



Plant Community Composition and Structure Monitoring at Jewel Cave National Monument

2021 Data Report

Natural Resource Data Series NPS/NGPN/NRDS—2022/1367



**ON THIS PAGE**

Overview of long-term monitoring plot PCM_015 in Jewel Cave National Monument in 2021.

Photograph courtesy of the National Park Service.

ON THE COVER

The Canyons reenters a small patch of forest just below the Historic Area at Jewel Cave National Monument.

Photograph courtesy of the National Park Service.

Plant Community Composition and Structure Monitoring at Jewel Cave National Monument

2021 Data Report

Natural Resource Data Series NPS/NGPN/NRDS—2022/1367

Louis E. Dupret¹, Daniel J. Swanson²

¹National Park Service
Northern Great Plains Inventory & Monitoring Network
820 Columbus St.
Rapid City, SD 57701

²National Park Service
Northern Great Plains Fire Management
26611 U.S. Hwy 385
Hot Springs, SD 57747

September 2022

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible and technically accurate.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the [Northern Great Plains Inventory & Monitoring Network website](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Dupret, L. E., and D. J. Swanson. 2022. Plant community composition and structure monitoring at Jewel Cave National Monument: 2021 data report. Natural Resource Data Series NPS/NGPN/NRDS—2022/1367. National Park Service, Fort Collins, Colorado.
<https://doi.org/10.36967/2293480>

Contents

	Page
Figures.....	iv
Tables.....	v
Abstract.....	vi
Acknowledgments.....	vii
Introduction.....	1
Methods.....	3
Sample Design.....	3
Plot Layout and Sampling	4
Data Management and Analysis.....	8
Results.....	9
Further Analysis.....	20
Literature Cited	21

Figures

Page

Figure 1. Map of Jewel Cave National Monument plant community monitoring plots visited in 2021 by the Northern Great Plains Network Inventory & Monitoring Program (NGPN) and the Northern Great Plains Fire Ecology Program (NGPFire).....	2
Figure 2. Long-term monitoring plot layout used for sampling vegetation used by the Northern Great Plains Inventory and Monitoring vegetation crew.....	5
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.....	6
Figure 4. Photograph of long-term monitoring plot PCM_016 at Jewel Cave National Monument in 2021.....	19

Tables

	Page
Table 1. Field journal for plant community monitoring plot visits at Jewel Cave National Monument in 2021.	3
Table 2. Field journal for fire plant community monitoring plot visits at Jewel Cave National Monument in 2021.	4
Table 3. Exotic species included in the Northern Great Plains Network’s early detection and rapid response program.	7
Table 4. List of all plant species identified in Jewel Cave National Monument (JECA) long-term plant community monitoring plots in 2021.	9
Table 5. Total number of plant species identified in each of the seven plots monitored at Jewel Cave National Monument (JECA) in 2021.....	15
Table 6. Absolute percent cover of native and exotic plant species in plots monitored at Jewel Cave National Monument (JECA) in 2021.....	15
Table 7. Woody species data from seven long-term monitoring plots visited at Jewel Cave National Monument (JECA) in 2021.....	16
Table 8. Surface fuels summary for 18 plots at Jewel Cave National Monument (JECA) in 2021.	17
Table 9. Disturbance types and occurrence in six plant community monitoring plots visited in 2021 at Jewel Cave National Monument (JECA).	18

Abstract

This report presents the results of vegetation monitoring in 2021 at Jewel Cave National Monument (JECA) by the Northern Great Plains Inventory and Monitoring Network (NGPN) and the Northern Great Plains Fire Ecology (NGPFire) program. This was the eleventh year of combined monitoring efforts.

Crew members from NGPN and NGPFire visited seven long-term monitoring plots to collect data on the plant communities at JECA. This work is part of a long-term monitoring effort designed to provide a better understanding of the condition of the vegetation community and how it changes over time. NGPN staff measured species richness, herb-layer height, native and non-native species abundance, ground cover, and site disturbance at each of the six plots. In plots where woody species were present, tree regeneration, tall shrub density, tree density, and woody fuel loads were also measured.

In 2021, the NGPN and NGPFire monitoring crews identified 133 unique plant species in seven Plant Community Monitoring (PCM) plots. Of those species, 16 were exotic species. On average, the absolute cover of native species was much greater than the absolute cover of exotic species. No rare species were observed in any plots. NGPN and NGPFire crews collected tree regeneration and fuel load data in seven plots. Four different tree and shrub species were present; however, ponderosa pine was the dominant species. Ground disturbances, observed in seventeen of the eighteen plots, included animal use, prescribed fire, and soil disturbance.

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, especially L. Filipi. The 2021 NGPN vegetation field crew—M. Davis, T. Bortz, A. Kuczera and A. Dahms—and the NGPFire crew—D. Swanson, I. Muirhead, C. Fossum, and Jennifer McCoy—collected the data included in this report.

Introduction

Jewel Cave National Monument (JECA) is located in the southwestern Black Hills of South Dakota. It was established in 1908 with the mission to preserve Jewel Cave through management of the surface and subsurface ecosystem, while providing opportunities for the pursuit of scientific interests and public enjoyment. While covering a relatively small area (516 ha, 1274 ac), JECA contains diverse native ponderosa forest and grassland communities (Marriot and Hartman 1986, Ashton et al. 2012a). The Jasper Fire greatly impacted the park in 2000, moderately to severely burning 75% of the landscape and resulting in more than 50% mortality of trees in the park (Lentile et al. 2005). Ninety-five percent of the monument was affected by this forest fire (NPS 2004), resulting in a patchwork of intact and entirely consumed ponderosa pine stands.

The Northern Great Plains Inventory & Monitoring Program (NGPN) began annual vegetation monitoring efforts in JECA in 2011 (Ashton et al. 2012a). Vegetation monitoring protocols and plot locations were chosen to represent the entire park and to coordinate efforts with the Northern Great Plains Fire Ecology Program (NGPFire; Figure 1). The NGPFire crew conducted a prescribed fire in the Hilltop Burn Unit which occurred on October 29, 2021. In this report, we provide summaries of the vegetation data collected in 2021 from six plant community plot visits and fourteen fire effects plot visits. For a more in-depth data report on long-term trends at JECA, refer to the 2011–2017 summary report (Ashton et al. 2018).

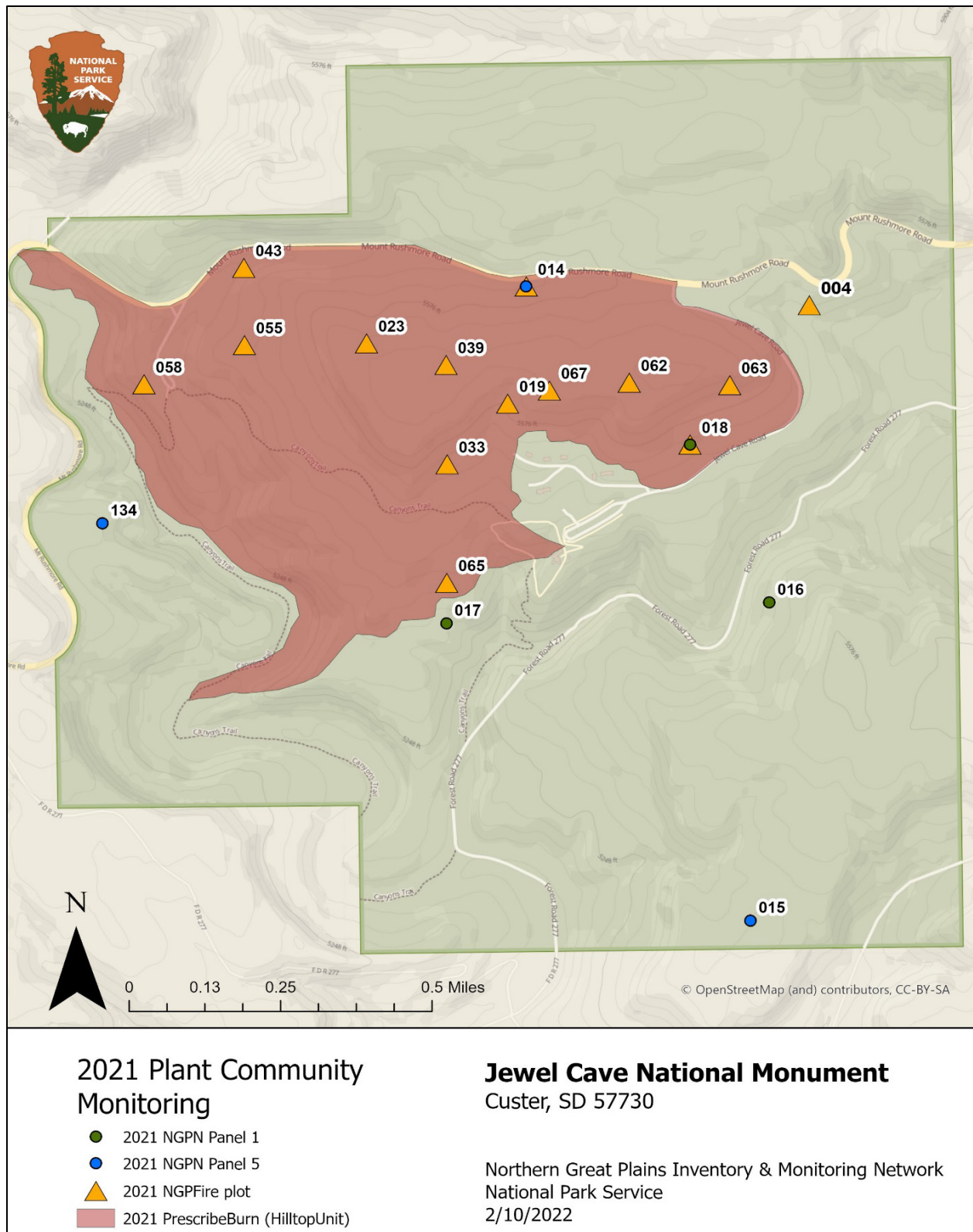


Figure 1. Map of Jewel Cave National Monument plant community monitoring plots visited in 2021 by the Northern Great Plains Network Inventory & Monitoring Program (NGPN) and the Northern Great Plains Fire Ecology Program (NGPFire).

Methods

The NGPN Plant Community Composition and Structure Monitoring Protocol (Symstad et al. 2012b, a) describes in detail the methods used for sampling long-term plots. The general approach is briefly described below. For more detail, please see Symstad et al. 2012a, available at <https://www.nps.gov/im/ngpn/plant-communities.htm>.

Sample Design

The NGPN team implemented a survey to monitor plant community structure and composition at JECA using a spatially balanced probability design (Generalized Random Tessellation Stratified [GRTS]; Stevens and Olsen 2003, 2004). Using a GRTS design, 15 randomly located sites were selected within JECA to be established as Plant Community Monitoring plots (PCM plots). These sites were split into five panels containing three sites each. An NGPN crew visits two panels (six PCM plots) during early July every year, using a rotating sampling scheme that consists of three plots visited the previous year and three plots that have not been visited for four years. Data from these randomly selected sites can be used to estimate the condition of vegetation communities for the whole park and to discern trends in condition over time. In 2021, the NGPN crew visited sites in panel 1 and panel 5 (Figure 1). Sampling was completed by one NGPN crew and one NGPFire crew, in approximately 150 crew hours (Table 1).

Table 1. Field journal for plant community monitoring plot visits at Jewel Cave National Monument in 2021. A total of 6 plots were visited by the Northern Great Plains Network Inventory & Monitoring crew.

Date Visited	Plot Name	Field Notes
June 28, 2021	PCM_015	4 person crew
June 28, 2021	PCM_134	4 person crew
June 29, 2021	PCM_016	4 person crew
June 29, 2021	PCM_017	4 person crew
June 30, 2021	PCM_014	4 person crew
June 30, 2021	PCM_018	4 person crew

When a site was located within an active burn unit, NGPFire added additional visits based on a pre-burn, 1, 2, 5, and 10-year post-burn sampling schedule using the GRTS sampling schema and establishing fire plant community monitoring (FPCM) plots. Post-burn monitoring by the NGPFire crew took place at thirteen plots in the Hilltop burn unit, and a pre-burn survey was performed in one plot in the Lithograph Canyon unit. (Table 2).

Table 2. Field journal for fire plant community monitoring plot visits at Jewel Cave National Monument in 2021. A total of 14 plots were visited by the Northern Great Plains Fire Ecology Program (NGPFire) crew.

Date Visited	Plot Name	Burn Unit	Field Notes
July 6, 2021	PCM_004	Lithograph Canyon	3 person crew
November 3, 2021	PCM_018	Hilltop	3 person crew; Immediate post-Burn
November 3, 2021	PCM_062	Hilltop	4 person crew; Immediate post-burn
November 3, 2021	PCM_063	Hilltop	4 person crew; Immediate post-burn
November 3, 2021	PCM_067	Hilltop	4 person crew; Immediate post-burn
November 4, 2021	PCM_014	Hilltop	2 person crew; Immediate post-burn
November 4, 2021	PCM_019	Hilltop	2 person crew; Immediate post-burn
November 4, 2021	PCM_039	Hilltop	2 person crew; Immediate post-burn
November 15, 2021	PCM_023	Hilltop	2 person crew; Immediate post-burn
November 15, 2021	PCM_033	Hilltop	2 person crew; Immediate post-burn
November 15, 2021	PCM_043	Hilltop	1 person crew; Immediate post-burn
November 15, 2021	PCM_058	Hilltop	2 person crew; Immediate post-burn
November 16, 2021	PCM_065	Hilltop	1 person crew; Immediate post-burn
November 29, 2021	PCM_055	Hilltop	2 person crew; Immediate post-burn

Plot Layout and Sampling

At each site visited, the NGPN crew recorded plant species cover and frequency in a rectangular, 50 m x 20 m (0.1 ha), permanent plot (Figure 2). Data on ground cover, herb-layer height (≤ 2 m), and plant cover were collected on two 50 m transects (the long sides of the plot) using a point-intercept method (Figure 3). Species richness data from the point-intercept method were supplemented with species presence data collected in five 1 m² quadrats located systematically along each transect (Figure 2). If a plant species was identified in the plot but was not included on the verified park species list, a voucher plant specimen was collected when possible and submitted to a botanist for independent verification. NGPFire collected only point-intercept data at one of the fire plots.

When woody species were present within 38 m of plot center, tree regeneration and tall shrub density data were collected within a 10 m radius subplot centered in the larger 50 m x 20 m (0.1 ha) plot. Trees within the entire 0.1 ha plot with a diameter at breast height (DBH) of > 15 cm were mapped and tagged. For each tree, the species, DBH, status (live or dead), and condition (e.g., leaf-discoloration, insect-damaged) were recorded. For all poles ($2.54 \leq \text{DBH} \leq 15$ cm) located within the 10 m radius subplot, only DBH and status were recorded. Tree and tall shrub species with $\text{DBH} < 2.54$ cm (seedlings) were tallied by species within the 10 m radius subplot. In 2019, NGPN changed the way these species counts were made. Previously, once the count for a species had reached 100, seedlings of that species were not counted in the following quarters and a calculated estimate was made when the data was analyzed. Now, all seedling species present are always counted or estimated in all four quarters of the 10 m radius subplot while in the field. Dead and downed woody fuel load data were collected along two perpendicular, 100 ft (30.49 m) transects (fuel lines) with midpoints at

the center of the plot (Figure 2), following Brown's Line methods (Brown 1974, Brown et al. 1982). Fuel load data were only collected if at least one piece of woody litter or fuel intersected a fuel line.

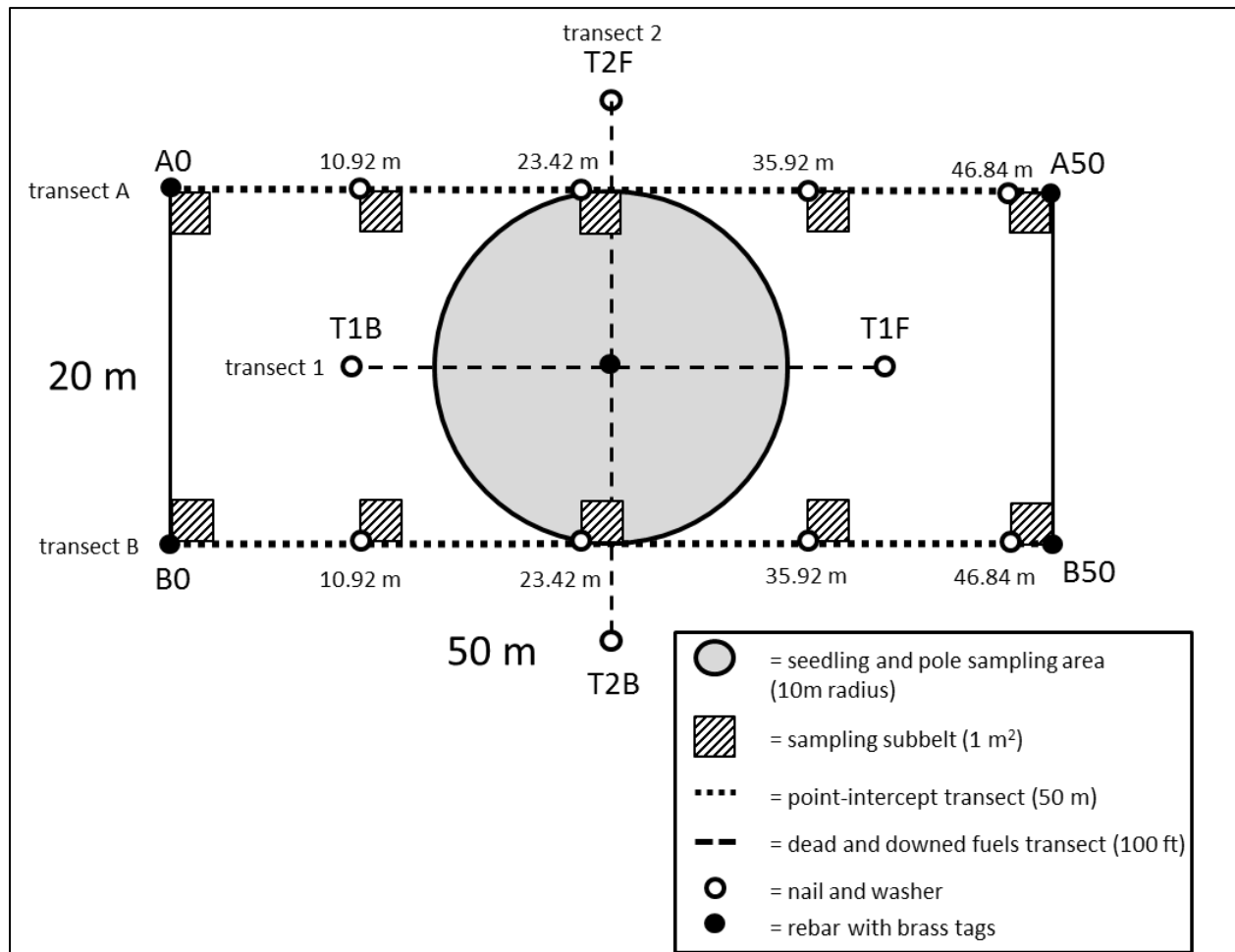


Figure 2. Long-term monitoring plot layout used for sampling vegetation used by the Northern Great Plains Inventory and Monitoring vegetation crew.

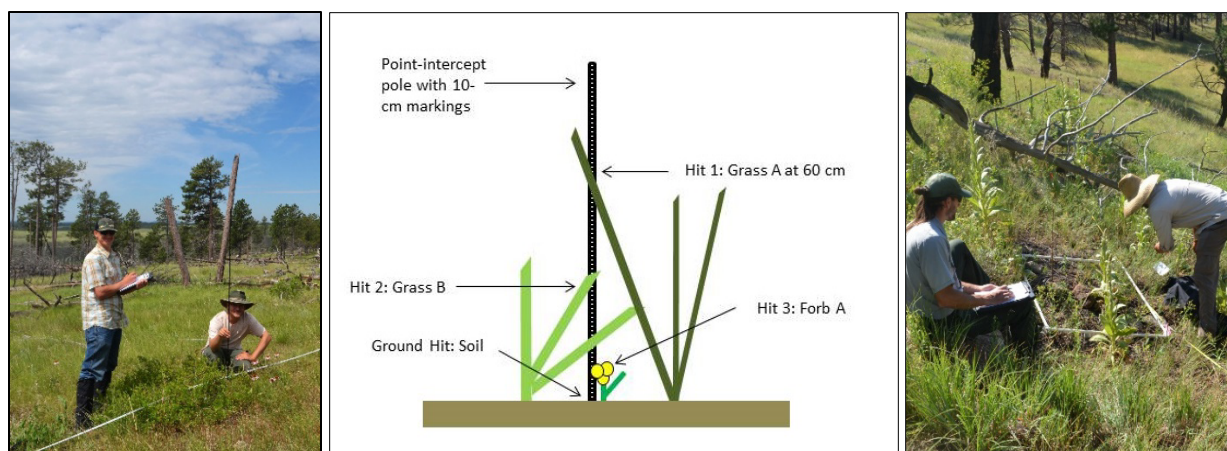


Figure 3. The Northern Great Plains Inventory & Monitoring vegetation crew used point-intercept (left and center panel) and quadrats (right panel) to document plant diversity and abundance.

Common disturbances were assessed and documented at each plot. The type, which included animal trails and fire, was recorded. In 2018 a new category called soil disturbance was added, which is defined as loose, exposed soil from all sources. Plots were also assessed for the presence and abundance of target exotic species (Table 3), which is critical for early detection and rapid response to exotic species threats. These species were chosen in collaboration with the Midwest Invasive Plant Network, Northern Great Plains Invasive Plant Management Team, park managers, and local weed experts. Each target species was assigned an abundance class from 1–5, based on an ocular estimate of cover, where 1 = one individual, 2 = few individuals, 3 = cover of 1–5%, 4 = cover of 5–25%, and 5 = cover > 25% of the plot.

Table 3. Exotic species included in the Northern Great Plains Network's early detection and rapid response program.

Habitat	Scientific Name	Common Name
Riparian	<i>Heracleum mantegazzianum</i>	giant hogweed
Riparian	<i>Alliaria petiolata</i>	garlic mustard
Riparian	<i>Lepidium latifolium</i>	perennial pepperweed
Riparian	<i>Pueraria montana</i> var. <i>lobata</i>	kudzu
Riparian	<i>Myriophyllum spicatum</i>	Eurasian Watermilfoil
Riparian	<i>Iris pseudacorus</i>	yellow iris
Riparian	<i>Arundo donax</i>	giant reed
Riparian	<i>Polygonum cuspidatum</i> ; <i>P. sachalinense</i> ; <i>P. x bohemicum</i>	knotweeds
Riparian	<i>Rhamnus cathartica</i>	common buckthorn
Riparian	<i>Ailanthus altissima</i>	tree of heaven
Upland	<i>Falcaria vulgaris</i>	Sickle Weed
Upland	<i>Pastinaca sativa</i>	Wild Parsnip
Upland	<i>Acroptilon repens</i>	Russian Knapweed
Upland	<i>Centaurea solstitialis</i>	yellow star thistle
Upland	<i>Centaurea virgata</i> ; <i>C. diffusa</i> ; <i>C. jacea</i>	knapweeds
Upland	<i>Chondrilla juncea</i>	rush skeletonweed
Upland	<i>Hieracium aurantiacum</i> ; <i>H. caespitosum</i> ; <i>H. piloselloides</i>	orange, meadow, and tall hawkweed
Upland	<i>Senecio jacobaeae</i>	Tansy Ragwort
Upland	<i>Isatis tinctoria</i>	Dyer's woad
Upland	<i>Gypsophila paniculata</i>	baby's breath
Upland	<i>Dipsacus fullonum</i> & <i>D. laciniatus</i>	common teasel
Upland	<i>Euphorbia myrsinites</i> & <i>E. cyparissias</i>	myrtle spurge
Upland	<i>Salvia aethiopis</i> ; <i>S. pratensis</i>	Mediterranean and Meadow sage
Upland	<i>Lythrum salicaria</i>	Purple Loosestrife
Upland	<i>Taeniatherum caput-medusae</i>	medusahead
Upland	<i>Ventenata dubia</i>	African wiregrass
Upland	<i>Ranunculus acris</i>	Tall Buttercup
Upland	<i>Linaria dalmatica</i> ; <i>L. vulgaris</i>	toadflax
Upland	<i>Thymelaea passerina</i>	Spurge Flax

Data Management and Analysis

FFI remote (FEAT/FIREMON Integrated; <http://frames.gov/ffi/>) was the primary software environment used 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 Inventory and Monitoring Program. Species scientific names, codes, common names, and native status are from the USDA Plants Database (USDA-NRCS 2022). However, nomenclature follows the [Integrated Taxonomic Information System](#) (ITIS). In the few cases where ITIS recognized a new name that was not in the USDA PLANTS database, the new name was used, and a unique plant code was assigned.

After data were entered in the database, 100% of records were verified with the original data sheets to minimize transcription errors, followed by a 10% review of records to confirm accuracy. When errors were identified by the crew, corrections were made to the original datasheets and the FFI database.

Data summaries were produced using the FFI reporting and query tools. The number of species encountered in each plot was calculated using data from point-intercept, quadrat, woody species, and target species protocols. Absolute cover was calculated using point-intercept data and is the total number of vegetation intercepts. This is often greater than 100% because more than one species can be intercepted per point due to overlapping vegetation.

The conservation status rank of plant species observed at JECA in 2021 was determined by cross-referencing with the [NatureServe](#) conservation status list, as well as the South Dakota rare plant species lists. For this report, a species is considered rare or of conservation concern if its global (G) or state (S) conservation status rank is classified as critically imperiled (G1/S1), imperiled (G2/S2), or vulnerable (G3/S3). The 2021 species list was also cross-referenced with the list of noxious weeds maintained by the [South Dakota Department of Agriculture](#).

Results

There are 480 vascular plant species on the JECA species list, and NGPN and NGPFire monitoring crews identified a total of 133 species from 18 monitoring plots in 2021 (Table 4). Of these species, 16 are exotic species for the park. The 2021 species list was cross-referenced with state-wide rare and noxious exotic species lists for South Dakota. One species matched the South Dakota exotic species list: Canada thistle (*Cirsium arvense*). Also, the Common mullein (*Verbascum thapsus*) is listed as noxious species in Custer County. No rare plant species were identified by either crew. Plant species identified in 2021 were also cross-referenced with the NPSpecies list for JECA, which resulted in two potential new species for the park: Lindsey's aster (*Symphyotrichum ciliolatum*) and wheat (*Triticum sp.*). Samples of these species were collected during the field season, vouchered and verified by the end of 2021.

Table 4. List of all plant species identified in Jewel Cave National Monument (JECA) long-term plant community monitoring plots in 2021. In the Notes column, “Exotic” indicates that a species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. State-wide noxious weed species designated as “Noxious” for South Dakota in the Notes column. Species that were not the NPS species list for JECA are indicated with “New” in the notes column.

Family	Species Code	Scientific Name	Common Name	Notes
Anacardiaceae	RHAR4	<i>Rhus aromatica</i>	fragrant sumac	–
Anacardiaceae	TORY	<i>Toxicodendron rydbergii</i>	western poison ivy	–
Apiaceae	MUTE3	<i>Musineon tenuifolium</i>	slender wildparsley	–
Apocynaceae	APAN2	<i>Apocynum androsaemifolium</i>	spreading dogbane	–
Asclepiadaceae	ASPU	<i>Asclepias pumila</i>	plains milkweed	–
Asclepiadaceae	ASVI	<i>Asclepias viridiflora</i>	green comet milkweed	–
Asteraceae	DICA18	<i>Dieteria canescens</i>	hoary tansyaster	–
Asteraceae	ACMI2	<i>Achillea millefolium</i>	common yarrow	–
Asteraceae	AMAR2	<i>Ambrosia artemisiifolia</i>	annual ragweed	–
Asteraceae	ANPA4	<i>Antennaria parvifolia</i>	small-leaf pussytoes	–
Asteraceae	ARLU	<i>Artemisia ludoviciana</i>	white sagebrush	–
Asteraceae	CIAR4	<i>Cirsium arvense</i>	Canada thistle	Exotic, Noxious
Asteraceae	CIFL	<i>Cirsium flodmanii</i>	Flodman's thistle	–
Asteraceae	CIRSI	<i>Cirsium</i>	thistle	Exotic
Asteraceae	CIUN	<i>Cirsium undulatum</i>	wavyleaf thistle	–
Asteraceae	COCA5	<i>Conyza canadensis</i>	horseweed	–
Asteraceae	ECAN2	<i>Echinacea angustifolia</i>	blacksamson echinacea	–
Asteraceae	ERFL	<i>Erigeron flagellaris</i>	trailing fleabane	–
Asteraceae	ERFO3	<i>Erigeron formosissimus</i>	beautiful fleabane	–

Table 4 (continued). List of all plant species identified in Jewel Cave National Monument (JECA) long-term plant community monitoring plots in 2021. In the Notes column, “Exotic” indicates that a species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. State-wide noxious weed species designated as “Noxious” for South Dakota in the Notes column. Species that were not the NPS species list for JECA are indicated with “New” in the notes. column.

Family	Species Code	Scientific Name	Common Name	Notes
Asteraceae	ERIGE2	<i>Erigeron</i>	fleabane	–
Asteraceae	ERST3	<i>Erigeron strigosus</i>	prairie fleabane	–
Asteraceae	ERSU2	<i>Erigeron subtrinervis</i>	threenerve fleabane	–
Asteraceae	GRSQ	<i>Grindelia squarrosa</i>	curlycup gumweed	–
Asteraceae	GUSA2	<i>Gutierrezia sarothrae</i>	broom snakeweed	–
Asteraceae	HELIA3	<i>Helianthus</i>	sunflower	–
Asteraceae	HEPA19	<i>Helianthus pauciflorus</i>	stiff sunflower	–
Asteraceae	LASE	<i>Lactuca serriola</i>	prickly lettuce	Exotic
Asteraceae	LIPU	<i>Liatris punctata</i>	dotted blazing star	–
Asteraceae	LYJU	<i>Lygodesmia juncea</i>	rush skeletonplant	–
Asteraceae	MUOB99	<i>Mulgedium oblongifolium</i>	blue lettuce	–
Asteraceae	PACA15	<i>Packera cana</i>	woolly groundsel	–
Asteraceae	PAPL12	<i>Packera plattensis</i>	prairie groundsel	–
Asteraceae	RUHI2	<i>Rudbeckia hirta</i>	blackeyed Susan	–
Asteraceae	SOCA6	<i>Solidago canadensis</i>	Canada goldenrod	–
Asteraceae	SOMI2	<i>Solidago missouriensis</i>	Missouri goldenrod	–
Asteraceae	SOMO	<i>Solidago mollis</i>	velvety goldenrod	–
Asteraceae	SONE	<i>Solidago nemoralis</i>	gray goldenrod	–
Asteraceae	SOPT4	<i>Solidago ptarmicoides</i>	prairie goldenrod	–
Asteraceae	SORI2	<i>Solidago rigida</i>	stiff goldenrod	–
Asteraceae	SYCI	<i>Symphyotrichum ciliolatum</i>	Lindley's aster	New
Asteraceae	SYER	<i>Symphyotrichum ericoides</i>	white heath aster	–
Asteraceae	SYLA3	<i>Symphyotrichum laeve</i>	smooth blue aster	–
Asteraceae	SYMPH4	<i>Symphyotrichum</i>	aster	–
Asteraceae	SYOB	<i>Symphyotrichum oblongifolium</i>	aromatic aster	–
Asteraceae	TAOF	<i>Taraxacum officinale</i>	common dandelion	Exotic
Asteraceae	TEAC	<i>Tetraneuris acaulis</i>	stemless four-nerve daisy	–
Asteraceae	TRDU	<i>Tragopogon dubius</i>	yellow salsify	Exotic
Boraginaceae	CYOF	<i>Cynoglossum officinale</i>	houndstongue	Exotic
Boraginaceae	LIIN2	<i>Lithospermum incisum</i>	narrowleaf stoneseed	–
Boraginaceae	MELA3	<i>Mertensia lanceolata</i>	prairie bluebells	–
Brassicaceae	ARPY4	<i>Arabis pycnocarpa</i>	creamflower rockcress	–
Brassicaceae	CAMI2	<i>Camelina microcarpa</i>	littlepod false flax	Exotic

Table 4 (continued). List of all plant species identified in Jewel Cave National Monument (JECA) long-term plant community monitoring plots in 2021. In the Notes column, “Exotic” indicates that a species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. State-wide noxious weed species designated as “Noxious” for South Dakota in the Notes column. Species that were not the NPS species list for JECA are indicated with “New” in the notes. column.

Family	Species Code	Scientific Name	Common Name	Notes
Brassicaceae	ERAS2	<i>Erysimum asperum</i>	western wallflower	–
Brassicaceae	PHAR99	<i>Physaria arenosa</i>	Great Plains bladderpod	–
Brassicaceae	SIAL2	<i>Sisymbrium altissimum</i>	tall tumblemustard	Exotic
Campanulaceae	CARO2	<i>Campanula rotundifolia</i>	bluebell bellflower	–
Caprifoliaceae	SYAL	<i>Symphoricarpos albus</i>	common snowberry	–
Caprifoliaceae	SYOC	<i>Symphoricarpos occidentalis</i>	western snowberry	–
Chenopodiaceae	CHENO	<i>Chenopodium</i>	goosefoot	Exotic
Chenopodiaceae	CHPR5	<i>Chenopodium pratericola</i>	desert goosefoot	–
Cyperaceae	CADU6	<i>Carex duriuscula</i>	needleleaf sedge	–
Cyperaceae	CAFI	<i>Carex filifolia</i>	threadleaf sedge	–
Cyperaceae	CAIN11	<i>Carex interior</i>	inland sedge	–
Cyperaceae	CAIN9	<i>Carex inops</i>	sun sedge	–
Cyperaceae	CARI	<i>Carex richardsonii</i>	Richardson's sedge	–
Cyperaceae	CARO5	<i>Carex rossii</i>	Ross' sedge	–
Elaeagnaceae	SHCA	<i>Shepherdia canadensis</i>	russet buffaloberry	–
Ericaceae	ARUV	<i>Arctostaphylos uva-ursi</i>	kinnikinnick	–
Fabaceae	ASAG2	<i>Astragalus agrestis</i>	purple milkvetch	–
Fabaceae	ASAL7	<i>Astragalus alpinus</i>	alpine milkvetch	–
Fabaceae	ASCR2	<i>Astragalus crassicaarpus</i>	groundplum milkvetch	–
Fabaceae	ASFL2	<i>Astragalus flexuosus</i>	flexile milkvetch	–
Fabaceae	ASLA27	<i>Astragalus laxmannii</i>	Laxmann's milkvetch	–
Fabaceae	ASMI10	<i>Astragalus missouriensis</i>	Missouri milkvetch	–
Fabaceae	ASSP6	<i>Astragalus spatulatus</i>	tufted milkvetch	–
Fabaceae	DACA7	<i>Dalea candida</i>	white prairie clover	–
Fabaceae	GLLE3	<i>Glycyrrhiza lepidota</i>	American licorice	–
Fabaceae	HEAL	<i>Hedysarum alpinum</i>	alpine sweetvetch	–
Fabaceae	LUAR3	<i>Lupinus argenteus</i>	silvery lupine	–
Fabaceae	MELU	<i>Medicago lupulina</i>	black medick	Exotic
Fabaceae	MEOF	<i>Melilotus officinalis</i>	yellow sweetclover	Exotic
Fabaceae	OXCA4	<i>Oxytropis campestris</i>	field locoweed	–
Fabaceae	OXLA3	<i>Oxytropis lambertii</i>	purple locoweed	–
Fabaceae	OXSE	<i>Oxytropis sericea</i>	white locoweed	–
Fabaceae	OXYTR	<i>Oxytropis</i>	locoweed	–

Table 4 (continued). List of all plant species identified in Jewel Cave National Monument (JECA) long-term plant community monitoring plots in 2021. In the Notes column, “Exotic” indicates that a species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. State-wide noxious weed species designated as “Noxious” for South Dakota in the Notes column. Species that were not the NPS species list for JECA are indicated with “New” in the notes. column.

Family	Species Code	Scientific Name	Common Name	Notes
Fabaceae	PEAR6	<i>Pedimelum argophyllum</i>	silverleaf Indian breadroot	–
Fabaceae	PEES	<i>Pedimelum esculentum</i>	large Indian breadroot	–
Fabaceae	VIAM	<i>Vicia americana</i>	American vetch	–
Grossulariaceae	RIAU	<i>Ribes aureum</i>	golden currant	–
Grossulariaceae	RICE	<i>Ribes cereum</i>	wax currant	–
Grossulariaceae	RIHI	<i>Ribes hirtellum</i>	hairystem gooseberry	–
Grossulariaceae	RIOX	<i>Ribes oxyacanthoides</i>	Canadian gooseberry	–
Iridaceae	IRMI	<i>Iris missouriensis</i>	Rocky Mountain iris	–
Iridaceae	SIMO2	<i>Sisyrinchium montanum</i>	strict blue-eyed grass	–
Lamiaceae	MOFI	<i>Monarda fistulosa</i>	wild bergamot	–
Liliaceae	ALCE2	<i>Allium cernuum</i>	nodding onion	–
Liliaceae	ALTE	<i>Allium textile</i>	textile onion	–
Liliaceae	ANEL5	<i>Anticlea elegans</i>	mountain deathcamas	–
Liliaceae	CANU3	<i>Calochortus nuttallii</i>	sego lily	–
Liliaceae	LEMO4	<i>Leucocrinum montanum</i>	common starlily	–
Liliaceae	MAST4	<i>Maianthemum stellatum</i>	starry false lily of the valley	–
Liliaceae	TOVE2	<i>Toxicoscordion venenosum</i>	meadow deathcamas	–
Linaceae	LILE3	<i>Linum lewisii</i>	Lewis flax	–
Malvaceae	SPCO	<i>Sphaeralcea coccinea</i>	scarlet globemallow	–
Onagraceae	OESU99	<i>Oenothera suffrutescens</i>	scarlet beeblossom	–
Pinaceae	PIPO	<i>Pinus ponderosa</i>	ponderosa pine	–
Plantaginaceae	SYWY99	<i>Synthyris wyomingensis</i>	Wyoming kittentails	–
Poaceae	PIMI7	<i>Piptatherum micranthum</i>	littleseed ricegrass	–
Poaceae	ACHY	<i>Achnatherum hymenoides</i>	Indian ricegrass	–
Poaceae	ACNE9	<i>Achnatherum nelsonii</i>	Columbia needlegrass	–
Poaceae	ACRI8	<i>Achnatherum richardsonii</i>	Richardson's needlegrass	–
Poaceae	ANGE	<i>Andropogon gerardii</i>	big bluestem	–
Poaceae	BOCU	<i>Bouteloua curtipendula</i>	sideoats grama	–
Poaceae	BOGR2	<i>Bouteloua gracilis</i>	blue grama	–
Poaceae	BRAN	<i>Bromus anomalus</i>	nodding brome	–
Poaceae	BRCI2	<i>Bromus ciliatus</i>	fringed brome	–
Poaceae	BRIN2	<i>Bromus inermis</i>	smooth brome	Exotic
Poaceae	BRJA	<i>Bromus japonicus</i>	Japanese brome	Exotic

Table 4 (continued). List of all plant species identified in Jewel Cave National Monument (JECA) long-term plant community monitoring plots in 2021. In the Notes column, “Exotic” indicates that a species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. State-wide noxious weed species designated as “Noxious” for South Dakota in the Notes column. Species that were not the NPS species list for JECA are indicated with “New” in the notes. column.

Family	Species Code	Scientific Name	Common Name	Notes
Poaceae	BRPO2	<i>Bromus porteri</i>	Porter brome	–
Poaceae	DASP2	<i>Danthonia spicata</i>	poverty oatgrass	–
Poaceae	ELEL5	<i>Elymus elymoides</i>	squirreltail	–
Poaceae	ELLA3	<i>Elymus lanceolatus</i>	thickspike wheatgrass	–
Poaceae	ELRE4	<i>Elymus repens</i>	quackgrass	Exotic
Poaceae	ELTR7	<i>Elymus trachycaulus</i>	slender wheatgrass	–
Poaceae	FESA	<i>Festuca saximontana</i>	Rocky Mountain fescue	–
Poaceae	HECO26	<i>Hesperostipa comata</i>	needle and thread	–
Poaceae	HESP11	<i>Hesperostipa spartea</i>	porcupinegrass	–
Poaceae	KOMA	<i>Koeleria macrantha</i>	prairie Junegrass	–
Poaceae	MUCU3	<i>Muhlenbergia cuspidata</i>	plains muhly	–
Poaceae	MURA	<i>Muhlenbergia racemosa</i>	marsh muhly	–
Poaceae	NAVI4	<i>Nassella viridula</i>	green needlegrass	–
Poaceae	ORAS	<i>Oryzopsis asperifolia</i>	roughleaf ricegrass	–
Poaceae	PASM	<i>Pascopyrum smithii</i>	western wheatgrass	–
Poaceae	POA	<i>Poa</i>	bluegrass	Exotic
Poaceae	POIN99	<i>Poa interior</i>	inland bluegrass	–
Poaceae	POPR	<i>Poa pratensis</i>	Kentucky bluegrass	Exotic
Poaceae	SCSC	<i>Schizachyrium scoparium</i>	little bluestem	–
Poaceae	SPHE	<i>Sporobolus heterolepis</i>	prairie dropseed	–
Poaceae	TRIT1	<i>Triticum</i> sp.	wheat	New, Exotic
Polemoniaceae	PHAL3	<i>Phlox alyssifolia</i>	alyssumleaf phlox	–
Polemoniaceae	PHHO	<i>Phlox hoodii</i>	spiny phlox	–
Polygalaceae	POAL4	<i>Polygala alba</i>	white milkwort	–
Ranunculaceae	ANCY	<i>Anemone cylindrica</i>	candle anemone	–
Ranunculaceae	ANPA19	<i>Anemone patens</i>	eastern pasqueflower	–
Rosaceae	DRFI3	<i>Drymocallis fissa</i>	bigflower cinquefoil	–
Rosaceae	AMAL2	<i>Amelanchier alnifolia</i>	Saskatoon serviceberry	–
Rosaceae	CEMO2	<i>Cercocarpus montanus</i>	mountain mahogany	–
Rosaceae	FRVI	<i>Fragaria virginiana</i>	Virginia strawberry	–
Rosaceae	GETR	<i>Geum triflorum</i>	prairie smoke	–
Rosaceae	PHMO4	<i>Physocarpus monogynus</i>	mountain ninebark	–

Table 4 (continued). List of all plant species identified in Jewel Cave National Monument (JECA) long-term plant community monitoring plots in 2021. In the Notes column, “Exotic” indicates that a species is not native to the park or, in the case where only the genus was identified, there are some species within that genus that are exotic. State-wide noxious weed species designated as “Noxious” for South Dakota in the Notes column. Species that were not the NPS species list for JECA are indicated with “New” in the notes. column.

Family	Species Code	Scientific Name	Common Name	Notes
Rosaceae	POCO13	<i>Potentilla concinna</i>	elegant cinquefoil	–
Rosaceae	PRVI	<i>Prunus virginiana</i>	chokecherry	–
Rosaceae	ROAC	<i>Rosa acicularis</i>	prickly rose	–
Rosaceae	ROAR3	<i>Rosa arkansana</i>	prairie rose	–
Rosaceae	ROSA5	<i>Rosa</i>	rose	–
Rosaceae	ROWO	<i>Rosa woodsii</i>	Woods' rose	–
Rosaceae	RUID	<i>Rubus idaeus</i>	American red raspberry	–
Rubiaceae	GABO2	<i>Galium boreale</i>	northern bedstraw	–
Rubiaceae	GATR3	<i>Galium triflorum</i>	fragrant bedstraw	–
Salicaceae	POTR5	<i>Populus tremuloides</i>	quaking aspen	–
Santalaceae	COUM	<i>Comandra umbellata</i>	bastard toadflax	–
Saxifragaceae	HERI	<i>Heuchera richardsonii</i>	Richardson's alumroot	–
Scrophulariaceae	VETH	<i>Verbascum thapsus</i>	common mullein	Exotic
Solanaceae	PHLO4	<i>Physalis longifolia</i>	longleaf groundcherry	–
Solanaceae	PHVI5	<i>Physalis virginiana</i>	Virginia groundcherry	–
Violaceae	VIAD	<i>Viola adunca</i>	hookedspur violet	–
Violaceae	VINU2	<i>Viola nuttallii</i>	Nuttall's violet	–
Violaceae	VIOLA	<i>Viola</i>	violet	–

Based on the total count of unique species observed in all plots in 2021, PCM_014 had the highest number with 66 total species (Table 5). This plot also had the highest number of native species, with 57 species. Absolute cover calculations (Table 6) reflected a greater percent of native species cover compared to exotic species cover in all seven PCM plots. PCM_018 had the highest absolute native species cover, and PCM_134 had the highest absolute exotic species cover.

Table 5. Total number of plant species identified in each of the seven plots monitored at Jewel Cave National Monument (JECA) in 2021. This is a count of all unique species identified in the plot using species data from point-intercept, quadrat, woody species, and target species protocols.

Plot	Native Species	Exotic Species	Total Species
PCM_004	23	1	24
PCM_014	57	9	66
PCM_015	31	6	37
PCM_016	48	4	52
PCM_017	47	7	54
PCM_018	34	11	45
PCM_134	37	8	45

Table 6. Absolute percent cover of native and exotic plant species in plots monitored at Jewel Cave National Monument (JECA) in 2021. Absolute percent cover is calculated using the point-intercept data. This includes overlapping species canopies, which can result in values greater than 100%.

Plot	Absolute % Native Cover	Absolute % Exotic Cover
PCM_004	93	8
PCM_014	141	40
PCM_015	110	26
PCM_016	97	6
PCM_017	67	9
PCM_018	153	20
PCM_134	88	50

The NGPN and NGPFire monitoring crews collected woody species data in seven plots visited in 2021 (Table 7). Four species were observed in the plots, and most were dominated by ponderosa pine trees (*Pinus ponderosa*). PCM_015, PCM_018, PCM_134 had no live trees or poles within the plot but live seedlings were observed. All plots had seedling regeneration, with Saskatoon serviceberry (*Amelanchier alnifolia*), quaking aspen (*Populus tremuloides*) and chokecherry (*Prunus virginiana*) respectively being the most observed species. Four of those seven plots also saw seedling regeneration of ponderosa pine, with PCM_014 having 87 seedlings.

Table 7. Woody species data from seven long-term monitoring plots visited at Jewel Cave National Monument (JECA) in 2021. DBH categories are tree (DBH>15 cm), pole (2.54 cm<DBH>15 cm), and seedling (DBH<2.54 cm).

Plot	Species	DBH	Count	Status	Density/hectare
PCM_004	<i>Pinus ponderosa</i>	Pole	6	Live	191.08
PCM_004	<i>Pinus ponderosa</i>	Tree	6	Live	191.08
PCM_014	<i>Pinus ponderosa</i>	Pole	1	Live	31.85
PCM_014	<i>Pinus ponderosa</i>	Tree	1	Dead	10
PCM_014	<i>Pinus ponderosa</i>	Tree	37	Live	370
PCM_014	<i>Amelanchier alnifolia</i>	Seedling	608	Live	19350.73
PCM_014	<i>Prunus virginiana</i>	Seedling	55	Live	1750.48
PCM_014	<i>Pinus ponderosa</i>	Seedling	87	Live	2768.94
PCM_015	<i>Pinus ponderosa</i>	Tree	2	Dead	20
PCM_015	<i>Pinus ponderosa</i>	Seedling	2	Live	63.65
PCM_016	<i>Pinus ponderosa</i>	Tree	5	Live	50
PCM_016	<i>Amelanchier alnifolia</i>	Seedling	157	Live	4996.82
PCM_016	<i>Prunus virginiana</i>	Seedling	32	Live	1018.46
PCM_016	<i>Pinus ponderosa</i>	Seedling	56	Live	1782.3
PCM_017	<i>Pinus ponderosa</i>	Seedling	1	Live	31.85
PCM_017	<i>Pinus ponderosa</i>	Pole	22	Live	700.64
PCM_017	<i>Pinus ponderosa</i>	Pole	2	Dead	20
PCM_017	<i>Pinus ponderosa</i>	Tree	2	Dead	20
PCM_017	<i>Pinus ponderosa</i>	Tree	31	Live	310
PCM_017	<i>Amelanchier alnifolia</i>	Seedling	5	Live	159.13
PCM_017	<i>Prunus virginiana</i>	Seedling	6	Live	190.96
PCM_018	<i>Pinus ponderosa</i>	Tree	2	Dead	20
PCM_018	<i>Pinus ponderosa</i>	Seedling	1	Live	31.83
PCM_134	<i>Pinus ponderosa</i>	Tree	2	Dead	20
PCM_134	<i>Populus tremuloides</i>	Seedling	137	Live	4360.28
PCM_134	<i>Amelanchier alnifolia</i>	Seedling	57	Live	1814.13
PCM_134	<i>Prunus virginiana</i>	Seedling	59	Live	1877.78

Surface fuels and dead and downed wood provide foraging habitat and refugia for small wildlife species, as well as substrate for mosses and fungi. Downed wood can also provide “nursery” logs for vascular plant establishment. However, when surface fuels are too abundant in a forest, they can increase the risk of high intensity fires. NGPFire has developed a management target for surface fuels with a goal to maintain fuel loads between 2 and 10 tons per acre within the Black Hills parks. NGPN and NGPFire surveyed and measured surface fuels in 18 plots visited in JECA (Table 8). We can see on average a reduction of surface fuels in the Pre and Post prescribed fire visits for PCM_014 and PCM-018.

Table 8. Surface fuels summary for 18 plots at Jewel Cave National Monument (JECA) in 2021.

Macroplot	Monitoring Status	Average Tons per Acre										Avg. Depth (in.)		
		1-hr	10-hr	100-hr	1-100-hr	1000-hr sound	1000-hr rotten	1-1000-hr	Duff	Litter	Total	Duff	Litt	Total
PCM_004	01Pre	0.02	1.40	0.00	1.42	0.00	2.03	3.45	1.58	1.36	6.39	0.1	0.3	0.4
PCM_014	2021_PCM	0.00	0.27	1.45	1.72	18.50	10.80	31.02	2.82	1.06	34.90	0.2	0.3	0.4
PCM_014	01Post	0.00	0.68	0.00	0.68	3.62	11.70	16.00	1.14	2.00	19.14	0.1	0.5	0.6
PCM_015	2021_PCM	0.08	0.68	2.18	2.94	0.00	24.04	26.98	1.85	0.90	29.73	0.1	0.2	0.3
PCM_016	2021_PCM	0.08	0.56	8.29	8.93	2.02	10.89	21.84	2.73	1.10	25.66	0.2	0.3	0.4
PCM_017	2021_PCM	0.08	1.23	2.18	3.49	9.40	1.85	14.75	4.05	5.73	24.53	0.2	1.4	1.7
PCM_018	2021_PCM	0.02	0.56	1.50	2.08	0.00	14.80	16.87	0.00	0.94	17.81	0.0	0.2	0.2
PCM_018	02Post	0.02	0.42	3.68	4.12	0.83	0.78	5.74	0.00	1.18	6.91	0.0	0.3	0.3
PCM_019	01Post	0.00	1.50	8.72	10.22	0.57	0.00	10.79	1.32	1.24	13.34	0.1	0.3	0.4
PCM_023	01Post	0.12	0.14	1.46	1.71	0.56	8.46	10.73	4.93	1.88	17.54	0.3	0.5	0.8
PCM_033	01Post	0.00	0.00	4.39	4.39	9.21	0.23	13.84	0.62	0.82	15.27	0.0	0.2	0.2
PCM_039	01Post	0.02	0.95	0.00	0.97	7.14	0.55	8.66	2.46	1.30	12.42	0.1	0.3	0.5
PCM_043	01Post	0.10	1.00	1.45	2.55	11.95	11.70	26.20	1.14	0.62	27.97	0.1	0.2	0.2
PCM_055	01Post	0.02	0.82	2.18	3.02	1.72	1.96	6.70	1.06	0.80	8.55	0.1	0.2	0.3
PCM_058	01Post	0.00	0.15	0.00	0.15	0.68	5.69	6.52	0.79	0.58	7.89	0.0	0.1	0.2
PCM_062	01Post	0.00	0.41	0.00	0.41	0.00	0.21	0.62	0.09	1.00	1.71	0.0	0.3	0.3
PCM_063	02Post	0.06	0.54	0.77	1.37	1.96	0.00	3.33	0.70	0.62	4.66	0.0	0.2	0.2
PCM_065	01Post	0.00	0.27	4.38	4.65	1.15	0.70	6.50	0.62	0.60	7.72	0.0	0.2	0.2
PCM_067	01Post	0.08	1.09	4.39	5.56	5.11	3.18	13.86	2.90	1.06	17.82	0.2	0.3	0.4
PCM_134	2021_PCM	0.00	0.14	2.18	2.31	1.07	2.23	5.62	1.14	1.12	7.88	0.1	0.3	0.3

Disturbances occurred in 17 of the 18 plots at JECA visited by NGPN and NGPFire in 2021 (Table 9). There was a variety of disturbances observed, including grazing, animal trails, small mammal disturbance, soil disturbance and prescribed fire.

Table 9. Disturbance types and occurrence in six plant community monitoring plots visited in 2021 at Jewel Cave National Monument (JECA).

Plot	Disturbance Type	Area (m ²)
PCM_004	Animal Trail	7
PCM_004	Small Mammal	9
PCM_014	Prescribed Fire (Hilltop Rx 10/29/21)	650
PCM_016	Soil Disturbance	3
PCM_017	Small Mammal	10
PCM_017	Soil Disturbance	3
PCM_017	Crew Disturbance	5
PCM_018	Grazing	5
PCM_018	Small Mammal	12
PCM_018	Soil Disturbance	10
PCM_018	Prescribed Fire (Hilltop Rx 10/29/21)	1000
PCM_018	Grazing	5
PCM_018	Small Mammal	12
PCM_019	Prescribed Fire (Hilltop Rx 10/29/21)	950
PCM_023	Prescribed Fire (Hilltop Rx 10/29/21)	300
PCM_033	Prescribed Fire (Hilltop Rx 10/29/21)	621
PCM_039	Prescribed Fire (Hilltop Rx 10/29/21)	66
PCM_043	Prescribed Fire (Hilltop Rx 10/29/21)	146
PCM_055	Prescribed Fire (Hilltop Rx 10/29/21)	701
PCM_058	Prescribed Fire (Hilltop Rx 10/29/21)	383
PCM_062	Prescribed Fire (Hilltop Rx 10/29/21)	292
PCM_063	Prescribed Fire (Hilltop Rx 10/29/21)	627
PCM_065	Prescribed Fire (Hilltop Rx 10/29/21)	694
PCM_067	Prescribed Fire (Hilltop Rx 10/29/21)	548
PCM_134	Soil Disturbance	5



Figure 4. Photograph of long-term monitoring plot PCM_016 at Jewel Cave National Monument in 2021. Photograph courtesy of the National Park Service.

Further Analysis

This 2021 Data Report is intended to provide a basic review of the data collected during the NGPN vegetation monitoring and NGPFire team's 2021 visit to Jewel Cave National Monument. All data included in this report is available upon request from the Northern Great Plains Inventory and Monitoring Network, as well as in the archives found in the [IRMA Data Store](#).

Literature Cited

- Ashton, I., M. Prowatzke, M. Bynum, T. Shepherd, S. K. Wilson, K. Paintner-Green, and D. Swanson. 2012a. Forest structure and fuel loads at Jewel Cave National Monument: 2011 status report. Natural Resource Technical Report NPS/NGPN/NRTR—2012/586. National Park Service, Fort Collins, Colorado.
- Ashton, I. W., C. J. Davis, and D. J. Swanson. 2018. Plant community composition and structure at Jewel Cave National Monument: 2011–2017 summary report. Natural Resource Report NPS/NGPN/NRR—2018/1642. National Park Service, Fort Collins, Colorado.
- Brown, J. K. 1974. Handbook for inventorying downed material. General Technical Report INT-16. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Brown, J. K., R. D. Oberhue, and C. M. Johnston. 1982. Inventorying surface fuels and biomass in the Interior West. General Technical Report INT-129. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.
- Lentile, L. B., F. W. Smith, and W. D. Shepperd. 2005. Patch structure, fire-scar formation, and tree regeneration in a large mixed-severity fire in the South Dakota Black Hills, USA. *Canadian Journal of Forest Research* **35**:2875–2885.
- Marriot, H., and R. L. Hartman. 1986. A survey of the vegetation of Jewel Cave National Monument. U.W. NPS Research Center Project
- National Park Service. 2004. Fire management plan for Jewel Cave National Monument. Custer, SD.
- R Core Team. 2022. R: A language and environment for statistical computing. Vienna, Austria. <https://www.R-project.org>
- Stevens, D. L., and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. *Environmetrics* **14**:593–610.
- Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal Of The American Statistical Association* **99**:262–278.
- Symstad, A. J., R.A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012a. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network-Standard Operating Procedures: version 1.01. Natural Resource Report NPS/NGPN/ NRR-2012/489.1.
- Symstad, A. J., R.A. Gitzen, C. L. Wienk, M. R. Bynum, D. J. Swanson, A. D. Thorstenson, and K. J. Paintner. 2012b. Plant community composition and structure monitoring protocol for the Northern Great Plains I&M Network: version 1.01. Natural Resource Report NPS/NGPN/ NRR-2012/489.

USDA-NRCS. 2022. The PLANTS Database (<http://plants.usda.gov>, 10 February 2022). National Plant Data Team, Greensboro, NC 27401-4901 USA.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 146/185242, September 2022

National Park Service
U.S. Department of the Interior



[Natural Resource Stewardship and Science](#)

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

EXPERIENCE YOUR AMERICA™