae	*Festuca idahoensis*	Idaho fescue	–
Poaceae	*Festuca saximontana*	Rocky Mountain fescue	–
Poaceae	*Hesperostipa comata*	needle and thread	–
Poaceae	*Hesperostipa curtiseta*	shortbristle needle and thread	–
Poaceae	*Hesperostipa spartea*	porcupinegrass	–
Poaceae	*Koeleria macrantha*	prairie Junegrass	–
Poaceae	*Leymus innovatus*	downy ryegrass	–
Poaceae	*Muhlenbergia cuspidata*	plains muhly	–
Poaceae	*Muhlenbergia paniculata*	tumblegrass	–
Poaceae	*Muhlenbergia racemosa*	marsh muhly	–
Poaceae	*Nassella viridula*	green needlegrass	–
Poaceae	*Oryzopsis asperifolia*	roughleaf ricegrass	–
Poaceae	*Panicum capillare*	witchgrass	–
Poaceae	*Pascopyrum smithii*	western wheatgrass	–
Poaceae	*Piptatherum micranthum*	littleseed ricegrass	–
Poaceae	*Poa*	bluegrass	Exotic
Poaceae	*Poa compressa*	Canada bluegrass	Exotic
Poaceae	*Poa interior*	inland bluegrass	–
Poaceae	*Poa palustris*	fowl bluegrass	–
Poaceae	*Poa pratensis*	Kentucky bluegrass	Exotic
Poaceae	*Poa secunda*	Sandberg bluegrass	–
Poaceae	*Pseudoroegneria spicata*	bluebunch wheatgrass	–
Poaceae	*Schizachne purpurascens*	false melic	–
Poaceae	*Schizachyrium scoparium*	little bluestem	–
Poaceae	*Sporobolus heterolepis*	prairie dropseed	WY-S1
Poaceae	*Vulpia octoflora*	sixweeks fescue	New

Family	Scientific Name	Common Name	Notes
Polemoniaceae	*Phlox alyssifolia*	alyssumleaf phlox	–
Polemoniaceae	*Phlox andicola*	prairie phlox	–
Polemoniaceae	*Phlox hoodii*	spiny phlox	–
Polygalaceae	*Polygala alba*	white milkwort	–
Polygonaceae	*Fallopia convolvulus*	black bindweed	Exotic
Polygonaceae	*Polygonum achoreum*	leathery knotweed	–
Primulaceae	*Androsace septentrionalis*	pygmyflower rockjasmine	–
Primulaceae	*Lysimachia ciliata*	fringed loosestrife	–
Pteridaceae	*Pellaea atropurpurea*	purple cliffbrake	WY-S1
Ranunculaceae	*Anemone*	anemone	–
Ranunculaceae	*Anemone cylindrica*	candle anemone	–
Ranunculaceae	*Anemone multifida*	cutleaf anemone	–
Ranunculaceae	*Anemone patens*	eastern pasqueflower	–
Rosaceae	*Amelanchier alnifolia*	Saskatoon serviceberry	–
Rosaceae	*Cercocarpus montanus*	mountain mahogany	–
Rosaceae	*Drymocallis fissa*	bigflower cinquefoil	–
Rosaceae	*Drymocallis pseudorupestris*	sticky cinquefoil	–
Rosaceae	*Fragaria vesca*	woodland strawberry	–
Rosaceae	*Fragaria virginiana*	Virginia strawberry	–
Rosaceae	*Geum aleppicum*	yellow avens	–
Rosaceae	*Geum triflorum*	prairie smoke	–
Rosaceae	*Physocarpus monogynus*	mountain ninebark	–
Rosaceae	*Potentilla*	cinquefoil	Exotic
Rosaceae	*Potentilla concinna*	elegant cinquefoil	–
Rosaceae	*Potentilla gracilis*	slender cinquefoil	–
Rosaceae	*Potentilla hippiana*	woolly cinquefoil	–
Rosaceae	*Potentilla pensylvanica*	Pennsylvania cinquefoil	–
Rosaceae	*Prunus virginiana*	chokecherry	–
Rosaceae	*Rosa acicularis*	prickly rose	–
Rosaceae	*Rosa arkansana*	prairie rose	–
Rosaceae	*Rosa woodsii*	Woods' rose	–
Rubiaceae	*Galium*	bedstraw	Exotic
Rubiaceae	*Galium boreale*	northern bedstraw	–
Rubiaceae	*Galium triflorum*	fragrant bedstraw	–
Salicaceae	*Populus tremuloides*	quaking aspen	–
Santalaceae	*Comandra umbellata*	bastard toadflax	–
Saxifragaceae	*Heuchera richardsonii*	Richardson's alumroot	–
Scrophulariaceae	*Castilleja sulphurea*	sulphur Indian paintbrush	–
Scrophulariaceae	*Penstemon eriantherus*	fuzzytongue penstemon	–
Scrophulariaceae	*Penstemon gracilis*	lilac penstemon	–
Scrophulariaceae	*Verbascum thapsus*	common mullein	Exotic, Target, Noxious-Custer County

Family	Scientific Name	Common Name	Notes
Solanaceae	*Hyoscyamus niger*	black henbane	Exotic, Target, Noxious-Custer County
Solanaceae	*Physalis longifolia*	longleaf groundcherry	–
Solanaceae	*Physalis virginiana*	Virginia groundcherry	–
Solanaceae	*Solanum*	nightshade	Exotic
Verbenaceae	*Verbena bracteata*	bigbract verbena	–
Verbenaceae	*Verbena stricta*	hoary verbena	–
Violaceae	*Viola*	violet	Exotic
Violaceae	*Viola adunca*	hookedspur violet	–
Violaceae	*Viola canadensis*	Canadian white violet	–
Violaceae	*Viola nuttallii*	Nuttall's violett	–

Appendix C: Natural Resource Condition Summary

Results were summarized in a Natural Resource Condition Table based on the templates from the State of the Park report series (Appendix C). 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 exotic species cover, 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 C-1.

We chose a set of indicators and specific measures that can describe the condition of vegetation in the Northern Great Plains and the status of exotic plant invasions. The measures include: native species richness, relative cover of exotic species, and relative cover of exotic perennial grasses (smooth brome and Kentucky bluegrass). Reference values were based on descriptions of historic condition and variation, past studies, and/or management targets. Current park condition was compared to the reference value, and status was scored as “good condition”, “warrants moderate concern”, or “warrants significant concern” (Table C-1). “Good condition” was applied to values that fell within the range of the reference value, and “warrants significant concern” was applied to conditions that fell outside the bounds of the reference value. Indicators were classified as “warrants moderate concern” when the average value was near the threshold of significant concern but the variation associated with that value (e.g., 1 standard error) fell within both good condition and significant concern. In some cases, reference conditions can only be determined after we have accumulated more years of data. When this is the case, we refer to these conditions as “To be determined”, or TBD, and estimate condition based on our professional judgment.

Table C-1. Key to the symbols used in the Natural Resource Condition Table. The symbol 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. A symbol that does not contain an arrow indicates that there is insufficient information to assess a trend. Based on the State of the Park reports.

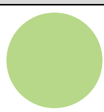
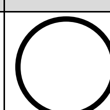
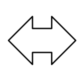
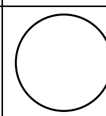
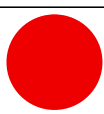
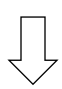
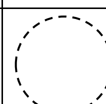
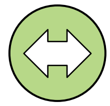
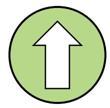
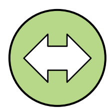
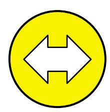
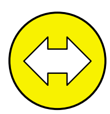
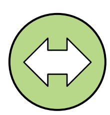
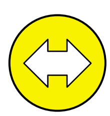
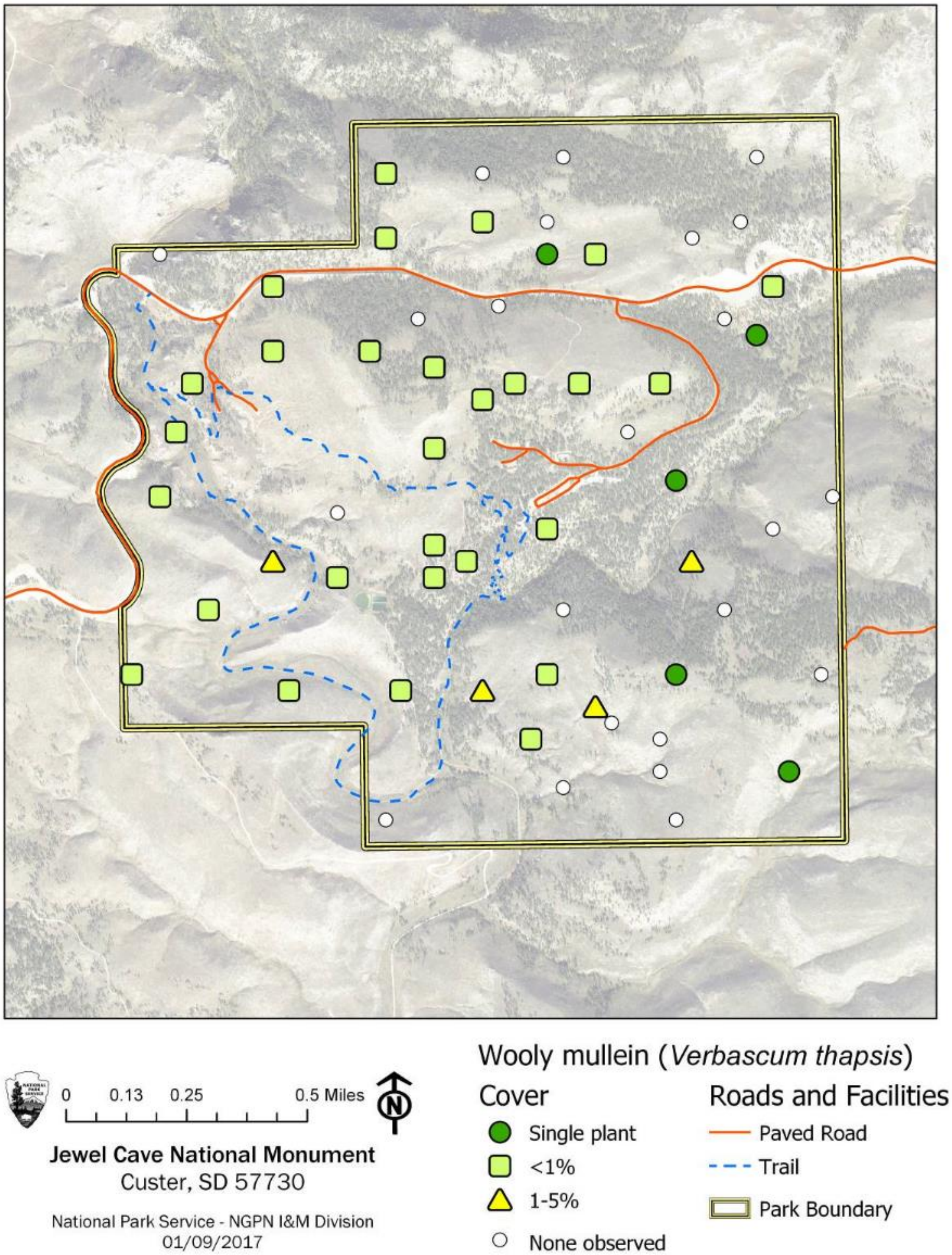
Condition Status		Trend in Condition		Confidence in Assessment	
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

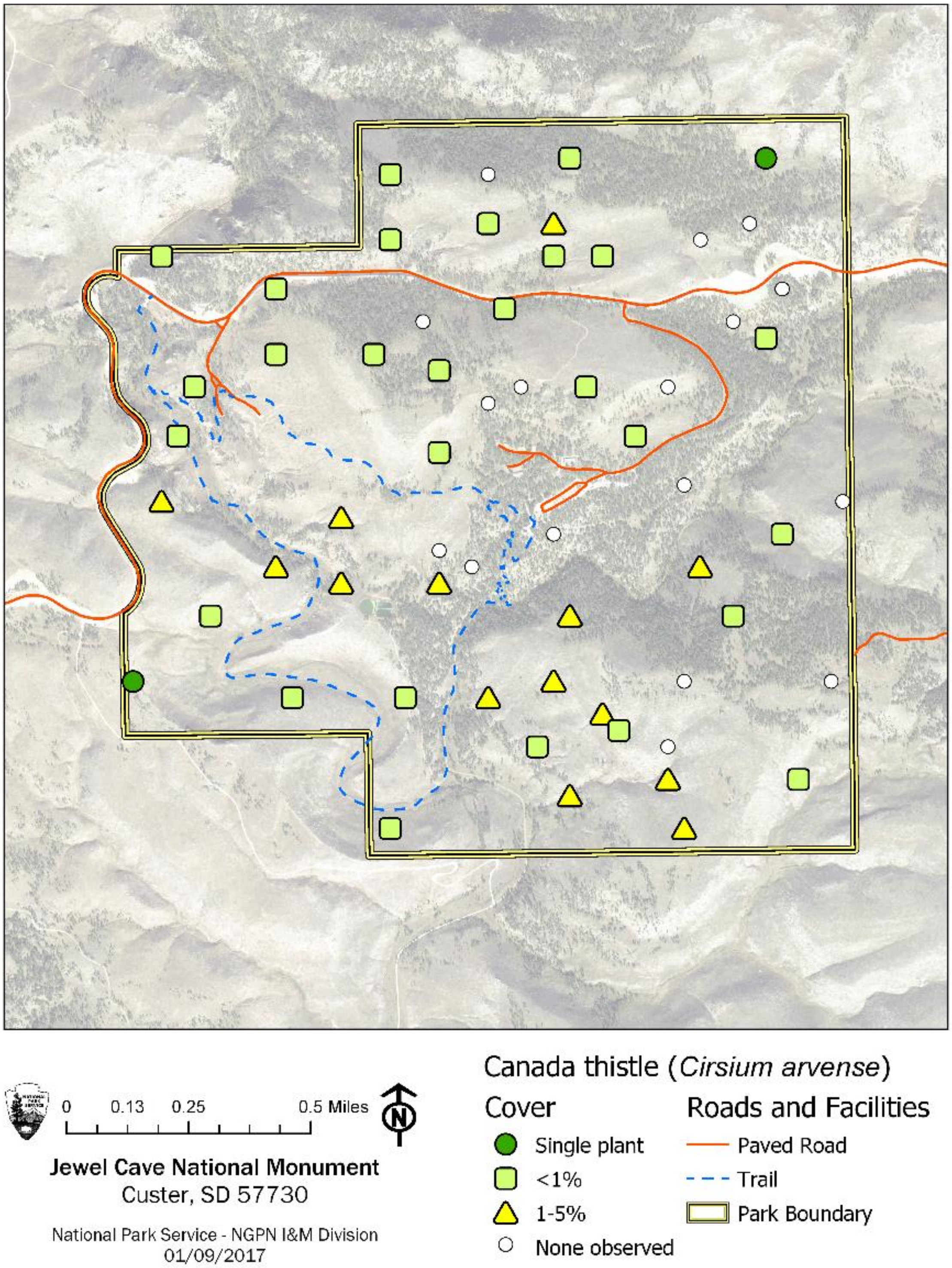
Table C-2. Natural resource condition summary table for upland plant communities in Jewel Cave National Monument (JECA). Trends are based on 2000–2017, current condition is 2013–2017 or 2016 (forest metrics).

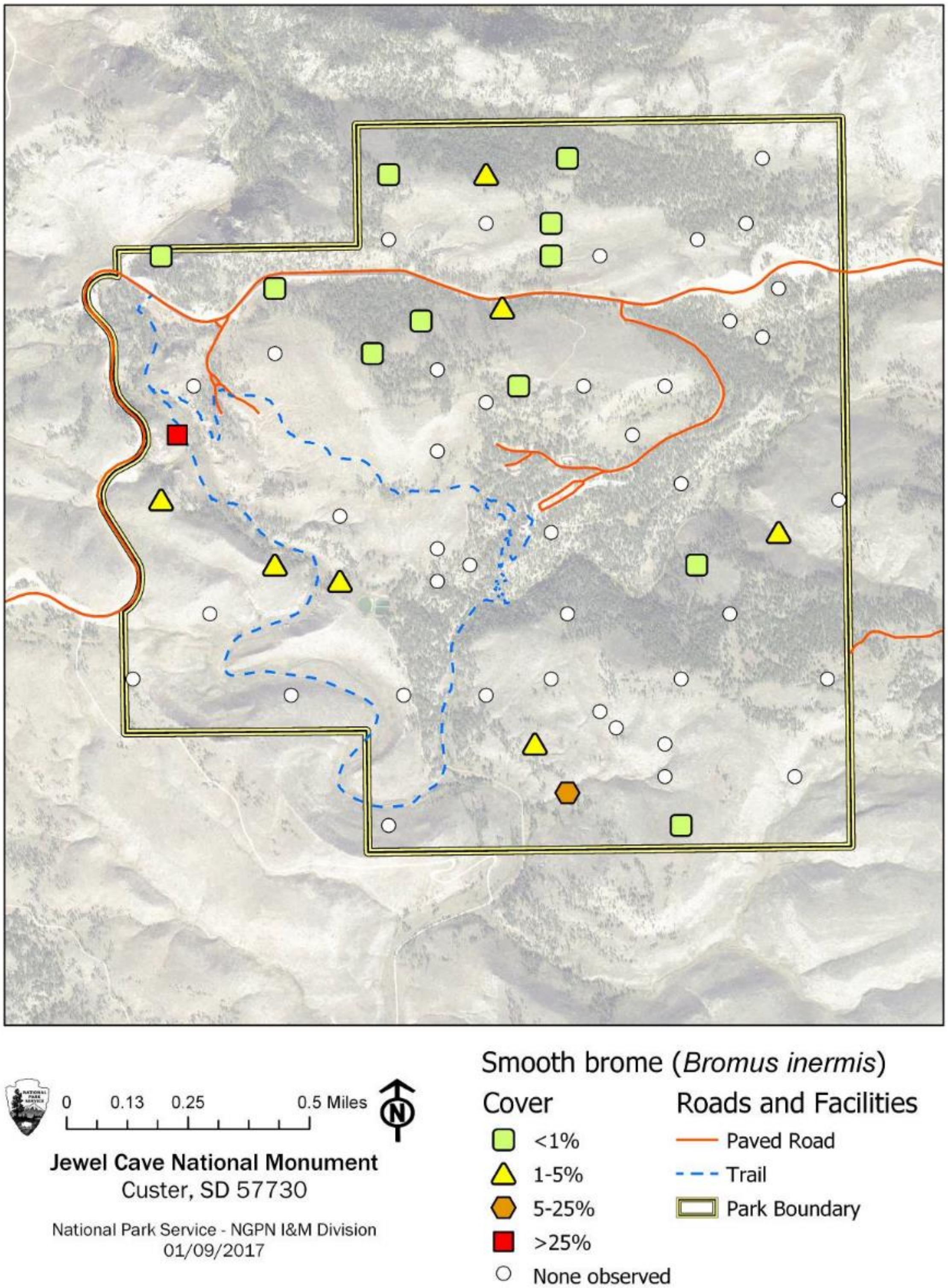
Indicator of Condition	Specific Measures	Current Value (mean ± SE)	Reference Condition and Data Source	Condition Status/ Trend	Rationale for Resource Condition
Upland Plant Community Structure and Composition	Native species richness (based on average of 10 1m² quadrats per plot)	10.1 ± 0.5 species	8–18 species [1]		JECA has a high herbaceous canopy cover and a moderate diversity of native plants when compared to the natural range of variability in surrounding grasslands.
Upland Plant Community Structure and Composition	Ponderosa pine seedling densities (stems / ha)	1617 ± 657	1392 ± 691[2]		Seedlings were found in 82% of plots in the 2016 Forest Survey. The densities are extremely variable but there has been an increase since 2011.
Upland Plant Community Structure and Composition	Forest basal area (m^2/ha)	7.1 ± 1.3	15.3 ± 2.7[3]		Forest densities are lower than historic conditions but are characterized by a mosaic of open and closed canopy sites.
Exotic Plant Early Detection and Management	Relative cover of exotic plant species	14.0 ± 1.8%	≤ 10 % cover [4]		In general, the sites in JECA have moderate exotic species cover. There has been no significant change in exotic cover since monitoring began in 2000.
Exotic Plant Early Detection and Management	Relative cover of exotic perennial graminoids	10.2 ± 1.6%	≤ 10 % cover [4]		Exotic perennial grasses are common throughout the park. Kentucky bluegrass is particularly abundant.
Exotic Plant Early Detection and Management	Relative cover of exotic annual graminoids	0.6 ± 0.3%	≤ 10 % cover [4]		Annual exotic graminoid cover remains low but cheatgrass and Japanese brome are present in the park.
Fire and Fuel Dynamics	Total downed fuel loads (tons/acre)	21.8 ± 1.5	Between 2 and 10 [4]		The current fire ecology program aims to maintain fuel loads of less than 10 tons/acre. The Jasper Fire in 2000 resulted in a large amount of coarse woody debris throughout the park. Because the forest structure is open and lacking ladder and fine fuels the high total fuels is only of moderate concern.

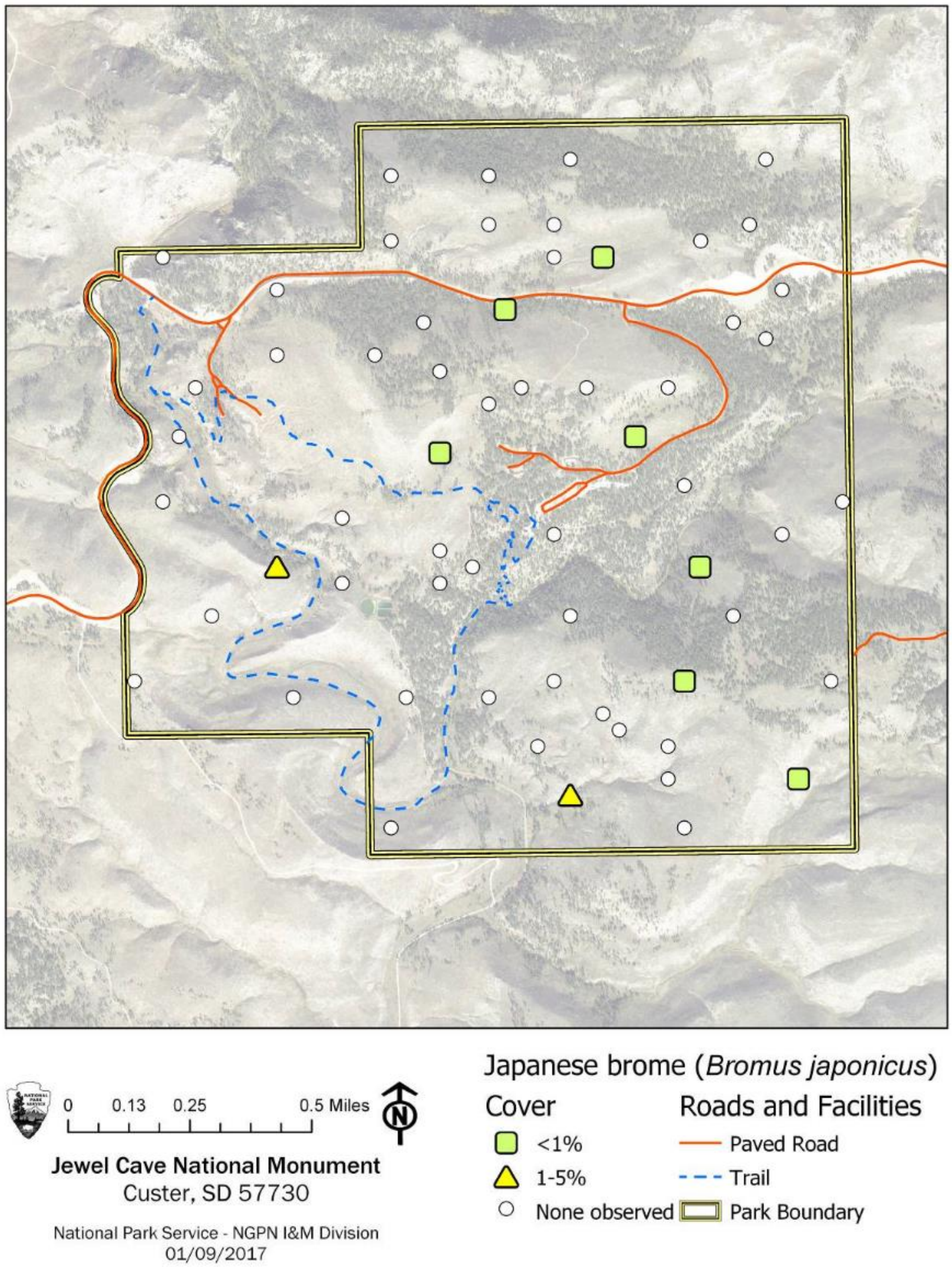
Notes: Reference condition based on 1. Symstad and Jonas (2011) 2. Baseline forest survey in 2011 3. Historical condition (Brown and Cook 2006) and 4. Management target based on professional judgment

Appendix D: Maps of 2016 Target Exotic Species Observations and Cover in Jewel Cave National Monument

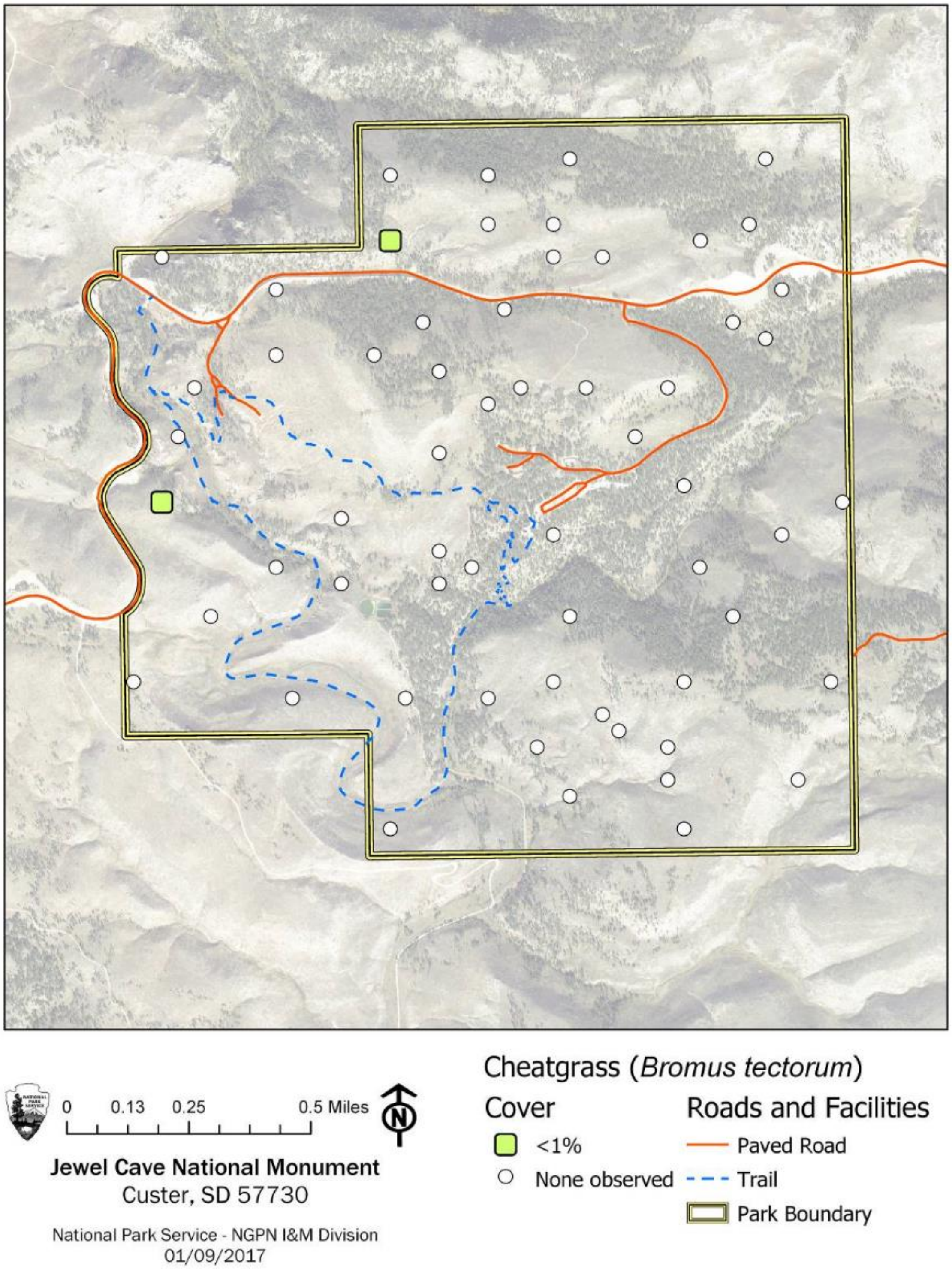


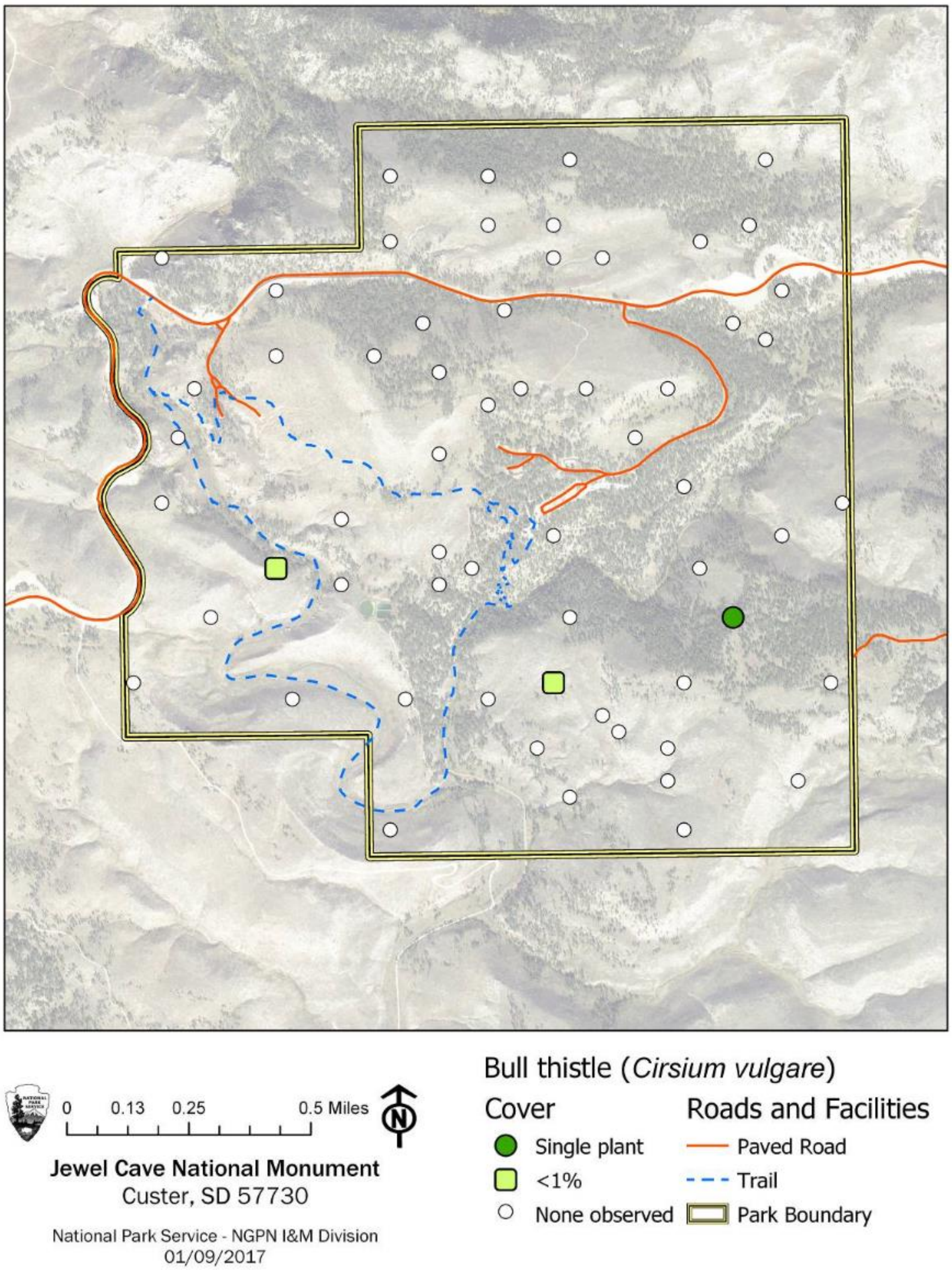

0
0.13
0.25
0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017
Canada thistle (*Cirsium arvense*)
Cover
Single plant
<1%
1-5%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary


0 0.13 0.25 0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017
Smooth brome (*Bromus inermis*)
Cover
<1%
1-5%
5-25%
>25%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary

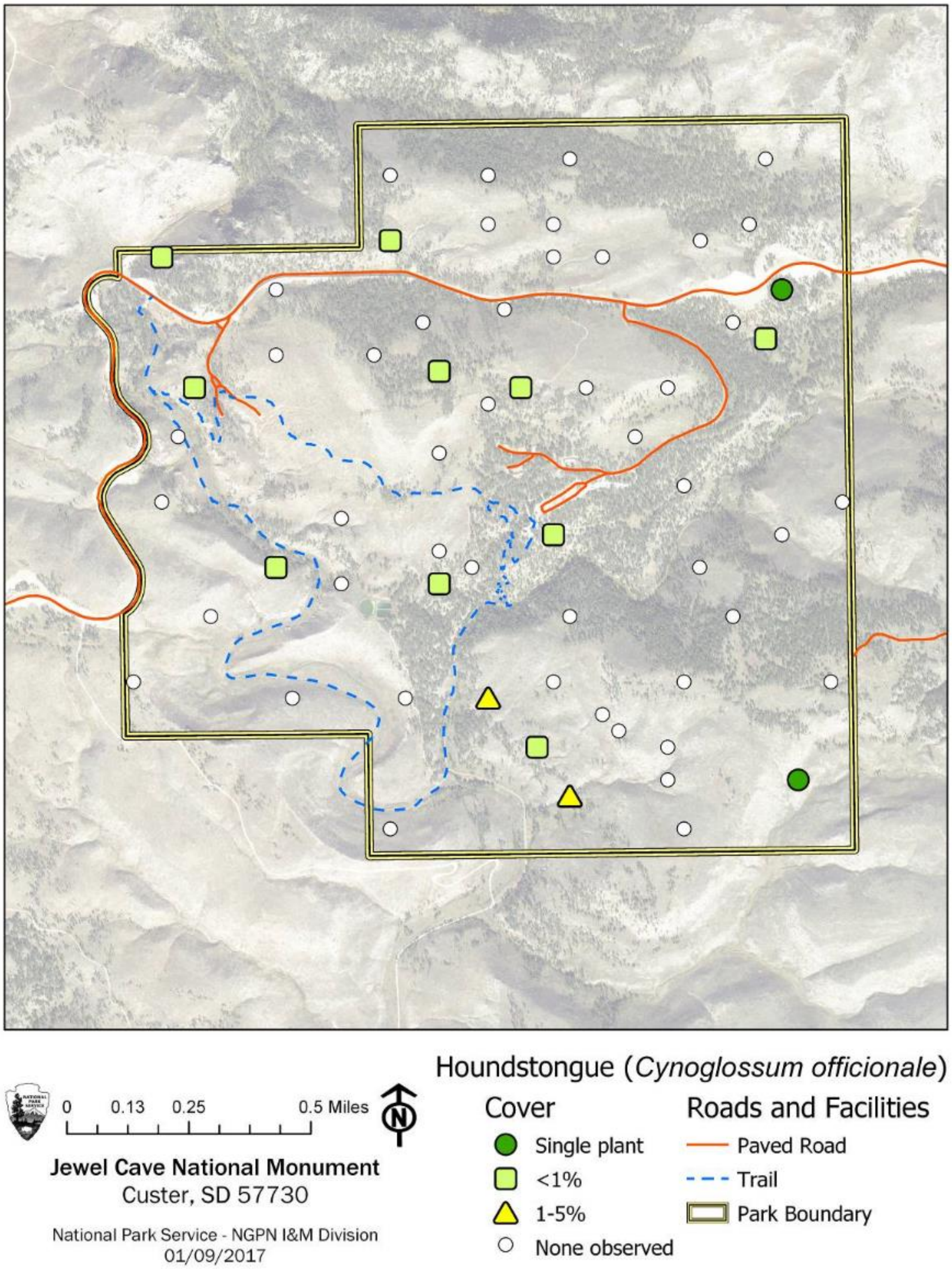


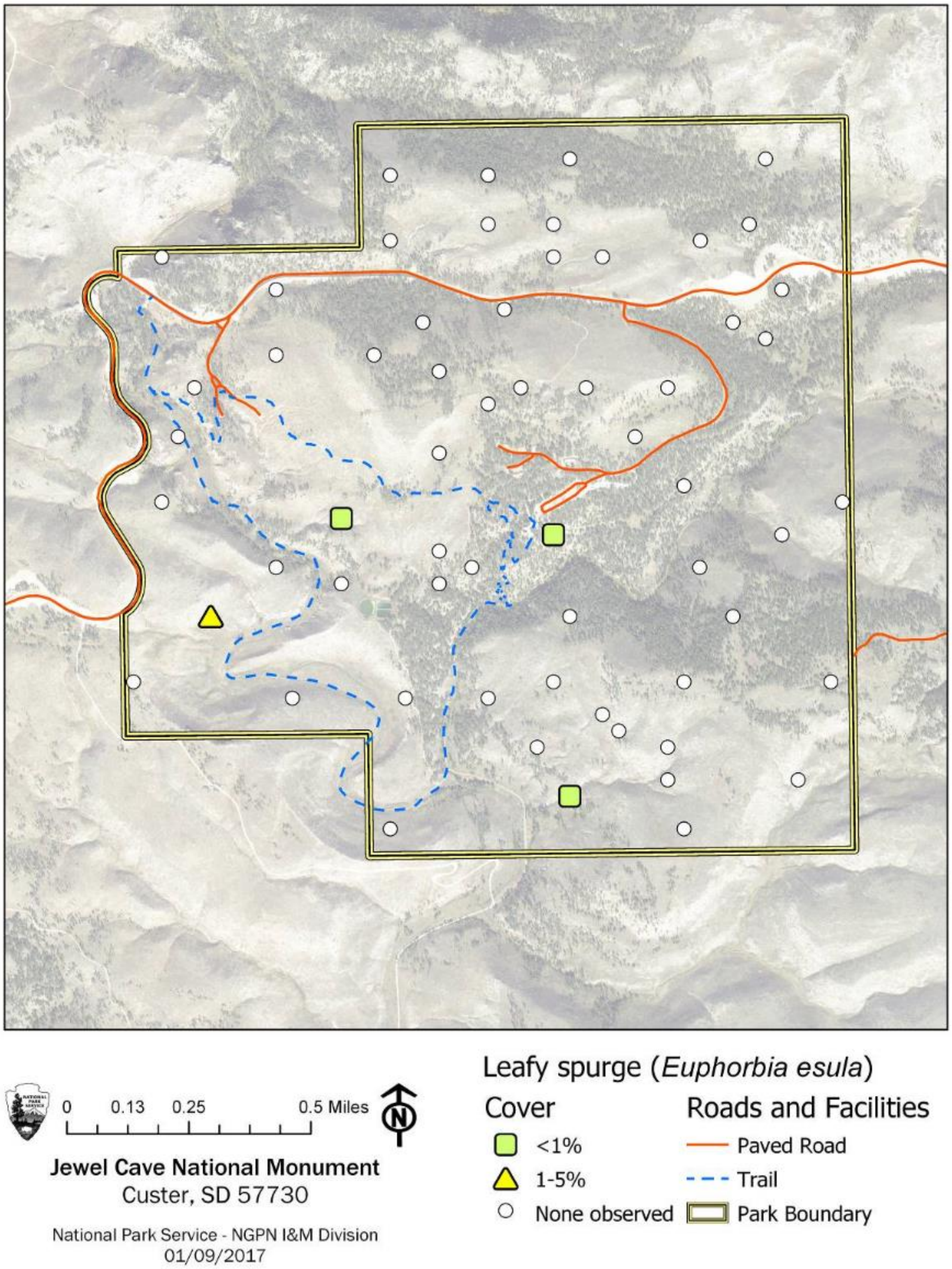
0
0.13
0.25
0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017
Japanese brome (*Bromus japonicus*)
Cover
<1%
1-5%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary

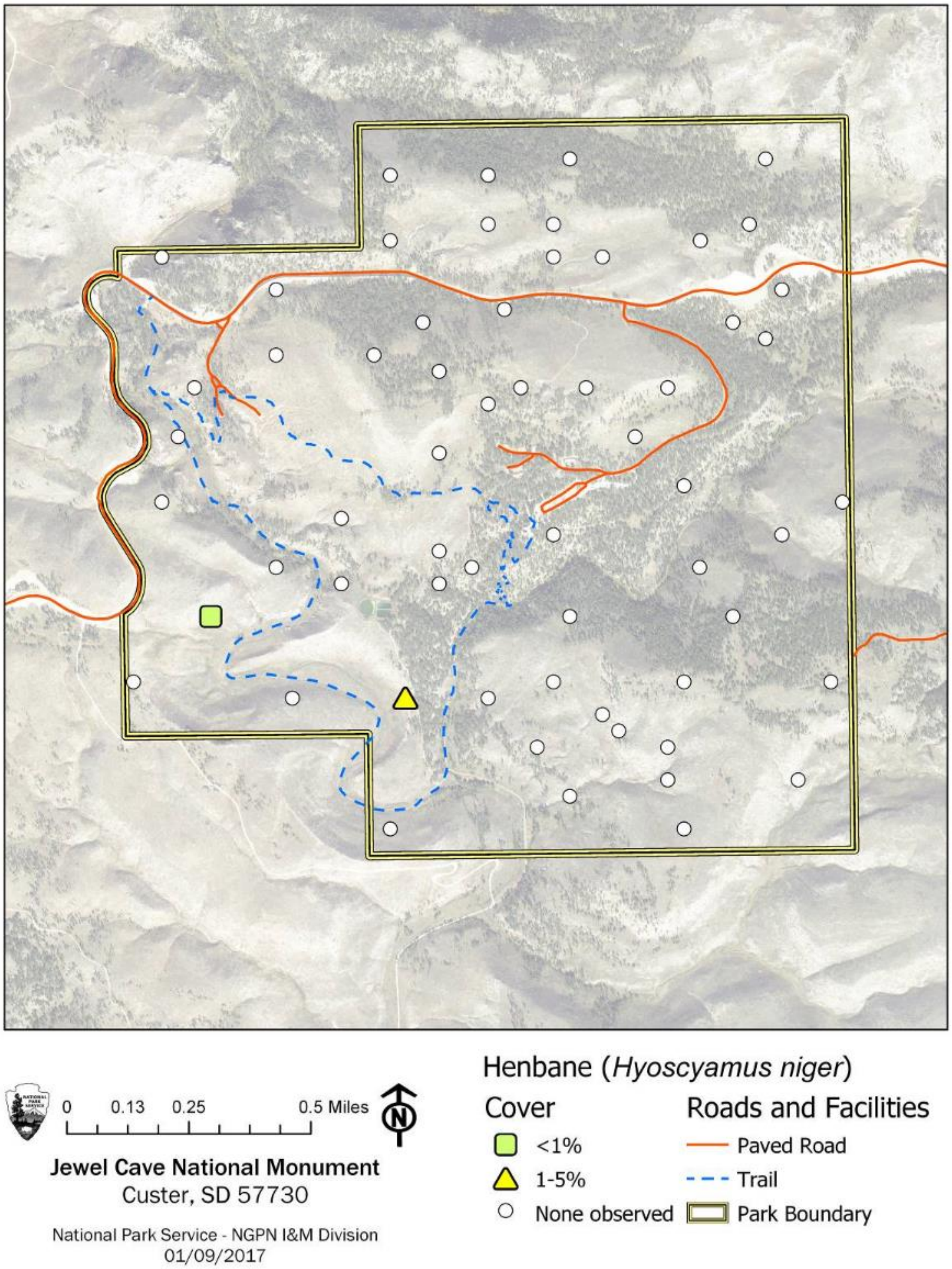

0
0.13
0.25
0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017
Cheatgrass (*Bromus tectorum*)
Cover
<1%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary



0
0.13
0.25
0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017
Bull thistle (*Cirsium vulgare*)
Cover
Single plant
<1%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary


0
0.13
0.25
0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017
Houndstongue (*Cynoglossum officionale*)
Cover
Single plant
<1%
1-5%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary


Leafy spurge (*Euphorbia esula*)
Cover
<1%
1-5%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary
0
0.13
0.25
0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017


0
0.13
0.25
0.5 Miles
N
Jewel Cave National Monument
Custer, SD 57730
National Park Service - NGPN I&M Division
01/09/2017
Henbane (Hyoscyamus niger)
Cover
<1%
1-5%
None observed
Roads and Facilities
Paved Road
Trail
Park Boundary

NPS 146/145055, May 2018

National Park Service
U.S. Department of the Interior

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