National Park Service
U.S. Department of the Interior
Shenandoah National Park

A Conceptual Basis For Monitoring Vital Signs: Shenandoah National Park







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A conceptual basis for monitoring vital signs: Shenandoah National Park

Contents

Understanding a national park's features and threats is essential for park resource preservation and monitoring 2

Shenandoah's unique natural features and location in the Mid-Atlantic region make the park ecologically valuable 4

Natural processes and disturbances play an important role in the condition of Shenandoah ecosystems 6

Shenandoah National Park is vulnerable due to its location in the Mid-Atlantic region 7

Healthy terrestrial ecosystems and enjoyable visitor experiences depend on good air quality 8

Acid rain, climate change, and exotic species cause declines in aquatic species abundance and richness 10

Native vegetation is threatened by exotic plants, insects, disease, air pollution, and visitor use ... 12

Park wildlife are threatened by exotic species, habitat loss, and wildlife disease 14

Monitoring at Shenandoah supports network- and service-wide vital signs programs 16

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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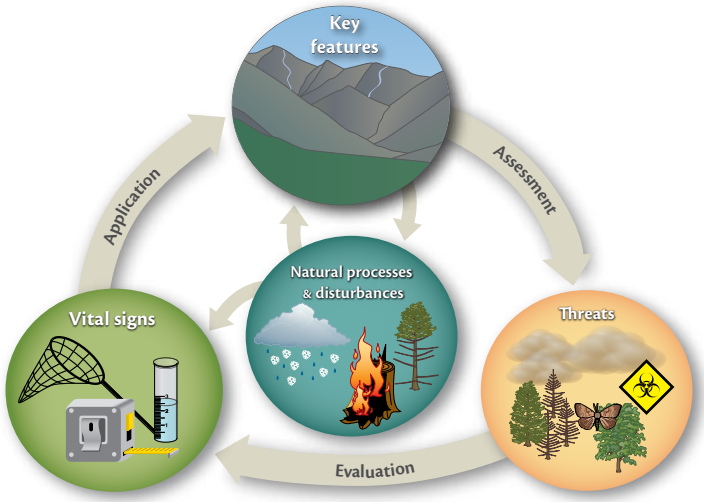
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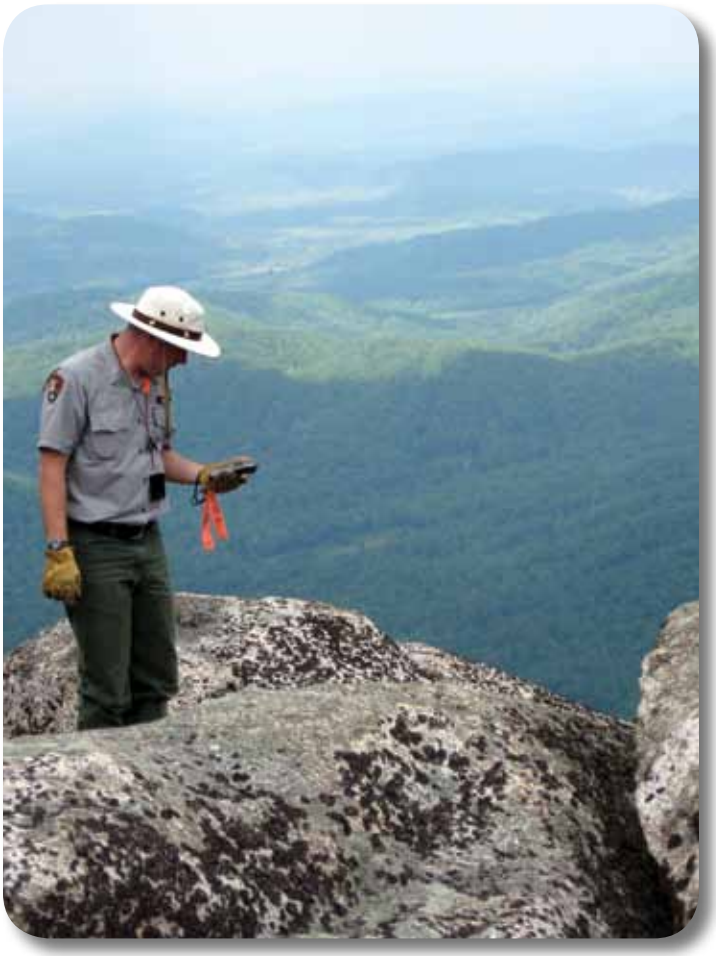
Understanding a national park's features and threats is essential for resource preservation and monitoring

Nearly 30 years ago, beginning with the first State of the Parks report in 1980, the National Park Service (NPS) and other organizations documented that the natural resources protected in the National Park System were under assault from a host of human activities.[1,2] Two major difficulties in responding to these threats were identified: 1) The NPS lacked adequate scientific information about the natural resources it was managing, and 2) information about current resource conditions and trends was also lacking. The NPS responded by placing greater emphasis on natural resource management and implementing a variety of programs, in particular the Inventory and Monitoring (I&M) Program. This booklet provides an introduction to I&M Program Vital Signs monitoring at Shenandoah National Park, a relatively large and ecologically important natural landscape in the densely populated Mid-Atlantic region.

The ***Inventory*** portion of the I&M Program documents the key features found within the parks—for example, plant and animal species, geologic substrates, and water resources.[3] Ideally, natural resource inventories also include documentation of natural processes such as weather patterns, wildland fire frequencies, and the impact of native insects and disease. Shenandoah National Park has a long history of scientific investigation, and park staff members and cooperating scientists have consistently worked to improve the quality of the park's inventory data—for example, as demonstrated by the recent development of geology and vegetation maps. Today there is ample, though not complete, documentation of the park's most obvious and easily studied key natural features.[4]



Effective monitoring is based on an understanding of key features and the processes, threats, and natural disturbances that affect those features.



NPS

The NPS uses global positioning systems (GPS) in monitoring vital signs, as when documenting rare plant locations on Old Rag Mountain.

The ***Monitoring*** portion of the I&M Program documents changes in the condition of natural resources over time and the possible impact of threats on those resources. Since the original State of the Parks report, the NPS and other organizations have regularly updated what is known about threats to park resources. These threat assessments, which can be found in several documents including the park's Resource Management Plan,[5,6] are often undertaken to call attention to park resource conditions, and to seek funding to address ecological issues. However, such synoptic, irregular assessments do not provide sufficient information to make strategic management decisions.

The NPS is charged with preserving park ecosystems for future generations. To achieve this, the Service needs to have a comprehensive understanding of the constantly changing resource conditions and the impacts of human uses in the parks.

Thus, as a significant part of I&M Program monitoring, each park selects *vital signs*—key indicators that measure the health of park resources. Monitoring these vital signs over time increases our understanding of park natural systems, the natural variations in those resources over time, and the influences of human activities on those resources.



NPS

In order to monitor stream health, park staff take water quality measurements that include sediment, nutrients, pH, and water temperature.



NPS

Park staff identify common, rare or uncommon, imperiled, and critically imperiled plant species to monitor vegetation in Shenandoah.

This document provides an explanation of the conceptual basis that was used to select the vital signs for Shenandoah National Park. The next two sections describe key natural resources in the park, the regional setting in which it is located, and some of the ecological disturbances and natural processes that occur in the park and environs. The following five sections provide thumbnail sketches of the threats to park resources, including in–depth explanations of the highest priority threats. Understanding both natural processes and threats is paramount to the process of selecting vital signs, which is summarized in the last section of the report. This last section also describes the broader objectives of monitoring; the relationship of monitoring to park management, research, and public education; and how the vital signs selected for Shenandoah National Park relate to those that have been chosen by the Mid–Atlantic Inventory and Monitoring Network of which Shenandoah is a part.



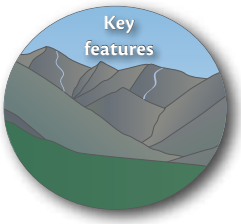
NPS

Park staff count seedlings to monitor forest regeneration.

Shenandoah National Park Vital Signs Monitoring

This publication explains why the National Park Service undertakes natural resource monitoring at Shenandoah National Park and why each vital sign has been selected for monitoring. Brief introductory material is presented, followed by the justification for resource monitoring. An effective resource monitoring is founded on three basic steps:

- Gain an understanding of the key features of a park together with the natural processes and disturbances that influence those features;
- Enumerate and assess the nature and extent of human-caused threats to those resources; and
- Make decisions about what is to be monitored based on the information established in the first two steps.



Shenandoah's unique natural features and location in the Mid-Atlantic region make the park ecologically valuable

Shenandoah has ecological and social connections to the Chesapeake Bay and surrounding areas

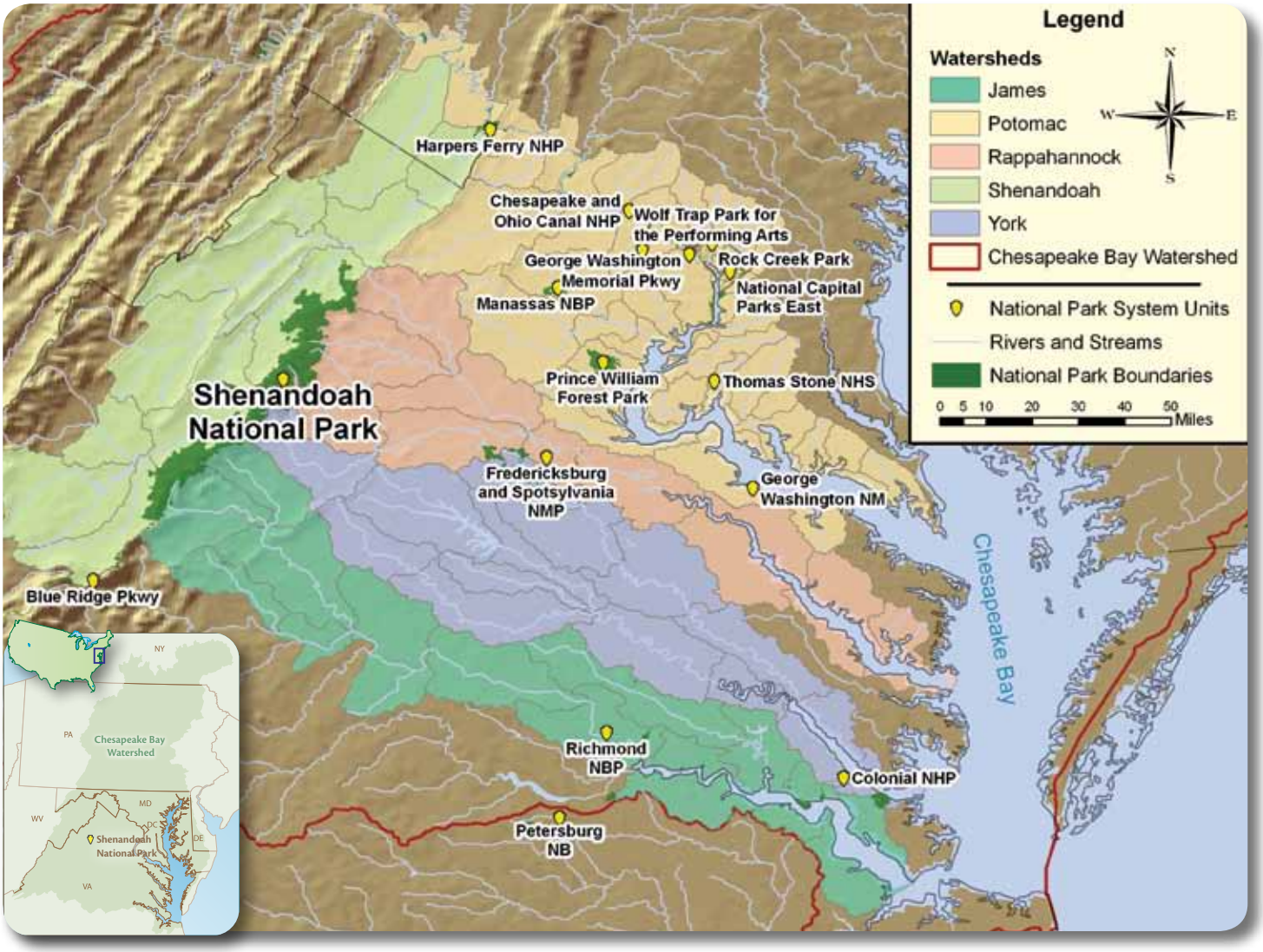
Located near one of the most densely populated parts of the country, Shenandoah National Park is a nearly 200,000–acre natural oasis in the midst of urban, suburban, and agricultural development. Spanning the Blue Ridge Mountains, Shenandoah is covered primarily by Appalachian Oak Forest, a diverse mix of oak-hickory communities that vary by elevation and along topographic and hydrologic gradients.[7] The park also contains the headwaters of three major rivers—the James, Potomac, and Rappahannock—which flow directly into the Chesapeake Bay.[8] Shenandoah National Park is ecologically similar to other NPS units in the Appalachian region, including the Blue Ridge Parkway, Great Smoky Mountains National Park, and Catoctin Mountain Park.

Shenandoah National Park's climate is typical of the Eastern Temperate Forest Ecoregion, characterized by warm summers and cold winters. In early spring, 'green–up' unfolds progressively up the mountain slopes. Throughout the summer, wildflowers, flowering trees, and shrubs bloom. When fall arrives, foliage turns a beautiful patchwork of colors.

A number of unique natural features and resources make Shenandoah National Park ecologically important and attractive to visitors. These features include steep mountain streams and riparian corridors, high–elevation rock outcrops, deciduous forest interspersed with conifers, and substantial parcels of designated wilderness.[4] Skyline Drive and nearly 500 miles of trails provide park visitors with outstanding scenic vistas of valleys and ridges to the west, the Piedmont to the east, and the many hilltops and mountains of the Blue Ridge to the north and south.

Park streams provide habitat for a diversity of aquatic species

Shenandoah National Park is well known for its relatively high–gradient coldwater streams. Over 200 streams and numerous associated springs, seeps, and wetlands provide cold, clean water that supports a diverse community of aquatic organisms—including more than 250 taxa of macroinvertebrates, 35 species





Left: NPS, Right: nps

Jen Hilke, NPS

NPS

Top: NPS; Bottom: nps; Right: Alan Williams, NPS

NPS

Shenandoah National Park has unique plant and animal communities, high-gradient streams, beautiful vistas, and rocky landscapes. Skyline Drive runs along the Blue Ridge Mountains and allows visitors to view scenic landscapes. Photos (clockwise from top right): Rock outcrops; Scenic vista; Cedar waxwing; Veiny pea; Blood root; High gradient stream; White-tailed deer; Black bear.

of fish, and 20 species of amphibians. Streams in the park represent a regional stronghold for brook trout, with more than 65 populations documented.[9,10] Park streams also provide an opportunity for visitors to wade and angle for native fish in relatively pristine habitats. A significant number of people visit the park to fish for brook trout.

The forest cover extends throughout the park

Ninety-five percent of Shenandoah National Park is forested with large unfragmented Eastern Deciduous Forest stands of oak-hickory, cove hardwood, and tuliptrees. Forest is a key component of the ecological foundation of the park and the matrix within which many aspects of park operations take place.

Shenandoah contains rare plant communities

Shenandoah National Park is a refuge for many locally and globally rare plant species, and 12 globally rare plant communities.[4] Rare plants are found throughout the park, especially in wetland and rock outcrop habitats. The wetland plant communities at Big Meadows and rock outcrop communities such as at Hawksbill Mountain are found only in the park.[7,11] Staff and volunteers are working to document the locations of over 500 populations of 80 rare plant species found in the park.

A diversity of animals live in Shenandoah

The park's large expanses of forested habitat support a variety of animals. Over 50 species of mammals live in the park, ranging from abundant large mammals, such as white-tail deer and black bear, to relatively rare small mammals, such as the Allegheny woodrat. Other abundant mammals include bobcats, raccoons, and skunks. The park is also home to over 200 species of resident and transient birds,[12] and provides essential breeding and migration corridor habitat for neotropical migrants. Over 50 documented species of reptiles and amphibians inhabit a variety of habitats in the park, from rock outcrops to forested ridges to seasonal wetlands. One amphibian, the federally endangered Shenandoah salamander, is found nowhere else on earth.

It is unknown how many different types of terrestrial invertebrates are present in the park. However, some groups are known more thoroughly, such as butterflies and native forest insects including the fall canker worm—that sometimes feed heavily on trees.



Natural processes and disturbances play an important role in the condition of Shenandoah ecosystems

Key features



- Mountain terrain
- Rock outcrops
- Deciduous forest
- High gradient streams

Natural processes



- Weather & climate
- Wildland fires
- Native insects
- Native plant diseases
- Flood & drought
- Herbivory & predation

Vital signs monitoring



- Weather & climate
- Wildfire behavior & effects
- Stream and river water dynamics

Shenandoah is influenced by a variety of natural disturbances and processes that are important to understanding the condition of park resources. Three vital signs (Weather, Wildfire behavior and effects, and Stream and river water dynamics) have been selected to help document the natural disturbances and processes listed below.

Weather and climate—Ice storms, wind storms, heavy snows, and hurricanes all occur fairly frequently in the region. These weather events influence the flow of ground and surface water, and create gaps in the forest.



NPS



Alan Williams, NPS

Native plant diseases—Naturally occurring diseases such as leaf spot and shoestring root rot play significant roles in park ecosystems. They may cause tree death, which reduces habitat and forage for some animals but increases habitat for others.



Alan Williams, NPS

Wildland fire—If fuel conditions are right, lightening strikes can ignite fires. Generally, fires are relatively small, but under certain conditions, they grow. They help decompose forest litter, create gaps in the forest, and regenerate species that depend on fire for seed release.



David Demarest, NPS

Flood and drought—Many ecosystems, like those in the park, experience cycles of wet and dry conditions. These conditions may be extreme and may lead to new or re-routed stream channels, plant die-back, declines in groundwater, and altered aquatic communities.



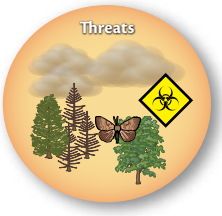
Top and Bottom: Alan Williams, NPS

Native insects—Native insects and other invertebrates play important roles in park ecosystems. They help to pollinate plants, aerate soil, and decompose debris—processes vital for proper ecosystem function.



NPS

Herbivory and predation—Park animals, large and small, depend on foraging mechanisms to survive. Often, foraging fosters nutrient cycling, habitat development for other animals, and vegetation growth.



Shenandoah National Park is vulnerable due to its location in the Mid-Atlantic region

The park's location within the Mid–Atlantic region exposes its natural resources to a number of threats including air pollution, water degradation, and land use change. Since Shenandoah National Park is within a half–day's drive of large urban areas such as Washington, D.C., Baltimore, and Philadelphia, the park attracts many visitors. Heavy visitor use and adjacent development result in increased habitat fragmentation, pollution, and spread of exotic pests and pathogens that threaten park resources.

Air pollution, primarily from burning fossil fuels in Virginia and the Ohio River Valley, affects the park as acid precipitation, ground–level ozone, poor air quality and resulting impaired visibility, and deposition of contaminants.[13]

A lesser–known, but just as serious, threat is the invasion of exotic species—plants such as Japanese stiltgrass, tree of heaven, and oriental bittersweet,[14] and insects including gypsy moth and hemlock woolly adelgid.[15] Exotic diseases such as dogwood anthracnose, beech bark disease, and chestnut blight also pose a threat.[16] Other exotic plants, insects, and diseases have not yet been found in the park but are known to be in close proximity.

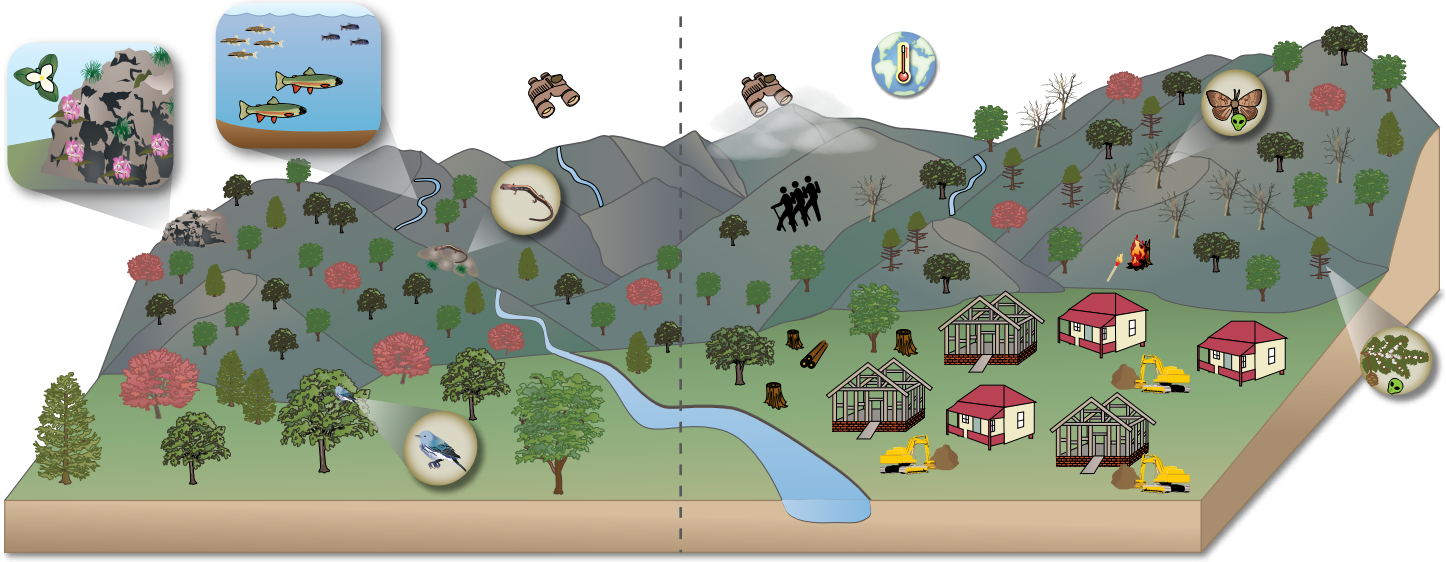
Human pressures and depreciative visitor behavior such as littering, improper disposal of human waste, trampling rare plants, and feeding wildlife threaten park resources. Climate change, largely induced by human activities, complicates the interrelationships of these threats.[17,18]

The selection of vital signs is guided, in part, by a need to better understand these influences and an interest in detecting emerging threats at an early stage—when combating them may be most effective.



Joanna Woerner, IAN/UMCES

Increased development around Shenandoah impacts park ecosystems.



Natural park conditions

- Pristine scenic views (good air quality)
- Native plant communities
- High–elevation cold–water streams
- Rare plant species (sword leaf phlox)
- Rare animal species (Shenandoah salamander)
- Bird habitat

Threats to park conditions

- Obstructed scenic views (poor air quality)
- Invasive exotic species (gypsy moth , Hemlock woolly adelgid)
- Exotic diseases and tree death
- Increased adjacent development
- Human–caused fire
- Global climate change
- Intensive/depreciative visitor use

Internal threats to the park include invasive exotic plants and insects, fire, and intensive or depreciative visitor use. External pollution from motor vehicle and power plant emissions add contaminants to the air and result in haze and acid rain within the park. Increased development encroaches on park habitat.

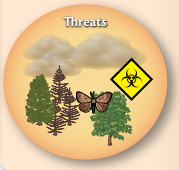
Healthy terrestrial ecosystems and enjoyable visitor experiences depend on good air quality

Key features



- Visibility & views
- Mountain elevations
- Respiration & water essential to all organisms

Threats



- Acid rain
- Ozone
- Haze
- Air pollutants
- Contaminants

Vital signs monitoring



- Visibility and particulate matter
- Ozone
- Mercury deposition
- Wet/dry deposition

Pollutants from a variety of sources impact air quality

Air pollutants have detrimental effects on sensitive resources in Shenandoah National Park. These include primary pollutants emitted directly from sources (e.g., sulfur and nitrogen oxides), and secondary pollutants that are formed as a result of chemical reactions in the atmosphere (e.g., sulfates and ozone). Pollutants are emitted from stationary sources (industry) and mobile sources (vehicles), and some can be transported very long distances. Stationary sources, mostly consisting of coal-fired power generators, produce 90% of the sulfur dioxide emissions from the five states that contribute most to air pollution in the park.[13] Fuel combustion in vehicles and heavy equipment, as well as some industrial emissions, are the principal sources of nitrogen oxide pollution. Long-term monitoring of these pollutants and of climate provides vital information to determine their environmental effects, and ultimately to protect ecosystem and human health.

Acid rain alters soils

Sulfuric and nitric acids are secondary pollutants that form in the air and reach the ground through rain, fog, and snow or through dry deposition. The main cause of acid rain in the park is sulfur oxides from burning fossil fuels. Shenandoah has some of the highest level of acid deposition of any NPS unit in the country where data are available.[19] An estimated 2.5 million pounds of sulfur were deposited across Shenandoah in 2006. Even more strikingly, much higher acid deposition levels were documented in previous decades.[20] About one-third of the park is underlain by silica-based geology that has a poor ability to neutralize acid deposition. Although only limited data are available, it appears that the soils in these sensitive areas are unable to absorb deposited sulfur, which leads to altered soil chemistry and contaminant accumulation, probably impacting plant health. Such chronic alterations to soil chemistry are not totally reversible and damage may persist for centuries even if all air pollution was stopped today.[13]



NASA

A red oak showing signs of ozone damage.



Adrian Jones, IAN/UMCES

Power plants both nearby and far from Shenandoah produce air pollutants that impact park ecosystems.

Ground ozone harms plant life and public health

Shenandoah National Park has some of the highest levels of ground-level ozone documented in any national park.[21] Ground-level ozone is a secondary pollutant that forms in warm weather when sunlight interacts with pollution from cars and industrial processes (often originating distant from the park). The effects of ozone on forest ecosystems include injured leaves, compromised plant respiration, increased tree stress in drought conditions, and reduced plant growth and survival. Elevated ground-level ozone also create serious health risks for people with asthma and lung disease.

Haze reduces the visibility of park vistas

Some of the most visited and well-loved features in the park include overlooks along Skyline Drive, vistas from the Appalachian Trail, rock outcrops, and mountain peaks such as Old Rag. Clear views from these locations are integral to visitor experiences, yet visibility (the distance at which a person can see an object clearly) is impaired by particulate air pollution, primarily ammonium sulfate. The current annual average visual range is only 20% of the estimated natural visual range (meaning 80% is lost to pollution). Regulatory agencies currently have a long-term goal of zero human-caused visual impairment in parks, which leaves much room for improvement.

The effects of environmental contaminants need further study

A variety of human–made chemical contaminants can be found in very remote locations including park ecosystems. Although airborne toxins and pollutants are deposited across the region, deposition rates are generally higher in mountainous terrain, increasing the burden of this pollution on Shenandoah National Park. Monitoring has yielded some information about how mercury, a toxic heavy metal that especially affects aquatic life, impacts the watersheds within the park.[22] Toxic pollutants may also have an effect beyond park boundaries when they are transported by rivers flowing through the park into parks in the adjoining NPS National Capital Region and ultimately into the Chesapeake Bay. The park staff need to learn much more about which harmful contaminants are present in the park and the possible threats they pose to park natural resources, which may in turn lead to a need for expanded monitoring activities.

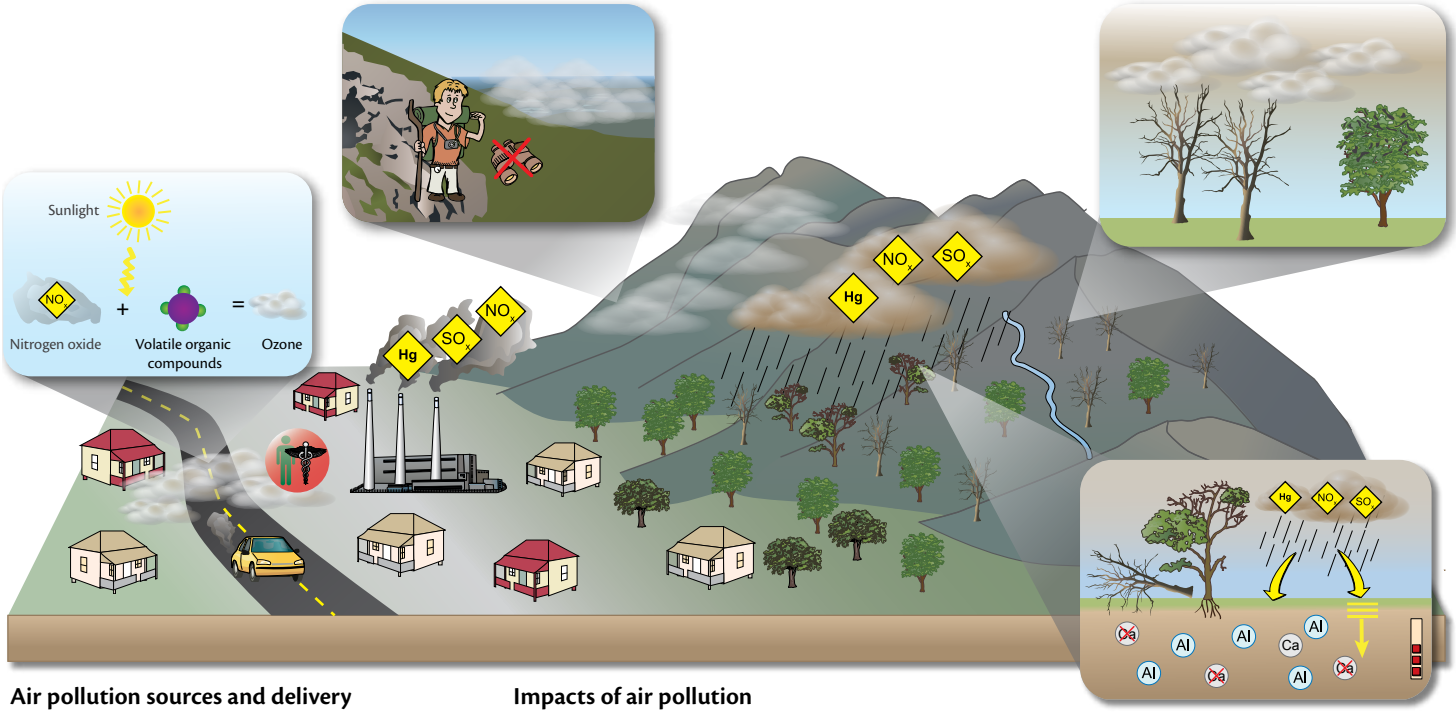
Air quality issues require complex monitoring

To understand the complex and serious impacts from air pollutants, the NPS has implemented a sophisticated monitoring program, often carried out in concert with other federal and state agencies and organizations. This program tracks the vital signs related to air quality for Shenandoah National Park: Visibility, Ozone and various gaseous pollutants, Mercury deposition, and Airborne particulates.



USGS, NPS

Differences in visibility from a park vista on a typical "good" summer visibility day versus a poor summer visibility day. Poor visibility caused by air pollution can obscure the ability to see beyond approximately 6 miles.



Air pollution sources and delivery

- Industrial and power plant emissions
- Vehicle emissions
- Household emissions
- Acid rain
- Ozone
- Haze

Impacts of air pollution

- Reduced visibility
- Contaminant accumulation (air)
  - Hg Mercury
  - NO_x Nitrogen oxides
  - SO_x Sulfur oxides
- Contaminant accumulation (soil)
- Altered soil chemistry (decreased calcium & mobilized aluminum)
- Acidification
- Foliar damage and tree death
- Public health threats (ground–level ozone)

External sources of air pollution, such as power plants and vehicles emit pollutants and volatile organic compounds into the air. These substances react with sunlight and create a smog made of ozone gas. Ozone at ground level poses potential public health risks. Contaminant accumulation and haze, a result of particulates and water molecules in the atmosphere, reduce visibility from park vistas, change soil chemistry, and damage plants.

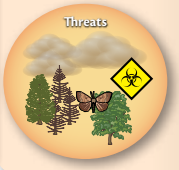
Acid rain, climate change, and exotic species cause declines in aquatic species abundance and richness

Key features



- High-elevation streams & waterfalls
- Clean, cold water
- Brook trout/angling

Threats



- Acid rain
- Weather events
- Climate change
- Exotic species

Vital signs monitoring



- Fish & stream habitat
- Aquatic macroinvertebrates
- Water quality/quantity
- Acid deposition

Shenandoah National Park is well known for its relatively high-gradient coldwater streams. Many of those streams and their associated wildlife are very sensitive to human-caused disturbances.

Air pollution, weather events, and exotic species threaten coldwater streams

Most known threats to aquatic ecosystems in the park are associated with air pollution and weather events. For example, acid deposition from air pollution is a pervasive issue in the park. The response of watersheds in the park to acid deposition depends on the characteristics of their underlying bedrock.[9] Basaltic and granitic bedrock is capable of buffering acid rain, thus reducing its effects. In contrast, siliciclastic bedrock has a poor buffering capacity; as a result, the pH of water flowing over siliciclastic bedrock is much reduced by acid rain, with negative effects on aquatic communities.[23] Chronic and episodic acidification events ultimately reduce aquatic species abundance and diversity in sensitive watersheds.[24] Monitoring data from some streams indicates that acid rain is associated with a decline in key macroinvertebrates, such as mayflies.[25,26] Similar effects may occur in fish communities, with fewer fish species observed in acidified streams.[27]



NPS

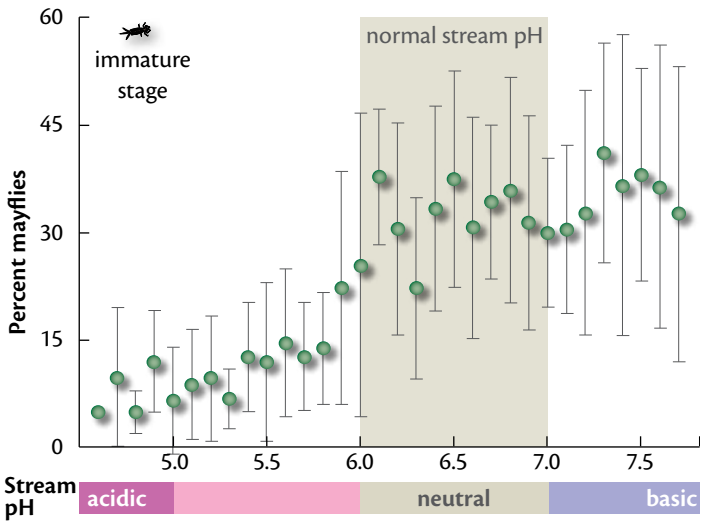
National Park Service personnel electrofishing on the Staunton River to gather information on fish populations.

In addition, climate change may increase air and water temperatures, and may also change the frequency and duration of both floods and droughts—all of which may threaten the



Hugh Crandall

Cold, clean water and associated aquatic communities are found throughout Shenandoah National Park.



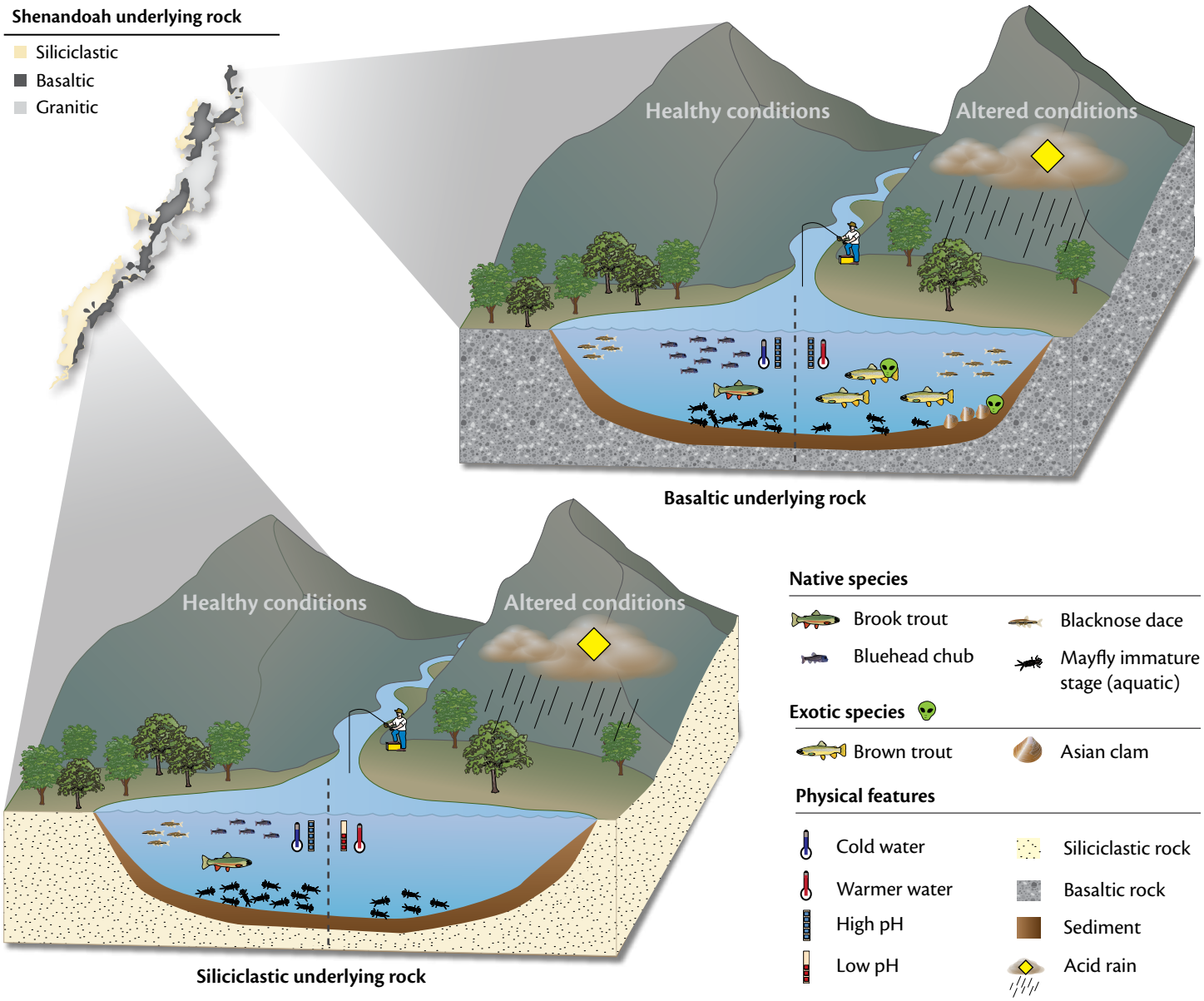
Sensitive aquatic organisms—such as mayfly larvae—can be negatively influenced by acid rain, which lowers water pH.[9]

cold–water aquatic communities characteristic of the park. Other threats to aquatic communities are localized, such as the presence of exotic animals in some park streams.[28] Exotic organisms can alter ecosystem processes by disrupting predator and prey relationships or by outcompeting native fauna.[29]

Biological, chemical, and physical monitoring are conducted to observe aquatic ecosystems

In order to document changes in aquatic ecosystems, park personnel and cooperators monitor a variety of biological, chemical, and physical vital signs in park watersheds: Fish and stream habitat, Aquatic macroinvertebrates, Water quality/quantity, and Acid deposition. More than 40 streams are monitored for both fish and macroinvertebrate community composition and species abundance. Staff and volunteers visit these sites and collect data on fish populations and macroinvertebrates using accepted protocols. Current distributions of warm– and cold–water fish species and macroinvertebrate abundance have been determined, and with this baseline documentation in hand, future changes in the aquatic biota can be detected.

Park staff physically quantify stream habitat, such as channel substrates, or use instruments to record information on water quality and quantity, such as volume of flow, water pH, temperature, and conductivity.[30] Cooperators and staff frequently monitor stream water chemistry across fourteen park watersheds with a range of geologic buffering capacities. Automated event samplers at three of these sites document episodic precipitation events that change stream chemistry—especially pH.



Effects of acid rain on water quality differ based on the underlying watershed geology. Basaltic underlying geology has a high capacity to buffer acid rain, but streams are still susceptible to a warming climate. As such, threats to aquatic ecosystems in basaltic situations are associated with warmer water temperatures but not an altered pH. Siliciclastic underlying geology has a low capacity to buffer acid rain, and streams are also susceptible to a warming climate. Thus, both warmer water temperatures and an altered pH influence stream biota. For example, fewer fish species or sensitive macroinvertabrates and insects are observed in acidified streams.

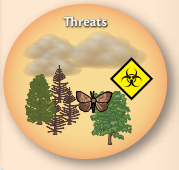
Native vegetation is threatened by exotic plants and insects, exotic disease, air pollution, and visitor use

Key features



- Forest vegetation
- Rare plants & communities

Threats



- Exotic plants & insects, & exotic diseases
- Air pollution
- Human impacts

Vital signs monitoring



- Forest plants
- Invasive/exotic plants
- Threatened/rare plants
- Exotic insects & diseases

Natural ecosystem processes lead to changes in plant species abundance and distribution over time, as has been well documented for some parts of Shenandoah National Park.[31] However, the park's plant communities also face a number of human–caused threats including exotic species, air pollution, and trampling by visitors.

Human–caused threats alter plant abundance and distribution

Studies have shown that a number of exotic plants widely regarded as invasive are abundant in Shenandoah National Park.[32] Although trends over time are less clear, it appears that the distribution of many exotics in the park may be increasing. In addition, the park has been severely impacted by exotic insects such as hemlock woolly adelgid and gypsy moth.[33,34] These insects are managed to minimize damage to native trees, protect visitor safety, and preserve the affected tree species for future restoration. Exotic plant diseases such as chestnut blight have caused severe damage to park trees.

Plant life in some locations of the park is also threatened by trampling. Key visitor locations, such as rock outcrops that provide sweeping views of vistas but are also home to rare plants, experience heavy visitor use resulting in trampling of plants and lichens.

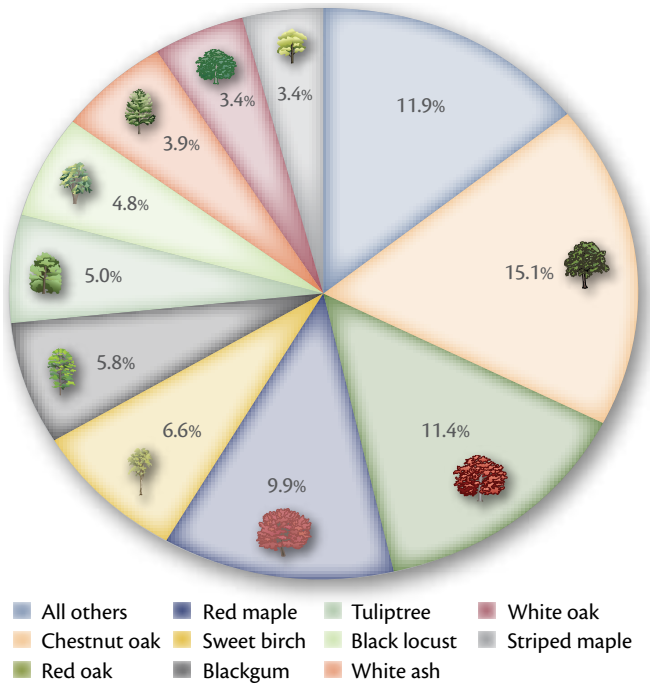
Early detection of large forest changes can help protect native species, communities, and ecosystems

Four vital signs have been selected to monitor the status of plant communities in Shenandoah National Park: Changes in forest vegetation, Rare plant status, Location and abundance of exotic plants, and Surveillance for emerging insects and disease. The park's forest monitoring program was initiated in 1987, and has gathered data on forest vegetation at regular intervals in order to detect changes in resource conditions and to make observations about emerging threats to forest health.[35,36,37] This program has included fire fuels monitoring, which provides information for fire behavior models critical to making decisions when fighting

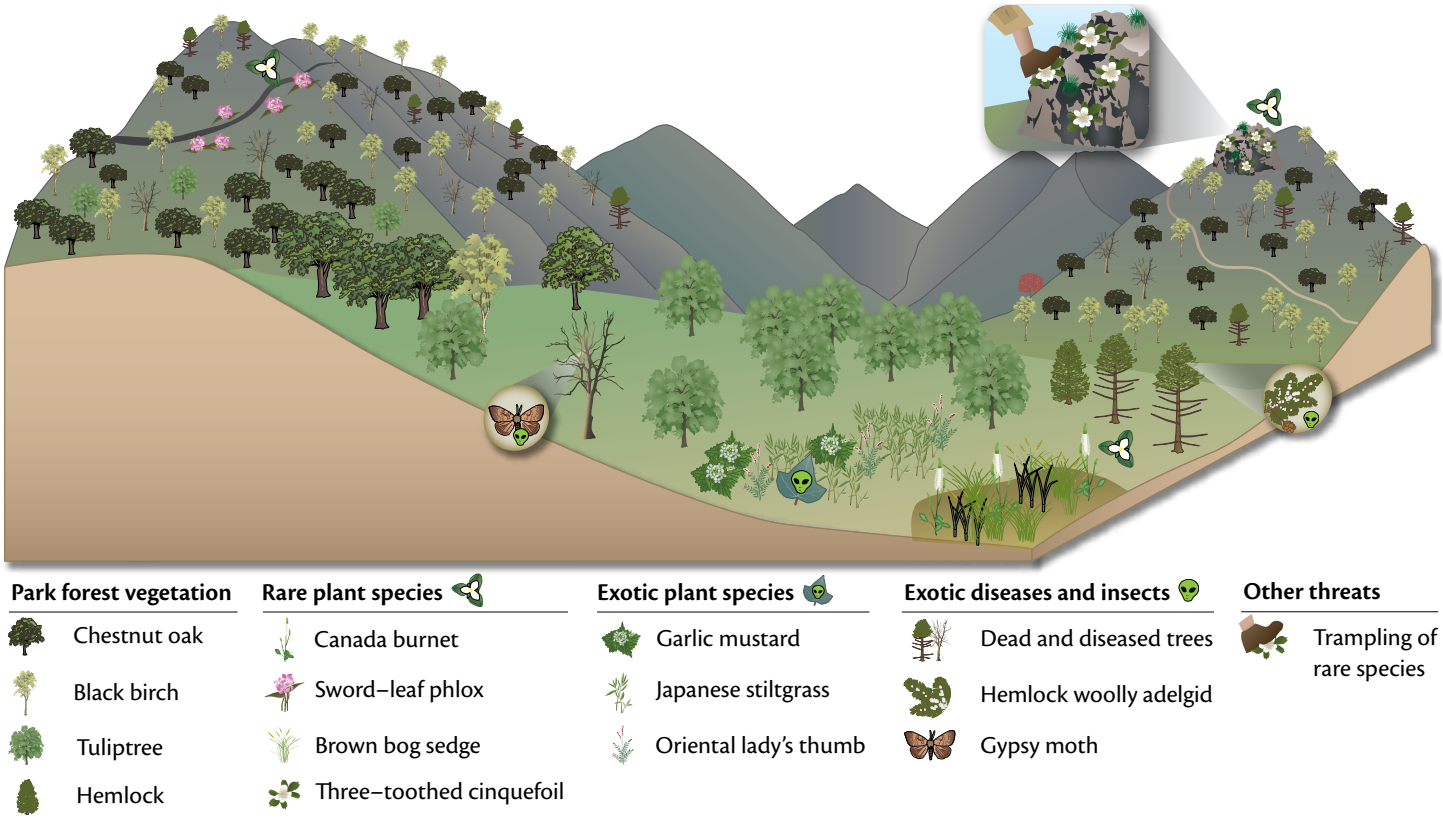


Gary Fleming, Virginia Department of Conservation & Recreation

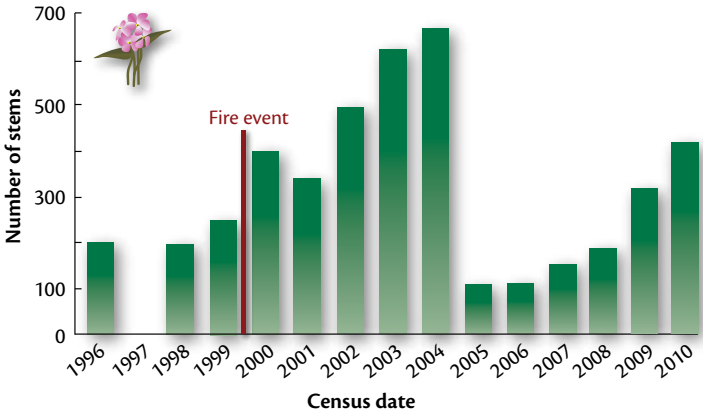
The rare high-elevation greenstone outcrop barren plant community is found on fewer than four acres.



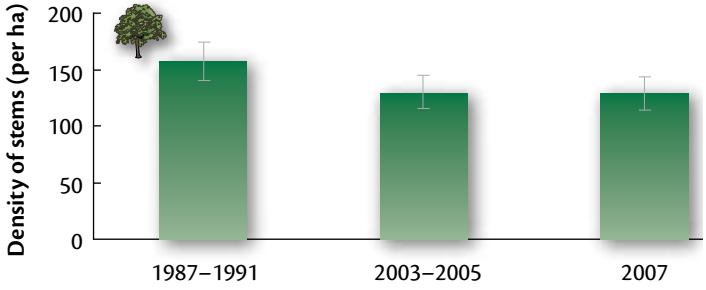
The 10 most prevalent of 53 tree species found in the forest monitoring plots at Shenandoah National Park.



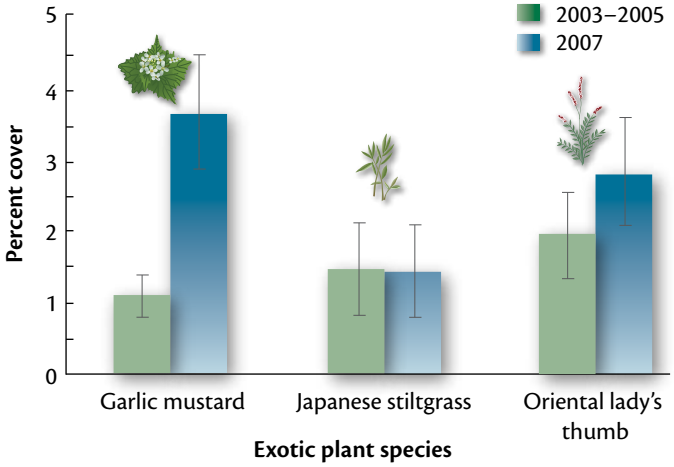
The park contains 80 rare plant species and 12 globally rare communities that also support wildlife. However, native plant species are threatened by invasive exotic plants, insects, and diseases.



Change over time in the number of stems of sword-leaf phlox, one of the rare plants in Shenandoah. Populations of this species are cyclic and respond favorably to disturbances, such as fire events.



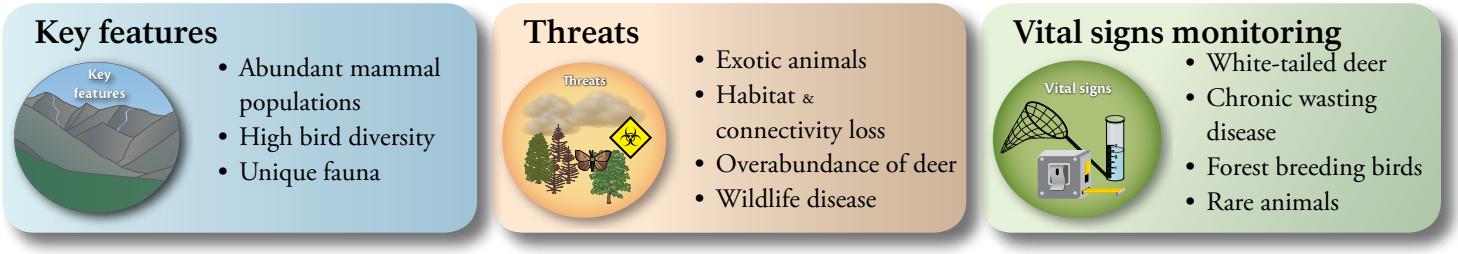
The density of oaks with a diameter greater than 20 cm (7.9 in) in forest monitoring plots in 1987–1991 was larger than in 2007. One possible explanation is that oak trees in the park have been heavily impacted by insects (primarily gypsy moth) and disease.



Park staff monitor exotic plant cover to inform management decisions. In general, exotic plant cover has increased or remained the same over time.

wildfire. Rare plant monitoring records the location and status of each species and detects threats such as trampling or invasive species encroachment. As of 2008, this program had collected data on 80% of the plants designated as rare by the State of Virginia, with extensive monitoring data available for 61%. Exotic plant monitoring identifies invasive species, assesses their proximity to high-value resources, and examines changes over time.[36] Emerging threats include emerald ash borer, sudden oak death, and beech bark disease.[15] These could potentially negatively impact the park's hardwood forest. To minimize these impacts, early detection surveys are conducted, often with the cooperation of the U.S. Forest Service and the Virginia Department of Forestry.

Park wildlife are threatened by exotic species, habitat loss, and wildlife disease



Natural ecosystem processes influence wildlife species abundance, distribution, and health but the park's wildlife also face many human–caused threats including the spread of exotic species and disease and habitat fragmentation.

Changes in forest communities affect mammals and birds

Changes in forest communities due to exotic species invasion, air pollution, and natural disturbances can affect mammal populations by altering food and cover availability.[38] In addition, development of nearby private lands can impact park mammals by isolating them from surrounding populations and habitat.[39] Some areas of the park have an overabundance of white–tailed deer (>100 white–tailed deer per square mile),[40] which has resulted in overgrazing of understory plants, limited forest regeneration, and altered insect, bird, and small mammal habitat.[41] Due to altered habitat continent–wide, some bird populations, including neotropical migrants, have declined during the past 30 years.[42] Because the most significant causes of this decline are habitat loss and fragmentation, large areas of protected refuge, including the park, have become increasingly important to neotropical birds.

Invasive exotic animals impact park ecosystems

Invasive forest insect pests are a major threat because they can devastate wildlife habitat and compete with native insects. Invasive insects include exotic hemlock woolly adelgid, gypsy moth, beech scale, and emerging threats such the emerald ash borer, which has been documented only 50 miles from the park.[33] Coyotes, an exotic mammal in the East, have been documented in the park, but their effect on native fauna is unknown.

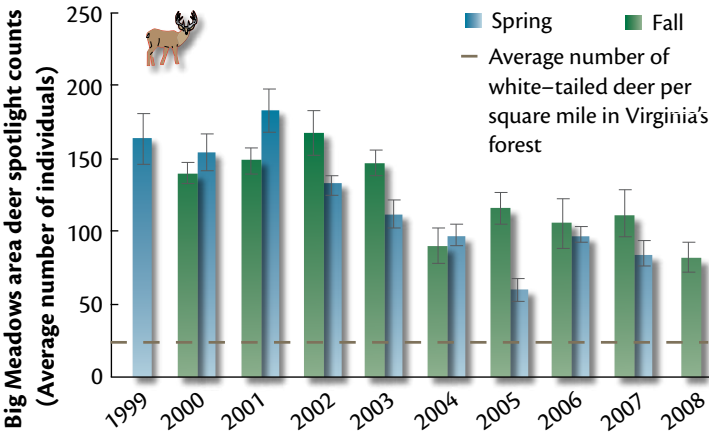


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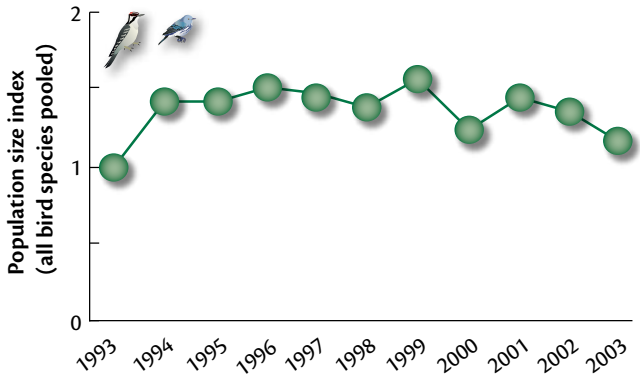
Peregrine falcons nest on the rock outcrops in the park.

Diverse monitoring efforts track wildlife status

A number of different monitoring programs provide data for vital signs related to wildlife—White–tailed deer abundance, Forest breeding birds, and Rare animal presence, and Chronic wasting



Compared to other forests in Virginia, Shenandoah has an overabundance of white–tailed deer. Grazing done by these deer creates a browse line in the vegetation.[40]



Overall, bird populations from 1993–2003 were stable. The population increase during 1993–1994 is likely due to a rebound from the effects of widespread gypsy moth defoliations prior to 1993.[43]



Lester Via, NPS

The Shenandoah salamander, a unique animal that lives on the high-elevation rocky slopes of the park, is found nowhere else on earth.



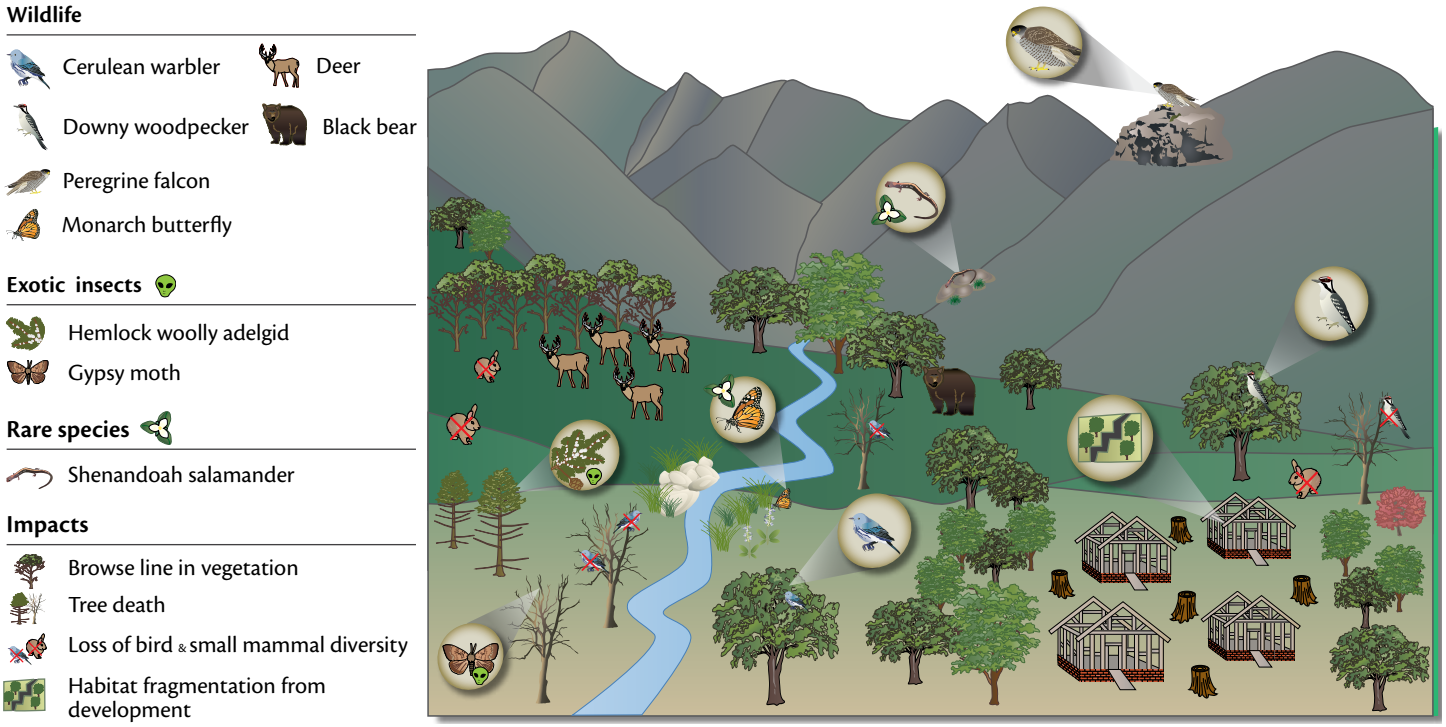
Eric Reuter, NPS

The monarch butterfly relies on road shoulder habitat along Skyline Drive.

disease presence. In order to document changes in mammal populations, staff conduct spotlight counts of white-tailed deer abundance, monitor the abundance of acorns and other mast crops (fruits or nuts eaten by wildlife) to detect variations in food availability, and cooperate with researchers to monitor key small mammals. Current bird monitoring efforts include breeding bird surveys, Christmas counts, high-priority species surveys, and cliff nesting surveys. Continued monitoring of bird populations is critical, as birds are indicators of ecosystem health.[44] Staff and cooperators also assess populations of select reptile and amphibian species at several sites in the park.

Due to the recent emergence of the exotic chronic wasting disease (CWD) in nearby Hampshire County, West Virginia,[45] the park monitors its white-tailed deer for the presence of this disease. CWD is a neurological disease in white-tailed deer that causes brain lesions, weight loss, behavioral changes, and eventually death. There is currently no evidence that CWD is transmissible to humans or domestic livestock. As of 2010, all lab results from sampled white-tailed deer in the park have been negative.[26]

Shenandoah National Park also uses volunteer groups to accomplish monitoring goals. For instance, annual butterfly counts are largely completed by volunteers. Finally, park staff monitor and manage select invasive animals, such as the gypsy moth, to minimize their impact on native flora and fauna and to protect visitor safety.

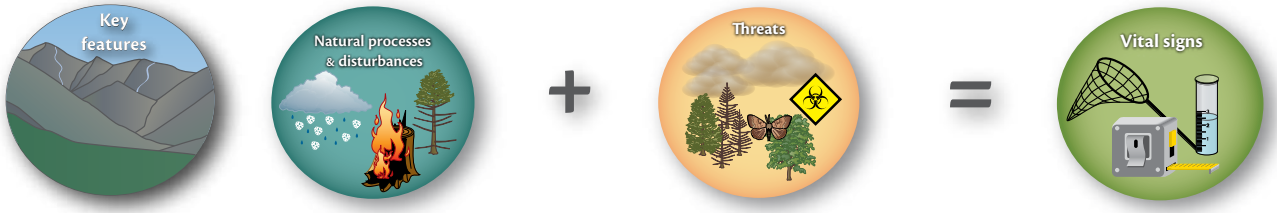


There are many threats to wildlife in Shenandoah. For example, an overabundance of deer causes overgrazing and a browseline appears in the vegetation. Exotic insects such as hemlock woolly adelgid and gypsy moth lead to tree death. Other threats include loss of bird and small mammal diversity. Development and growth on nearby private lands can fragment habitat and isolate wildlife populations.



Monitoring at Shenandoah supports network- and service-wide vital signs programs

Shenandoah vital signs selection process



An understanding of park resources and the threats to those resources leads to informed vital sign decision-making.

Vital signs were chosen to represent the overall health of Shenandoah

Because vital signs are intended to represent the overall health of park natural resources, their selection depends on a sound understanding of park conditions. Thus, information on key features of the park, natural processes occurring in the park, and the nature and extent of threats to those resources was used to identify potential vital signs for monitoring in Shenandoah National Park. Park staff selected potential vital signs to achieve the following:

- Determine the status and trends in park ecosystems to allow managers to make better–informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources;
- Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management;
- Provide data to better understand the dynamic nature and condition of park ecosystems and to determine reference points for comparisons with other, altered environments;
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment; and
- Provide a means of measuring progress towards performance goals.

After, the potential vital signs were peer reviewed and vetted by the Mid-Atlantic Inventory and Monitoring Network, a final list of park vital signs were selected for monitoring.[46]

Monitoring vital signs supports management, research, and education

The information obtained through vital signs monitoring is applied to management planning, research, education, and outreach about park natural resources. For example, fisheries monitoring not only gives an indication of the health of park fisheries but is used to evaluate park fishing regulations and actions taken to control exotic fish species. Also, ozone information is used to make decisions about the issuance of public health advisories. Vital signs data about exotic plants and insects help park resource managers determine when and where control efforts will be undertaken.

Vital signs data are also useful to scientists conducting research in the park. For instance, a research project may require weather and climate data to understand the context in which natural resource conditions are changing. Similarly, park staff present many public programs and exhibits and produce monitoring publications. Frequently, the basis for those programs and publications is vital signs data.

Data gained from monitoring these vital signs inform management decisions and support the NPS goal of preserving natural resources for future generations.



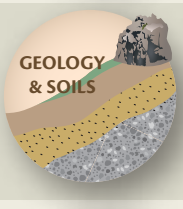
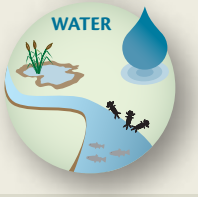
NPS

Vital signs help park staff monitor trends in park ecosystems and gather information that allows managers to make better-informed decisions.

Monitoring vital signs supports Network–wide monitoring

Shenandoah National Park is part of the Mid–Atlantic Inventory and Monitoring Network, which includes nine NPS units in the Piedmont and Coastal Plain of Virginia and Pennsylvania. Many of the Mid–Atlantic Network units are small cultural parks, so Shenandoah is unique in being a large natural area.

The vital signs developed by the Mid–Atlantic Network and Shenandoah staff are tiered from a larger service–wide framework. The table below lists the vital signs chosen for Shenandoah, how they fit in the service–wide framework, and how they overlap with network vital signs. The park's long monitoring history continues to provide a wealth of experience for other networks and monitoring programs.

NPS Vital Sign category	Shenandoah Vital Sign	Vital Sign measurement	Mid–Atlantic Network Vital Sign
			
Air quality	Ozone	Atmospheric ozone concentration	✓
	Wet/dry deposition	Wet/dry deposition chemistry	✓
	Visibility and particulate matter	Haze index, particulate matter	✓
	Contaminants (mercury)	Mercury deposition	✓
Weather & Climate	Weather & climate	Ambient air temperature, precipitation, wind speed, wind direction, relative humidity	✓
			
Geo–morphology	Stream/river channel characteristics	Substrate material, channel width & depth, pool to riffle ration	✓
	Hillslope features & processes	Slope, aspect, elevation	–
			
Hydrology	Stream/river water dynamics	Discharge	✓
Water quality	Water chemistry	Water temperature, water pH, water conductivity, acid neutralization capacity, dissolved oxygen	✓
	Aquatic macroinvertebrates	Number of taxa, percentage of orders	✓
			
Invasive species	Invasive/exotic plants	Species found, acres of infestation	✓
Infestations & disease	Invasive/exotic animals	Presence, egg mass density, hemlock crown health	✓
	Exotic diseases	Evidence of disease	✓
Focal species or communities	Forest plant communities	Tree & shrub density, species richness, basal area, crown health	✓
	Fish communities	Game fish length & weight, species abundance	–
	Forest breeding birds	Species detected	✓
	Mast crop	Hard & soft mast production	–
	White-tailed deer (herbivory)	Deer density	✓
	Vegetation communities	Species richness, photopoints	–
At–risk biota	Threatened or rare plants	Vigor, areal coverage, photopoints	–
	Threatened or rare animals	To be determined	–
			
Visitor & recreation use	Visitor usage	Annual park visitation, number of back country users	–
			
Fire & fuel dynamics	Fire behavior	Fuel model, flame length, smoke spread direction	–
	Composite burn index	Litter depth, percent plot burned	–
	Fuel moisture	Moisture of 1, 10, & 100 hour fuels	–
	Fire effects	Burn severity, char height on trees	–

Summary of vital signs selected for Shenandoah National Park and their relationship to Mid-Atlantic Network vital signs.

National Park Service
U.S. Department of the Interior
Shenandoah National Park






Shenandoah National Park is a nearly 200,000–acre natural oasis in the densely populated Mid–Atlantic region. The park is an important refuge of natural habitat for both wildlife and people, but its location in the midst of urban, suburban, and agricultural development exposes its natural resources to threats including air pollution, water degradation, land use change, and alteration of biological communities. In order to understand and minimize these threats, park staff gather data about natural resource conditions and trends. As part of the National Park Service's Mid–Atlantic Inventory and Monitoring Network, Shenandoah National Park's long monitoring history has provided and continues to provide a wealth of experience for the regional networks initiating natural resource monitoring programs. This experience helps develop comparable monitoring protocols that will enable data sharing and comparison at a regional scale.

This publication explains why the National Park Service undertakes natural resource monitoring at Shenandoah National Park. Brief introductory material is presented followed by the justification for resource monitoring. In short, three basic steps must be taken to form an effective monitoring program:

- Gain an understanding of the key features of a park together with the natural processes and disturbances that influence those features;
- Enumerate and assess the nature and extent of human–caused threats to those resources; and
- Make decisions about what is to be monitored based on the information established in the first two steps.

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Integration & Application Network