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# Natural Resource Conditions at Cedar Creek & Belle Grove National Historical Park

*Findings & Management Considerations for Selected Resources*


View of the Massanutten Mountains from a restored section of the Morning Attack Trail meadow. The interpretive wayside explains the strategic significance of Signal Knob (first peak on the right) to the Confederate Army's attack during the Battle of Cedar Creek.

NPS / NATHAN WENDER

# Natural resource conditions at Cedar Creek & Belle Grove National Historical Park: Findings & management considerations for selected resources

Science Report NPS/SR—2024/118

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# Abstract

The National Park Service's Natural Resource Condition Assessment (NRCA) Program developed an NRCA with managers at Cedar Creek & Belle Grove National Historical Park (CEBE), a partner park located in western Virginia in Frederick, Shenandoah, and Warren counties. An NRCA's purpose is to synthesize information on the primary drivers and stressors affecting natural resource conditions, and to report conditions for specific natural resources selected by park managers. Condition assessments were conducted for three of CEBE's resources—visual resources, night sky, and soundscape—and gap analyses were conducted for two resources—woodlands and meadows. The condition assessment for visual resources, based on an inventory of scenic views at three of the park's most important viewpoints, led to condition ratings of good/fair for two locations and fair for one location. CEBE's night sky, assessed using modeled data from the NPS Natural Sounds & Night Skies Division (NSNSD), was found to be about 392% brighter than the natural night sky, leading to a condition rating of fair. To assess CEBE's soundscape, an NPS NSNSD geospatial model that predicts daytime sound was used. Results indicated a poor condition of sound level park-wide. Stressors for these three resources include adjacent/surrounding residential and commercial development and associated roads, vehicle traffic, and lighting. Both woodlands and meadows were evaluated through gap analyses. Potential stressors on woodlands include non-native invasive plants, non-native invasive insect pests, over-browsing by native white-tailed deer, and climate change. Although some park-specific data exist on these stressors, more information is needed. Similarly, more information is needed on meadows. Most of the data available are related to ongoing work to bring back native vegetation in CEBE's Morning Attack Trail field.

# Executive Summary

The National Park Service (NPS) Water Resources Division's Natural Resource Condition Assessment (NRCA) Program initiated an NRCA project with Cedar Creek and Belle Grove National Historical Park (CEBE) in 2022. The purpose of an NRCA is to synthesize information related to the primary drivers and stressors affecting natural resource conditions at a park and to report conditions for natural resource topics selected by park managers. Resource conditions are evaluated as either a condition assessment or a gap analysis, depending on data availability. For CEBE's NRCA, managers selected visual resources, night sky, soundscape, woodlands, and meadows as the focal resources. We conducted condition assessments for the first three topics and gap analyses for the last two topics.

CEBE is located in western Virginia, approximately 140 km (87 mi) west of Washington, DC, and 24 km (15 mi) northwest of Shenandoah National Park's north entrance. The park's legislated boundary encompasses 1,500 ha (3,708 ac) in Frederick, Shenandoah, and Warren counties. Although CEBE is mostly rural, it contains developed areas of Middletown and is near the town of Strasburg. CEBE is a partner park and includes sites that are owned and operated independently of the NPS, such as Belle Grove Plantation and some portions of the Cedar Creek Battlefield. CEBE and its five key partners work together to preserve a Civil War landscape and antebellum plantation by sharing the story of Shenandoah Valley history from early settlement through the Civil War and beyond.

Scenic views in the park include battlefields, historic structures, natural areas, mountains, and pastoral surroundings. A visual resources inventory was conducted for the NRCA in late 2022 to determine the condition of scenic views at three of the most important viewpoints in the park. Two measures, scenic quality and view importance, were rated separately and then combined into an overall scenic inventory value. This value for each location corresponded to NRCA condition ratings of good/fair for two locations (Thoburn's Redoubt Trailhead and Belle Grove View from Back of Barn) and fair for one location (Heater House and Battlefield). Surrounding development is the primary factor impacting the park's visual resources; although the visual resource inventory pointed out some elements in the park that detract from views, more detractions were noted from existing development outside the park.

Natural dark night skies are critical to ecosystem function and environmental health, and they are a valued resource within the NPS. CEBE staff provide opportunities to experience the night sky by hosting public "star parties" in partnership with the Shenandoah Astronomical Society. The night sky at CEBE was assessed using modeled data for the all-sky light pollution ratio metric (ALR) from the NPS Natural Sounds & Night Skies Division (NSNSD). The ALR is an objective measure of night sky condition based on the amount of light in the night sky attributed to human sources. The modeled data indicate that CEBE's night sky is, on average, 392% brighter than the natural night sky, leading to an NRCA condition rating of fair. Residential and commercial development near CEBE and associated night-time lighting, as well as vehicle traffic and lighting on highways and smaller roads, contribute to unnatural light and likely impact the night sky condition at the park. Night-time lighting within park boundaries probably also contributes to existing levels of unnatural light.

Environments without noise pollution are important to visitors, wildlife, and plants. We assessed CEBE's soundscape by using an NPS NSNSD geospatial model that predicts daytime sound levels during midsummer. To determine condition, we used the model's predicted sound level impact, which is a measure of how much human noise contributes to the existing natural soundscape. Model results indicated a poor condition of sound level park-wide at CEBE, and a reduction in the listening area of 78%. Sources of noise at CEBE include major highways and roads, including vehicle traffic and road construction projects, and operation of a new outdoor, open-air firing range. A preliminary modeling analysis by NPS NSNSD to estimate predicted sound levels at the park from the discharge of a 12-gauge shotgun at the firing range found (without the use of onsite data) that sound from a shot could exceed 60 dB in much of the park without mitigation. An onsite acoustic monitoring study at CEBE would be beneficial to collect data on park sound levels and noise from the firing range.

Woodlands at CEBE, which cover about 39% of the park, are comprised of deciduous, evergreen, and mixed vegetation, as well as shrub/scrub species, that are representative of plant communities in the Valley and Ridge province in northern Virginia. CEBE's woodlands are essential components of the park landscape, provide wildlife habitat, protect the north fork of the Shenandoah River and Cedar Creek, and include trees that marked early settlement property boundaries. Stressors on park woodlands include non-native invasive plants, non-native invasive insect pests, over-browsing by native white-tailed deer, and climate change. To the extent possible, we provided park-specific information on each of these stressors. For example, according to the sources used, at least 12 non-native invasive plant species occur in or adjacent to park woodlands. Eight of these species have an invasiveness rank of "high" and four have a rank of "medium" according to the Virginia Invasive Plant Species List. At least two non-native, invasive insect pests—emerald ash borer and spotted lanternfly—have been reported in the park, with the first causing damage to the park's ash trees.

Areas of open vegetation within CEBE (e.g., hay/pasture, crops, and herbaceous cover) include meadow habitat undergoing restoration. Restoration activities in the Morning Attack Trail field, about 19 ha (47 ac) in size and on NPS property, began in 2016 and include a 2022 project in which half of the field was planted with native grasses and wildflowers. Restoration goals for the field include creating habitat for native pollinators and grassland birds, improving the viewshed, and reducing non-native invasive plants. As of mid-2023, the restoration area appeared to be in better condition than when restoration activities began. For example, some woody invasive species have been controlled to maintenance levels, and other species are greatly reduced. Although there have been no NPS surveys for birds in the park, sighting information from eBird for two locations reported 91 species, including grassland and shrubland birds. We compiled a list of butterfly species reported in Frederick, Shenandoah, and Warren counties to obtain a list of species (98) with potential to occur in the park. CEBE's meadows are at risk of non-native, invasive plant proliferation and native woody species encroachment through succession.

The last chapter of the NRCA (Chapter 4) provides management considerations for each focal resource, based on the NRCA findings and information gathered, to provide managers with next steps for furthering science-informed management. These considerations include the identification of data gaps for the resources addressed.

# Acknowledgments

We thank everyone who participated in CEBE's NRCA study plan scoping meeting, provided data and reports, and served as technical report peer reviewers. We extend a special thank you to Karen Beck-Herzog, CEBE Site Manager, for providing excellent feedback throughout the entire NRCA development process.

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# Glossary

**Condition Assessment:** A condition assessment reports on the current condition of one or more indicators of condition for a focal natural resource when enough data are available. What constitutes "enough" data is a professional judgement based on a review of all available data and conceptual models and discussions with park staff, subject matter experts, and researchers involved in collecting the applicable data. Indicators of condition are rated using a three- or five-level rating system, ranging between good-fair-poor; if trend can be reported for a measure, it is reported as improving, stable, deteriorating, or unknown/indeterminate.

**Condition Evaluation:** A condition evaluation is either a condition assessment or a gap analysis. Which one depends on the amount of data with which to evaluate conditions and assign a condition rating(s). If enough data are available for key indicators of condition, then a condition assessment is developed. If data are lacking, a gap analysis is developed.

**Condition Rating Statements:** These correspond to the three- or five-level rating system developed to evaluate the indicators of condition. The five-level rating scheme includes good, good/fair, fair, fair/poor, and poor, and the three-level rating scheme includes good, fair, and poor, with corresponding "stop light" colors. Condition ratings statements are developed at the indicator level for the combination of measures evaluated for each indicator of condition. The condition rating statements reference criteria must be logical and defensible based on the best available science.

**Confidence Level:** These correspond to a three-level rating system of low–medium–high described for the indicators of condition ratings. The levels are based on the repeatability of evaluation findings and how confident the author is in the information used to rate condition.

**Current Condition:** This defines the status of condition for an indicator based on the evaluation of one or more measures. "Current" applies to the condition as it exists today based on what has previously occurred, not on what is likely to occur. For example, something such as hazard level or risk, which identifies the proposed or likelihood of what may occur because of the intrinsic characteristics of the resource, will not be used to report on current condition. In general, data collected within the last ten years can be used to determine current condition, although this will depend on the rate of change for a particular indicator of condition and its corresponding measures.

**Data Gap:** A data gap is when information is lacking, whether in the form of unavailable literature or subject matter expertise to adequately evaluate conditions.

**Driver:** Ecosystem drivers are major (and most often) external influencers of change to natural systems, functioning across extensive areas or scales. Drivers are defined as "any relatively discrete events in space and time that disrupt ecosystem, community, or population structure and change resources, substrate, or the physical environment (White and Pickett 1985)." Drivers are most often beyond a manager's ability to influence or change.

**Gap Analysis:** A gap analysis summarizes what is known about a focal natural resource, in addition to highlighting critical information that is lacking. A gap analysis does not rate indicators of

condition. Instead, a summary of *proposed* indicators, measures, and reference criteria are reported, if possible, with the goal of providing a framework for a future study.

**Indicator of Condition:** An indicator of condition (or simply indicator) is a descriptor of something useful to measure, but it is not the measure itself. Indicators consist of one or more measures. Condition ratings are assigned at the indicator level. This is because natural resources are often more complex and nuanced than what is reflected in just a few measures and associated indicators.

**Measure:** A measure is qualitative, quantitative, or a combination of both and provides specific information about the indicator of condition. There can be one or more measure(s) for each indicator. Selected indicators and measures are often those that are commonly used by NPS staff in monitoring the status of a resource, as well as those that are well represented in the literature and can provide context when park-specific data are lacking.

**Pressure:** A pressure results from a driver, potentially affecting a resource. An NRCA presents drivers and pressures as the fundamental forces that play important roles in regulating or altering ecological resource conditions in the park. NRCAs do not differentiate between drivers and pressures because the focus of the report content is on the manifestation of those influences on natural resource conditions, not on the differentiation of drivers and pressures.

**Reference Criteria:** Reference criteria are pivot points, thresholds, or ranges based on peer-reviewed literature, state standards, known criteria, or some other justifiable source of information that forms the basis of the condition rating statements. Quantitative reference criteria are generally better than qualitative reference criteria, but when specific data are lacking, qualitative reference criteria are useful. Regardless of the type of reference criteria used, they must be justifiable and cited appropriately for the repeatability of future condition evaluations.

**Response:** Useful near-term actions/activities park managers can consider for protecting, maintaining, and/or restoring important ecological resource conditions in parks.

**State (Condition):** The current "health" or condition of the focal natural resource reported at the indicator of condition level. State is synonymous with condition.

**Stressor:** "Stressors can manifest as physical, chemical, or biological perturbations [disturbances] to a system that are either foreign to that system, or natural to the system, but occurring at an excessive or deficient level. Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. They act together with drivers on ecosystem attributes (Barrett et al. 1976)." When possible, stressors are selected as measures with which to evaluate the current condition of an indicator.

**Trend:** A trend is a statistical analysis intended to find patterns in data. If a trend can be reported for a measure, it is reported as improving, stable, deteriorating, or unknown/indeterminate. Only quantitative trends are reported in the NRCA technical report.

# Natural Resource Condition Assessment – Introduction

The National Park Service (NPS) Natural Resource Stewardship and Science Directorate provides scientific, technical, and administrative support to national parks for the management of natural resources. The directorate includes nine Service-wide divisions that assist NPS managers across the United States with protecting park resources and values sustainably over time. The NPS Natural Resource Condition Assessment (NRCA) Program is within the Service-wide's Water Resources Division, and its mission is to assess and report the conditions and trends of natural resources.

View during a star party at Cedar Creek & Belle Grove National Historical Park. Image Credit: NPS/Buddy Secor.

## NRCA Goals

The primary goal of an NRCA is to deliver scientifically credible natural resource condition and trend information for park manager-selected topics of interest. NRCAs distill existing information into concise, easily understood assessments that inform management decisions. NRCAs also highlight data gaps to help managers prioritize information that is needed to inform future management decisions.

Each NRCA project is completed in approximately one year from the scoping workshop to the development of the technical report, using a standard workflow. The NRCA findings are published in a technical report, which is posted to the NPS Data Store along with any supporting materials. (https://irma.nps.gov/DataStore/).

### *Technical Report*

The content of every NRCA report is organized using an ecological drivers, pressures, stressors, states, and responses (DPSSR) logic framework (Figure 1; adapted from the Office of National Marine Sanctuaries [2020] and Harwell et al. [2019]). The DPSSR framework emphasizes the connection between the natural and human (or anthropogenic) drivers-pressures (hereafter referred to as drivers) that influence ecosystem or natural resource change. A change may affect the condition (or state) of a resource as a positive or negative stressor. In turn, park managers may respond to a stressor(s) that negatively impacts a resource to restore its condition to a desired state, such as controlling non-native invasive plants in a high priority habitat or submitting a study proposal for funding to further a park manager's understanding of the resource.

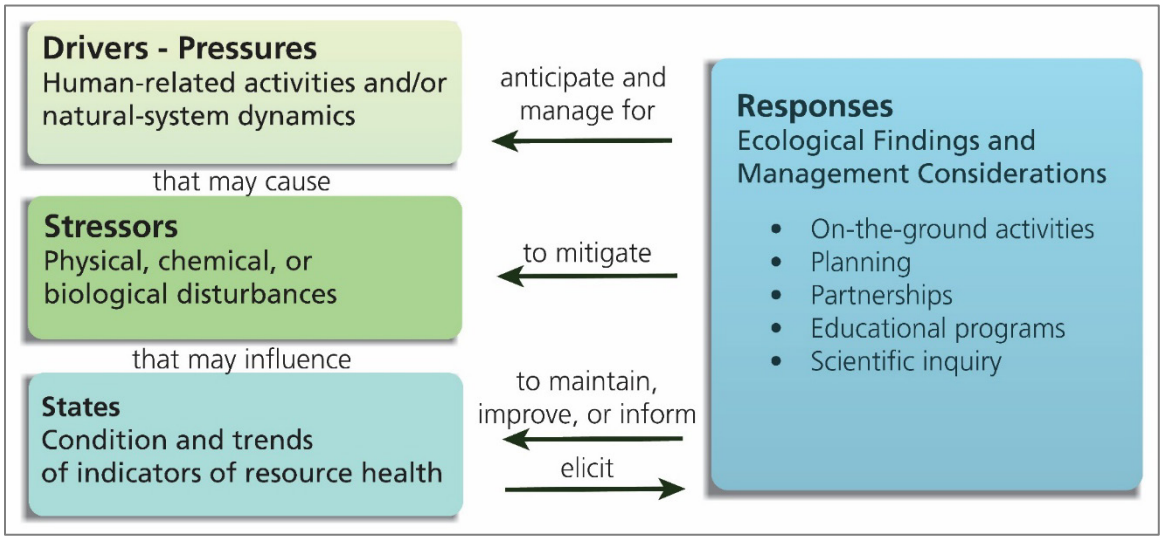



**Figure 1.** The drivers, pressures, stressors, states, responses (DPSSR) logic framework used to organize NRCA report content (adapted from Harwell et al. [2019] and the Office of National Marine Sanctuaries [2020]).

Even though there are stressors that managers cannot directly influence, it is still helpful to understand the potential resource impacts, especially when setting realistic resource management goals. The DPSSR framework helps to illuminate these connections between drivers, stressors,

resource conditions (states), and management responses, and guides the selection of the most relevant NRCA content to report.

It is important to note that while an NRCA project does not report on conditions for all the natural resources at a park, the DPSSR framework can guide the evaluation of additional natural resource conditions in the future. This is especially important as drivers or stressors change, or as new information becomes available with which to evaluate natural resource conditions.

# Chapter 1. Introduction to Park Setting and Resources

Cedar Creek & Belle Grove National Historical Park (CEBE) is one of 62 national historical parks included in a system of 423 national park units. Congressionally legislated in 2002, CEBE's purpose is to "preserve, protect, and interpret a nationally significant Civil War landscape and antebellum agricultural community; to tell the rich story of Shenandoah Valley history from early [Native American] occupation onward; to preserve and interpret the significant historic, natural, cultural, military, and scenic resources associated with the Cedar Creek Battlefield and Belle Grove Plantation areas through partnerships with local landowners and the community; and to serve as a focal point within the Shenandoah Valley Battlefields National Historic District to recognize and interpret important Civil War events, including the key battles and campaigns of 1862 and 1864" (NPS 2018a; Public Law 107-373, Cedar Creek & Belle Grove National Historical Park Act 2002). CEBE is administered by the NPS, which is one of nine bureaus and offices of the Department of Interior that manages America's vast natural and cultural resources for the enjoyment and use of future generations.


The 8th Vermont Monument, dedicated in 1885, marks the site of fierce fighting during the Battle of Cedar Creek. The monument is along the Morning Attack Trails. Image Credit: NPS NRCA Program.

## 1.1. Location

CEBE is located in western Virginia, approximately 140 kilometers (km; 87 miles [mi]) west of Washington, DC, and 24 km (15 mi) northwest of Shenandoah National Park's north entrance. The park's legislative boundary encompasses 1,500 hectares (ha; 3,708 acres [ac]) (NPS Land Resources Division 2023) across Frederick, Shenandoah, and Warren counties, with about 55% of the park's total area in Frederick County (NPS 2010). CEBE is a partner park and includes sites that are owned and operated independently of the NPS: Belle Grove Plantation (owned by the National Trust for Historic Preservation and managed by Belle Grove, Inc.), Belle Grove, Inc. lands (including Harmony Hall/Fort Bowman), Cedar Creek Battlefield Foundation lands and Headquarters, Shenandoah Valley Battlefields Foundation lands, and Shenandoah County lands (Figure 2). The key partners preserve a Civil War landscape and antebellum plantation by "sharing the story of Shenandoah Valley history from early settlement through the Civil War and beyond" (NPS 2022a). CEBE is also part of the congressionally designated Shenandoah Valley Battlefields National Historic District that also includes Shenandoah National Park and eight counties within Shenandoah Valley (NPS 2022b). The district "preserves and interprets the region's significant Civil War battlefields and related historic sites" (Shenandoah Valley Battlefields Foundation 2023).

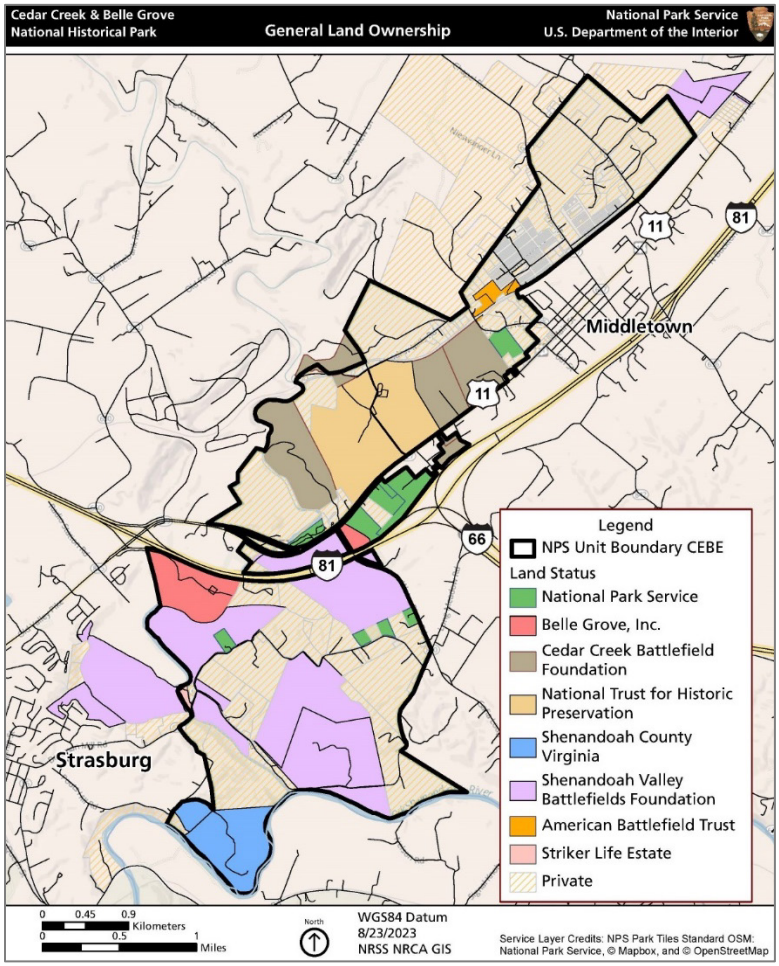



**Figure 2.** Map of CEBE showing NPS (in green) and partner properties.

## 1.2. Setting and Resources

CEBE is one of 17 national park units located in the Valley and Ridge province of the Appalachian Mountain region (Figure 3), which spans from Vermont to Alabama (NPS 2018b). The ridge tops of the province are comprised primarily of sandstone, while the valleys are composed largely of erodible limestones and shales, which create karst topography such as caves and sinkholes (Virginia Department of Conservation and Recreation Natural Heritage Program [VNHP] 2021). The Great Valley is a basin on the eastern side of the province, with Virginia naming its portion of the basin the Shenandoah Valley (in which CEBE is located). The portion of the Valley and Ridge province in Virginia is dominated by forests (63% of the area), and of the forested area, 88% is comprised of deciduous species. The limestones and shales of the valleys supplied early settlers with "land that was rich, varied, able to support a variety of crops, and provided the settlers with varied resources, including timber and game" (Katen et al. 2020 [p. 34]). According to Katen et al. (2020), the varied topography of the shale-limestone interface was also conducive to settlers' establishment of mills along Cedar Creek and its tributaries. Elevations in the park are between 152 and 213 meters (500 and 700 feet) (Donaldson 2005).

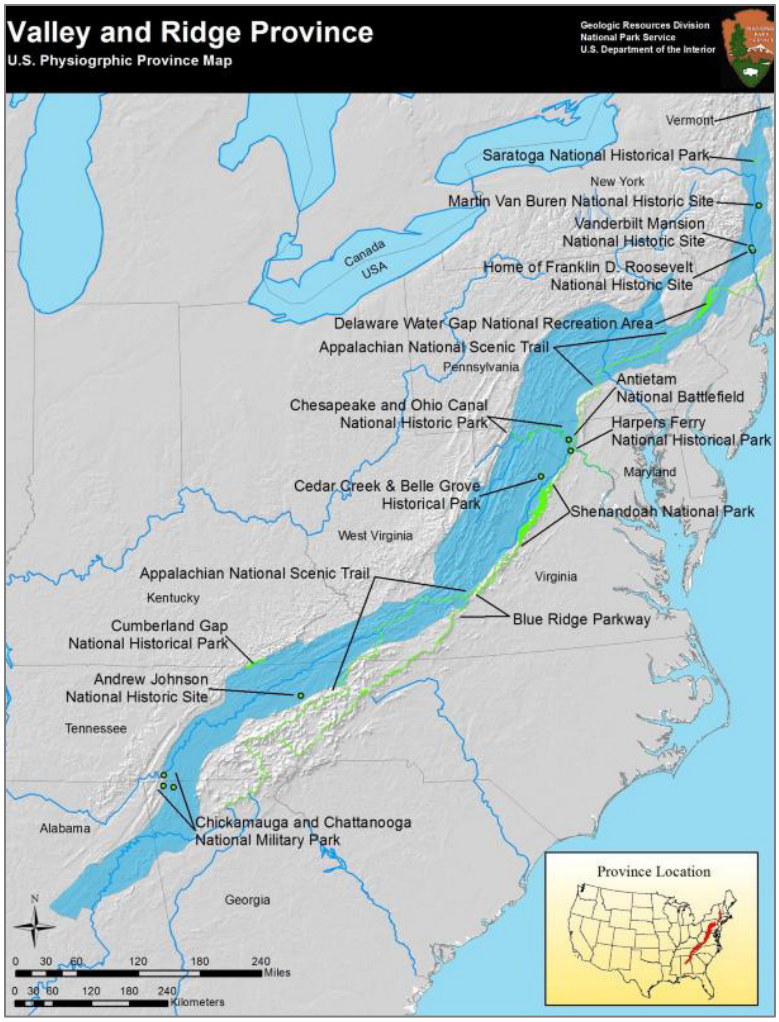



**Figure 3.** Map of the Valley and Ridge province, including the location of CEBE and 16 other national park units. The eastern side of the province is known as the Great Valley, which includes Shenandoah Valley in Virginia. Figure Credit: NPS Geologic Resources Division.

### *1.2.1. Historical/Cultural Setting*

CEBE and the surrounding landscapes have been shaped by a long history of human influence. Around 9,500–10,000 BCE (Before Common Era), Indigenous peoples were thought to have begun moving through the Shenandoah Valley as hunter-gatherers (NPS 2010), and they may have been practicing agriculture and living permanently in the region by around 900 CE (Common Era) (Koons and Noyalas 2010). The Shenandoah Valley was covered by forests, thickets, bottomland meadows, and clearings prior to colonial settlement, and Indigenous peoples may have been at least partially responsible for clearings and bottomland meadows (Commisso and Foulds 2007). Other factors (e.g., soil compaction from herd animals, accidental fire), however, may have also contributed. Forest openings were important to Indigenous peoples (Commisso and Foulds 2007), and they used fire for clearing land, as well as range management, hunting, and agriculture (summarized by VNHP 2021).

While populations of Indigenous peoples living permanently in the valley continued to increase through the mid-1600s, most had left the area by the late 1600s (Koons and Noyalas 2010). Many of

the earliest Europeans to pass through the CEBE area were traders (NPS 2010). After the Indigenous peoples who had lived permanently in the valley left, some Indigenous groups continued to hunt and trap in the area to trade animal hides with the European newcomers (Koons and Noyalas 2010).

By the 1730s, immigrants with agricultural skills and of mostly Scots-Irish and German descent began settling Shenandoah Valley (Commisso and Foulds 2007), including three locations near current CEBE (Koons and Noyalas 2010). These settlers used many of the same travel paths and cleared sites as the Indigenous peoples did before them (Commisso and Foulds 2007). They grew corn, wheat, rye, barley, flax, and oats (Commisso and Foulds 2007) and maintained livestock, including horses, cattle, pigs, and sheep (Koons and Noyalas 2010). Though earlier agricultural practices in the Shenandoah Valley were conducted primarily for subsistence and local commerce, tobacco and hemp later became the first cash crops (Katen et al. 2020). Wheat gradually became the primary cash crop throughout the valley during the mid- and late-1700s; no other region in Virginia produced more wheat by 1800 (Commisso and Foulds 2007).

The population of the Shenandoah Valley continued to mostly increase throughout the 1700s, and there were around 27 towns in the area by 1800 (Commisso and Foulds 2007). Slavery became more prominent in the valley during the early 19$^{th}$ century, with enslaved people representing around 20% of the total population from 1800 to 1850 (Koons and Noyalas 2010). Largely with the assistance of enslaved labor, the 3,035-ha (7,500-ac) Belle Grove Plantation produced wheat, flour, whiskey, livestock, and lumber (Katen et al. 2020; Belle Grove, Inc. 2023). The plantation was one of the largest and included one of the first manor houses in the valley. Just over 157 ha (387 ac) of the original Belle Grove Plantation lands, including the manor house, are part of present-day CEBE (NPS 2010).

The Civil War greatly impacted residents, farming, and the landscape of the Shenandoah Valley (Commisso and Foulds 2007; Koons and Noyalas 2010). Multiple battles were fought in the region, including some within current CEBE boundaries (Commisso and Foulds 2007). The Confederate army had the strongest hold on the valley early in the war (Commisso and Foulds 2007), and they used the region for food to the extent that it became known as “the Breadbasket of the Confederacy” (Koons and Noyalas 2010). Although both the Confederate and Union armies confiscated or burned the area’s resources, implementation of Union General Phillip Sheridan’s policy, known as “the Burning,” may have been responsible for most of the destruction to canals, crops, barns, homes, livestock, mills, and railroads that occurred between 1862 and 1864 (Commisso and Foulds 2007; Koons and Noyalas 2010). The constant movement of the armies up and down the region over these years also contributed to the trampling of fields, confiscation of food, and removal of fences, etc. (NPS, J. Tracey, CEBE Cultural Resource Manager, draft NRCA review, 22 November 2023). The Valley Pike was the major travel corridor.

Belle Grove Plantation manor house today. Image Credit: NPS NRCA Program.

The Battle of Cedar Creek began on October 19, 1864 (Figure 4) (Commisso and Foulds 2007). While Union army casualties were high early in the battle, Confederate forces ultimately retreated and permanently lost control of the Shenandoah Valley, along with its resources and strategic position (Commisso and Foulds 2007). This major battle contributed to both the reelection of Abraham Lincoln as president and the Confederate's eventual loss of the Civil War (NPS 2010). Cedar Creek Battlefield and Belle Grove Plantation became a national historic landmark in 1969 (NPS 2010).

Following the Civil War, wheat production within Shenandoah Valley increased, even as wheat market prices continued declining (Koons and Noyalas 2010). Later, more emphasis was placed on mixed farming, and apples replaced wheat as the primary cash crop by 1930 (Commisso and Foulds 2007). Agricultural production in the valley began to decline by the late 1940s (Commisso and Foulds 2007). Increasing automobile use during the mid-20$^{th}$ century contributed to further land use and landscape change within Shenandoah Valley, through road system expansion and continued population growth (Commisso and Foulds 2007).

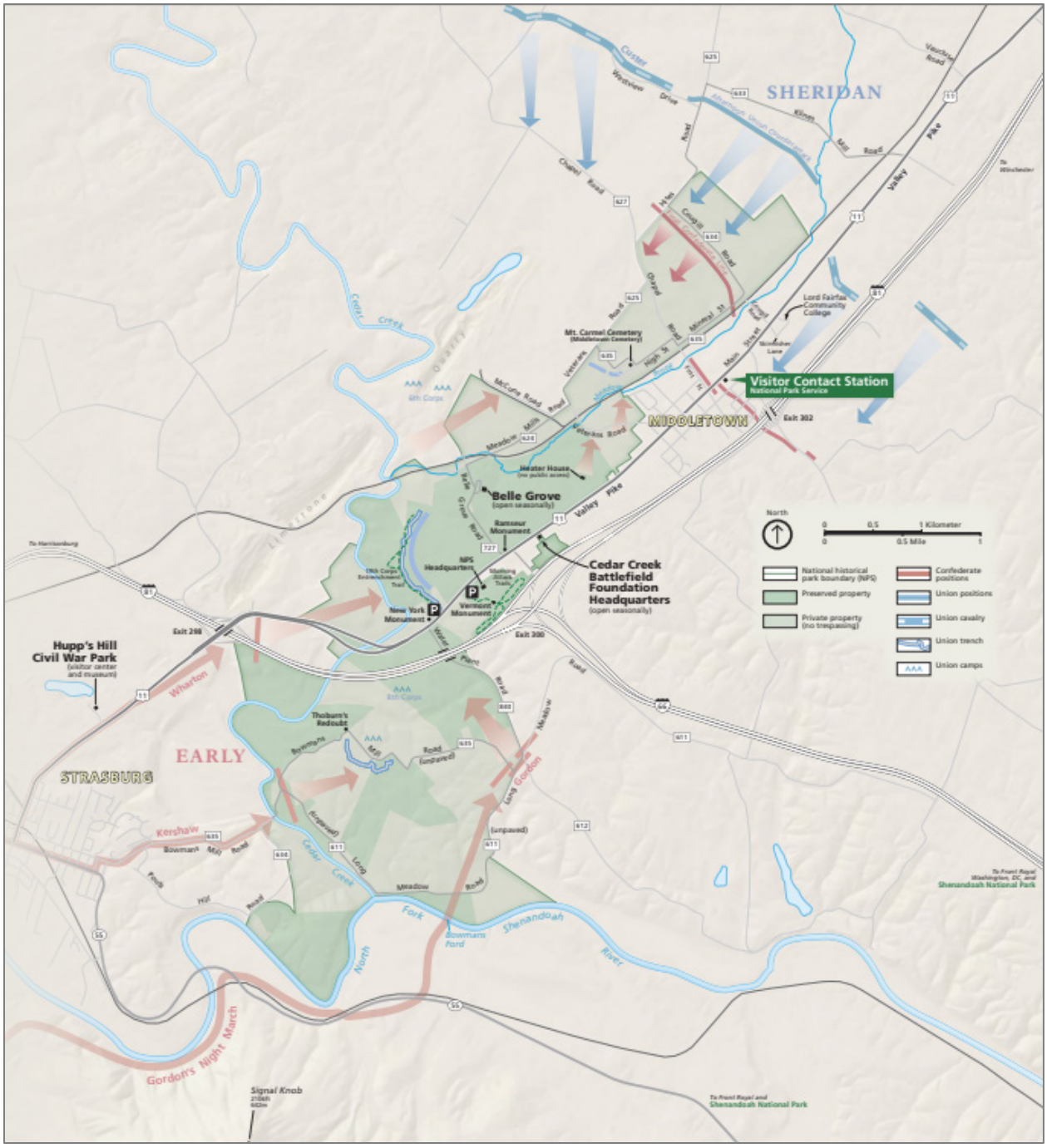



**Figure 4.** NPS map of CEBE and surrounding area, including Union troop positions (blue lines), Union troop movements (blue arrows), Confederate troop positions (red lines), and Confederate troop movements (red arrows) during the Battle of Cedar Creek, October 19, 1864. Figure Credit: NPS (2018a).

Some of the many cultural resources within Cedar Creek Battlefield include trenches built by the US 19th Corps in 1864, Thoburn's Redoubt, and Mount Carmel Cemetery (NPS 2023a, NPS 2023b, NPS 2023c). Additional cultural (and natural) resources can be toured via the 8th Vermont Monument, Thomas Brigade Loop, and Hayes-Ramseur Loop trails—collectively known as the Morning Attack

Trails (NPS 2023d). In addition to the manor house (mentioned above), Belle Grove Plantation cultural resources include an apple orchard characteristic of crops of the 1800s, outbuildings including an icehouse and smokehouse, and an enslaved burial ground (Belle Grove, Inc. 2020). A 1700s farmhouse, named both Harmony Hall and Fort Bowman, is one of multiple other historic structures within CEBE's boundaries (NPS 2023e).

#### *1.2.2. Present-day Setting*

Although CEBE is mostly rural, it contains incorporated, developed areas of Middletown, and it is influenced by adjacent development in Strasburg, to the southwest (NPS 2010). Both Middletown and Strasburg are historic towns. Middletown was established as a town in 1796 and incorporated by 1878 (Middletown, Virginia 2023). As of 2020, the town had a population of approximately 1,585 people (Data USA 2023). Strasburg was chartered in 1761 and incorporated in 1922 (Strasburg, Virginia 2023a). Today, Strasburg has a population of 7,083 people (Strasburg, Virginia 2023b). These towns and the three counties in which the park occurs (Frederick, Shenandoah, and Warren) are considered park community partners. Shenandoah County owns land within the CEBE boundary and is considered both a key partner and a community partner (NPS 2010, NPS 2018a).

Construction of the Interstate Highway System contributed to people moving to the Shenandoah Valley, and growth continues to occur in Middletown and Strasburg (Commisso and Foulds 2007). Construction of Interstate 81 (I-81) was complete through the entire Shenandoah Valley by 1971 and was described by Commisso and Foulds (2007) as the "underlying agent of suburbanization" within the area. Population growth has occurred particularly along the U.S. Highway 11 corridor and Hite Mill Road areas. Interstate 81 and U.S. Route 11 run through and/or border the park. Interstate 66 (I-66) joins I-81 near the east side of the park; Figure 5, discussed below, shows these highways. The three counites in which CEBE is located are now considered within the Washington, DC commuting area, which has contributed to further growth, particularly along I-66 (NPS 2010).

The predominant agricultural land uses in Shenandoah Valley as of 2007 were vineyards and cattle-raising (Commisso and Foulds 2007). In CEBE, much of the land cover within park boundaries is currently hay/pasture, and landscapes are generally more natural and less disturbed in the southern half of the park (Figure 5) (NPS 2010). Other land use changes in the valley were the increase in suburban developments and limestone mining in the mid-twentieth and early twenty-first centuries (Commisso and Foulds 2007). Figure 5 shows "developed, low intensity" through "developed, high intensity" areas especially in Middletown and along the interstates and U.S. Route 11, and mining areas mapped as "barren land" are located near the northwest side of CEBE. Forest succession has also occurred, including within CEBE historic agricultural and battle fields, contributing to the change in landscape views (NPS 2018a). Commisso and Foulds (2007) wrote that "Excellent views can still be obtained from within the study area (legislated park boundary). However, residential, commercial, and industrial development outside the boundaries of the study area have negatively impacted views to Hupps Hill, Stickley Hill and the Appalachian and Allegheny Plateaus."

Tourism became increasingly economically important to Virginia and the Shenandoah Valley beginning in the late 17$^{th}$ century and continues to be important today. Although current CEBE visitor use statistics are not available, nearby Shenandoah National Park has received around 1.5

million visitors annually from 2019 to 2022 (NPS 2023f). The NPS (NPS 2010) projected that CEBE visitor use could continue to increase as more areas within and around the park are further developed to facilitate and/or accommodate visitation.

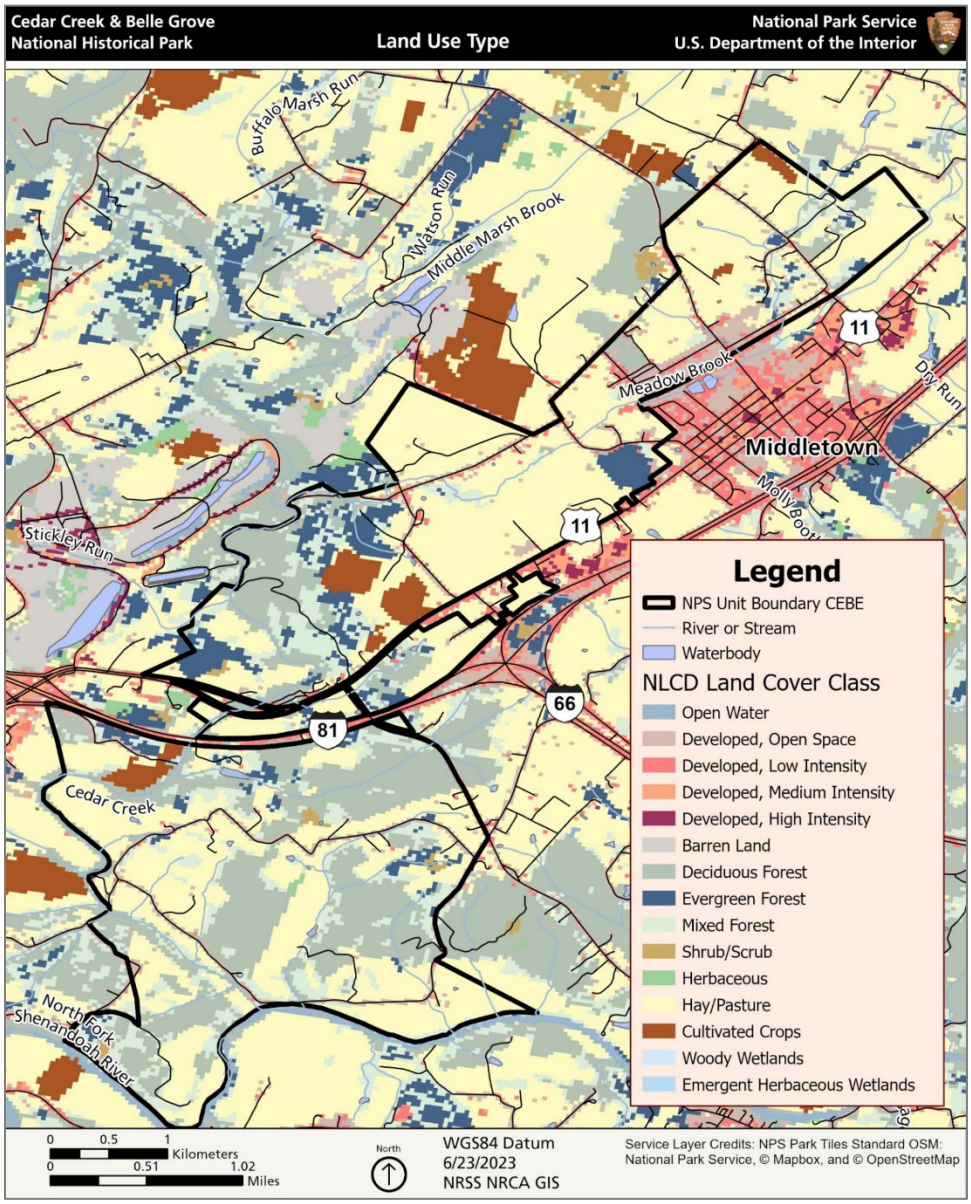



**Figure 5.** Land use categories in CEBE and the surrounding area as of 2019 (Figure by NPS NRCA Program based on National Land Cover Database [NLCD] land use data [Dewitz and U.S. Geological Survey {USGS} 2021]). Also shown are water courses that run along or through the park.

### *1.2.3. Natural Setting and Natural Resources*

The CEBE foundation document identified intertwined landscapes and scenic viewsheds among the park's fundamental resources and values and the following as a significance statement "The panoramic views of the mountains, natural areas, waterways, and pastoral surroundings convey an

aesthetic and historic sense of life in the Shenandoah Valley, provide visitors with an inspiring setting of great natural beauty, and offer outstanding opportunities for quiet and solitude in an ever-expanding suburban area" (NPS 2018a). These natural areas are also important as wildlife habitat within and outside the park. CEBE is located within the Chesapeake Bay Watershed and includes a diversity of habitats ranging from the Shenandoah River and creeks to terrestrial habitats like forests/woodlands and meadows.

One of multiple water courses within CEBE. Image Credit: NPS NRCA Program.

The North Fork of the Shenandoah River flows along the park's southern boundary, and Cedar Creek flows along parts of the western boundary; the two water courses join within the park. Other streams are also present, including Meadow Brook, Middle Marsh Brook, and Buffalo Marsh Run (see Figure 5 above). Some of these water features are designated as "threatened and endangered species waters" due to the presence of three state-listed species: brook floater (*Alasmidonta varicosa*; endangered mussel), wood turtle (*Glyptemys insculpta*; threatened turtle), and green floater (*Lasmigona subviridis*; threatened mussel) (NPS 2010). Vegetative cover within CEBE is composed of forests/woodlands (about 40%), grasslands (about 50%), and riparian/wetland (about 10%) (NPS 2010). Some of the grassland areas are being restored to native meadow habitat. [Note that meadows and grasslands are distinguished from one another by the proportions of grasses and forbs. Meadows have greater than 50% cover by forbs (herbaceous plants other than grasses and grass-like plants), while grasslands have more than 50% cover by grasses (e.g., Chapin et al. 2021). We may at times use these terms interchangeably in the NRCA.] Other significant natural features include a unique dry calcareous forest with high biodiversity along Cedar Creek, and cave and karst features,

including Panther Cave along Cedar Creek—designated a "significant cave" by the Virginia Cave Board because of its archaeological significance (NPS 2010).

The forests/woodlands, grasslands/meadows, riparian corridors, and agricultural areas provide habitat to wildlife species that prefer edge and early successional habitats (Donaldson 2005). Caves provide unusual habitats for uncommon species, including bats. Waterfowl and other birds may use wetland areas scattered throughout the park (NPS 2010). The river, creek, and streams in CEBE provide habitat for aquatic species (Donaldson 2005), including fish such as Potomac sculpin (*Cottus girardi*), rock bass (*Ambloplites rupestris*), and central stoneroller (*Campostoma anomalum*), as well as the three state-listed species mentioned above—brook floater, wood turtle, and green floater (NPS 2010). Mammals commonly found within CEBE include white-tailed deer (*Odocoileus virginianus*), gray squirrel (*Sciurus carolinensis*), chipmunk (*Tamias* sp.), bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), and raccoon (*Procyon lotor*); many songbird, passerine, and raptor species are also common (NPS 2010).

Mid-Atlantic Invasive Plant Management Team (MA-IPMT) crew member planting little bluestem (*Schizachyrium scoparium*) as part of CEBE's restoration of native meadow habitat from agricultural field. Image Credit: NPS.

Although no federally listed plant or animal species are known to be present in the park, some occur within the broader, three-county area (NPS 2010). A list from the Virginia Natural Heritage Program obtained in 2022 for Frederick, Shenandoah, and Warren counties included three federally listed species for the three-county area—one threatened mussel (yellow lance [*Elliptio lanceolata*]) and two endangered bats (Virginia big-eared bat [*Corynorhinus townsendii virginianus*] and Indiana bat [*Myotis sodalis*]) (VNHP 2022). In addition to these three species (which are also state listed), three additional species are listed as state threatened or endangered in one or more of the three counties (two birds and one snail [Peregrine Falcon {*Falco peregrinus*}, Loggerhead Shrike {*Lanius ludovicianus*}, and Appalachian springsnail {*Fontigens bottimeri*}]), and two more are proposed as state threatened/endangered (a beetle and a plant) (VNHP 2022). The plant is Canby's mountain-

lover (*Paxistima canbyi*), state proposed and a federal species of concern. This small, evergreen shrub was observed on a limestone bluff that appears to be on private land within the park boundary (Bousquet et al. 2004). Additionally, the monarch butterfly (*Danaus plexippus*), a species reported within CEBE (iNaturalist 2023a), is currently a candidate for federal listing under the Endangered Species Act (U.S. Fish and Wildlife Service [USFWS] 2023).

# Chapter 2. Drivers and Stressors

The drivers and stressors that are likely influencing CEBE's natural resource conditions were discussed among the invited subject matter experts and park managers during the 2022 NRCA scoping workshop. Because CEBE is relatively long and narrow, in close proximity to two towns, especially Middletown, and the legislated park boundary includes privates lands (residential and commercial), many of the drivers and stressors identified are related to human development and/or disturbance. This chapter includes summaries of these main landscape-scale drivers and stressors, while Chapters 3 and 4 provide more park-specific details and, in some cases, more resource-specific stressors. When stressor-related data are available, they are used as indicators of condition and/or measures to evaluate the states of CEBE's selected focal natural resources in Chapter 3. In most cases, the drivers-pressures and stressors categories used follow those in NPS Resource Stewardship Strategy National Working Group (2021 [Table 1 of the report]).

**Agriculture:** Agriculture is a long-standing activity and land use in the northern Shenandoah Valley and in CEBE (see Chapter 1, Setting and Resources), and it also keeps lands that were in an open condition during the Civil War period open today. However, agriculture also influences the natural resources in and around the park. Within CEBE's legislated boundary, there are agricultural activities on private lands both south and north of I-81 where it bisects the park. Agriculture is also a land use on some of the partner properties, including Belle Grove Plantation (owned by the National Trust for Historic Preservation and operated by Belle Grove, Inc.), Harmony Hall (owned and operated by Belle Grove, Inc.), and Heater House (owned by Cedar Creek Battlefield Foundation) (NPS 2010). NPS (2010) characterized the park as having a modest amount of land in agricultural production. Grasslands (also known as "open areas" in this report), which make up roughly one-half of the park, include pastures, old fields, and meadows, and are used mostly for cattle grazing and hay production (NPS 2010). The NPS has undertaken the process of restoring agricultural fields in CEBE that are owned by NPS to meadows; the restoration of these areas is addressed in the Meadows gap analysis (Section 3.5). Figure 5 (above) shows areas mapped as hay/pasture and cultivated crops in CEBE, and Figure 2 (above) shows locations of private lands within the park.

Past agricultural development led to the alteration of native plant communities and fragmentation of the habitat for wildlife. For example, forest cover had declined by the late 19$^{th}$ and early 20$^{th}$ centuries due to considerable clearing for pasture and agricultural use (NPS 2010). Today, agriculture can negatively impact the park's natural resources through impacts to water quality (NPS 2018a). The park's foundation document reports that agricultural uses threaten the water quality of the Shenandoah River and Cedar Creek, and portions of Cedar Creek within CEBE have been listed as impaired due to *Escherichia coli* (*E. coli*) contamination in the past (NPS 2018a). The protection of waterways and their water quality are made challenging because they are under various ownership, with most passing through private property (NPS 2018a). Agriculture may also be a potential source of invasive plants, but no specific data are available. Once the restored park meadows are well established and on a regular maintenance cycle, they should be less prone to invasion by non-native plants related to agriculture or other sources (NPS Mid-Atlantic Invasive Plant Management Team [MA-IPMT], N. Wender, Team Leader, email communication, 27 September 2023).

**External development, land use change, and encroachment:** A trend of increasing population size and urban development is expected to continue around CEBE, with the northern end of the park in Frederick County experiencing the largest industrial and residential development pressure (NPS 2018a). There is also potential for development along I-66 (NPS 2018a), which meets up with I-81 on the east side of the park. Land use change can have substantial effects, depending on what the previous and new land use is. Along with development generally comes increases in road traffic, human-related noise, lighting, and visual obstructions, as well as decreases in open space and/or natural vegetation and habitats available to wildlife. Modern development also detracts from historic views and natural scenery, and external developments and land use changes may negatively affect a park's soundscape and night skies. Viewsheds and soundscapes are critical for visitor understanding of battle landscapes and other aspects of CEBE, as well as enabling night sky appreciation and programs and allowing for other environmental learning opportunities (NPS 2018a).

Roads and highways, and their car and truck traffic, are a significant factor at CEBE. Vehicle traffic from I-81 and U.S. Route 11, which run through or border part of the park (see land use figure, Figure 5, in Chapter 1), affect the atmosphere of the park (NPS 2018a), including the views and sounds. Also, when stopping along the roadside for interpretive waysides/auto tour signs, some visitors may be affected by vehicles passing nearby at high speeds.

Industrial developments in the area include the Carmuese limestone quarries, the Middletown operation and the Strasburg operation, both on the northwest side of the park (see Figure 5 for substantial quarry areas mapped as barren land and water bodies). The quarries impact viewsheds from within the park (NPS 2018a; this report).

The National Land Cover Database (NLCD) 2001–2019 land cover change index/map (Dewitz and U.S. Geological Survey [USGS] 2021; Homer et al. 2020) (Figure 6) shows areas of urban change near the park (reddish-orange areas) around Middletown, Strasburg, and the quarries.

**Light and noise pollution:** As growth of towns and cities continues, fewer places are available for the public to find and enjoy clear views of the night sky (NPS 2010). A significant source of light pollution—the intrusion of light into our nighttime environment—is outdoor light fixtures that are poorly designed and allow light to extend past where it is needed (NPS 2010). Light pollution negatively impacts night skies, diminishes wilderness character, reduces recreational opportunities for visitors (including viewing the night sky; Gallaway 2010), and adversely affects wildlife species that rely on natural patterns of light and dark (Royal Commission on Environmental Pollution 2009; Sanders et al. 2021). The external developments described above (e.g., roads and highways, nearby residential, commercial, and industrial operations) are all potential sources of light pollution at CEBE. Also, interior and exterior lighting at visitor centers, administration/operation buildings, and other outdoor spaces within the park can contribute to light pollution.

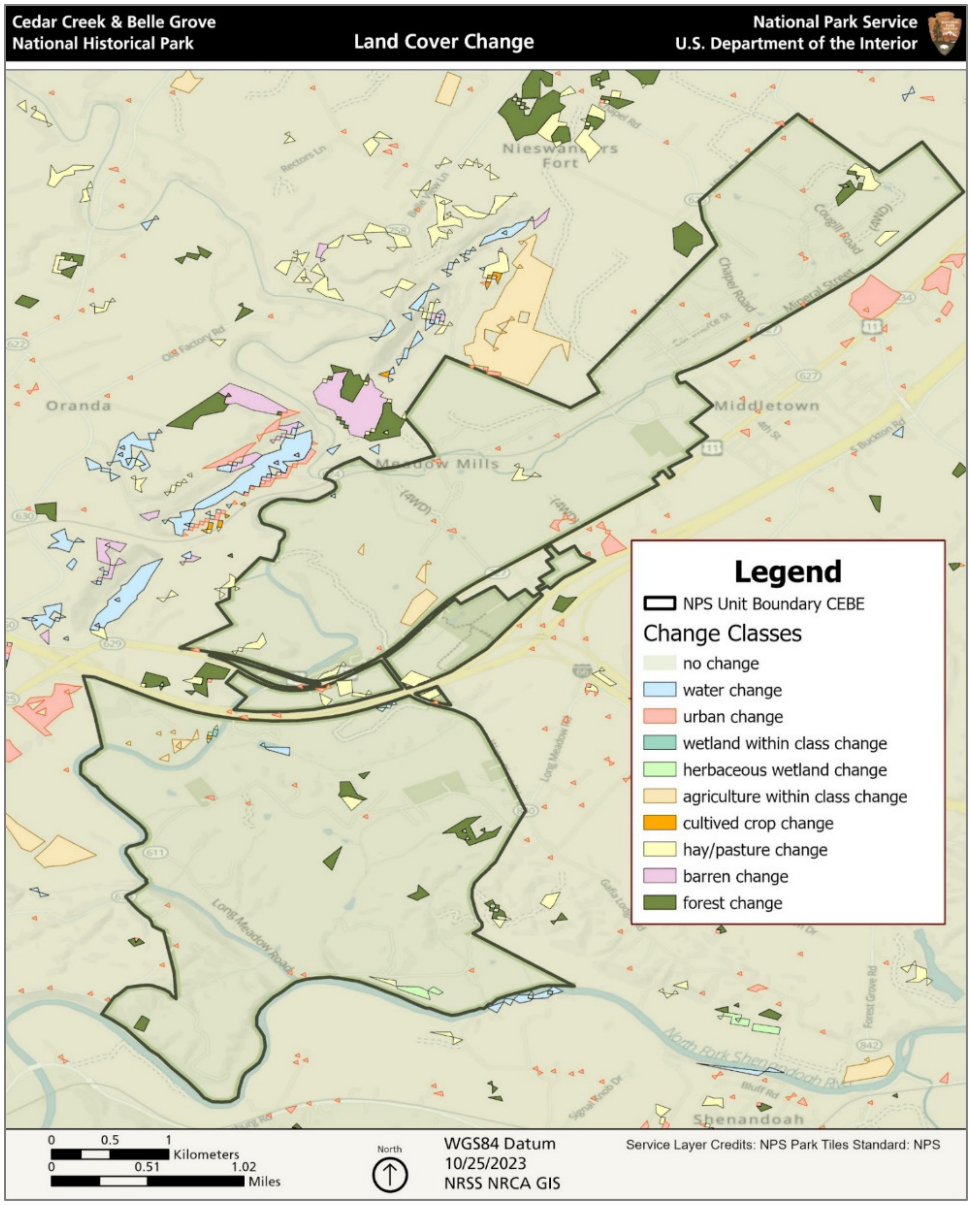



**Figure 6.** Land cover change in and around CEBE, 2001–2019 (Dewitz and USGS 2021; Homer et al. 2020).

Each national park unit has a unique soundscape, and these sounds are central to a visitor's experience in a park. A soundscape is composed of all the various natural and cultural sounds that help create a sense of place. A natural acoustic environment is vital for wildlife and their ability to avoid predators, perform courtship rituals, and effectively use their habitats.

Noise—unwanted or intrusive sound—from outside and inside a park can impact the soundscape. The developments described under "External development, land use change, and encroachment," such as roads and highways, are all potential sources of noise at CEBE. A major source of noise in the park is vehicles on roads that pass through the park, especially I-81 and U.S. Route 11, that contribute erratic, but permanent sounds (NPS 2010). Other sources of noise within the park could

include maintenance activities (e.g., lawn mowing), and visitors talking or shouting. Also, an outdoor firing range near CEBE, that received a permit for operation in 2022, represents a new and additional source of noise that may be heard in at least the parts of the park nearest the range. This firing range is addressed in the Soundscape condition assessment in Chapter 3.

**Invasive species:** Invasive species negatively influence native ecosystems, cultivated ecosystems, and managed landscapes (Tobin 2018). In natural ecosystems, invasives can reduce the services ecosystems provide, decrease species richness, and result in population decreases or extinction of native species (Tobin 2018). Invasive species cost governments, industries, and private citizens billions of dollars on an annual basis, such as through expensive treatment actions (Tobin 2018) and through damage to buildings and power, water, and transportation facilities (Vissichelli 2018, as cited in NPS Climate Change Response Program [CCRP] 2023). Even non-native species that are not necessarily considered invasive can contribute to decreases in biodiversity (Tobin 2018).

In temperate zone ecosystems, climate change can favor non-native invasive plants because of the increased warmth, humidity, vegetation disturbances, and atmospheric carbon dioxide (Hellmann et al. 2008, Davidson et al. 2011, Liu et al. 2017, all as cited in NPS CCRP 2023). Climate change can also benefit invasive aquatic species due to the warmer waters and other altered conditions in freshwater ecosystems (Havel et al. 2015, as cited in NPS CCRP 2023).

*Invasive plants:* Non-native invasive plants can outcompete native plants, lead to reductions in biodiversity, and provide little, if any, benefit to native insects and pollinators (Blandy Experimental Farm 2023). At CEBE, non-native invasive plants have been recorded in woodlands, meadows, and other park areas. For example, non-native invasive plants were reported in woodland study plots from past studies that we reviewed for the Woodlands gap analysis, and they occurred over the majority (89%) of an agricultural field at CEBE that is in the process of being restored to native meadow. Also, an invasive plant survey was conducted in some parts of the park in 2017 on land owned by NPS and its partners, and invasive plants were found in many of the areas surveyed (NPS 2017). Invasive plants can also threaten the park's cultural resources, such as CEBE's earthworks (NPS 2018a).

For the most part, only limited treatment activities of targeted invasive species are conducted at CEBE (NPS 2018a), and there are no monitoring programs in place for natural resources (NPS 2018a), including for invasive plant species. The main exception to this is for vegetation monitoring being conducted in the meadow restoration area by the NPS MA-IPMT (see Meadows gap analysis for details).

*Invasive insects:* The emerald ash borer (*Agrilus planipennis*), or EAB, is a wood-boring beetle native to Asia that has killed ash trees in CEBE and in at least 35 states and the District of Columbia (Animal and Plant Health Inspection Service [APHIS] 2023a). The beetle was first recorded in the United States, in Michigan, in 2002. All 16 species of ash trees in the U.S. are susceptible to the beetle (APHIS 2023b). Infected materials, such as firewood, infested ash plantings and trees, and ash wood packing material, can spread the infestation (APHIS 2023b). The EAB is a threat to ash trees on both NPS and partner lands in CEBE.

The spotted lanternfly (*Lycorma delicatula*), or SLF, is a small insect from Southeast Asia that feeds on the sap of a wide variety of plants and trees, including fruit and ornamental trees and native trees (e.g., maples, oaks, and pines) (APHIS 2023c). It was found in the United States for the first time in 2014 in Pennsylvania (APHIS 2023c), and in Virginia in 2018 in Frederick County (Virginia Cooperative Extension [VCE] 2023a). The insect is currently found in 14 states (APHIS 2023c). Signs that plants are infested with SLFs include oozing or weeping, having a fermented odor, having an accumulation of sticky fluid on vegetation and on the ground below, and/or the presence of dark mold.

When populations of SLF are high, they can cause substantial damage (Leach 2020), but Leach (2020) notes that plant mortality has primarily been seen in sapling trees, sumac (*Rhus* spp.), grapevines, and tree-of-heaven (*Ailanthus altissima*, a non-native invasive plant discussed in this report). Although the insects cannot fly long distances, they can spread to new locations by people inadvertently moving infested material or items containing SLF egg masses (APHIS 2023c). Starting in the fall, SLFs lay egg masses, which are about an inch long and look like mud, on tree bark and other outdoor surfaces (including vehicles). CEBE has a number of types of trees known to be susceptible to SLF.

*Other non-native species:* Other non-native animal species within CEBE that can threaten the park's native wildlife include domestic pets (dogs or cats), green sunfish (*Lepomis cyanellus*), and European Starling (*Sturnus vulgaris*) (NPS 2010; Fuller et al. 2023). Three additional bird species not native to the CEBE area that have been observed in the park include House Sparrow (*Passer domesticus*), House Finch (*Haemorhous mexicanus*), and Rock Pigeon (*Columba livia*) (eBird 2023a, 2023b). European Starlings may damage crops, including apples, and can negatively impact cavity-nesting native species such as Eastern Bluebird (*Sialia sialis*) and Wood Duck (*Aix sponsa*) (AHPIS 2017), two species observed within CEBE (eBird 2023a, 2023b). House Finches compete with other species, including Purple Finches (*Haemorhous purpureus*), a native species observed within the park (eBird 2023b), for habitat and food (Audubon N.D.). Rock Pigeons, which prefer developed areas, may spread pathogens and cause maintenance issues (Williams and Corrigan 1994).

*Disease and pathogens:* Native white-tailed deer are adversely affecting forests in eastern U.S. national parks due to their high population numbers and resulting over-browsing (e.g., Miller et al. 2023); such impacts on vegetation are addressed in the Woodlands gap analysis. Deer also carry ticks, including the deer tick or blacklegged tick (*Ixodes scapularis*), which transmits Lyme and other diseases. Pathogens transmitted by this tick species are increasing in occurrence and distribution in the United States (Johnson et al. 2017). Lyme disease, which can impact humans, is the most common vector-transmitted disease in North America (Brinkerhoff et al. 2014). The disease is caused by infection with the bacterium *Borrelia burgdorferi*, carried by infected ticks, especially the black-legged tick in the eastern United States (Brinkerhoff et al. 2014). The ticks (as nymphs or larva) get infected with Lyme disease after feeding on infected small mammals, such as white-footed mice (*Peromyscus leucopus*). White-tailed deer are a main host species for adult blacklegged ticks, but deer themselves do not become infected with Lyme disease bacteria. Nymph-stage ticks are the primary vector of the Lyme disease bacterium to humans (Eisen 2020), but all life stages bite humans

(Centers for Disease Control and Prevention [CDC] 2022). Ticks of this and other species also transmit a number of other diseases, such as anaplasmosis, tularemia, and ehrlichiosis (CDC 2022).

The Virginia Department of Game and Inland Fisheries (VDGIF; 2015) reported that "with the exception of one long-term study in a small, peninsular community in Connecticut (Kilpatrick et al. 2014), there have been no robust assessments of a relationship between deer populations and incidence of Lyme disease... Further, a clear relationship has not been established between deer populations and the abundance of blacklegged ticks." Other authors have, however, reported a link between deer and ticks, such as Eisen (2020) who indicated "There is broad consensus that white-tailed deer is a main driver for the remarkable increase in *I. scapularis* ticks in the northern parts of the United States over the past 40 years." Tsao et al. (2021) also discussed the link between the abundance of deer and ticks, but also pointed out the relationship is nonlinear (i.e., above a certain point, further increases in deer density do not noticeably increase black-legged tick abundance). These authors also provide a substantial discussion of ticks and tick-borne diseases in North America, including on deer and other tick hosts, approaches to combat the rise of ticks and tick-borne diseases, and knowledge gaps.

**Climate/Climate Change:** Climate change, which is resulting in rising temperatures, changes in precipitation regimes, stronger storms, and other changes, is impacting and will continue to impact natural and cultural resources, assets and operations, visitation, and human wellbeing across our national parks and the United States (NPS CCRP 2023). Of the focal resources addressed in this NRCA, changes in temperatures, precipitation, and extreme events would be expected to affect woodlands and meadows most directly, but also visual resources and night skies. Although not a focal natural resource, agriculture within the park would also be expected to be affected.

Note that unless stated otherwise, the information on climate/climate change that follows was summarized or taken directly from NPS CCRP (2023). When text is presented exactly as it appeared in the climate report, we enclosed the text in quotation marks. We present temperature measurements in this section in degrees Fahrenheit (°F) only (as in the original report), and other measurements in English units first. Also, importantly, note that while a substantial amount of information is presented here on climate change, it was beyond the scope of the NRCA to provide estimates on how each of the current or projected changes would be expected to affect the focal resources.

*Historical trends:* In CEBE, as in other national park units, temperatures have already increased significantly. Average annual temperature in the park increased at the rate of 1.63°F per century from 1900–2022, and by the extremely rapid rate of 5.14°F per century since 1970 (Figure 7, top panel). Anomalies in annual average temperatures in 1990 and 1991 were exceeded seven years (31.8%) since 2000. Also since 1970, nighttime (daily minimum) temperatures have increased faster than daytime (daily maximum) temperatures, so the range between daytime and nighttime temperatures has decreased. Precipitation has increased since 1970, but it is still variable (Figure 7, bottom panel). The trend for rainfall at CEBE is consistent with regional trends towards more frequent extreme rainfall events. Historically, CEBE had an average of 35.6 inches (90.4 centimeters [cm]) of precipitation per year.

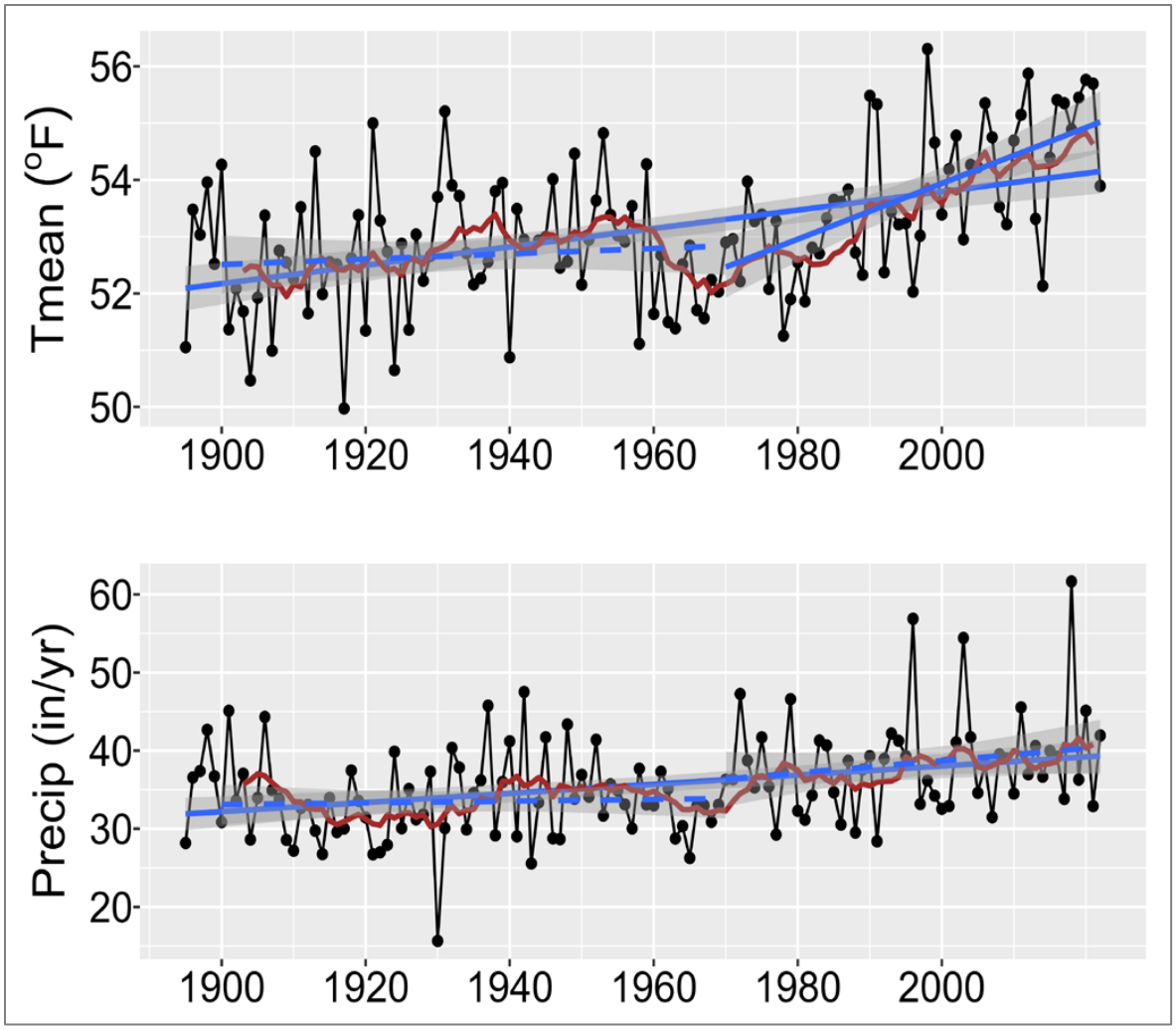



**Figure 7.** Historical trends in annual average temperature (upper plot) and annual total precipitation (lower plot) for CEBE from 1895–2022. Black points show yearly values, while the red line represents the 10-year rolling average. Blue lines are linear regressions for the entire period of record, up to 1970, and 1970–present. Solid lines are significant trends (i.e., $p<0.05$); dashed lines are not statistically significant. Data Source: NClimGrid (Vose et al. 2014). Figure Source (and caption): NPS CCRP (2023; Figure 1).

Some additional climate change information is available for nearby Antietam National Battlefield. Two indicators of the onset of Spring, first leaf index (FLI) and first bloom index (FBI), indicate that Spring is arriving earlier. The statistics for FLI indicate it is occurring early (6$^{th}$ percentile [out of 5$^{th}$ to 25$^{th}$ percentile]), and those for FBI indicate it is occurring extremely early (1$^{st}$ percentile [out of <5$^{th}$ percentile]) (NPS, A. Babson, Coastal Landscape Adaptation Coordinator, email communication, 8 February 2023). In addition to Antietam National Battlefield, NPS and partners evaluated these changes in phenology in 275 other national park units (NPS 2020a). These broader results show that half of the 276 parks are (and have been over the past 10–30 years) experiencing an "extreme" early Spring that exceeds 95% of historical conditions, as indicated by FLI and/or FBI from plant species used as indicators.

*Projected climate change:* In addition to providing the information on recent climate changes at CEBE as described above, NPS CCRP (2023) described "plausible climate trajectories" at the park. "Characterization of potential climate change includes a small set of divergent climate futures that span a broad range of ways in which climate might plausibly change in the park in coming decades" (NPS CCRP 2023).

Changes that are projected at CEBE, relative to a 1979–2012 baseline period, include significant warming by about 2050 (average of 2035–2065) and increases in mean annual precipitation. For temperature, climate models projected a range of increases in average annual temperature from +1.97°F to +7.16°F. Compared to historical (1979–2012) annual precipitation averages, annual precipitation is projected to change by −0.15 (-0.4%) to 5.59 inches (+14.56%). "Seasonal shifts in precipitation patterns and growing season length vary among climate models and climate futures. Given this range of projections, planning for a single future is highly unlikely to help prepare for what will transpire…To support planning for a broad range of plausible climate changes at CEBE," NPS CCRP (2023) chose two climate futures, referred to as "Warm Wet" and "Hot Damp" future circa 2050, "to capture relevant variation across the climate models and greenhouse gas emissions scenarios." The discussion that follows focuses on these two climate futures.

"Average annual temperatures are projected to continue increasing relative to the 1979–2012 historical period in both climate futures, but the magnitude of that increase differs with considerable warming (+3.6°F) in the Warm Wet climate future and extreme warming (+5.83°F) in the Hot Damp climate future" (Figure 8). Although these trends may seem modest, temperatures during the hottest two years (i.e., 1990 and 1991) in the historical record would be "average years" in the Warm Wet climate future, and a "hot" year at that time would exceed the historical range of variation. By 2050, temperatures every year in the Hot Damp climate future would exceed those experienced at CEBE since 1895. These are large changes that would be associated with a large reduction in frost days, many more days with high temperatures, and a much longer growing season."

Mean annual precipitation would increase under both climate futures (relative to 1979–2012) (NPS CCRP 2023). An increase of 4.4 inches/year (11.2 cm/year) is projected for the Warm Wet climate future, and an increase of 1.4 inches/year (3.56 cm/year) is projected for the Hot Damp climate future. Under both climate futures, the variability in precipitation CEBE has always experienced would continue.

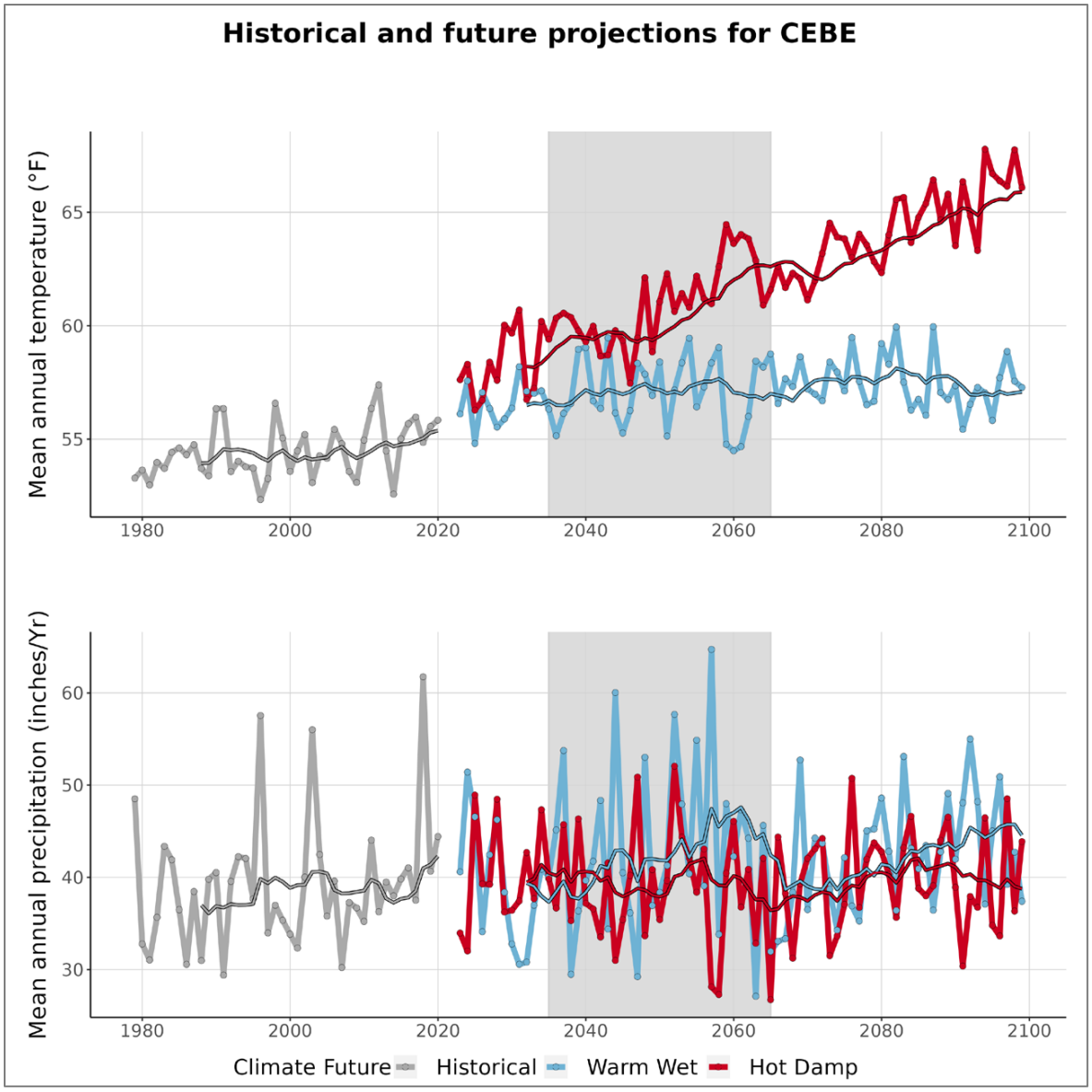



**Figure 8.** Historically observed data (gray lines; 1979–2020) and climate futures (blue and red lines; 2023–2099 [Abatzoglou and Brown 2012]) for annual mean temperature and precipitation in CEBE. The blue and red lines, respectively, represent the Warm Wet and Hot Damp climate futures. The smooth, dark line running through each projection is the 10-year running average. Gray-shaded area represents the time period (2035–2065) over which projections were averaged to summarize changes from the baseline. Figure Source (and caption): NPS CCRP (2023; Figure 3).

Other climate change projections for CEBE are related to extreme temperatures, extreme precipitation, drought, and water deficit (plant-available water) (NPS CCRP 2023). Climatic water deficit "is an indicator of the amount of additional water plants would use if it were available, and is often used to indicate landscape dryness." It usually corresponds with increased plant stress and fire risk (Thoma et al. 2020). We provide a brief summary of findings related to these aspects of the climate here, and refer the reader to NPS CCRP's full report for more details.

- Extreme temperatures are expected to increase under both climate futures at CEBE, with +16 days per year exceeding the dangerous heat index threshold (103°F) under the Warm Wet future, and +27 days per year exceeding the threshold under the Hot Damp future. This compares to about 2.5 days exceeding the threshold historically.
- CEBE is expected to experience an increase in extreme precipitation under both climate futures. Historically (1979–2012), 3.9 inches (9.9 cm) of rain in a 24-hour period was a 40-year return precipitation event. This same amount of rain in a 24-hr period is expected to have a return interval of 6 years under the Warm Wet climate future, and 27 years under the Hot Damp climate future. The analysis also found that a 40-year precipitation event would increase to 8.5 inches (21.6 cm) in a 24-hour period under the Warm Wet future, and 4.4 inches (11.2 cm) under the Hot Damp future.
- Under the Warm Wet climate future, droughts would become longer, be more severe, and occur less frequently (have a longer drought-free interval) relative to historical drought (Figure 9). Under the Hot Damp future, droughts would become longer, be more severe, and occur more frequently relative to historical drought.
- The average annual water deficit at CEBE would increase under both climate futures (+0.27 inches/year [slightly drier] under the Warm Wet future, and +3.36 inches/year [drier] under the Hot Damp future). "Both climate futures have many more years that are wetter or drier relative to the past, and fewer years that are "average." Under the Hot Damp climate future, water deficit in the average year would be comparable to years that currently would be considered dry. For that (Hot Damp) future, the park can expect **most years to have reduced plant growth, lower stream flow, and increased fire risk and plant stress**" (NPS CCRP 2023).

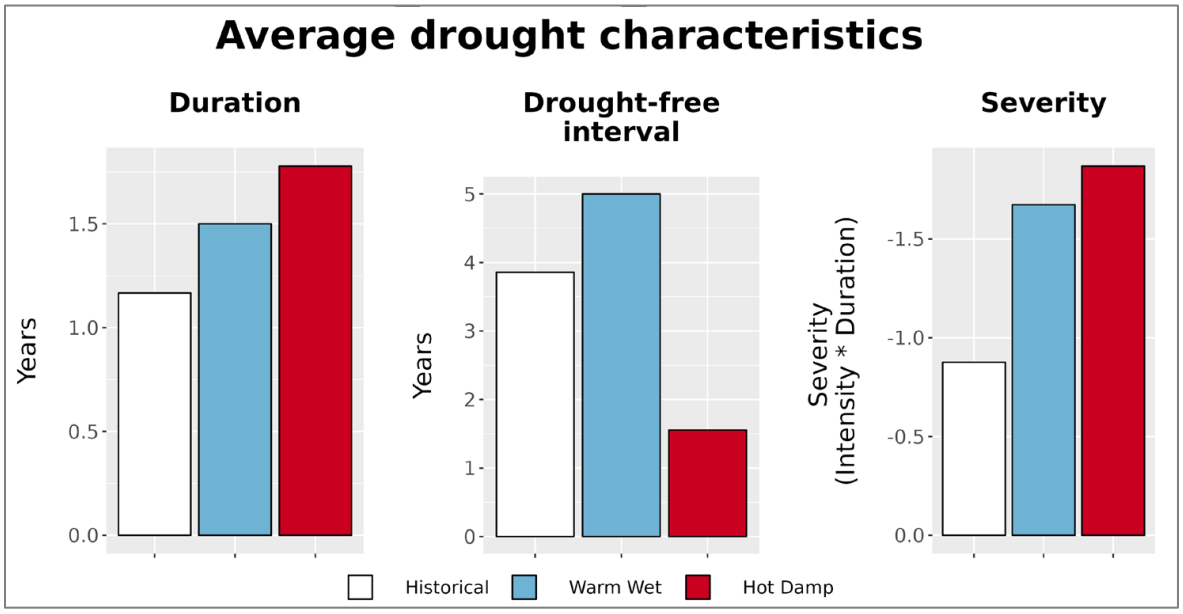



**Figure 9.** Characteristics of average drought conditions for the historical period (1979–2012) and two climate futures (2035–2065). Figure Source: NPS CCRP (2023; Figure 6).

# Chapter 3. Focal Resource Evaluations

Chapter 3 reports on the conditions (states) of CEBE's selected focal natural resources. We evaluated these resources, as either a condition assessment or a gap analysis, depending on data availability.

For focal resources that lacked adequate data for credible evaluations of their current conditions, we developed a gap analysis. A literature review, combined with expert input, summarizes the focal resource: its ecological importance, the general status of knowledge regarding factors influencing conditions, and indicators, measures, and studies to consider in the future for improving the park's understanding of the resource.

For focal resources that had adequate data to assess current conditions for one or more indicators of condition, we developed a condition assessment. For each indicator, data for one or more measures were evaluated either qualitatively and/or quantitatively and combined to report a condition rating at the indicator level. Rating statements included the combined measures' qualitative characteristics, and, when available, quantitative values, for a range of good to poor conditions for each indicator (see Figure 10 for rating classes and colors). Sometimes, the indicator of condition is unknown and is shown in gray. The rating statements in Appendix A include logical and defensible criteria for assigning a condition level. We did not report a condition rating for the focal resource itself because of the complexity of characterizing the condition at that level adequately.


**Figure 10.** Indicators of condition rating classes and colors.

Each condition rating was assigned a confidence level, reported as high, medium, or low, depending on factors such as repeatability, age of data, and whether data were collected or modeled. If available, a statistical trend was reported as improving, stable, deteriorating, or unknown.

The natural resources evaluated as condition assessments for CEBE included visual resources, night sky, and soundscape. Gap analyses were completed for woodlands and meadows.

**It is important to note how land cover area (hectares/acres) was determined for CEBE in this report. We found a difference between the total area of the park based on the GIS park boundary layer and the official acreage of the park per the NPS Land Resources Division (NPS Land Resources Division 2023). Therefore, measurements of area (in hectares and/or acres) provided in the NRCA for particular cover types were determined by calculating the proportion of a particular land cover type in the park (based on the park boundaries in GIS), and then multiplying by the official acreage of the park per NPS Land Resources Division (2023).**

### 3.1. Visual Resources

The conservation of scenery was established in the NPS Organic Act of 1916, reaffirmed by the General Authorities Act, and addressed in the NPS (2006) Management Policies sections 1.4.6 and 4.0 (Hill et al. 2009). Although no management policy currently exists for only scenic or visual resource management and preservation, parks are still required to protect scenic quality as one of their most fundamental resources. According to Wondrak-Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early twentieth century. Aesthetic conservation strives to protect scenic beauty for NPS visitors to better experience the values of each park unit. The need for scenic preservation is as relevant today as ever, particularly with the pervasive development pressures that challenge NPS managers. CEBE's foundation document (NPS 2018a) identifies the importance of scenic views to the historic significance of the park and surrounding region:

> *"The panoramic views of the mountains, natural areas, waterways, and pastoral surroundings convey an aesthetic and historic sense of life in the Shenandoah Valley, provide visitors with an inspiring setting of great natural beauty, and offer outstanding opportunities for quiet and solitude in an ever-expanding suburban area."*

A scenic view across a rural landscape in CEBE, with the town of Strasburg visible in the far distance. Image Credit: NPS.

### *Condition Assessment Summary*

Methods

The NPS Air Resources Division's (ARD's) methodology for conducting visual resources inventories (Meyer et al. 2018) was used to determine the condition of scenic views at three locations in the park. The visual resources inventory (VRI) approach provides specific guidance to evaluate two components or measures: scenic quality and view importance (Table 1). Each measure is rated separately based on a standardized approach and established criteria. A matrix is then used to combine the two measures into an overall scenic inventory value (SIV) (see Table 4 in Appendix A). The SIV is what we used to determine the visual resource condition at each selected location in CEBE.

**Table 1.** Study details for visual resources (Meyer et al. 2018).

| Indicator | Measure | Reference Criteria for Measure |
|---|---|---|
| Visual Resources | Scenic quality | Most views include landscapes in good condition with very few, or minor, features that detract from the desirable visual characteristics. Most views are also aesthetically pleasing and memorable because of bold forms and colors. Elements in the view seem well proportioned and balanced. |
| | View importance | Views are key to the purpose of the park and/or a primary reason that visitors come to the park. Views are well publicized, and extensive effort goes into facilitating the visitor experience at the viewpoint. Extensive interpretive services are offered, such as talks, interpretive panels, or kiosks. |

CEBE staff and partners chose three visual resource inventory points from which to assess the condition of visual resources (Figure 11). The three locations represent some of the most important views in the park, with one also included because of potential development in the background (Viewpoint 3). Viewpoint 1 is the location of park astronomy events at which visitors observe the night sky.

CEBE staff and partners took photos at each of the three inventory points using a cell phone (iPhone 11) camera on 14 December 2022. The views ranged from a framed, 40-degree view (Viewpoint 1) to a 160-degree view (Viewpoint 3). CEBE staff submitted VRI photographs and viewpoint and rating data into the NPS ARD (2023a) Enjoy the View spatial database, from which the information will be available to CEBE staff and partners for future needs (e.g., maps, additional visual analysis, and the addition of new VRI data).

Results and Discussion

On a scale of A to E (with A being the highest), the scenic quality was rated as a B at two locations and a D at one location (Table 2). On a scale of 1 to 5 (with 1 being the highest), the view importance was rated as a 2 at one location and a 3 at two locations. Combining the two measures (using the matrix in Table 4 of Appendix A) at each viewpoint led to two SIVs of "high" and one of "medium." Note that the corresponding NRCA condition ratings are discussed below.

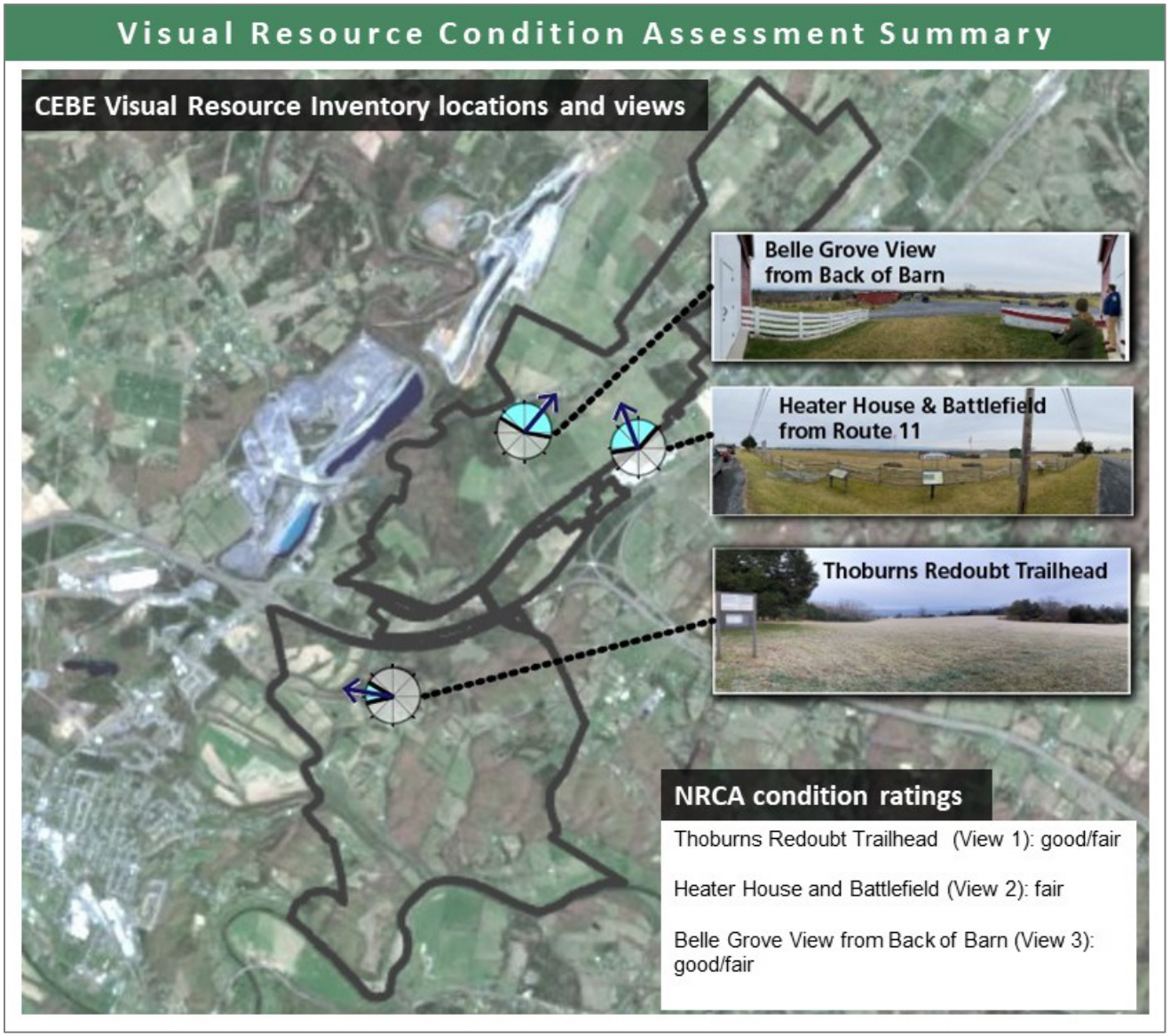



**Figure 11.** Locations, headings, and views of CEBE's Visual Resource Inventory points, and corresponding NRCA condition ratings. Base map (aerial) from ERSI Imagery, Maxar.

**Table 2.** Results of the scenic quality and view importance evaluation, as well as corresponding NRCA conditions. Note that the 5-class rating system from NPS ARD (see Table 4 in Appendix A) corresponds to the 5-class rating system from NRCA (see Figure 10).

| Inventory Point | Scenic Quality | View Importance | Scenic Inventory Value (SIV) | NRCA Condition Rating |
|---|---|---|---|---|
| Viewpoint 1: Thoburn's Redoubt Trailhead | B (33.0) | 3 (25.5) | High | Good/fair |
| Viewpoint 2: Heater House and Battlefield | D (19.5) | 2 (32.0) | Medium | Fair |
| Viewpoint 3: Belle Grove | B (33.0) | 3 (29.0) | High | Good/fair |

Viewpoint 1 of the VRI is from Thoburn's Redoubt Trailhead, looking down a mowed pastoral hill with patches of deciduous and evergreen trees; the foreground extends to Bowman Hite Farmstead (in the center of the photo), the middle ground extends to Strasburg, and the background extends to the Allegheny Mountains (Figure 12). The VRI team gave high scores for some of the individual scenic quality rating factors, including for the subject/content of the view, the quality and condition of what appears in the view, and the balanced scale of the view. The main detraction from the scenic quality is light development in Strasburg along U.S. Route 11. Park astronomy events take place at night at this location.

**Figure 12.** Framed view from Viewpoint 1, Thoburn's Redoubt Trailhead (on Shenandoah Valley Battlefields Foundation property).

Viewpoint 2 of the VRI is from U.S. Route 11 and looks toward the Heater House (to right of center in photo) and the battlefield on Cedar Creek Battlefield Foundation property (Figure 13). It includes pastureland (with cows at time of photo) and the Allegheny Mountains in the distance. Most visitors take in this view from just in front of the wayside signs. [Note that in the view photo below, the

photographer intended to take the photo closer to the interpretive signs, which would omit the view of the closest utility pole. Also note that the road bordering the image is actually less curved than it appears in the photo]. A number of detractions from the scenic quality exist. These detractions include inconsistent elements (e.g., quarry tower and building [white structures beyond and behind the battlefield sign in the photo] and excess/tailing piles [in the distance and to the left of the battlefield sign], modern residential structures, and signs), as well as the relative scale of components of the view (e.g., quarry tower and tailing piles, large signs, and poles interrupt the scale). Also note that as currently shown, utility poles and wires are also detractions; in reality, they are somewhat less so.

**Figure 13.** View from Viewpoint 2, Heater House and the battlefield from U.S. Route 11.

Viewpoint 3 is from the back doors of the Belle Grove barn and includes views of agricultural fields, the enslaved burial ground (near center of photo, to the right of the small gray administrative building), barn outbuildings, Monte Vista historic home (on the right side of photo, beyond the first line of trees), forested areas, and the mountains (Figure 14). The parking lot is also a component of the view and does somewhat interrupt it. High scores were given for some of the individual scenic quality rating factors because of color harmony and vividness in the view (a striking difference, yet not unpleasant, between the mountains and pasture and the red of the buildings), and the landscape character with no missing elements. Some detractions from the scenic quality exist, including inconsistent elements (e.g., green dumpster, gray administrative building, quarry tailing piles [on left beneath the mountain line] and industrial buildings [e.g., over corner of dumpster beyond the park]), and the quality/condition of what appears in the view (i.e., some structures are somewhat deteriorating). This is an important view for the park because it is publicized for events occurring in the barn, and this is what visitors see when entering and exiting the barn. There is the potential for future development in the background of the view's right half.

Using the SIV matrix in Table 4 in Appendix A, the SIV value of each of the three locations was rated as either high or medium (see Table 2). These ratings correspond to NRCA condition rating categories (see Figure 10) of good/fair and fair, respectively. Therefore, the condition of Viewpoints 1 and 3 is good/fair and that of Viewpoint 2 is fair. It is also important to recall that while Viewpoint 2 (Heater House and Battlefield) received a scenic quality rating lower than the other two viewpoints,

it received a higher view importance rating. It may be worth considering whether any actions can be taken to improve the view. It would most likely be easier to mitigate detractions on NPS and partner lands than on lands outside the legislated boundary.

**Figure 14.** View from Viewpoint 3, Belle Grove view from back of barn. The land is owned by the National Trust for Historic Preservation and managed by Belle Grove, Inc.

Because this condition assessment is based on the VRI standardized methodology and its specific criteria and rating elements, we have high confidence in the ratings and assessment. The VRI is repeatable, and the data were collected onsite and recently (December 2022). No information is available for trends. Only three locations were evaluated for CEBE's visual resources condition assessment, however, and condition ratings are limited to these locations.

As noted in CEBE's foundation document (NPS 2018a), surrounding development is the primary stressor impacting the park's scenic and historic viewsheds. Although the VRI pointed out some factors within the park that detract from the views (mentioned here and discussed more in Chapter 4), a good number of detractions from development adjacent to and outside of the park were recorded during the inventory. For the three viewpoints in the assessment, these detractions included development along U.S. Route 11 towards Strasburg, the Carmuese Quarry's tower, building, and tailing (excess) piles, and power lines along U.S. Route 11 (at Viewpoint 2). As mentioned above in the assessment, there is the potential for future development (a roughly 91m-tall [300ft-tall] public safety [self-support] tower with lights) in the background of Viewpoint 3.

Using a five-year (2014–2018) index of haze, the NPS ARD estimated CEBE's visibility to be of fair condition (NPS ARD 2023b). They also estimated a visual range between 66 and 206 km (41 and 128 mi) in 2018. Without the effects of air pollution, the estimated visual range would be between 132 and 275 km (82 and 171 mi) (NPS ARD 2023b). The degree of confidence in these estimates is medium because they are based on interpolated data from more distant visibility monitors (NPS ARD 2023b). Although the view importance for the three viewpoints included here is largely related to resources within the park, more distant features (such as the mountains and sky) are an important component of the view. The fair (as opposed to good) air quality condition for visibility/haze at CEBE may influence the ability to clearly view these more distant features.

Although this assessment focused on visual resources during the day, one of the viewpoints assessed (i.e., Thoburn's Redoubt Trailhead) is the location of astronomy events in the park. Condition of the night sky is assessed in the night sky condition assessment section of this report.

### 3.2. Night Sky

Natural dark night skies are a valued resource within national parks (NPS 2006; lightscape management policy 4.10), and CEBE staff host public "Star Parties" in partnership with the Shenandoah Astronomical Society, drawing as many as 100 or more visitors to the park during each event. The NPS (2006) lightscape policy highlights the value of dark night skies for both the visitor experience and for the natural resource processes of species. The photic environment is integral to ecosystems and is a natural physical process (Moore et al. 2013), varying in light intensity during the day-night (diurnal) cycle, the lunar cycle, and seasonal cycles. Organisms have evolved to respond to these cyclic changes in light levels in ways that control or influence movement, feeding, mating, emergence, breeding, migration, hibernation, and dormancy (Royal Commission on Environmental Pollution 2009). Research has shown that introducing artificial light into the natural light/dark cycle disturbs the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009; Rich and Longcore 2006; Sanders et al. 2021) and diminishes recreational stargazing opportunities (Gallaway 2010).

Viewing the night sky at CEBE. Image Credit: NPS/Buddy Secor.

### *Condition Assessment Summary*

Methods

The NPS Natural Sounds & Night Skies Division (NSNSD) provided modeled data and a map for the all-sky light pollution ratio metric (ALR) (NPS NSNSD 2022). The ALR is an objective measure of night sky condition based on the amount of light in the night sky attributed to human sources (e.g., city lights, streetlights, vehicle headlights) (Duriscoe 2013). The metric reports a ratio of how much brighter than average natural conditions the night sky is at a particular park.

The reference criteria for evaluating the ALR metric are based on a threshold established by the NPS Inventory & Monitoring (I&M) Division (Moore et al. 2013). The I&M Division identified Level 1 and 2 parks based on the number and significance of natural resources present. CEBE is a Level 2 park, where there are fewer natural resources, and light pollution has less of an influence on wildlife and ecological systems. Level 2 parks are often located in urban or suburban areas, and although their night skies are often degraded due to high levels of anthropogenic light, they may include relatively dark areas. Resources in Level 2 parks often serve as an important access to nature for nearby residents and may provide some of the best available night sky conditions for nearby residents and visitors. The ALR condition ratings for Level 2 parks are good, fair, and poor, and are based on ALR values of <2.00, 2.00–18.00, and >18.00, respectively (Moore et al. 2013; Hung et al. 2019) (see Table 5 in Appendix A).

Results and Discussion

The ALR map provided by NSNSD in 2022 for this assessment is shown in Figure 15. The modeled data indicate that CEBE has a minimum ALR of 3.57, a maximum ALR of 4.45, and an average ALR of 3.92. For comparison, a ratio of 0.0 indicates a pristine night sky, and a ratio of 1.0 indicates a night sky that is 100% brighter than average natural conditions (Moore et al. 2013). This means that CEBE's night skies are, on average, 392% brighter than the natural night sky. With these ALR values, the condition rating of this (the only) indicator of CEBE's night sky is fair.

The ALR map indicates that all areas within CEBE were modeled at the same range of values (2.56–5.12 [orange areas on the map], see Figure 15). For this reason, it is not possible to identify darker or lighter areas within the park based on the analysis.

Outside of CEBE's boundary, however, there are areas with lower ratio values (less anthropogenic light) to the west and south of the park (yellow shading), and areas with greater ratio values (more anthropogenic light) to the north and northeast of the park (red shading). Based on the ALR map in Figure 15, the closest area with less anthropogenic light (i.e., in a different color-coded area) is approximately 6.1 km (3.8 mi) to the southwest of the park, and the closest area with more anthropogenic light is approximately 3.4 km (2.1 mi) to the northeast of the park. Residential and commercial development near CEBE and associated night-time lighting, as well as vehicle traffic and lighting on Interstate 81, U.S. Route 11, and other roads (see 2019 land use map [Figure 5] in Chapter 2), contribute to unnatural light and likely impact the night sky condition at the park. Night-time lighting within park boundaries probably also contributes to existing levels of unnatural light.

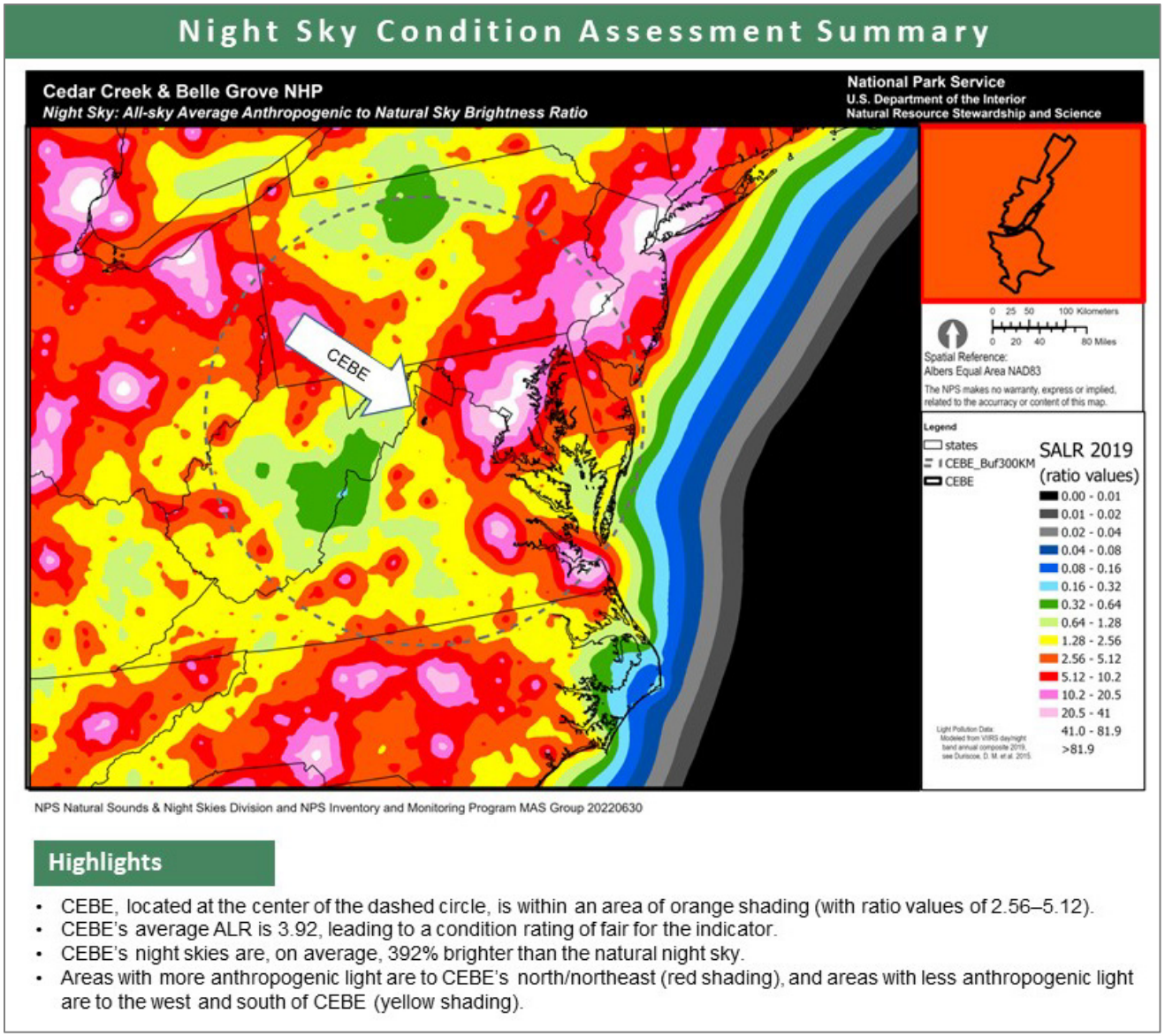



**Figure 15.** The all-sky light pollution ratio metric (ALR) map, provided by NPS Natural Sounds & Night Skies Division in 2022, and assessment highlights.

Other factors that may also impact the quality of the night sky are air pollution (Kocifaj and Barentine 2021) and, potentially, the effects of climate change. The NPS ARD (2023b) estimated that CEBE's visibility is in fair condition based on a five-year (2014–2018) index of haze. They also estimated a visual range of between 66 and 206 km (41 and 128 mi) in 2018, which would be greater (132 to 275 km [82 to 171 mi]) without the effects of air pollution. Haze, which is caused by airborne particulates, can reduce how well and how far people can see. It is possible that reduced visibility in the vicinity of the park negatively impacts the quality of the night sky, including for stargazing visitors.

Precipitation has increased at CEBE since 1970 (NPS CCRP 2023). Future changes that are projected for the park include further increases in precipitation. Compared to historical (1979–2012) annual precipitation averages, annual precipitation is projected to change by −0.15 to 5.59 inches (-0.4% and +14.56%, respectively), with most of the future projections (including the Wet Warm and Hot Damp scenarios discussed in Chapter 2) showing increasing precipitation. Increased precipitation would possibly, and perhaps probably, result in or from increased cloudiness (NPS CCRP, A. Runyon, Climate Change Ecologist, email communication, 11 September 2023), but no data on this are available. Increased cloudiness would be expected to affect the quality of, or opportunities for viewing, the night sky.

**What potential actions can CEBE managers take to improve conditions for the night sky?** This question is addressed in more detail in Chapter 4, Management Considerations. However, one action that CEBE could take is to assess park lighting and minimize the harmful effects of light pollution, which might even call for retrofitting some lighting. To be most effective, lighting could be assessed on both NPS-owned and partner properties.

**Summary:** The condition of CEBE's night sky, based on the modeled data and map provided by NSNSD, is fair. Although the ALR is considered the best single parameter for measuring lightscapes, these data were modeled and may not reflect actual conditions within the park. Therefore, our confidence in the condition rating is medium. Although no information on trends is available, it is likely that night-time lighting levels will increase with future development in the vicinity of the park. According to the park's foundation document, increased population and urban development is expected to continue to rise, with the northern end of the park experiencing the largest nearby increase in housing developments (NPS 2018a). The areas experiencing increased suburban and industrial sprawl are north of Middletown and between Middletown and Strasburg (NPS 2018a).

## 3.3. Soundscape

A park's acoustic environment is an inherent component of the NPS Organic Act of 1916 and should remain "…unimpaired for the enjoyment of future generations" (16 U.S.C. 1, 2, 3, and 4; 39 Stat. 535). Environments without noise pollution are important to visitors, and for wildlife and their ability to avoid predators, perform courtship rituals, and effectively use their habitats. Studies show that wildlife can exhibit avoidance behaviors due to increased noise levels (McLaughlin and Kunc 2013; Shannon et al. 2015), and while the severity of impact varies by species, documented responses include increased heart rate, startle responses, flight, disruption of behavior, separation of mothers and young, and interference with communication (Selye 1956; Clough 1982; U.S. Forest Service [USFS] 1992; Anderssen et al. 1993; NPS 1994; Kaseloo 2006; Dooling and Popper 2007). In addition, plant communities may be adversely affected by noise because key pollinators and seed dispersers will avoid certain areas (Francis et al. 2012). With a better understanding of an area's acoustic environment, strategic planning and preventative actions can safeguard the natural acoustic environment.

The sounds heard today along the Morning Attack Trail in CEBE are much different than those heard during the morning of 19 October 1864, during the Confederate's attack. Image Credit: NPS.

### *Condition Assessment Summary*

Methods

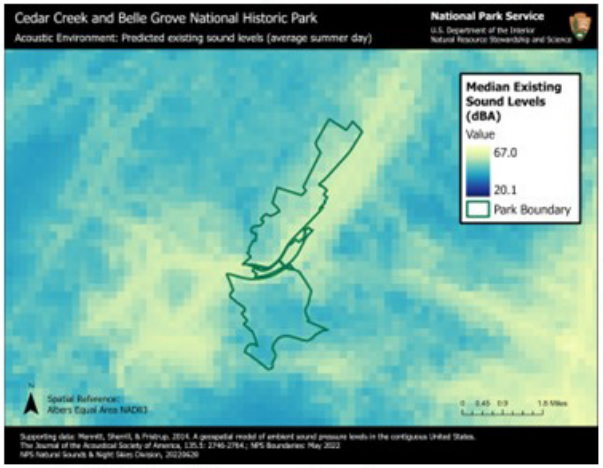
The NPS NSNSD developed a geospatial model from 2013 to 2015. The model estimates sound pressure levels for the continental United States using actual acoustical measurements combined with a multitude of explanatory variables, such as location, climate, landcover, hydrology, wind speed, and proximity to noise sources (e.g., roads, railroads, and airports) (Turina et al. 2013; NPS 2015).

The 270-m- (886-ft-) resolution geospatial model predicts daytime sound levels during midsummer (Figure 16 [a and b]). Each pixel on the map represents the daytime median sound pressure level (also known as the $L_{50}$, or level exceeded 50% of the time). Figure 16 (a) plots the existing median sound levels, and Figure 16 (b) plots the median sound levels if no human-caused sounds were present (e.g., vehicles, air traffic, etc.). The decibel (dB) values are A-weighted (dBA), which is a frequency-based adjustment that reflects how the human ear perceives sounds. Although the model excels at predicting acoustic conditions over large landscapes, it may not reflect recent localized changes, such as new access roads or other types of developments that increase the presence of noise sources. The predicted sound level impact is the difference between existing and natural ambient sound levels (Turina et al. 2013) and is the indicator of condition for CEBE's soundscape evaluation. This impact value is a measure of how much human noise contributes to the existing natural soundscape at a given location. It is important to remember that a decibel is logarithmic, so a small change in decibels equates to a large change in sound (e.g., 10dB equals a 10-fold increase, and 20dB equals a 100-fold increase).

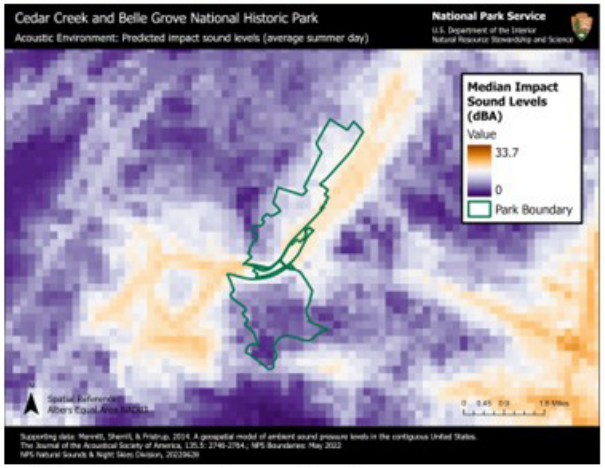
Reference criteria for non-urban parks like CEBE (i.e., 90% of the park area is located outside of an urban environment) are more stringent than for urban parks (Turina et al. 2013). A mean impact of ≤1.5 dBA is good, an impact value that is >1.5 and ≤ 3.0 dBA is fair, and a mean impact value above 3.0 dBA is poor (Turina et al. 2013) (see Table 6 in Appendix A). Another way to interpret these values is to look at the corresponding reduction in the listening area for a given impact value. For example, "a 3-dB increase in background sound levels reduces the area from which you could have previously heard a natural sound by 50%" (NPS 2020b). Thus, at a 1.5-dB increase, the listening area is reduced by 30% (Turina et al. 2013).

## Soundscape Condition Assessment Summary

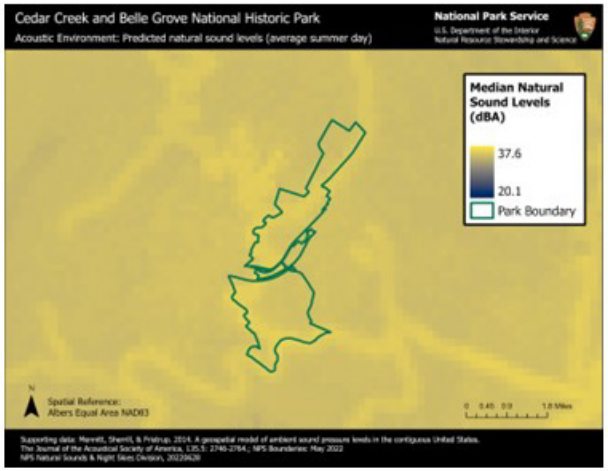
### Geospatial sound model maps and table data provided by NPS NSNSD




a) Predicted existing sound levels




c) Predicted impact sound levels




b) Predicted natural sound levels

**Predicted median sound levels for an average summer day in CEBE. The table summarizes, in numeric terms, what the maps show.**

| Sound level type | Minimum (dBA) | Mean (dBA) | Maximum (dBA) |
|---|---|---|---|
| Predicted existing | 36.53 | 40.79 | 44.44 |
| Predicted natural | 33.41 | 34.15 | 34.91 |
| Predicted impact | 2.34 | 6.64* | 10.53 |

* The mean impact value is 6.64 dBA, which indicates a poor condition of sound level park-wide and a reduction in listening area of 78%.

**Figure 16.** Soundscape assessment summary showing geospatial model results. Note that interstate/highway corridors near CEBE are within the more heavily impacted areas in maps a and c (i.e., the yellow/orangish areas, respectively).

Results and Discussion

The mean existing sound level at CEBE is estimated at 40.79 dBA (Figure 16 [(a) and table]), and the mean natural sound level is estimated at 34.15 (Figure 16 [(b) and table]). This leads to a mean $L_{50}$ impact of 6.64 dBA (Figure 16 [(c) and table]), which indicates a poor condition of sound level park-wide and a reduction in the listening area of 78%. Note, however, that different areas of the park have different sound levels depending on their proximity to noise sources. Because this assessment is based on the geospatial model alone (and not on current, onsite acoustic monitoring data), we have medium confidence in the condition rating.

The section of the park south of I-81 and U.S. Route 11 (U.S. 11) is the least impacted, with the most southern portion of the park having almost no impact at all (see Figure 16[c]).The area north of and closest to I-81 and U.S. 11 has the highest impact (both in percentage of area and levels). The remaining, large area north of I-81 has more of a gradient north to south, and east to west, with greatest impact closer to I-81/U.S. 11.

Sources of noise near CEBE include major highways and roads that run through or next to the park (also see 2019 land use map [Figure 5] in Chapter 2), with vehicle traffic, road construction projects, and operation of an outdoor, open-air firing range that opened near the park in 2022/early 2023. Other potential projects, if they occur, that may contribute to noise levels at CEBE are widening of I-81 and construction on the I-81 and I-66 interchange near the park, and a private truck-related development (e.g., truck retail store, maintenance area, and restaurant) that would span the area between I-81 and U.S. Route 11 across from partner property (northeast of the I-81 and I-66 interchange) (information on potential projects provided by NPS, K. Beck-Herzog, CEBE Site Manager, pers. comm., 15 March 2023). Existing sources of anthropogenic noise degrade CEBE's soundscape and may adversely affect the visitor experience and wildlife using park habitats. Planned or potential new projects, if they occur, could further degrade the park's soundscape. The Carmeuse Quarry is not a primary source of noise pollution in CEBE, although about once per day a blast can be felt (and a sound somewhat like thunder may be heard) (NPS, K. Beck-Herzog, CEBE Site Manager, pers. comm., 15 March 2023).

**How does activity at the commercial firing range, next to CEBE and partner lands, affect the soundscape?** An outdoor, open-air firing range began operating near CEBE (permitted in 2022) on about 1.6 ha (4 ac) of a 21.4-ha (53-ac) parcel of land south of I-81 and east of Water Plant Road/State Road 840. The areas of CEBE closest to the range are Shenandoah Valley Battlefields Foundation lands south of I-81 and on both sides of Water Plant Road, and Belle Grove Inc. and NPS-owned lands north of I-81. The approximate distance from the firing range to the closest section of CEBE's Morning Attack Trail (the Thomas Brigade Loop Trail) is about 341 m (1,120 ft) (based on an approximate location of the firing range). The Morning Attack Trails (three in total) are a combined 2.7 km ( 1.7 mi) long and located off Valley Pike Road/U.S. 11. If gunshots can be heard at the trails, the 8th Vermont Monument, and/or other areas of the park, the visitor experience could be adversely affected. The range's Conditional Use Permit (recommended conditions) allows for the outdoor discharge of firearms from Monday through Saturday, 9 AM to 6 PM/or sunset, and Sunday, 12 to 4 PM (Warren County 2021).

In late 2021, the NSNSD conducted a preliminary modeling analysis (using an attenuation calculator model) to estimate predicted sound levels at/near the park from the discharge of a 12-gauge shotgun at the firing range location. Note that the analysis did not use data collected onsite. The analysis of predicted sound levels indicated that a shot from the range location could exceed 60 dB in much of the park without mitigation (McFarland 2021). Predicted sound levels at the Morning Attack Trails could exceed 70 dB, and at the trail portions nearest the firing range boundary sound levels were predicted to be above 85 LAmax (LAmax is the highest noise level, measured in dB, that occurs during a measurement period).

In 2024, NSNSD may be conducting an onsite acoustic monitoring study to collect data on baseline sound levels in the park (1–2 sites for 30 days), as well as an additional, short-term collection at the park location closest to the firing range. Results of this study would provide better information on the park's acoustic environment and sound impacts from the firing range and other noise sources, such as roads and highways, thus filling an existing data gap for the park.

**Summary:** The condition of CEBE's soundscape based on the geospatial model is poor, and, as previously mentioned, we have medium confidence in the condition rating. Although we have no data on trends in soundscape condition, it seems likely that, with increased and continuing development (including the open-air firing range) outside of the park, noise sources and levels may also be increasing.

### 3.4. Woodlands

CEBE's vegetation is a mosaic of woodlands and open areas covering approximately 39% and 52% of the total park area, respectively (National Land Cover Database [NLCD] 2019—Dewitz and USGS 2021). CEBE's woodlands are comprised of deciduous, evergreen, and mixed forests, as well as shrub/scrub species that are representative of the vegetation communities in the northern portion of Virginia's Valley and Ridge province, where the park is located (Virginia Department of Conservation and Recreation Natural Heritage Program [VNHP] 2021). For thousands of years, the fires of Indigenous peoples, combined with lightning-caused fires, were significant ecological factors in the oak and pine forests, as well as savannas and grasslands, that developed in Virginia and the southeastern United States (VNHP 2021). Woodlands are essential components of CEBE's landscape, providing habitat for wildlife and helping to protect (e.g., from erosion, pollutants) the north fork of the Shenandoah River and Cedar Creek that run along or through them. In addition, some of the trees in CEBE are witness trees—marking early settlement property boundaries (Katen et al. 2020 [page 32])—that were present during key Civil War battles and events (NPS 2018a). Other common benefits of woodlands include carbon storage for climate change mitigation, air quality improvement, and importance to the visitor experience and local communities (Miller 2022).

A woodland trail at CEBE adjacent to the 8th Vermont Monument, which honors the regiment's sacrifice against Confederate soldiers who outnumbered the regiment by four times. Image Credits: NPS NRCA Program.

#### *Gap Analysis Summary*

The NLCD 2019 proportions of wooded and open areas within CEBE's present-day boundary are similar to those reported in 1864, 1937, and 2002 (see percentages in Figure 17 table) (land use data for 1864, 1937, and 2002 compiled by the Olmsted Center for Landscape Preservation [OCLP] 2007, as cited in Commisso and Foulds 2007), with the majority of woodlands situated primarily in the

southern portion of the park as early as 1864 (Figure 17, left map). The coverage of forests/woodlands in 2019 is also shown in Figure 17 (right map) and includes deciduous (about 21.4% of park area), evergreen (~5.4% of park area), and mixed forests (~11.8% of park area) (NLCD 2019, Dewitz and USGS 2021). Side-by-side maps of woodland coverage in 1864 and 2019 are included in Figure 22 of Appendix B, but note that the method for estimating coverage in 1864 was very different than that used in 2019 (i.e., historical sketches and maps of battles versus satellite imagery). The locations and scales of features on the 1864 map are approximate (OCLP 2007).

Based on Shenandoah Valley's boundary survey descriptions of witness trees, it is projected that oaks (*Quercus* spp., 71%) and hickories (*Carya* spp., 14%) dominated the valley's forests when surveyed between 1830 and 1855, with pines (*Pinus* spp., 6%), walnut (*Juglans* spp., 3%), and other species (6% total) also present (Mitchell et al. 2001; Katen et al. 2012, both as cited in Katen et al. 2020). This is consistent with many of the dominant and subdominant tree species recorded at CEBE by Bousquet et al. (2004), Donaldson (2005), and Clark et al. (2008), although percentages of these species are unknown. In addition, VNHP's (2022) terrestrial natural community lists for Frederick, Shenandoah, and Warren counties include five community types that include oak and hickory species, as well as red cedar and pines reported in Bousquet et al. (2004), Clark et al. (2008), and Katen et al. (2020). Also note that American chestnut (*Castanea dentata*) may have been an important component of the valley's forests (NPS, J. Comiskey, Inventory & Monitoring [I&M] Division Program Manager for Interior Region 1 North Atlantic–Appalachian, draft NRCA review, 20 July 2023), but of the reports above only Donaldson (2005) mentioned this species. We also reviewed the VNHP list for federally and state-protected plant species. The only such protected species we found was Canby's mountain-lover (*Paxistima canbyi*), a federal species of concern and state proposed, in Shenandoah and Frederick counties. This species, a small evergreen shrub, was reported by Bousquet et al. (2004) in a limestone bluff study plot (north of CCT-7; see below) that appears to be on private land within the park boundary.

From the vegetation studies of Bousquet et al. (2004) and Clark et al. (2008), we reviewed information on six woodland study plots within the park—three plots (CCT-7, CCT-8, CCT-9; described as mesic or dry upland forest and located on Cedar Creek Battlefield Foundation land) from the first study, and three plots (KT-1, KT-4, and KT-5; described as oak-hickory forest or xeric shale woodland and located on Shenandoah County partner land) from the second study (see study plot locations in Figure 17). From these two studies, as well as species mentioned in Katen et al. (2020), we found 14 tree species that were described as dominant, subdominant, characterizing the habitat, or important in one or more of the six plots. These species include pignut hickory (*Carya glabra*), reported in four of the six sites, white oak (*Quercus alba*), reported in four of the sites, and chestnut oak (*Quercus prinus*), reported in three of the sites. These 14 tree species are addressed below in the discussion on potential climate change effects. Two of the three Bousquet et al. plots contained some of the most diverse herbaceous species documented throughout the entire study area (Bousquet et al. 2004).

## WOODLANDS GAP ANALYSIS SUMMARY (1 of 2)

### Landuse Summary of CEBE Wooded & Open Areas: 1864, 1937, 2002, & 2019

| Year | Forest (% of park) | Field / Agriculture (% of park) | Orchard (% of park) | Other (% of park) |
|---|---|---|---|---|
| 1864 | 38 | 58 | 3 | 1 |
| 1937 | 36 | 50 | 13 | 1 |
| 2002 | 40 | 55 | 2 | 3 |
| 2019 | 39 | 59 * | ≤ 2.5 ** | 2 |

* Value includes the developed, open space category (which is mostly lawn grasses, with impervious surfaces <20%). The value excluding this category is 52%.
** Value is included in the Field/Agriculture category/percentage.


**Estimated location of woodlands in CEBE in 1864 (based on OCLP map presented in Commisso and Foulds 2007)**

**The coverage of woodlands is based on 1864 battle sketches and maps (see full citations in Appendix B)**

### Forests/Woodlands in CEBE in 2019: Deciduous (~794 acres), Evergreen (~200 acres), Mixed Forest (~437 acres)

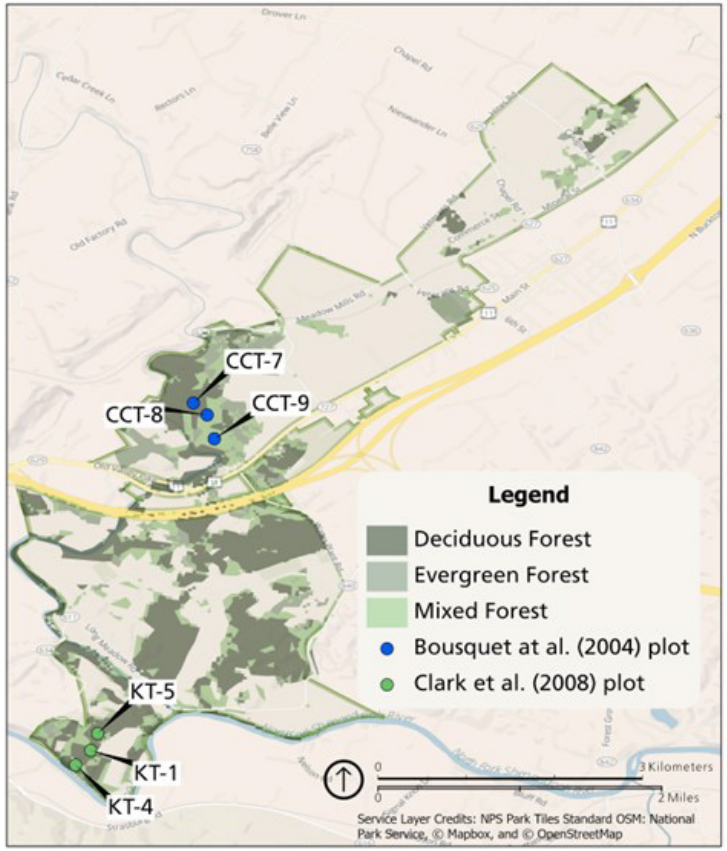



**Figure 17.** Information on forests/woodlands in CEBE, including estimated proportions of woodlands at different time periods, estimated location of woodlands in 1864, and the locations and types of CEBE's woodlands in 2019. Note that woodland plot locations CCT-7, CCT-8, and CCT-9 are approximations (GPS coordinates were not provided in every case). Maps and table created by NPS NRCA Program using data sources shown on maps and OCLP (2007) for 1864, 1937, and 2002, and Dewitz and USGS (2021) for 2019.

The NLCD 2001–2019 land cover change database (Dewitz and USGS 2021; Homer et al. 2020) shows a total area of forest change within CEBE of 0.6% (or approximately 9.6 ha [23.7 ac]) over the 2001–2019 time period. The vast majority of land within the CEBE boundary (97.8%) experienced no change in land use/land cover from 2001 to 2019. The database, unfortunately, provides no details on the areas of mapped forest change. The land cover change map is provided in Chapter 2 of this report (i.e., Figure 6).

The Virginia Department of Forestry developed a model to identify the highest priority forests for conservation in the state (Virginia Department of Conservation and Recreation [VDCR] 2021). The 2020 model is based on six components—forested blocks, forest management potential, connectivity, watershed integrity, threat of conversion, and significant forest communities and diminished tree species—and ranks forests from 1 (lowest) to 5 (highest). The Forest Conservation Value (FCV) model shows private lands and Shenandoah Valley Battlefields Foundation lands (south of I-81 and north of the CEBE boundary) to be the highest priority forestland (for conservation) within CEBE's legislated boundary. Although a very small area is rated as outstanding (5), most of these highest priority areas are rated as very high (4) (Figure 18). Of the other identified woodlands within CEBE, one is owned by NPS and is rated as average (1) and moderate (2) conservation value (near the I-81/I-66 interchange). Small areas rated as very high (4) and high (3) are north of and close to the Clark et al. (2008) forest plots on Shenandoah County land (see Figure 17 for Clark et al. plots).

**What are the projected effects on tree species due to climate change?** Climate changes already observed and climate projections for the CEBE area were described in Chapter 2 of this report. To examine projected climate change effects on some of CEBE's most common woodland tree species (i.e., those mentioned previously as dominant, subdominant, characterizing the habitat, or important), we used an assessment by the NPS Climate Change Response Program (i.e., NPS CCRP 2015, based on Fisichelli et al. 2014). Because CEBE was not one of the park units studied in the 2014/2015 work, we used information for a nearby park with similar woodland vegetation—Antietam National Battlefield (as suggested by J. Comiskey, NPS I&M Division Program Manager for Interior Region 1 North Atlantic–Appalachian), about a 50-mile drive away. NPS CCRP (2015) and Fisichelli et al. (2014) include potential changes in tree habitat suitability (2100 compared with 1990) under two climate change scenarios ("least change" and "major change"). "The scenarios bracket a range of plausible future conditions based on greenhouse gas emissions and global climate model projections..."

Of the 14 CEBE tree species of interest: four species are predicted to have decreases in potential habitat under both climate change scenarios; two species are predicted to have no change in potential habitat under both scenarios; two species would have increases in potential habitat under both scenarios; one species would have no change to increases in potential habitat; four species would have no change to decreases in potential habitat; and one species would have new potential habitat under climate change projections. Figure 18 includes a summary of the 14 species (listed by common name) and their potential changes in habitat suitability. See Table 7 in Appendix B for the tree species' scientific names. Also see a short discussion in the summary section below on the interaction of climate change with the stressors discussed in the following section.

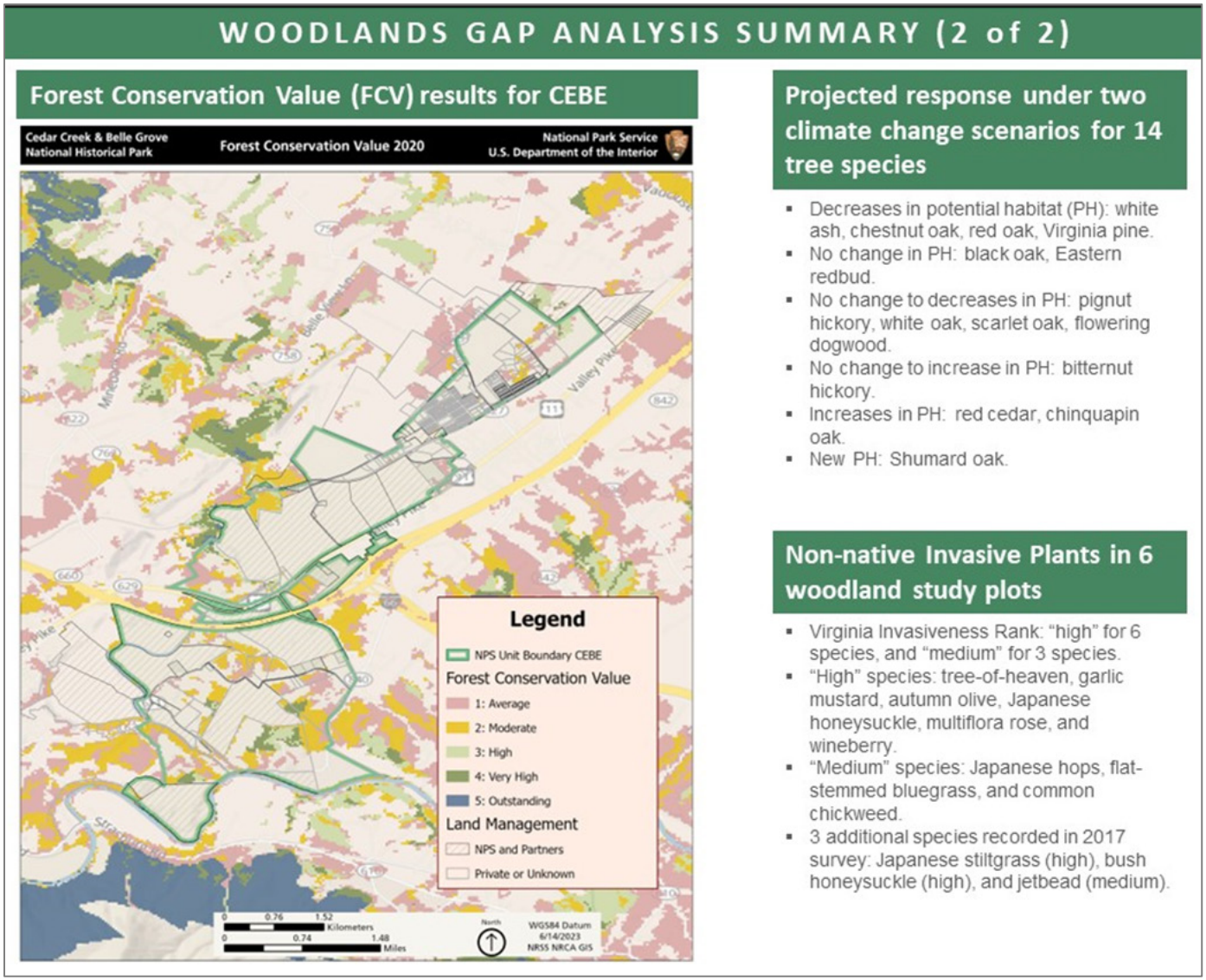



**Figure 18.** Gap analysis summary showing Forest Conservation Value model results (VDCR 2021) for CEBE and vicinity, summary of potential changes in tree habitat suitability (2100 compared with 1990) for species common in CEBE, and non-native invasive plants recorded in park woodlands. Map created by NPS NRCA Program using VDCR (2021).

**What are the effects of invasive plants, animals, and pests?** Woodlands at CEBE may be experiencing impacts from non-native invasive plants, at least two non-native invasive insect pests, and over-browsing from native white-tailed deer. Although little current information exists on the effects of these stressors in the park's woodlands, we summarize the available information.

*Non-native invasive plants:* We used the six study plots in CEBE from Bousquet et al. (2004) and Clark et al. (2008), as well as an NPS Mid-Atlantic Exotic Plant Management Team (NPS 2017) report to obtain information on non-native invasive plants within park woodlands. Note, however, that these first two studies are 15 or more years old. Although Bousquet et al. (2004) did not specifically report which non-native species occurred in each of their three wooded plots, they reported that invasives were present in all three plots. Clark et al. (2008) listed 14 "introduced" plant species as occurring in their plots. Because introduced plants are not necessarily invasive, we compared the 14 species to the Virginia Invasive Plant Species List (Heffernan et al. 2014). We also compared this state list to the entire list of plants in our three study plots from Bousquet et al. (2004 [their Table 16]). We emerged with a list of nine species, six with an invasiveness rank of "high" and three with a rank of "medium" (see Figure 18 [above] and Table 8 in Appendix B, which includes scientific names). We also checked a list of non-native invasive species reported in Donaldson (2005) for the park (not just the woodlands) and did not discover any additional species to note.

There are no data on how prevalent these non-native species were or currently are within park woodlands. The six highly invasive species on our list were also commonly reported in the 2017 Mid-Atlantic Exotic Plant Management Team survey. Although it was difficult to compare the areas surveyed in the 2017 report to mapped woodlands in CEBE, we believe about six of the areas surveyed were in or immediately adjacent to woodlands (i.e., E, G, J, M, P, and R in the report, with E and P on NPS property). Invasive plants mentioned in these areas included the six highly invasive species mentioned above and three additional species (Japanese stiltgrass [*Microstegium vimineum*], bush honeysuckle [*Lonicera* spp.], and jetbead [*Rhodotypos scandens*], with the first two having a "high" invasiveness rank and the third a "medium" rank).

*Non-native invasive insect pests:* Ash trees (*Fraxinus* spp.) in CEBE have been impacted by the emerald ash borer (*Agrilus planipennis*, or EAB) (NPS 2018a), but no specific data on the number of trees affected are available. During the scoping meeting for the NRCA, it was mentioned that ash mortality in the park's woodlands has led to openings in the understory where invasive plants are emerging, but no specific data are available. Ash trees are dispersed throughout NPS and partner properties, and they have been affected throughout the park, including in the Vermont Monument area and the 19th Corps trail) (NPS, K. Beck-Herzog, CEBE Site Manager, pers. comm., 10 July 2023). CEBE managers have cut down hazardous ash trees that caused concern for visitor areas and structures, but no other tree monitoring has been conducted. The woodland plot information we reviewed from Bousquet et al. (2004; 3 plots) and Clark et al. (2008; 3 plots) did not provide any data on the relative proportion of ash in the plots within CEBE; however, white ash occurred in all six plots, with it being noted as important in the tree layer in one of the Bousquet et al. plots (CCT-7) and as a dominant species in the tree and shrub layers of another of the plots (CCT-9). Although not

within any of our six plots, green (or red) ash (*Fraxinus pennsylvanica*) was reported in a floodplain forest plot within the park (Clark et al. 2008).

The EAB, a wood-boring beetle native to Asia, can impact all 16 species of ash trees in the U.S. (APHIS 2020; APHIS 2023b). The beetle first infested Frederick County in 2010, Warren County in 2012, and Shenandoah County in 2014 (Brandeis et al. 2016 [Figure 24]). Signs of affected trees include foliage that is yellow, thin, or wilted; beetle exit holes that are D-shaped; unexpected woodpecker activity or pecking holes; and/or shoots growing from a tree's trunk or roots (APHIS 2023b). The EAB can kill healthy or stressed trees, with many dying in two to three years of infestation (APHIS 2020). The EAB has killed tens of millions of ash trees in the United States (APHIS 2023a).

The spotted lanternfly (*Lycorma delicatula*, or SLF), from Southeast Asia and with no natural enemies in the U.S., has heavily infested Frederick and Warren counties (Virginia Department of Agriculture and Consumer Services [VDACS] 2023), and Shenandoah County is within the state's infested area (New York State Integrated Pest Management Program 2023). This pest was found in Virginia for the first time in Frederick County in 2018 (VCE 2023a). Spotted lanternflies feed on the sap of a wide variety of plants and trees, including fruit and ornamental trees, grape vines, and native trees. Heavy feeding by the pest can cause small trees to die and large trees to lose tips (VDACS and U.S. Department of Agriculture 2022). The non-native invasive tree, tree-of-heaven (*Ailanthus altissima*), which has been found in CEBE, is one of the SLF's preferred hosts. This tree was reported in two of the three plots from Bousquet et al. (2004; plots CCT-8 and CCT-9) and one of the plots from Clark et al. (2008; plot KT-4), and it was included on a species list of "common" trees in the CEBE area (Donaldson 2005). It was also reported in the 2017 CEBE Invasive Plant Survey. Native trees that can be impacted by the SLF include maples, oaks, pines, poplars, sycamores, walnuts, and willows (APHIS 2023c); note that this source did not provide information on the specific species known to be susceptible, but all these types of trees have been reported in CEBE (Donaldson 2005 [Appendix 8 of their report]).

Some information is available on SLF occurrence at CEBE. Monitoring by NPS was conducted in 2020–2021, with no observations of SLF. In 2022, adults were observed, and as of July 2023, egg masses and nymphs have been observed (NPS MA-IPMT, N. Wender, Team Leader, email communication with K. Beck-Herzog, 12 July 2023), but formal monitoring of the pest at CEBE is not ongoing. Additionally, the iNaturalist database includes a research grade report of a SLF in CEBE on Long Meadow Road (611) near the intersection with Water Plant Road (612) (Shell 2022). Nearby Shenandoah NP monitors tree-of-heaven trees and other high-risk areas in Shenandoah for SLF and works with federal and state partners to share detection information (NPS 2021a). Note that Shenandoah NP has hundreds of acres infested by tree-of-heaven (NPS 2022c).

Other non-native invasive forest pests may also occur in CEBE. For example, NPS CCRP (2015) listed about 47 species of non-native tree insects and diseases that have infestation areas including Antietam National Battlefield (which was used to examine potential climate change effects on trees within CEBE). The NPS CCRP (2015) list included the spongy moth (*Lymantria dispar*), which has been defoliating trees in the eastern U.S. for decades. There is a verified sighting of this species in

Warren County from 2015 (Butterflies and Moths of North America [BAMONA] 2023a). A comprehensive list of non-native invasive forest tree pests at CEBE is a data gap for the park.

*White-tailed deer over-browsing:* During a May 2022 field outing at CEBE, J. Comiskey, NPS I&M Division Program Manager for Interior Region 1 North Atlantic–Appalachian, commented that over-browsing by white-tailed deer is probably impacting woodlands in CEBE; however, there are no existing data on deer use of the park's woodlands (e.g., numbers, locations of deer present) or on plants (locations, species) impacted by deer. Forest regeneration has been impacted by deer browsing in some Mid-Atlantic I&M Network parks (Comiskey et al. 2009), and, on a broader scale, in at least about 39 eastern U.S. national parks (Miller et al. 2023). Although we have no data on deer populations in the vicinity of CEBE, park staff report seeing deer occasionally. Also, J. Comiskey reports that on visits to various locations within the park he has observed a distinct browse line in many wooded areas, a lack of healthy regeneration of tree species, and largely absent herbaceous species preferred by deer (information provided during draft NRCA review, 20 July 2023). We also located data on deer kills for Frederick, Shenandoah, and Warren counties and found that, combined, 6,585 deer were taken in 2021, and 8,080 deer were taken in 2020 (Virginia Department of Wildlife Resources [VDWR] 2023)—indicating that considerable numbers of deer are in the general area.

Miller et al. (2023) studied forests in 39 national parks in the eastern U.S. from Virginia to Maine and found that over-browsing by deer (along with invasive plant proliferation) was a main reason for the absence or low density of canopy species in the understory of most of the parks. An absence of or too few seedlings and saplings means that the forests are not regenerating. The study, which used forest data spanning 12 years, also found that in some cases the species regenerating did not match the species composition in the canopy. Neither CEBE nor nearby Shenandoah NP were included in the study; however, Antietam National Battlefield, which we used to look at the projected effects of climate change on tree species (see above), was categorized as "probable failure" in terms of regeneration status. Miller et al. (2023) categorized 70% of the study's parks as either "imminent failure" or "probable failure" in terms of regeneration abundance and composition (out of secure, insecure, probable failure, and imminent failure). The authors point to the need for long-term management of white-tailed deer and invasive plants as part of an integrated forest management approach. Another important point if ash trees are a component of the forest regeneration, is that the ash are unlikely to survive to become part of the canopy due to EAB (Miller et al. 2023). This situation is being observed in Gettysburg National Military Park, for example, where much of the regeneration is ash (more than half of the total seedlings and one quarter of all saplings).

Another concern related to the overabundance of deer is that of ticks—especially because ticks can carry Lyme disease. Lyme disease is caused by infection with the bacterium *Borrelia burgdorferi* and is the most common vector-transmitted disease in North America (Brinkerhoff et al. 2014). We addressed the topic of ticks in Chapter 2 of the NRCA. Also note that white-tailed deer can serve as a vector for non-native invasive plant species proliferation (Williams and Ward 2006).

**Summary:** This NRCA evaluation is a gap analysis due to the lack of current and ample information on woodlands at CEBE. In the analysis, we reviewed the estimated occurrence of woodlands in the legislated park boundary in 1864, 1937, 2002, and 2019. We used two past studies (Bousquet et al.

[2004] and Clark et al. [2008]) to review information, such as tree species occurrence, in six sample plots in CEBE woodlands, and we used several tree species from these reports to examine projected climate change effects under two climate change scenarios (NPS CCRP 2015). We also discussed other stressors on park woodlands, namely non-native invasive plants, invasive insect pests, and over-browsing by native white-tailed deer. It is also important to mention here the convergence of stressors on CEBE's woodlands. For example, when tree species such as ash die due to EAB, they leave gaps in the canopy that increase the chance of non-native invasive plants invading. These same gaps can lead to more treefalls and even larger canopy openings during storm events (likely more severe and frequent due to climate change) (NPS, J. Comiskey, I&M Division Program Manager for Interior Region 1 North Atlantic–Appalachian, draft NRCA review, 20 July 2023). This in turn further increases the opportunity for the spread of invasive plants in the understory. In some national park units in the Mid-Atlantic and Northeast Temperate I&M Networks, a transition to invasive shrub thickets is being observed (NPS, J. Comiskey, I&M Division Program Manager for Interior Region 1 North Atlantic–Appalachian; draft NRCA review, 20 July 2023). Chapter 4 of the NRCA provides some considerations for management, including ideas for woodlands monitoring or data collection for future condition assessments.

### 3.5. Meadows

CEBE's vegetation is a mosaic of open and wooded areas covering approximately 52% and 39% of the total park area, respectively (National Land Cover Database [NLCD] 2019—Dewitz and USGS 2021). The open areas include hay/pasture, crops, herbaceous cover, and meadow habitat undergoing restoration. NPS Mid-Atlantic Invasive Plant Management Team (MA-IPMT) staff are restoring (see next paragraph) an approximately 19-ha (47-acre) former agricultural field in CEBE to meadow to create and manage habitat for native pollinators, grassland birds (which are also addressed in this analysis), and other wildlife. An added benefit is maintaining the meadow to look more like it would have in the 1860s, as well as reducing the occurrence of non-native invasive plant species. In addition to providing habitat for native insects and wildlife, meadows provide critical ecosystem services, such as nutrient cycling, water quality improvement, and maintenance of soil health (Southeastern Grasslands Institute 2023). Development pressure outside the park, described in earlier sections of the NRCA, emphasizes the importance of preservation and restoration of such habitats within the park.

Note that in this report we use the word "restoration" in discussing NPS efforts in the Morning Attack Trail field. These efforts are to bring back a predominance of native vegetation in the field (which was used for agriculture, most recently cattle pasturing and hay production) for the reasons stated above. Note that we are not implying that the area will necessarily be returned to its original natural condition, but rather that efforts are being made to bring back a predominance of native plants and the benefits they provide. A map based on sketches from the late 1800s shows this area as "field" in 1864 (see Figure 23 in Appendix C).

An actively managed meadow (the Morning Attack Trail field) undergoing restoration efforts at CEBE. Primarily native vegetation dominates the view. Image Credit: NPS/Nathan Wender.

The land in and around CEBE has historically been a mosaic of meadows, woodlands, and open lands along streams and "old fields," with the latter referring to areas used by Indigenous peoples for growing crops near their villages (Katen et al. 2012). The origin of the old fields remains unknown, with some believing they are a result of frequent burning by Indigenous peoples, and others (i.e., Mitchell 1998) believing they were created primarily by natural processes along the river and stream floodplains (as cited in Katen et al. 2020). The shale-limestone boundary in CEBE created a "balanced, sustainable mix of…bottomlands for crops, uplands for growing wheat and for use as pasture, and with steeper uplands used for maintaining woodlots" (Katen et al. 2012). Katen et al. (2012) observed that the "post-Civil War maps of the Battle of Cedar Creek depicted the mosaicked landscape that exists in present-day CEBE."

### *Gap Analysis Summary*

As described in the Woodlands gap analysis, and as noted above, the proportions of open and wooded areas within CEBE's present-day (NLCD 2019 coverage) boundary are generally similar to those reported in 1864, 1937, and 2002 (see tabular percentages in Figure 17 of Section 3.4, Woodlands) (land use data for 1864, 1937, and 2002 compiled by OCLP [2007], as cited in Commisso and Foulds 2007). Based on 2019 coverages, open areas occur throughout the park, but they are more dispersed among forest/woodland areas in the southern portion of the park compared to the northern portion of the park. Open areas include hay/pasture (about 49.4% of CEBE), cultivated crops (~2.5% of CEBE), and herbaceous cover (~0.1% of CEBE) (Figure 19) (Dewitz and USGS 2021). Additionally, about 0.3% of the park is transitional shrub/scrub land cover, and 6.6% of the park is developed, open space (described as mostly lawn grasses, with impervious surfaces less than 20%). Side-by-side maps of open area coverage in 1864 and 2019 are shown in Figure 23 of Appendix C.

The NLCD 2001–2019 land cover change database (Dewitz and USGS 2021; Homer et al. 2020) shows relatively small changes in open area land use within CEBE, including 0.8% (or about 11.7 ha [28.9 ac]) in hay/pasture and less than 0.01% (or about 0.08 ha [0.2 ac]) in cultivated crops, over the years 2001–2019. The majority of land within the CEBE boundary (97.8%) experienced no change in land use/land cover from 2001 to 2019 (see Figure 6 in Chapter 2).

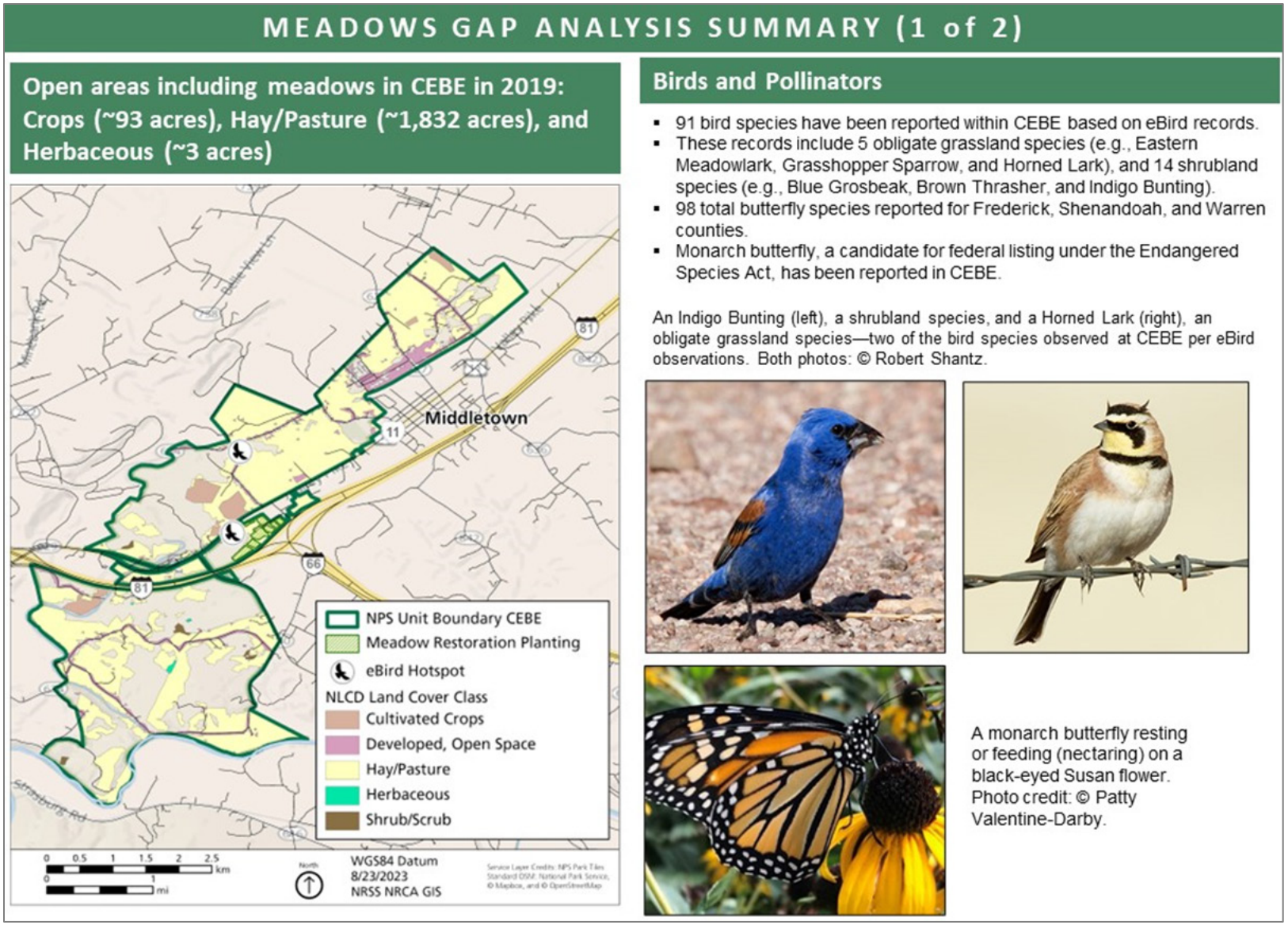



**Figure 19.** Map showing coverage of open areas, including meadows, within CEBE, and summary information on birds and pollinators. Map created by NPS NRCA Program using NLCD 2019 data (Dewitz and USGS 2021).

**Vegetation:** The open areas within CEBE are primarily hay/pasture (Dewitz and USGS 2021), but also include the approximately 19-ha (47-ac) native meadow restoration area within the Morning Attack Trail field, where the Morning Attack Trail is located (NPS 2021b) (see Figure 19). NPS MA-IPMT staff began restoration of the field in 2016, and from 2016 to 2019 they conducted control efforts focused on the removal of non-native invasive woody plant species (e.g., autumn olive [*Elaeagnus umbellata*], multi-flora rose [*Rosa multiflora*], bush honeysuckle [*Lonicera tatarica*], and callery pear [*Pyrus calleryana*]). The first two of these species have an invasiveness rank of "high," and the last two have a rank of "medium" (Heffernan et al. 2014). From 2019 to 2020, the MA-IPMT converted 2.4 ha (6 ac) of fescue grasses in the Morning Attack Trail field to native grass and wildflower species (through the use of invasives treatment and native plant seeds) (NPS 2021b). An additional 4.9 ha (12 ac) within the field were seeded in 2021 with primarily the native grass, little bluestem (*Schizachyrium scoparium*). The Morning Attack Trail field is the largest field in CEBE owned by NPS, and it includes the only CEBE trail maintained by NPS.

In 2021, NPS MA-IPMT surveyed the Morning Attack Trail field, identifying 89% of the vegetation as non-native (Figure 20) (NPS ArcGIS On-line [AGOL] 2021). Figure 20 and Table 9 of Appendix C show the 27 dominant cover species reported from the survey, including 13 non-native species. Eight of the 13 non-native species recorded during the survey are on the Virginia Department of Conservation and Recreation list of invasive species. Five have a rank of high: Japanese honeysuckle (*Lonicera japonica*), Japanese stiltgrass (*Microstegium vimineum*), Johnsongrass (*Sorghum halepense*), Canada thistle (*Cirsium arvense*), and sericea lespedeza (*Lespedeza cuneata*); one has a rank of medium: wild teasel (*Dipsacus fullonum*); and two have a rank of low: crown vetch (*Securigera varia*) and curly dock (*Rumex crispus*) (Heffernan et al. 2014). Additionally, the extensive (blue) area mapped as *Festuca* spp./Unclassified in Figure 20 had a wide mixture of plants, with tall fescue (*Lolium arundinaceum* [formerly *Festuca arundinacea*]), a non-native, cool-season grass, dominant in most of this area. A few of the other non-native species in this area were sweet vernal grass (*Anthoxanthum odoratum*) and quackgrass (*Elymus repens*) (NPS, N. Wender, MA-IPMT Team Leader, email communication, 16 August 2023).

In 2022, the MA-IPMT planted the remaining 10 ha (25 ac) of the Morning Attack Trail field restoration area with native grasses and wildflowers (NPS 2021b; Wender 2022). These species include seven grasses (e.g., little bluestem and sideoats grama [*Bouteloua curtipendula*]), three milkweeds (e.g., butterfly milkweed [*Asclepias tuberosa*]), and 14 asters (e.g., early goldenrod [*Solidago juncea*] and heath aster [*Symphyotrichum pilosum*]), as well as nine other species (see Table 10 in Appendix C). The seed mixes were selected considering both their endemicity to the local area, following Weakley et al. (2012), and their importance to pollinators per Ernst Conservation Seeds (2023) (NPS, N. Wender, MA-IPMT Team Leader, email communication, 14 December 2022 and 16 August 2023). Except for the three milkweed species, no species was selected specifically to benefit a particular pollinator (N. Wender, email communication, 14 December 2022). Milkweed species are the only host plants for monarch butterfly (*Danaus plexippus*) caterpillars (University of Florida Institute of Food & Agricultural Sciences [UF IFAS] 2021), a species known to occur within CEBE (iNaturalist 2023a).

## MEADOWS GAP ANALYSIS SUMMARY (2 of 2)

### NPS MA-IPMT 2021 vegetation survey location and results for meadow restoration area. Map and legend credit: NPS AGOL (2021)


### Highlights and notes

- The extensive blue area (*Festuca* spp./Unclassified) had a wide mixture of plants, but the **non-native** grass, tall fescue (*Lolium arundinaceum*) was dominant in most of the area.
- Some of the additional, most predominant plants based on the survey: *Lespedeza cuneata* (sericea lespedeza; nearly all of the red-shaded area; **non-native**), *Elymus virginicus* (Virginia wildrye; light purple; **native**), *Vernonia glauca* (broadleaf ironweed; medium purple; **native**), *Setaria pumila* (yellow foxtail; brown; **non-native**), and *Apocynum cannabinum* (Indian hemp; teal; **native**).
- 89% of the vegetation (by area) was non-native.
- Of the 27 species shown, 13 are non-native, with 8 of those on the VDCR list of invasive species (5 with a rank of "high," 1 with a rank of "medium," and two with a rank of "low").

**Figure 20.** Results and highlights of the 2021 MA-IPMT survey in the Morning Attack Trail field. Note that the map is oriented so that northwest is pointing up (NPS AGOL 2021).

Although CEBE managers have focused on the restoration of the Morning Attack Trail field to date, there are additional, smaller, fields on NPS property in CEBE that park managers would like to restore. These areas, about 13 ha (33 ac) in total, are discussed in Chapter 4 of this document.

**How will CEBE's meadow vegetation change over time?** CEBE meadows are susceptible to native woody species encroachment through succession and non-native invasive species invasion. NPS (2018a) identified encroachment and invasion of CEBE meadows as a threat to the park viewshed. This is one of the benefits of CEBE's restoration efforts—to improve the viewshed to better evoke the 1864 landscape (NPS 2021b). Although the Morning Attack Field is currently being restored, ongoing management of the meadow will be necessary to protect its integrity, including through vegetation monitoring, spot treatments of non-native invasive plants, and appropriate mowing (NPS 2021b). As of mid-2023, the restoration site is in better condition than when work first began (NPS, N. Wender, MA-IPMT Team Leader, pers. comm., 29 June 2023). In 2018, woody invasive species occurred in patchy monocultures, and as of mid-2023, bush honey suckle has been controlled to maintenance levels and other species (e.g., multi-flora rose, lespedeza) are greatly reduced. Some species, such as callery pear, will continue to require intensive management because they are encroaching from adjacent property (NPS, N. Wender, MA-IPMT Team Leader, pers. comm., 29 June 2023). Native shrubs (e.g., *Rhus* and *Rubus* species), important habitat for birds and butterflies, are also growing on the site.

In 2022, the MA-IPMT implemented a more formalized vegetation monitoring program in CEBE's meadow restoration area. The purpose is to track species composition and richness trends over a five-year period, and to evaluate the effectiveness, in terms of plant diversity, of treating versus not treating non-native plants. In 2022 they surveyed 125 randomly selected, square-meter plots in the Morning Attack Field, identifying and quantifying all species in the herbaceous, shrub, and tree layers in the plots. Of the total number of plots, 100 were in areas where herbicide treatments have been conducted, and 25 were in areas without treatment (except mowing). Monitoring will occur every year for five years, and survey plots will be randomly selected on each sampling occasion (i.e., no permanent monitoring plots). Chapter 4 includes some additional ideas for plant and other monitoring in the restoration area.

**Grassland Birds:** One of the reasons for restoring CEBE's meadow habitat is to improve habitat for birds, especially grassland species such as Grasshopper Sparrow (*Ammodramus savannarum*) and Eastern Meadowlark (*Sturnella magna*) (NPS, N. Wender, MA-IPMT Team Leader, email communication, 14 December 2022). Although there have been no NPS surveys for birds within the park, some information on species occurrence is available from citizen science databases—namely eBird and iNaturalist. eBird is a citizen science application that tracks individual bird observations and associated metadata from around the world (Sullivan et al. 2014). We reviewed eBird observation data for two locations within CEBE—the Morning Attack Trail fields (eBird 2023a) and a field along Belle Grove Road (eBird 2023b) (see Figure 19 for approximate locations).

From 2018 to June 2023, 75 species were reported at the Morning Attack Trail location, and from 2006 to June 2023, 72 species were observed at the Belle Grove Road field location (see Table 11 in Appendix C for species reported). It should be noted that we used all reports of birds at CEBE

regardless of the time of year recorded. The two sites had 56 species in common. Nineteen species were specific to the Morning Attack Trail location, and 16 species were specific to the Belle Grove Road location. The two grassland species mentioned above were reported in eBird at both CEBE locations. Of all the species observed within the park, four were non-native/non-native to the CEBE area—European Starling (*Sturnus vulgaris*), House Sparrow *(Passer domesticus*), House Finch (*Haemorhous mexicanus*), and Rock Pigeon (*Columba livia*) (eBird 2023a, 2023b).

Bird species that require grassland habitat for reproduction are classified as breeding grassland birds. Peterjohn (2006a) identified breeding grassland birds that occur within the Mid-Atlantic Region, including Virginia. Of the five species identified by Peterjohn as having "fairly common" occurrence in Virginia, four were reported to eBird within CEBE at both the Morning Attack Trail and Belle Grove Road locations: Eastern Meadowlark, Grasshopper Sparrow, Horned Lark (*Eremophila alpestris*), and Savannah Sparrow (*Passerculus sandwichensis*) (eBird 2023a, 2023b; see Table 11 in Appendix C). Vesper Sparrow (*Pooecetes gramineus*), identified as fairly common in Virginia by Peterjohn, has not been reported at either location. One uncommon breeding grassland bird in Virginia, Bobolink (*Dolichonyx oryzivorus*), was reported at the Belle Grove Road location (eBird 2023b; see Table 11). Bobolink is considered critically imperiled in Virginia and vulnerable (S3) in neighboring West Virginia (NatureServe 2023).

Peterjohn (2006a) provides summaries of nesting habitat requirements for these breeding grassland species, as well as information on area requirements, maintaining and managing grassland habitats, and source and sink habitats. Although the author cautioned against generalizing area requirements to all landscapes or regions, he reported that grassland birds avoid fields smaller than 5 ha (12 ac) (Norment et al. 1999, as cited by Peterjohn 2006a). To be consistently occupied by some species, fields must be 10 to 20 ha (25 to 50 ac) in size (Beason 1995, as cited by Peterjohn 2006a).

Shrublands are composed of primarily shrub and sapling vegetation and are formed as grasslands go through successional changes towards becoming forestlands. Birds that require shrubland as habitat for reproduction are considered breeding shrubland birds. Peterjohn (2006b) identified breeding shrubland bird species that occur in the Mid-Atlantic Region, including 16 species with common or fairly common occurrence in Virginia. Of these 16 species, 13 have been reported to eBird at one or both CEBE locations: Blue Grosbeak (*Guiraca caerulea*), Brown Thrasher (*Toxostoma rufum*), Carolina Wren (*Thryothorus ludovicianus*), Common Yellowthroat (*Geothlypis trichas*), Eastern Towhee (*Pipilo erythrophthalmus*), Field Sparrow (*Spizella pusilla*), Gray Catbird (*Dumetella carolinensis*), Indigo Bunting (*Passerina cyanea*), Northern Cardinal (*Cardinalis cardinalis*), Northern Mockingbird (*Mimus polyglottos*), Prairie Warbler (*Setophaga discolor*), Song Sparrow (*Melospiza melodia*), and Yellow-billed Cuckoo (*Coccyzus americanus*) (eBird 2023a, 2023b; see Table 11 in Appendix C). Of the eight breeding shrubland birds identified by Peterjohn (2006b) as uncommon or rare within Virginia, one has been reported within CEBE to date—Yellow Warbler (*Setophaga petechia*). Similar to Peterjohn (2006a) for breeding grassland birds, Peterjohn (2006b) provides information on habitat requirements for breeding shrubland birds.

We also reviewed research grade observations from within CEBE that have been reported to the citizen science application iNaturalist (2023b). Only three bird species have been reported to

iNaturalist from within the park. None of these are breeding grassland birds per Peterjohn (2006a); one is a breeding shrubland bird (Song Sparrow) (Peterjohn 2006b). All three species (also American Goldfinch [*Carduelis tristis*] and Eastern Bluebird [*Sialia sialis*]) have also been reported to eBird at both CEBE locations (eBird 2023a, 2023b).

**Pollinators:** Many insects (e.g., bees, butterflies, moths, flies, beetles), as well as birds, bats, and small mammals serve as pollinators. Pollinators are important because they transfer genetic material within flowers and between plants, which is necessary for approximately 78–94% of all flowering plant reproduction (Ollerton et al. 2011), including for many of the foods we eat. Many pollinator populations are in decline due to loss of habitat, disease, exposure to chemicals, and changes in climate/climate patterns (Pollinator Partnership 2023; Pollinator Health Task Force 2015; National Research Council 2007). In 2014, a Presidential Memorandum "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," was issued to reduce stressors on pollinator health. As previously mentioned, one of the reasons for CEBE's meadow restoration work is to provide habitat for native pollinators. Because butterflies are an important group of pollinators and are used as indicators of ecosystem health (Nelson 2009), caterpillars (larvae of butterflies and moths) are a critical food source for birds, especially nestlings (UF IFAS 2023), and because more information was available on butterflies than on other insect pollinators, we focus on butterflies here.

Although no systematic inventory or monitoring data are available for pollinators or butterflies in CEBE, limited research grade insect observations from within CEBE have been reported to iNaturalist (iNaturalist 2023a). We reviewed these observations, and the 11 reported species include three known pollinators, all of which are butterflies: juniper hairstreak (*Callophrys gryneus*), monarch, and zebra swallowtail (*Eurytides marcellus*). The monarch butterfly is currently a candidate species for federal listing under the Endangered Species Act (USFWS 2023).

The Butterflies and Moths of North America (BAMONA) is a citizen science project that includes a database of Lepidoptera (butterflies and moths) observations from throughout North America, including from the three Virginia counties in which CEBE is located (Frederick, Shenandoah, Warren) (BAMONA 2023b). All observations reported to BAMONA go through a quality control process, and only observations confirmed through photograph identification by a lepidopterist are accepted as official records. We reviewed the BAMONA butterfly checklists for the state of Virginia and for Frederick, Shenandoah, and Warren counties.

The current BAMONA checklist for Virginia includes 173 species of butterflies (BAMONA 2023c), and checklists from the three counties in which CEBE is located include a total of 98 butterfly species (BAMONA 2023d, 2023e, 2023f; see Table 12 in Appendix C). By county, the greatest number of species has been reported for Frederick County (83), followed by Shenandoah (75) and Warren (74) counties. While these county lists are not specific to CEBE, they serve as local checklists of species that may occur within the park. However, also note that many butterfly species require specific host plants to complete their life cycle (e.g., monarchs require milkweed plants), so a species occurring near or in CEBE may not reproduce within the park if its required host plant is absent. Plants are used by butterflies and moths (which are also pollinators) for adult food sources (i.e., nectar), host plants (upon which eggs are laid and caterpillars feed), and resting sites.

**White-tailed deer browsing/grazing:** White-tailed deer can negatively impact grasslands by decreasing native plant diversity through both over-browsing of preferred forage species (Pruszenski and Hernandez 2020), and by serving as a vector for non-native invasive species proliferation (Myers et al. 2004; Williams and Ward 2006). Deer, however, also spread seeds of several native plant species (Segelken 2003; Myers et al. 2004). While it is possible that deer are impacting meadows in CEBE (also see the Woodlands gap analysis), no data exist on deer populations or habitat use within the park. Also, N. Wender, NPS MA-IPMT Team Leader, indicated that while he has observed some scattered evidence of plants being eaten by deer, there is no evidence that they are adversely affecting meadow plants to any substantial degree (NPS, N. Wender, MA-IPMT Team Leader, email communication, 16 August 2023).

The Blandy Experimental Farm, associated with the State Arboretum of Virginia, maintains lists of plants that are frequently or rarely damaged by deer (Blandy Experimental Farm 2023). Two of the lists that might be of greatest interest to the park, with the meadow restoration work in mind, are the lists of rarely damaged native perennials and frequently damaged native perennials. The "rarely damaged" list includes a handful of species that have been seeded in the meadow restoration site (e.g., Virginia mountain mint [*Pycnanthemum virginianum*], wild bergamot [*Monarda fistulosa*], goldenrod [*Solidago* sp.], and milkweed [*Asclepias* sp.]; note that the list did not provide species names in every case). For more information on deer, see Chapter 2 (Drivers and Stressors) and Section 3.4 (Woodlands) of this NRCA.

**Summary:** Because there is a lack of current and ample information on meadows at CEBE, except with regards to vegetation in the meadow restoration area, this NRCA evaluation is a gap analysis. While recent information on vegetation in the Morning Attack Trail field exists from surveys by the MA-IPMT, other information, such as on wildlife and pollinators and other aspects of the meadows (such as soils), is lacking. As of 2019, about 780 ha (1,928 ac) of open areas (cultivated crops, hay/pasture, and herbaceous cover) occurred in CEBE. These areas include the approximately 19-ha (47-ac) native meadow restoration site, where restoration activities began in 2016. In 2022, the MA-IPMT planted the remaining 10 ha (25 ac) with native grasses and wildflowers. The purpose of this effort includes controlling non-native invasive plants (one of the greatest stressors on park meadows and other habitats), providing habitat for birds and pollinators, as well as other wildlife, and improving the viewshed to better represent the 1864 landscape. Although no quantitative analysis was presented in the NRCA, the MA-IPMT team leader reported the restoration site is currently in better condition than it was when restoration work first began. A 5-year vegetation monitoring effort, started in 2022, in the meadow restoration area will provide quantitative information on restoration progress. There are also smaller NPS-owned fields that the park would like to restore/convert to native vegetation.

Because no NPS standardized surveys or inventories of birds or other wildlife were available for CEBE's meadows, we reviewed information from eBird for reputable sightings of birds. Sightings from eBird for two locations in the park resulted in a list of 91 bird species total, including species considered grassland breeding species and shrubland species. To obtain information on one group of pollinators—butterflies—we compiled a list of species known to occur in Frederick, Shenandoah,

and Warren counties. This list of 98 species includes the monarch butterfly, which has been reported in CEBE and whose host plant (multiple milkweed species) was included in restoration plantings. Chapter 4 of the NRCA provides some considerations for management of CEBE's meadows, including ideas for filling gaps in our knowledge.

# Chapter 4. Management Considerations

The Chapter 4 management considerations are presented by the focal resources evaluated in Chapter 3. They are based on the NRCA findings and information gathered, for the purpose of providing managers with next steps for furthering science-informed management. While the purpose of an NRCA is to synthesize information to deliver natural resource conditions or status of knowledge summaries for topics of park interest, the purpose of the NPS Resource Stewardship Strategy (RSS) and other park planning processes is to establish resource goals and strategies to achieve desired resource outcomes.

## 4.1. Visual Resources

- **Reinventory the VRI's three viewpoints.** The VRI conducted in 2022 for the NRCA provides a baseline for monitoring changes to scenic quality over time at the three viewpoints selected. Meyer et al. (2018) recommended that views be reinventoried at 5- to 10-year intervals. Since there is development pressure around the park, a 5-year interval may be desirable, especially at Viewpoint 3, given the potential development (i.e., tall security tower) in the background of the view.
- **Consider additional VRI locations.** The 2022 VRI included three viewpoint locations. It may be beneficial for CEBE staff and partners to collect visual resource data at additional, high priority locations in the park.
- **Remaining questions.** Questions that CEBE staff may wish to pursue with its partners include:
    - Are there priority locations for visual resource protection?
    - For priority locations, what are the best tools to use in working with partners and landowners to protect scenic views?

### 4.2. Night Sky

- **Minimize and/or avoid artificial light intrusion.** According to NPS (2006) guidance, NPS will minimize light that emanates from park facilities, and seek the cooperation of park visitors, neighbors, partners, and local government agencies to prevent or minimize the intrusion of artificial light into the night scene of park ecosystems.
    - NPS (2023g) provides a number of best practices for outdoor lighting that could be considered for CEBE. These include: provide lighting only where and when needed; use LEDs in warm colors (e.g., yellow or amber, not blue or white); use recessed and fully shielded lights; use downward-facing lights; use fixtures that include or can accommodate timers, motion detectors, hue adapters, and dimmers; use the lowest lumens possible (lumens are the unit of measurement to specify brightness in bulbs); and install lights at the proper angle and height. The International Dark-Sky Association (IDA), which provides similar guidance, has a program that certifies dark-sky-friendly outdoor lighting and provides a searchable database that lists certified lighting fixtures (IDA 2023). CEBE managers could also share information with legislated partners on what they can do about lighting to restore natural night skies.
    - Educate local governments about the importance of natural night skies and measures that can be taken to plan for and restore natural night skies. Many night sky issues in CEBE's vicinity area are on private property, and zoning by local governments could help.
- **Determine needs for a baseline study.** Identify park needs for a baseline night sky study via a Technical Assistance Request (identified as a data need in NPS 2018a).

## 4.3. Soundscape

- **Acoustic monitoring project at CEBE.** A Technical Assistance Request related to the soundscape has been initiated and is planned for 2024. The project will deploy one or two acoustic monitoring systems for approximately 30 days in CEBE and conduct short-term data collection in the area of the park closest to the open-air firing range. Prior to the existence of the firing range, NPS (2018a) noted the importance of collecting baseline data for the park's acoustic environment to "support monitoring efforts related to noise pollution from traffic along major interstates and roads that run through or are next to the park…to inform future management decisions related to the impact of sound levels on the visitor experience."
- **Determine acoustic zones at CEBE.** Identify acoustic zones based on physical attributes (e.g., elevation, habitat) and management type (visitor center, hiking trails, etc.) throughout the park, and set desired conditions for each zone.
- **Explore ways to reduce noise from Interstate 81.** The park's foundation document (NPS 2018a) reported that the exploration of ways to reduce noise from Interstate 81 is an important opportunity.

## 4.4. Woodlands

- **Tree species predicted to have no change, increases, or new potential habitat.** The woodlands gap analysis, based on work by NPS CCRP (2015) for nearby (~50-mi-drive) Antietam National Battlefield, identified tree species that occur in CEBE that are predicted to have no change or increases in potential habitat under two climate change scenarios. These species are out of 14 tree species identified as dominant, subdominant, characterizing the habitat, or important in CEBE studies we reviewed (see Chapter 3). Note that there are additional species that occur within the park (that are less common or that did not occur in the six forest plots and other studies we examined) that may be predicted to have increases in potential habitat under the climate change scenarios considered by NPS CCRP (2015). Table 3, below, provides a summary of the species **predicted to have no change in potential habitat, increases in potential habitat, or new potential habitat**. Although this list is not comprehensive, it provides examples of native species and may help the park with planning for the future.

**Table 3.** Potential changes in habitat suitability for tree species in CEBE that were reported as dominant, subdominant, characterizing the habitat, or important in Bousquet et al. (2004), Clark et al. (2008), and Katen et al. (2020). The "potential change" category is from NPS CCRP (2015) for Antietam National Battlefield. This table does not include the four species predicted to have decreases in potential habitat under both climate change scenarios (see Chapter 3 for those species).

| Tree species Common Name | Tree species Scientific Name | Potential changes in habitat suitability category |
|---|---|---|
| Chinkapin oak | *Quercus muehlenbergii* | Increases in potential habitat |
| Eastern red cedar | *Juniperus virginiana* | Increases in potential habitat |
| Shumard oak | *Quercus shumardii* | New potential habitat |
| Black oak | *Quercus velutina* | No change in potential habitat |
| Eastern redbud | *Cercis canadensis* | No change in potential habitat |
| Bitternut hickory | *Carya cordiformis* | No change to increase * |
| Pignut hickory | *Carya glabra* | No change to decrease * |
| Flowering dogwood | *Cornus florida* | No change to decrease * |
| White oak | *Quercus alba* | No change to decrease * |
| Scarlet oak | *Quercus coccinea* | No change to decrease * |

* No change in habitat suitability is predicted under the "least change" scenario but decreases (or increases) are predicted under the "major change" scenario.

- Also, as discussed in the climate change section of Chapter 2, an NPS analysis for spring onset at Antietam National Battlefield indicated that the First Leaf Index is early and the First Bloom Index is extreme early (NPS CCRP 2016; Antietam data provided by A. Babson, NPS Interior Region 1, email communication, 8 February 2023). Measures in the extreme early category fall in the <5$^{th}$ percentile (meaning they exceed 95% of historical conditions), and those in the early category fall in the 5$^{th}$–25$^{th}$ percentile (NPS CCRP 2016). Advances in the timing of Spring could lead to ecological mismatches among interacting species (e.g., plant–

pollinator interactions) and non-native species invasions (NPS CCRP 2016), as well as the potential to impact the timing of park operations (e.g., invasive plant treatments), events, and visitor uses (Monahan et al. 2016).

- **Consider monitoring deer populations and/or deer-browse impacts.** Because of the findings of Miller et al. (2023), and because NPS staff have reported the potential for deer over-browsing impacts to CEBE's woodlands, CEBE staff and partners might consider beginning efforts to monitor deer populations and/or deer impacts to vegetation (including to tree regeneration) in the park. Also see the last bullet below.
- **How will emerald ash borer and spotted lantern fly impact CEBE's woodlands in the future?** Although the gap analysis in Chapter 3 provided general information on these two insect pests, the topics of impacts now and in the future are data gaps for the park. It is possible that with increased temperatures and increased stress to some tree species in the future, existing pests could have a greater impact on tree survival and/or new pests could invade (e.g., Wetli 2022). Also, greater intensity and frequency of storms (due to climate change) will likely promote larger canopy gaps created by the loss of ash trees due to emerald ash borer.
- **Work with partners to increase awareness of non-native invasive pests.** CEBE managers could work with park partners to increase awareness and efforts to minimize impacts of non-native invasive pests, such as the EAB and SLF. Emerald ash borer can be spread through infected materials, such as firewood, infested ash plantings and trees, and ash wood packing material (APHIS 2023b). Information on the pest for landowners is available from Virginia Cooperative Extension (VCE 2023b). For the SLF, CEBE is within a SLF quarantine area (including Frederick, Warren, and Shenandoah counties) established by VDACS (VDACS 2023), in which businesses must obtain permits and inspect regulated articles for SLF life stages before transporting regulated articles. Best management practices for SLF in landscapes and yards, which may provide useful information for the park, are available from APHIS (2023c) and VCE (2023c).
- **Remaining questions.** Although CEBE's woodlands are an ecologically and historically valuable resource, CEBE managers would like to know if there are locations within park boundaries where present-day woodlands encroach on historical viewsheds. For example, it is known there was a woodland near the Vermont Monument, but it is not clear where the historic woodland line was. The question of if and where present-day woodland extent encroaches on historical viewsheds is also relevant for the Visual Resources condition assessment and is currently a data gap.
- **Encroachment inventory.** Similarly, CEBE managers would like to have an assessment/inventory of where woodlands affect parts of the battlefield and/or park historic features, such as trenches, earthworks, and other historic structures (e.g., historic bridge abutments).
- Also, Katen et al. (2020 [page 380]) reported that some woodland areas have "encroached into previously open agricultural fields and pasture areas since the Battle of Cedar Creek."

CEBE managers have the following questions with regards to the historic agricultural fields and pastures: Where was the forest line in the historic period? What would the impacts be of returning the forest line to that point? And how should the forest line be managed to maintain it at that location/appearance?

Old Valley Pike bridge abutment with woodland and other vegetation growing on and around it. This abutment, which is on NPS property, dates back to about the 1830s. Image Credit: NPS NRCA Program.

- **Priority areas for invasive plant management.** Invasive plant species are known to occur in CEBE and may increase with the loss of ash trees across the park. An important need would be to develop an invasive plant strategic plan that identifies priority areas for management (NPS, J. Comiskey, I&M Division Program Manager for Interior Region 1 North Atlantic–Appalachian, draft NRCA comment, 25 July 2023).
- **Ideas for monitoring and/or assessing the condition of woodlands.** Although we did not have adequate, current data available to assess the condition of woodlands in CEBE for this report, ideas for future monitoring and/or indicators/measures for a baseline condition assessment could be taken from forest vegetation monitoring in the Mid-Atlantic I&M Network (MIDN) (i.e., Comiskey et al. 2009) and Shenandoah NP (i.e., Cass et al. 2011). Although the two protocols have similar monitoring objectives, the MIDN protocol has the following objectives:
    - determine the status of and trends in forest structure, composition, and dynamics of canopy and understory woody species.

- determine the status of and trends in the density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse.
- detect and monitor the presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests.
- determine the status of and trends in forest coarse woody debris and the availability of snags.
- determine the status of and trends in forest soil chemistry (Ca:Al and C:N ratios) to determine impacts from acid deposition.

### 4.5. Meadows

- **Conduct pollinator surveys.** Consider surveying butterflies and other pollinators, such as moths and bees, within CEBE meadows. Similar work has occurred at Manassas National Battlefield Park with Virginia Department of Conservation and Recreation, Division of Natural Heritage (NPS 2022d). Managers at Valley Forge National Historical Park (NHP) have also completed such surveys and use interns to conduct periodic monitoring (NPS, A. Ruhe, Valley Forge NHP and Hopewell Furnace National Historic Site, Chief, Planning & Resource Management, draft NRCA comment, 29 October 2023).
- **Comprehensive inventory/monitoring effort.** CEBE might also want to consider a more comprehensive inventory or monitoring effort at the 19-ha (47-ac) Morning Attack Trail meadow restoration site. In addition to the vegetation surveys already conducted by the MA-IPMT, an inventory and/or monitoring could be conducted on breeding birds, following a protocol of the Mid-Atlantic I&M Network (MIDN), as well as butterflies and other pollinators (see first bullet). Incidental observations of other wildlife species could also be recorded. The MIDN breeding bird monitoring protocol is implemented by trained volunteers (NPS 2023h).
- **Consider a Species Inventory proposal (NPS I&M Division).** Because CEBE is a relatively young park, not part of an Inventory & Monitoring network, and there are significant gaps in knowledge about natural resources, the park might consider a proposal for a baseline inventory (https://www.nps.gov/im/inventories-2.htm#:~:text=with%20other%20programs.-,The%20Ten%20Inventories,other%20species%20of%20management%20concern) as related to the bullet above, or another important information need at CEBE. Surveys on birds and pollinators in the meadow restoration area(s) would provide managers data on species using the area and assist in monitoring progress in meeting restoration goals (as described in Chapin et al. [2021], for example). Although no pre-restoration information is available for butterflies and other pollinators, limited information on bird sightings in the vicinity of the Morning Attack Trail field, from eBird, dates back to 2018.
- **Citizen science sources of information.** CEBE might also consider other ways to collect information on wildlife and insects that occur in the park. Three ideas are: 1) continuing the new partnership with Master Naturalists; 2) conducting a BioBlitz (https://www.nps.gov/subjects/biodiversity/the-nps-national-geographic-society-bioblitzes.htm) in high priority areas of the park; and 3) encourage/continue to encourage wildlife, insect, and plant observation reporting to eBird and iNaturalist. For #3, CEBE could use the park website and other means to encourage citizen scientist reporting.
- **NPS areas needing restoration or management for improved wildlife habitat.** In addition to the Morning Attack Trail field, there are other, smaller, fields where CEBE managers would like to bring back native vegetation. These four fields are on NPS-owned land and are, in total, about 13.3 ha (33 ac) in size (Figure 21). Initial stages of restoration at one of the fields (near Bowman Hite House) began in the spring of 2023, when invasive shrubs were removed. To develop plans/goals for restoration of all four fields, CEBE managers need

assistance with determining ecological/habitat goals for the individual fields while maintaining the park's cultural landscape. Goals should also be prioritized and achievable based on resources available to the park. Additionally, given the goals and the type of existing vegetation and condition of each field, CEBE managers need assistance answering questions such as: what types of plantings would best support the restoration goals? Do the relatively small sizes of the individual fields limit or affect their value for some wildlife species (e.g., some birds)? [For example, at Valley Forge NHP, smaller fields are managed as foraging habitat for birds (NPS, A. Ruhe, Valley Forge NHP and Hopewell Furnace National Historic Site, Chief, Planning & Resource Management, draft NRCA comment, 29 October 2023)]. Other important considerations might include: the type of vegetation that dominated historically, the type of habitat/vegetation that surrounds or is adjacent to them, and whether the soils present influence restoration goals or the probability of invasive plant species invasions. Also see Chapin et al. (2021) for other considerations.

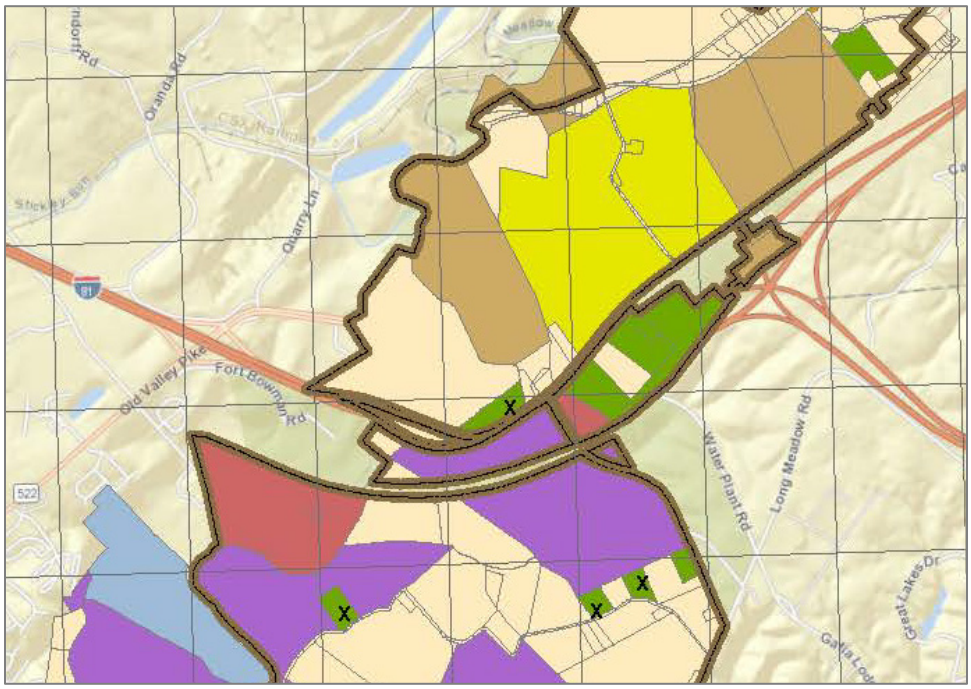



**Figure 21.** Central portion of CEBE showing NPS-owned areas in green, with field areas that CEBE managers would like to restore designated with an "x". Note that the Morning Attack Trail field is within the largest green polygon (without an "x") on the map. Figure Credit: NPS.

  - CEBE managers may want to consider requesting support from NPS staff with the expertise to assist; or they may want to consider submitting a proposal to an appropriate funding source, such as NRCA for a Resource Restoration Design project, for supporting the work through a partnership agreement with an external principal investigator.

- **Consider adding evidence of deer herbivory to meadow restoration monitoring.** As discussed in the Woodlands gap analysis, NPS staff have reported the potential for deer over-

browsing impacts to CEBE's woodlands, like have occurred in other national parks in the eastern United States (Miller et al. 2023). There is also the potential for deer to impact CEBE meadow vegetation, but the NPS MA-IPMT has not observed evidence that deer are adversely affecting meadow plants to any substantial degree (NPS MA-IPMT, N. Wender, Team Leader, email communication, 16 August 2023). However, the MA-IPMT might consider adding the recording of deer herbivory evidence to its meadow restoration monitoring activities (Chapin et al. 2021 [Page 20]).

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# Appendix A. Condition Rating Statements

Condition rating statements for the visual resources, night sky, and soundscape assessments are presented in Tables 4, 5, and 6, respectively.

**Table 4.** Matrix for deriving a visual resource condition rating (i.e., the Scenic Inventory Value matrix from Meyer et al. 2018). Note: The NPS ARD condition rating scale differs from the NRCA Program's condition rating levels (in Figure 10).

| | View Importance Rating | | | | |
|---|---|---|---|---|---|
| **Scenic Quality Rating** | **1** | **2** | **3** | **4** | **5** |
| A | Very High | Very High | Very High | High | Medium |
| B | Very High | Very High | High | Medium | Low |
| C | High | High | Medium | Low | Low |
| D | High | Medium | Low | Very Low | Very Low |
| E | Medium | Low | Very Low | Very Low | Very Low |

**Table 5.** Condition rating statements for the status of the night sky indicator at Cedar Creek & Bell Grove National Historical Park.

| **Condition Rating *** | **All-sky Light Pollution Ratio (ALR)** |
|---|---|
| **Good** | ALR value is <2.00. |
| **Good/Fair** | – |
| **Fair** | ALR value is between 2.00–18.00. |
| **Fair/Poor** | – |
| **Poor** | ALR value is >18.00. |

* Values are based on the NPS Natural Sounds and Night Skies Division benchmarks (Moore et al. 2013; Hung et al. 2019).

**Table 6.** Condition rating statements for the indicator of soundscape at Cedar Creek & Bell Grove National Historical Park.

| **Condition Rating** | **$LA_{50}$ Impact * (Mean dBA)** |
|---|---|
| **Good** | ≤1.5: Listening area reduced by ≤30%. |
| **Good/Fair** | – |
| **Fair** | >1.5 but ≤3.0: Listening area reduced by >30-50%. |
| **Fair/Poor** | – |
| **Poor** | >3.0: Listening area reduced by >50%. |

* NPS Natural Sounds and Night Skies Division $LA_{50}$ impact thresholds for non-urban parks. Non-urban parks are those with at least 90% of their land located outside an urban area (Turina et al. 2013).

# Appendix B. Additional Information for Woodlands Gap Analysis

## Figures

Figure 22 compares the estimated 1864 vegetation coverage of forests and woodlands with what was observed in 2019.

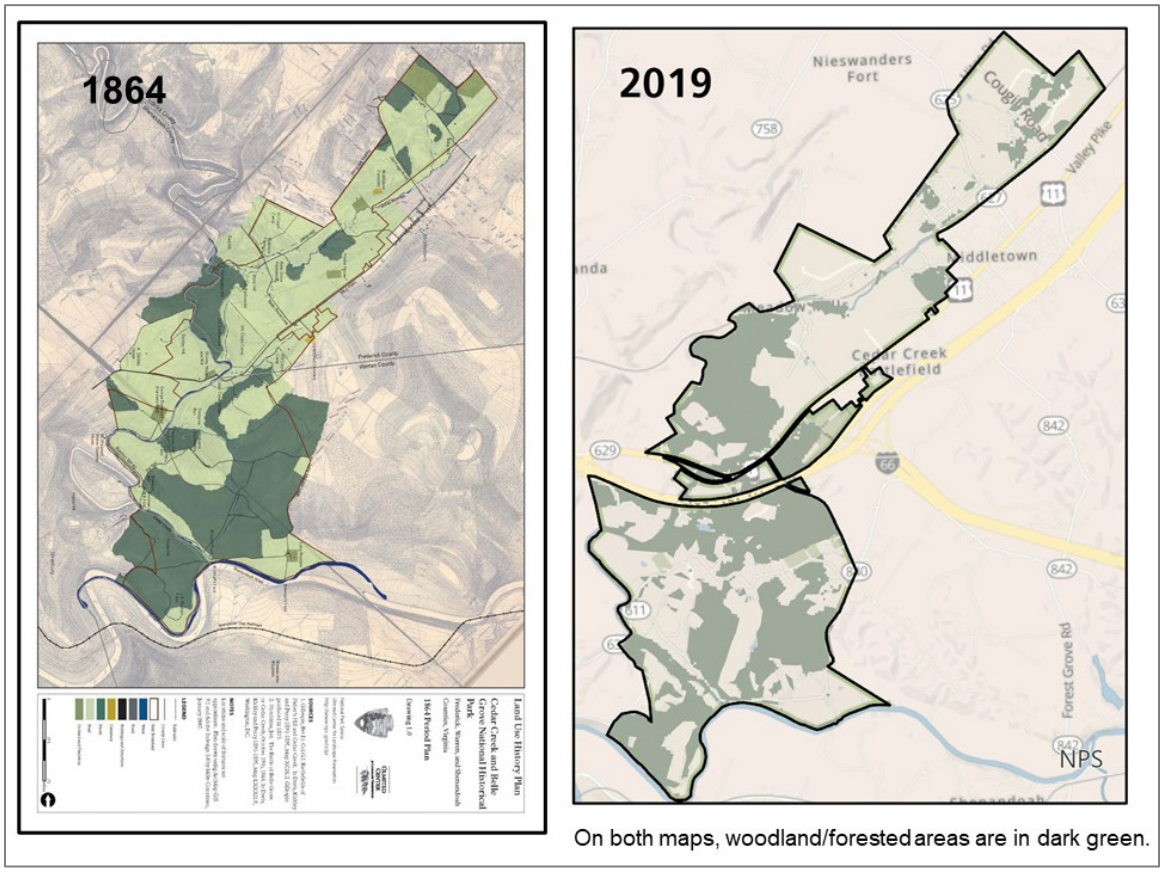


**Figure 22.** Estimated coverage of forests/woodlands (dark green) within present-day CEBE in 1864 and 2019. Coverage for 1864 (left) is based on land use data for 1864 compiled by the NPS Olmsted Center for Landscape Preservation (2007, as cited in Commisso and Foulds 2007); the map is from Commisso and Foulds (2007, Page 67). Coverage data for forests/woodlands in 2019 (right) are from Dewitz and USGS (2021); map created by NPS. Specific sources used to create the 1864 map are shown below.

### *1864 Map Sources*

Gillespie, Bvt. Lt. Col. G. L. Battlefields of Fisher's Hill and Cedar Creek. In Davis, Kirkley, and Perry 1891–1895, Map XCIX.2. Gillespie produced in 1873. As cited on 1864 Period Plan, Drawing 1.0 (page 67 of Commisso and Foulds [2007]). [Sketch available from the Library of Congress: https://www.loc.gov/item/2006626068/].

Hotchkiss, Jed. The Battle of Belle Grove or Cedar Creek, October 19th, 1864. In Davis, Kirkley, and Perry 1891–1895, Map LXXXII.9, Washington, DC. As cited on 1864 Period Plan, Drawing 1.0 (page 67 of Commisso and Foulds [2007]). [Sketch available from the Library of Congress: https://www.loc.gov/collections/hotchkiss-maps/?q=The+Battle+of+Belle+Grove+or+Cedar+Creek]

## Tables

Table 7 shows the native tree species discussed in the woodlands gap analysis, and Table 8 shows the non-native, invasive plants observed in CEBE according to three vegetation sampling efforts.

**Table 7.** Native tree species discussed in the CEBE woodlands gap analysis, as well as which study reported them.

| Common Name | Scientific Name | Reported in Bousquet et al. (2004)* | Reported in Clark et al. (2008)* | Reported in Katen et al. (2020)* |
|---|---|---|---|---|
| Bitternut hickory | *Carya cordiformis* | X | – | X |
| Black oak | *Quercus velutina* | X | X | X |
| Chestnut oak | *Quercus prinus* | – | X | – |
| Chinquapin oak | *Quercus muehlenbergii* | X | – | – |
| Eastern red cedar | *Juniperus virginiana* | X | X | – |
| Eastern redbud | *Cercis canadensis* | X | – | – |
| Flowering dogwood | *Cornus florida* | X | – | – |
| Pignut hickory | *Carya glabra* | X | X | X |
| Red oak | *Quercus rubra* | X | – | X |
| Scarlet oak | *Quercus coccinea* | – | X | – |
| Shumard oak | *Quercus shumardii* | X | – | – |
| Virginia pine | *Pinus virginiana* | – | X | – |
| White oak | *Quercus alba* | X | X | X |
| White ash | *Fraxinus americana* | X | – | – |

* An "X" indicates that a species was observed by a sampling study and an endash (–) indicates that it was not.

**Table 8.** Non-native, invasive plants in the woodland plots of Bousquet et al. (2004) and Clark et al. (2008), and as reported for selected plots surveyed by the NPS Mid-Atlantic Exotic Plant Management Team in 2017 (NPS 2017). Each species' invasiveness rank is also shown.

| Common Name | Scientific Name | Virginia Invasiveness Rank (Heffernan et al. 2014)* | Reported in Bousquet et al. (2004)* | Reported in Clark et al. (2008)* | Reported in NPS (2017)* |
|---|---|---|---|---|---|
| Tree-of-heaven | *Ailanthus altissima* | high | X | X | X |
| Garlic mustard | *Alliaria petiolata* | high | X | X | X |
| Autumn olive | *Elaeagnus umbellata* | high | X | – | X |
| Japanese honeysuckle | *Lonicera japonica* | high | X | – | X |
| Multiflora rose | *Rosa multiflora* | high | X | – | X |
| Wineberry | *Rubus phoenicolasius* | high | – | X | X |
| Japanese hops | *Humulus japonicus* | medium | – | X | – |
| Flat-stemmed bluegrass | *Poa compressa* | medium | X | – | – |
| Common chickweed | *Stellaria media* | medium | – | X | – |
| Japanese stiltgrass | *Microstegium vimineum* | high | – | – | X |
| Bush honeysuckle | *Lonicera* spp. | high | – | – | X |
| Jetbead | *Rhodotypos scandens* | medium | – | – | X |

* An "X" indicates that a species was observed by a sampling study and an endash (–) indicates that it was not.

# Appendix C. Additional Information for Meadows Gap Analysis

## Figures

Figure 23 compares the estimated 1864 vegetation coverage of field areas with what was observed in 2019.

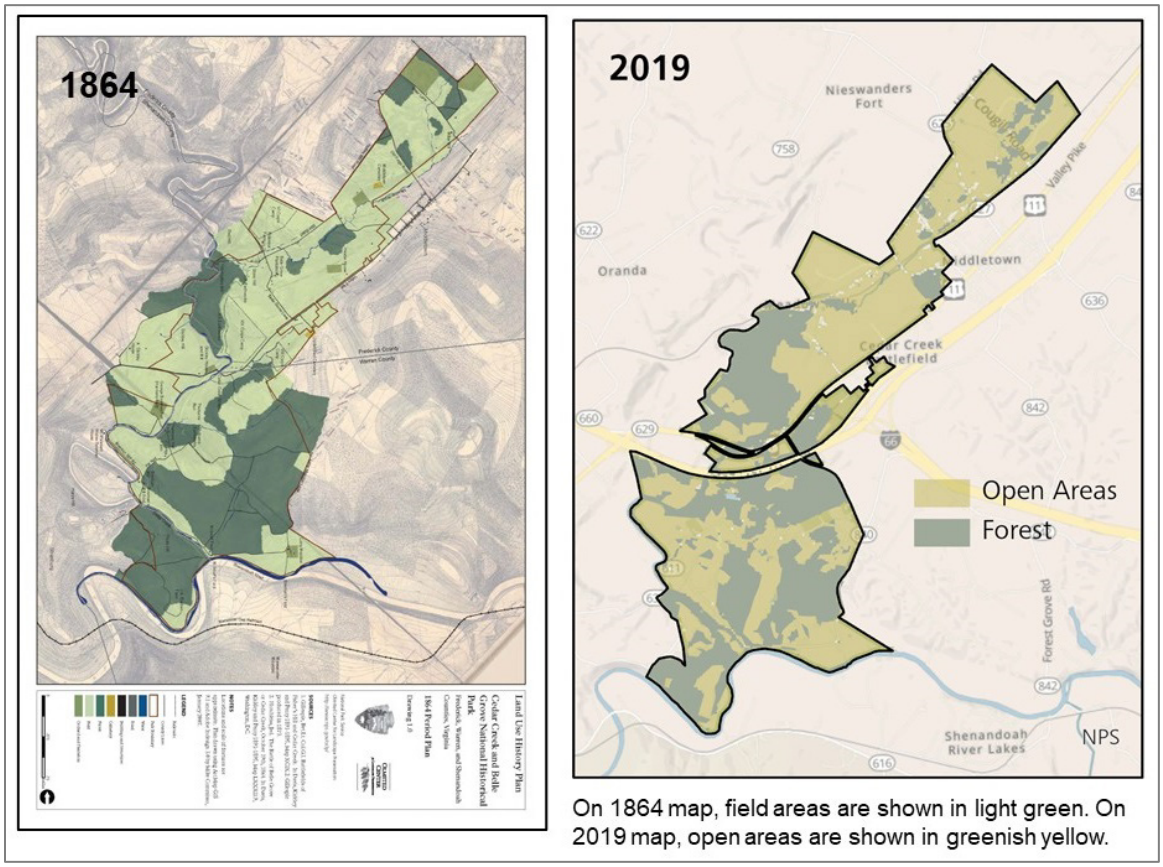


**Figure 23.** Estimated coverage of field areas (light green) and forests/woodlands (dark green) within present-day CEBE based on land use data for 1864 compiled by the NPS Olmsted Center for Landscape Preservation (2007, as cited in Commisso and Foulds 2007); map is from Commisso and Foulds (2007, Page 67) (left). Data for open areas in 2019 (yellowish-green) (on right) are from Dewitz and USGS (2021) and mapped by NPS. Specific sources used to create the 1864 map are shown below. Areas shown as open areas in 2019 include those categorized as hay/pasture (the majority of the open areas), cultivated crops, herbaceous, shrub/scrub, and developed open space (described as mostly lawn grasses, with impervious surfaces less than 20%) (also see Figure 19 in Chapter 3).

### *1864 Map Sources*

Gillespie, Bvt. Lt. Col. G. L. Battlefields of Fisher's Hill and Cedar Creek. In Davis, Kirkley, and Perry 1891–1895, Map XCIX.2. Gillespie produced in 1873. As cited on 1864 Period Plan, Drawing 1.0 (Page 67 of Commisso and Foulds [2007]). [Sketch available from the Library of Congress: https://www.loc.gov/item/2006626068/].

Hotchkiss, Jed. The Battle of Belle Grove or Cedar Creek, October 19th, 1864. In Davis, Kirkley, and Perry 1891–1895, Map LXXXII.9, Washington, DC. As cited on 1864 Period Plan, Drawing 1.0 (Page 67 of Commisso and Foulds [2007]). [Sketch available from the Library of Congress: https://www.loc.gov/collections/hotchkiss-maps/?q=The+Battle+of+Belle+Grove+or+Cedar+Creek].

## Tables

Table 9 lists the dominant plant species, including non-native species, observed during the 2021 invasive plant survey at CEBE. Table 10 lists the native seed species, including those important to pollinators, used during CEBE's meadow restoration. Table 11 lists the bird species observed at two locations in CEBE from 2006 through 2023 according to eBird (eBird 2023a, 2023b). Table 12 lists the butterfly species that have been reported in Frederick, Shenandoah, and Warren counties (BAMONA 2023d, 2023e, 2023f).

**Table 9.** The 27 dominant species recorded during the NPS Mid-Atlantic Invasive Plant Management Team vegetation survey conducted in 2021, including non-native species and those assigned an invasive rank (I-Rank) by the Virginia Department of Conservation and Recreation (Heffernan et al. 2014). A map of the coverages of these species is shown in Figure 20.

| Common Name | Scientific Name | Non-native* | Virginia Invasiveness Rank* |
|---|---|---|---|
| Blackberry | *Rubus allegheniensis* | – | – |
| Broadleaf ironweed | *Vernonia glauca* | – | – |
| Canada thistle | *Cirsium arvense* | X | High |
| Common/broadleaf milkweed | *Asclepia syriaca* | – | – |
| Crown vetch | *Securigera varia* | X | Low |
| Curly dock | *Rumex crispus* | X | Low |
| Fescue subspecies | *Festuca* ssp/*Unclassified* | X | – |
| Giant foxtail | *Setaria faberi* | X | – |
| Goldenrod | *Solidago pumila* | – | – |
| Hairy white oldfield aster | *Symphyotrichum pilosum* | – | – |
| Hemp dogbane | *Erigeron strigosus* | – | – |
| Horsenettle | *Solanum carolinese* | – | – |
| Indian hemp | *Apocynum cannabinum* | – | – |
| Indiangrass | *Sorghastrum nutans* | – | – |
| Japanese honeysuckle | *Lonicera japonica* | X | High |
| Japanese stiltgrass | *Microstegium vimineum* | X | High |
| Johnsongrass | *Sorghum halepense* | X | High |
| Purpletop | *Tridens flavus* | – | – |
| Sericea lespedeza | *Lespedeza cuneata* | X | High |

* An "X" indicates that a species is non-native and an endash (–) indicates that it is either native or does not have a Virginia Invasiveness Rank.

**Table 9 (continued).** The 27 dominant species recorded during the NPS Mid-Atlantic Invasive Plant Management Team vegetation survey conducted in 2021, including non-native species and those assigned an invasive rank (I-Rank) by the Virginia Department of Conservation and Recreation (Heffernan et al. 2014). A map of the coverages of these species is shown in Figure 20.

| Common Name | Scientific Name | Non-native* | Virginia Invasiveness Rank* |
|---|---|---|---|
| Spiny plumeless thistle | *Carduus acanthoides* | X | – |
| Swamp milkweed | *Asclepias incarnata* | – | – |
| Virginia wildrye | *Elymus virginicus* | – | – |
| White snakeroot | *Ageratina altissima* | – | – |
| Wild bergamot | *Monarda fistulosa* | – | – |
| Wild carrot | *Daucus carota* | X | – |
| Wild teasel | *Dipsacus fullonum* | X | Medium |
| Yellow foxtail | *Setaria pumila* | X | – |

* An "X" indicates that a species is non-native and an endash (–) indicates that it is either native or does not have a Virginia Invasiveness Rank.

**Table 10.** Native seed species (33) and associated families used by the NPS Mid-Atlantic Invasive Plant Management Team for CEBE meadows restoration. Species used are native meadow plants that are found in the local area and are important to pollinators. List source: Wender (2022).

| Common Name | Scientific Name | Family Common Name | Family Scientific Name |
|---|---|---|---|
| Appalachian beardtongue | *Penstemon laevigatus* | Figwort | Scrophulariaceae |
| Aromatic aster | *Symphyotrichum oblongifolium* | Aster | Asteraceae |
| Blue vervain | *Verbena hastata* | Verbena | Verbenaceae |
| Boneset | *Eupatorium perfoliatum* | Aster | Asteraceae |
| Broomsedge | *Andropogon virginicus* | Grass | Poaceae |
| Butterfly milkweed | *Asclepias tuberosa* | Milkweed | Asclepiadaceae |
| Calico aster | *Symphyotrichum lateriflorum* | Aster | Asteraceae |
| Common milkweed | *Asclepias syriaca* | Milkweed | Asclepiadaceae |
| Common sneezeweed | *Helenium autumnale* | Aster | Asteraceae |
| Early goldenrod | *Solidago juncea* | Aster | Asteraceae |
| Evening primrose | *Oenothera biennis* | Evening primrose | Onagraceae |
| Grassleaf goldenrod | *Euthamia graminifolia* | Aster | Asteraceae |
| Gray goldenrod | *Solidago nemoralis* | Aster | Asteraceae |
| Heath aster | *Symphyotrichum pilosum* | Aster | Asteraceae |
| Indiangrass | *Sorghastrum nutans* | Grass | Poaceae |
| Little bluestem | *Schizachyrium scoparium* | Grass | Poaceae |
| Mistflower | *Conoclinium coelestinum* | Aster | Asteraceae |
| New England aster | *Symphyotrichum novae-angliae* | Aster | Asteraceae |
| New York ironweed | *Vernonia noveboracensis* | Aster | Asteraceae |
| Partridge pea | *Chamaecrista fasciculata* | Pea | Fabaceae |
| Purple lovegrass | *Eragrostis spectabilis* | Grass | Poaceae |
| Purpletop | *Tridens flavus* | Grass | Poaceae |
| Sideoats grama | *Bouteloua curtipendula* | Grass | Poaceae |
| Slender mountain mint | *Pycnanthemum tenuifolium* | Mint | Lamiaceae |

**Table 10 (continued).** Native seed species (33) and associated families used by the NPS Mid-Atlantic Invasive Plant Management Team for CEBE meadows restoration. Species used are native meadow plants that are found in the local area and are important to pollinators. List source: Wender (2022).

| Common Name | Scientific Name | Family Common Name | Family Scientific Name |
|---|---|---|---|
| Smooth blue aster | *Symphyotrichum laeve* | Aster | Asteraceae |
| Stiff goldenrod | *Solidago rigida* | Aster | Asteraceae |
| Swamp milkweed | *Asclepias incarnata* | Milkweed | Asclepiadaceae |
| Switchgrass | *Panicum virgatum* | Grass | Poaceae |
| Tall white beardtongue | *Penstemon digitalis* | Figwort | Scrophulariaceae |
| Virginia mountain mint | *Pycnanthemum virginianum* | Mint | Lamiaceae |
| Wild bergamot | *Monarda fistulosa* | Mint | Lamiaceae |
| Wild senna | *Senna hebecarpa* | Pea | Fabaceae |
| Wrinkleleaf goldenrod | *Solidago rugosa* | Aster | Asteraceae |

**Table 11.** Summary of eBird bird observations for two locations within CEBE: Morning Attack Trails (eBird 2023a, covering 2018–June 2023), and CEBE Belle Grove Road location (eBird 2023b, covering 2006–June 2023). As applicable, observed species are identified as grassland breeding birds (Peterjohn 2006a) or shrubland breeding birds (Peterjohn 2006b).

| Common Name | Scientific Name | Observed at CEBE Morning Attack Trails location (eBird)* | Observed at CEBE Belle Grove Road location (eBird)* | Grassland Breeding Birds (Peterjohn 2006a)* | Shrubland Breeding Birds (Peterjohn 2006b)* |
|---|---|---|---|---|---|
| Acadian Flycatcher | *Empidonax virescens* | X | X | – | – |
| American Crow | *Corvus brachyrhynchos* | X | X | – | – |
| American Goldfinch | *Carduelis tristis* | X | X | – | – |
| American Kestrel | *Falco sparverius* | – | X | – | – |
| American Robin | *Turdus migratorius* | X | X | – | – |
| Bald Eagle | *Haliaeetus leucocephalus* | X | – | – | – |

* An "X" indicates that a species was observed or listed by the particular reference and an endash (–) indicates that it was not.

**Table 11 (continued).** Summary of eBird bird observations for two locations within CEBE: Morning Attack Trails (eBird 2023a, covering 2018–June 2023), and CEBE Belle Grove Road location (eBird 2023b, covering 2006–June 2023). As applicable, observed species are identified as grassland breeding birds (Peterjohn 2006a) or shrubland breeding birds (Peterjohn 2006b).

| Common Name | Scientific Name | Observed at CEBE Morning Attack Trails location (eBird)* | Observed at CEBE Belle Grove Road location (eBird)* | Grassland Breeding Birds (Peterjohn 2006a)* | Shrubland Breeding Birds (Peterjohn 2006b)* |
|---|---|---|---|---|---|
| Baltimore Oriole | *Icterus galbula* | X | – | – | – |
| Barn Swallow | *Hirundo rustica* | X | X | – | – |
| Belted Kingfisher | *Megaceryle alcyon* | X | X | – | – |
| Black Vulture | *Coragyps atratus* | X | X | – | – |
| Blackpoll Warbler | *Setophaga striata* | X | – | – | – |
| Blue Grosbeak | *Guiraca caerulea* | X | – | – | X |
| Blue Jay | *Cyanocitta cristata* | X | X | – | – |
| Blue-gray Gnatcatcher | *Polioptila caerulea* | X | X | – | – |
| Bobolink | *Dolichonyx oryzivorus* | – | X | X | – |
| Brown Thrasher | *Toxostoma rufum* | X | X | – | X |
| Brown-headed Cowbird | *Molothrus ater* | X | X | – | – |
| Canada Goose | *Branta canadensis* | X | X | – | – |
| Carolina Chickadee | *Poecile carolinensis* | X | X | – | – |
| Carolina Wren | *Thryothorus ludovicianus* | X | X | – | X |
| Cedar Waxwing | *Bombycilla cedrorum* | X | X | – | – |
| Chimney Swift | *Chaetura pelagica* | X | X | – | – |
| Chipping Sparrow | *Spizella passerina* | X | X | – | – |
| Common Grackle | *Quiscalus quiscula* | X | X | – | – |
| Common Raven | *Corvus corax* | X | X | – | – |
| Common Yellowthroat | *Geothlypis trichas* | X | – | – | X |

* An "X" indicates that a species was observed or listed by the particular reference and an endash (–) indicates that it was not.

**Table 11 (continued).** Summary of eBird bird observations for two locations within CEBE: Morning Attack Trails (eBird 2023a, covering 2018–June 2023), and CEBE Belle Grove Road location (eBird 2023b, covering 2006–June 2023). As applicable, observed species are identified as grassland breeding birds (Peterjohn 2006a) or shrubland breeding birds (Peterjohn 2006b).

| Common Name | Scientific Name | Observed at CEBE Morning Attack Trails location (eBird)* | Observed at CEBE Belle Grove Road location (eBird)* | Grassland Breeding Birds (Peterjohn 2006a)* | Shrubland Breeding Birds (Peterjohn 2006b)* |
|---|---|---|---|---|---|
| Cooper's Hawk | *Accipiter cooperii* | – | X | – | – |
| Dark-eyed Junco | *Junco hyemalis* | – | X | – | – |
| Downy Woodpecker | *Dryobates pubescens* | X | X | – | – |
| Eastern Bluebird | *Sialia sialis* | X | X | – | – |
| Eastern Kingbird | *Tyrannus tyrannus* | X | X | – | – |
| Eastern Meadowlark | *Sturnella magna* | X | X | X | – |
| Eastern Phoebe | *Sayornis phoebe* | X | X | – | – |
| Eastern Towhee | *Pipilo erythrophthalmus* | X | X | – | X |
| Eastern Wood-Pewee | *Contopus virens* | X | – | – | – |
| European Starling | *Sturnus vulgaris* | X | X | – | – |
| Field Sparrow | *Spizella pusilla* | X | X | – | X |
| Fish Crow | *Corvus ossifragus* | X | X | – | – |
| Grasshopper Sparrow | *Ammodramus savannarum* | X | X | X | – |
| Gray Catbird | *Dumetella carolinensis* | X | X | – | X |
| Great Blue Heron | *Ardea herodias* | X | X | – | – |
| Great Crested Flycatcher | *Myiarchus crinitus* | X | X | – | – |
| Great Horned Owl | *Bubo virginianus* | X | – | – | – |
| Hairy Woodpecker | *Leuconotopicus villosus* | X | – | – | – |
| Hooded Merganser | *Lophodytes cucullatus* | – | X | – | – |
| Horned Lark | *Eremophila alpestris* | X | X | X | – |

* An "X" indicates that a species was observed or listed by the particular reference and an endash (–) indicates that it was not.

**Table 11 (continued).** Summary of eBird bird observations for two locations within CEBE: Morning Attack Trails (eBird 2023a, covering 2018–June 2023), and CEBE Belle Grove Road location (eBird 2023b, covering 2006–June 2023). As applicable, observed species are identified as grassland breeding birds (Peterjohn 2006a) or shrubland breeding birds (Peterjohn 2006b).

| Common Name | Scientific Name | Observed at CEBE Morning Attack Trails location (eBird)* | Observed at CEBE Belle Grove Road location (eBird)* | Grassland Breeding Birds (Peterjohn 2006a)* | Shrubland Breeding Birds (Peterjohn 2006b)* |
|---|---|---|---|---|---|
| House Finch | *Haemorhous mexicanus* | X | X | – | – |
| House Sparrow | *Passer domesticus* | X | X | – | – |
| House Wren | *Troglodytes aedon* | – | X | – | – |
| Indigo Bunting | *Passerina cyanea* | X | – | – | X |
| Killdeer | *Charadrius vociferus* | X | X | – | – |
| Louisiana Waterthrush | *Parkesia motacilla* | X | – | – | – |
| Mallard | *Anas platyrhynchos* | X | X | – | – |
| Merlin | *Isoetes tegetiformans* | – | X | – | – |
| Mourning Dove | *Zenaida macroura* | X | X | – | – |
| Northern Cardinal | *Cardinalis cardinalis* | X | X | – | X |
| Northern Flicker | *Colaptes auratus* | X | X | – | – |
| Northern Mockingbird | *Mimus polyglottos* | X | X | – | X |
| Northern Parula | *Setophaga americana* | X | – | – | – |
| Northern Rough-winged Swallow | *Stelgidopteryx serripennis* | – | X | – | – |
| Orchard Oriole | *Icterus spurius* | X | X | – | – |
| Pileated Woodpecker | *Dryocopus pileatus* | X | X | – | – |
| Prairie Warbler | *Setophaga discolor* | X | – | – | X |
| Purple Finch | *Haemorhous purpureus* | – | X | – | – |
| Red-bellied Woodpecker | *Melanerpes carolinus* | X | X | – | – |

* An "X" indicates that a species was observed or listed by the particular reference and an endash (–) indicates that it was not.

**Table 11 (continued).** Summary of eBird bird observations for two locations within CEBE: Morning Attack Trails (eBird 2023a, covering 2018–June 2023), and CEBE Belle Grove Road location (eBird 2023b, covering 2006–June 2023). As applicable, observed species are identified as grassland breeding birds (Peterjohn 2006a) or shrubland breeding birds (Peterjohn 2006b).

| Common Name | Scientific Name | Observed at CEBE Morning Attack Trails location (eBird)* | Observed at CEBE Belle Grove Road location (eBird)* | Grassland Breeding Birds (Peterjohn 2006a)* | Shrubland Breeding Birds (Peterjohn 2006b)* |
|---|---|---|---|---|---|
| Red-eyed Vireo | *Vireo olivaceus* | X | – | – | – |
| Red-headed Woodpecker | *Melanerpes erythrocephalus* | X | X | – | – |
| Red-shouldered Hawk | *Buteo lineatus* | X | X | – | – |
| Red-tailed Hawk | *Buteo jamaicensis* | X | X | – | – |
| Red-winged Blackbird | *Agelaius phoeniceus* | X | X | – | – |
| Rock Pigeon | *Columba livia* | – | X | – | – |
| Ruby-throated Hummingbird | *Archilochus colubris* | X | – | – | – |
| Savannah Sparrow | *Passerculus sandwichensis* | X | X | X | – |
| Scarlet Tanager | *Piranga olivacea* | X | – | – | – |
| Song Sparrow | *Melospiza melodia* | X | X | – | X |
| Swamp Sparrow | *Melospiza georgiana* | – | X | – | – |
| Tree Swallow | *Tachycineta bicolor* | – | X | – | – |
| Tufted Titmouse | *Baeolophus bicolor* | X | X | – | – |
| Turkey Vulture | *Cathartes aura* | X | X | – | – |
| Warbling Vireo | *Vireo gilvus* | X | X | – | – |
| White-breasted Nuthatch | *Sitta carolinensis* | X | X | – | – |
| White-crowned Sparrow | *Zonotrichia leucophrys* | – | X | – | – |
| White-throated Sparrow | *Zonotrichia albicollis* | X | X | – | – |
| Wild Turkey | *Meleagris gallopavo* | – | X | – | – |
| Wilson's Snipe | *Gallinago delicata* | – | X | – | – |

* An "X" indicates that a species was observed or listed by the particular reference and an endash (–) indicates that it was not.

**Table 11 (continued).** Summary of eBird bird observations for two locations within CEBE: Morning Attack Trails (eBird 2023a, covering 2018–June 2023), and CEBE Belle Grove Road location (eBird 2023b, covering 2006–June 2023). As applicable, observed species are identified as grassland breeding birds (Peterjohn 2006a) or shrubland breeding birds (Peterjohn 2006b).

| Common Name | Scientific Name | Observed at CEBE Morning Attack Trails location (eBird)* | Observed at CEBE Belle Grove Road location (eBird)* | Grassland Breeding Birds (Peterjohn 2006a)* | Shrubland Breeding Birds (Peterjohn 2006b)* |
|---|---|---|---|---|---|
| Wood Duck | *Aix sponsa* | X | – | – | – |
| Wood Thrush | *Hylocichla mustelina* | X | – | – | – |
| Yellow Warbler | *Setophaga petechia* | X | – | – | X |
| Yellow-bellied Sapsucker | *Sphyrapicus varius* | – | X | – | – |
| Yellow-billed Cuckoo | *Coccyzus americanus* | X | – | – | X |
| Yellow-rumped Warbler | *Setophaga coronata* | X | X | – | – |

* An "X" indicates that a species was observed or listed by the particular reference and an endash (–) indicates that it was not.

**Table 12.** Butterfly species reported within the three Virginia counties in which CEBE is located according to Butterflies and Moths of North America (BAMONA) (BAMONA 2023d, 2023e, 2023f).

| Common name | Scientific Name | Frederick County (BAMONA 2023d)* | Shenandoah County (BAMONA 2023e)* | Warren County (BAMONA 2023f)* |
|---|---|---|---|---|
| American copper | *Lycaena phlaeas* | X | X | X |
| American lady | *Vanessa virginiensis* | X | X | X |
| American snout | *Libytheana carinenta* | X | X | – |
| Aphrodite fritillary | *Speyeria aphrodite* | X | X | X |
| Appalachian azure | *Celastrina neglectamajor* | – | – | X |
| Appalachian brown | *Satyrodes appalachia* | X | – | – |
| Appalachian tiger swallowtail | *Papilio appalachiensis* | – | X | – |

* An "X" indicates that a species was reported in the county and an endash (–) indicates that it was not.

**Table 12 (continued).** Butterfly species reported within the three Virginia counties in which CEBE is located according to Butterflies and Moths of North America (BAMONA) (BAMONA 2023d, 2023e, 2023f).

| Common name | Scientific Name | Frederick County (BAMONA 2023d)* | Shenandoah County (BAMONA 2023e)* | Warren County (BAMONA 2023f)* |
|---|---|---|---|---|
| Baltimore checkerspot | *Euphydryas phaeton* | – | X | X |
| Banded hairstreak | *Satyrium calanus* | X | X | – |
| Black swallowtail | *Papilio polyxenes* | X | X | X |
| Brown elfin | *Callophrys augustinus* | X | X | X |
| Cabbage white | *Pieris rapae* | X | X | X |
| Checkered white | *Pontia protodice* | X | X | – |
| Clouded skipper | *Lerema accius* | – | – | X |
| Clouded sulphur | *Colias philodice* | X | X | X |
| Cloudless sulphur | *Phoebis sennae* | – | – | X |
| Cobweb skipper | *Hesperia metea* | X | – | – |
| Common buckeye | *Junonia coenia* | X | X | X |
| Common checkered-skipper | *Burnsius communis* | X | X | X |
| Common roadside-skipper | *Amblyscirtes vialis* | X | X | X |
| Common sootywing | *Pholisora catullus* | X | X | X |
| Common wood-nymph | *Cercyonis pegala* | X | X | – |
| Coral hairstreak | *Satyrium titus* | – | X | X |
| Crossline skipper | *Polites origenes* | X | – | – |
| Delaware skipper | *Anatrytone logan* | X | – | – |
| Dreamy duskywing | *Erynnis icelus* | X | X | X |
| Dun skipper | *Euphyes vestris* | X | – | X |
| Dusky azure | *Celastrina nigra* | X | X | – |
| Eastern comma | *Polygonia comma* | X | X | X |

* An "X" indicates that a species was reported in the county and an endash (–) indicates that it was not.

**Table 12 (continued).** Butterfly species reported within the three Virginia counties in which CEBE is located according to Butterflies and Moths of North America (BAMONA) (BAMONA 2023d, 2023e, 2023f).

| Common name | Scientific Name | Frederick County (BAMONA 2023d)* | Shenandoah County (BAMONA 2023e)* | Warren County (BAMONA 2023f)* |
|---|---|---|---|---|
| Eastern pine elfin | *Callophrys niphon* | X | X | – |
| Eastern tailed-blue | *Cupido comyntas* | X | X | X |
| Eastern tiger swallowtail | *Papilio glaucus* | X | X | X |
| European skipper | *Thymelicus lineola* | X | X | X |
| Falcate orangetip | *Anthocharis midea* | X | X | X |
| Frosted elfin | *Callophrys irus* | X | – | – |
| Giant swallowtail | *Papilio cresphontes* | X | X | X |
| Gray comma | *Polygonia progne* | – | X | X |
| Gray hairstreak | *Strymon melinus* | X | X | X |
| Great spangled fritillary | *Speyeria cybele* | X | X | X |
| Grizzled skipper | *Pyrgus centaureae* | X | X | – |
| Hackberry emperor | *Asterocampa celtis* | X | X | X |
| Harvester | *Feniseca tarquinius* | X | – | X |
| Hayhurst's scallopwing | *Staphylus hayhurstii* | – | – | X |
| Henry's elfin | *Callophrys henrici* | X | X | – |
| Hoary edge | *Achalarus lyciades* | X | X | – |
| Hobomok skipper | *Poanes hobomok* | X | X | X |
| Horace's duskywing | *Erynnis horatius* | – | X | X |
| Indian skipper | *Hesperia sassacus* | X | – | X |
| Juniper hairstreak | *Callophrys gryneus* | X | X | X |
| Juvenal's duskywing | *Erynnis juvenalis* | X | X | X |
| Least skipper | *Ancyloxypha numitor* | X | X | X |

* An "X" indicates that a species was reported in the county and an endash (–) indicates that it was not.

**Table 12 (continued).** Butterfly species reported within the three Virginia counties in which CEBE is located according to Butterflies and Moths of North America (BAMONA) (BAMONA 2023d, 2023e, 2023f).

| Common name | Scientific Name | Frederick County (BAMONA 2023d)* | Shenandoah County (BAMONA 2023e)* | Warren County (BAMONA 2023f)* |
|---|---|---|---|---|
| Little glassywing | *Pompeius verna* | X | X | – |
| Little wood-satyr | *Megisto cymela* | X | X | X |
| Little yellow | *Pyrisitia lisa* | X | X | X |
| Meadow fritillary | *Boloria bellona* | X | X | X |
| Monarch | *Danaus plexippus* | X | X | X |
| Mottled duskywing | *Erynnis martialis* | – | – | X |
| Mourning cloak | *Nymphalis antiopa* | X | X | X |
| Northern azure | *Celastrina lucia* | – | X | – |
| Northern cloudywing | *Thorybes pylades* | X | X | – |
| Northern pearly-eye | *Enodia anthedon* | X | – | X |
| Ocola skipper | *Panoquina ocola* | – | – | X |
| Olympia marble | *Euchloe olympia* | X | X | – |
| Orange sulphur | *Colias eurytheme* | X | X | X |
| Painted lady | *Vanessa cardui* | X | – | X |
| Pearl crescent | *Phyciodes tharos* | X | X | X |
| Peck's skipper | *Polites peckius* | X | X | X |
| Pepper and salt skipper | *Amblyscirtes hegon* | – | X | X |
| Pipevine swallowtail | *Battus philenor* | X | X | X |
| Question mark | *Polygonia interrogationis* | X | X | X |
| Red admiral | *Vanessa atalanta* | X | – | X |
| Red-banded hairstreak | *Calycopis cecrops* | X | X | X |
| Red-spotted purple | *Limenitis arthemis* | X | X | X |

* An "X" indicates that a species was reported in the county and an endash (–) indicates that it was not.

**Table 12 (continued).** Butterfly species reported within the three Virginia counties in which CEBE is located according to Butterflies and Moths of North America (BAMONA) (BAMONA 2023d, 2023e, 2023f).

| Common name | Scientific Name | Frederick County (BAMONA 2023d)* | Shenandoah County (BAMONA 2023e)* | Warren County (BAMONA 2023f)* |
|---|---|---|---|---|
| Regal fritillary | *Speyeria idalia* | X | X | X |
| Sachem | *Atalopedes campestris* | X | X | X |
| Silver-spotted skipper | *Epargyreus clarus* | X | X | X |
| Silvery blue | *Glaucopsyche lygdamus* | X | X | X |
| Silvery checkerspot | *Chlosyne nycteis* | X | X | X |
| Sleepy duskywing | *Erynnis brizo* | X | X | X |
| Sleepy orange | *Abaeis nicippe* | X | – | X |
| Southern cloudywing | *Thorybes bathyllus* | X | X | – |
| Spicebush swallowtail | *Papilio troilus* | X | X | X |
| Spring azure | *Celastrina ladon* | X | X | – |
| Striped hairstreak | *Satyrium liparops* | – | X | – |
| Summer azure | *Celastrina neglecta* | X | X | X |
| Swarthy skipper | *Nastra lherminier* | X | – | – |
| Tawny crescent | *Phyciodes batesii* | X | – | – |
| Tawny emperor | *Asterocampa clyton* | X | X | X |
| Tawny-edged skipper | *Polites themistocles* | X | X | X |
| Two-spotted skipper | *Euphyes bimacula* | X | – | – |
| Variegated fritillary | *Euptoieta claudia* | X | – | X |
| Viceroy | *Limenitis archippus* | X | X | X |
| West Virginia white | *Pieris virginiensis* | X | X | X |
| White admiral | *Limenitis arthemis arthemis* | X | – | – |
| White-M hairstreak | *Parrhasius m-album* | – | – | X |

* An "X" indicates that a species was reported in the county and an endash (–) indicates that it was not.

**Table 12 (continued).** Butterfly species reported within the three Virginia counties in which CEBE is located according to Butterflies and Moths of North America (BAMONA) (BAMONA 2023d, 2023e, 2023f).

| Common name | Scientific Name | Frederick County (BAMONA 2023d)* | Shenandoah County (BAMONA 2023e)* | Warren County (BAMONA 2023f)* |
|---|---|---|---|---|
| Wild indigo duskywing | *Erynnis baptisiae* | – | X | X |
| Zabulon skipper | *Poanes zabulon* | X | X | X |
| Zebra swallowtail | *Neographium marcellus* | X | X | X |

* An "X" indicates that a species was reported in the county and an endash (–) indicates that it was not.

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