Recreational Impacts to Natural Resources at Shenandoah National Park (Including Skyline Drive)

Recreation is a critical consideration in the assessment of natural resources at SHEN. Recreation is often cited as a central purpose for creating and managing our national parks, but recreational activities can inevitably change the parks and may endanger the other goal of resource protection (Williams and Marion 1995). Approximately two million people visit SHEN annually, with visitation peaking in July and October (Bair 1998). In SHEN, day hiking, backcountry camping, campground use, horseback riding, rock climbing, and fishing are commonly occurring recreational activities that potentially affect natural resources. In addition, driving along park roads (e.g, Skyline Drive) may be considered a recreational activity. The effects of driving (e.g., wildlife roadkills) and the ecological effect of roads (e.g., forest fragmentation) may adversely impact natural resources in the park. Furthermore, maintenance activities associated with Skyline Drive, including road repair and roadsalt application, may have adverse effects on natural resources in the park. Automobile pollutants, including contribution to ozone formation, are concentrated along Skyline Drive. Overall, however, SHEN is resistant to long-term recreational impacts due to a moderate climate with ample rainfall and a long growing season that produces vigorous plant communities with good regenerative qualities. However, intense or poorly planned recreational use could exceed the natural ability of natural resources to resist or recover in the park (Bair 1998).

Trail Use

Day use activities accounted for 98% of visitor use in 2002. Examples of specific day-use activities include driving Skyline Drive with stops at scenic overlooks, day hiking, fishing, rock climbing, and horseback riding. With over 800 km (500 mi) of hiking trails, day hiking is probably the most popular off-Skyline Drive activity, and most visitors (71%) visiting SHEN found hiking to be a very important part of their visit (Reid and Teer 1989). Most park trails can be accessed from Skyline Drive, but many visitors also access trails from the park boundary (Bair 1998).

A variety of natural resource impacts are associated with hiking trails. For example, soil erosion and vegetation loss on and around hiking trails is a persistent problem at SHEN (Jewell 2001). In addition, the development, deterioration, and proliferation of visitor-created informal trails, widening of existing trails, root and rock exposure, soil compaction, and spread of nonnative vegetation along trails adversely affect vegetation and contribute to soil erosion at SHEN (Jewell 2001). Without proper trail maintenance, soil erosion may alter natural patterns of water runoff and cause turbidity and soil deposition in streams and other water bodies (Marion et al. 1993; Hammitt and Cole 1998). While some visitor impacts to trails are unavoidable, excessive trail impacts threaten the safety of trail users, the quality of recreational experiences, and natural resource quality (Jewell 2001). Jewell (2001) examined 69.43 km (43.14 mi) or 10.8% of SHEN's formal hiking trail system, including portions of the Appalachian Trail. His findings indicate that the trails at SHEN are in good condition with an average trail width of 65.3 cm (25.7 in) and a grade of 10%. However, he also estimated that an average of 8.9 cm (3.5 in) of soil has been eroded from the tread surface since the trails were constructed. In addition, the trails most heavily used by hikers were 22.6 cm (8.9 in) wider, had 1.4% more informal trails, 11.1% more exposed soil, and 14.3% less organic litter cover, and were incised by 6.1 cm (2.4 in) more than trails in less accessible (less used) portions of SHEN.

One of the most popular and well-known hiking trails in SHEN is the Appalachian Trail (AT). Approximately 150 km (95 mi) of the AT are located within SHEN. Despite its popularity, the AT is in very good condition according to Jewell (2001). For example, the average trail width of the AT is 61 cm vs. 65.3 cm (24 in [vs. 25.7 in]) for all trails combined. In addition, the AT was 40% less incised than other hiking trails in SHEN. The above-average condition of the AT in SHEN is, in part, due to the “single file” style of hiking that this linear trail promotes (Jewell 2001). In addition, the AT receives more trail maintenance than other park trails due to the efforts of the Potomac Appalachian Trail Club.

Although many of the formal hiking trails in SHEN are in good condition, recent studies indicate that day hikers may be negatively affecting soil, plant, and animal resources on and around cliffs and rock outcrops in the park. Cliff and rock outcrops afford hikers with scenic vistas and are often popular destinations of day hikers (NPS, Marion, pers. comm., 2005). Almost all (88%) cliffs and rock outcrops examined for visitor impacts in 2005 contained informal, visitor-created trails, and most recreational impacts occurred at the tops of cliffs, suggesting their use as scenic overlooks by hikers (Marion 2005b). The informal, visitor-created trails that threaten sensitive resources should generally be closed or rehabilitated. In many instances, this rehabilitation may include realigning popular, formal trails away from cliff or rock outcrops. Marion (2005a) outlines several techniques for managing and rehabilitating these informal, visitor-created trail networks.

A thorough investigation of hiking trails at SHEN using well-established assessment techniques (Jewell and Hammitt 2000) may indicate areas where maintenance of formal trails can be improved and where visitor-created trails can be rehabilitated. For example, Jewell (2001) recommends that a comprehensive evaluation of the park’s trail system be conducted, beginning with the resource capabilities and deficiencies of trails to support appropriate types and amounts of use. A variety of other factors, including intended purposes, linkages, existing tread conditions, elevation gain/loss, scenic attractions, and sensitive natural or historic sites, could also be evaluated. In addition, surveys of trail users should be conducted to identify trail maintenance needs, direct on-the-ground maintenance activities, set priorities for apportion funding and staffing among park districts, and justify budget and staffing initiatives for additional trail management activities (Jewell 2001). Raphael (1982) provided a hiking trail system model for the Central District of SHEN. It is unclear whether the proposed system was completely implemented.

Almost 320 km (200 mi) of designated horse trails and administrative roads are available for horse and pack animal use in SHEN (Bair 1998). Currently, horse use on trails in SHEN is relatively low, but may be increasing (Bair 1998). Several studies have demonstrated that horse trails have a more negative impact on natural resources than hiking trails (Nagey and Scotter 1974; Weaver and Dale 1978; Whittaker 1978). For instance, Whittaker (1978) found vegetation cover on horse trails to be churned-up and often cut off at the roots, instead of flattened as on hiking trails. Furthermore, horse hoofs tend to dig up and puncture the soil surface, making horse trails more prone to erosion (McQuaid-Cook 1978). Wilson and Seney (1994) found that the erosional impacts from horses were greater than those from hikers, off-road bicycles, and motorcycles. Due to these effects, caution should be used when considering placement and design of trails that may be used by horses. Biking can also cause vegetation loss, widening, and erosion on trails, but their use in SHEN is prohibited. However, bicyclists often enter SHEN from the park boundary (Bair 1998).

Camping

Most visitors to SHEN view the backcountry as a day-use area, but the park does receive substantial overnight backcountry use (Bair 1998). Backcountry recreation is leisure activity occurring in largely natural, undeveloped, and protected areas or wildlands (Hammitt and Cole 1998). Backcountry overnight visitation in SHEN amounted to 39,960 nights in 2002, representing a 9% decline since 1999 when backcountry overnight visitation was 43,913 nights (Reid and Marion 2004). Backcountry overnight use of natural areas has been declining in SHEN since the 1970s. Despite this decline, SHEN has one of the highest backcountry overnight use densities in the national park system. Thus, a backcountry management plan and program are critical to achieving a balance between park resource protection and recreation provision objectives (Bair 1998; Reid and Marion 2004). Primitive camping is permitted in the backcountry of SHEN by obtaining a free backcountry camping permit. Backcountry primitive camping can negatively affect natural resources, including loss of vegetation, erosion of organic litter, soil exposure, erosion and compaction, exposure of tree roots, and damage to tree trunks (Cole and Marion 1988; Marion and Haskell 1988). In addition, littering and human waste potentially threaten water quality and human health, and may lead to visitor dissatisfaction (Williams and Marion 1995). Furthermore, food and trash storage may attract wildlife and contribute to bear and other wildlife/human interactions in the park.

SHEN originally allowed at-large camping in which visitors could camp anywhere in backcountry areas (Marion and Haskell 1988). In 1972, increased impacts to natural resources prompted resource managers to restrict backcountry camping to 39 locations. By 1974, continued natural resource and social condition degradation at many of these locations led to the adoption of a dispersed camping policy that directed visitors to camp more than 7.6 m (25 ft) from water and out of sight of other trails and other campers and forego campfires (Marion and Haskell 1988). This dispersal policy resulted in the creation of approximately 1,100 campsites by 1983 (Marion and Haskell 1988). However, declining visitation and a park closure and rehabilitation of non-approved campsites reduced the number of campsites to 725 by 1994 (Reid and Marion 2004). Williams and Marion (1995) conducted a comprehensive study and assessment of these remaining backcountry campsites in SHEN and found that they were in good condition with minimal natural resource impacts. For example, 22% of campsites were barely distinguishable and 46% had minimal loss of vegetation, limited exposure and disturbance of organic litter, and no exposure of soil. Another 23% had experienced substantial loss of vegetation and organic litter with exposed soil occurring in the center of the campsite. Only 10% of the campsites had lost most of their vegetation and organic litter cover and exhibit widespread soil exposure (Williams and Marion 1995).

Although these campsites minimally affected natural resources, 68% of them violated the park's camping regulations. Therefore, in 2000, SHEN managers revised their backcountry camping policy and asked visitors to use only well-established campsites in most areas of the backcountry, with designated campsites created near shelters for Appalachian Trail hikers (Reid and Marion 2004). This containment strategy resulted in a reduction in campsite numbers and in the total area of camping disturbance in the park (Reid and Marion 2004). Despite increased visitation at the limited number of established campsites, mean campsite size, area of vegetation loss, and area of exposed soil did not increase significantly (Reid and Marion 2004). Campsite conditions, however, should continually be monitored to ensure that natural resource impacts do not increase significantly. Campsite monitoring following established procedures (Williams and Marion 1995; Reid and Marion 2004) is critical as SHEN implements a Limits-of-Acceptable-Change (LAC) planning and management framework (Stankey et al 1985). Monitoring provides periodic data on campsite conditions for comparison to indicator standards of quality that define minimally acceptable conditions. If standards are violated, then campsite management actions must be identified and implemented. For example, posting “No camping” signs and the placement of natural barriers on non-approved campsites and access trails have been effective in permitting campsites to recover at SHEN (Marion and Haskell 1988).

Aside from backcountry camping, camping also occurs at SHEN in car-accessible campgrounds within the park. These campgrounds include Matthews Arm, Big Meadows, Lewis Mountain, and Loft Mountain, which have similar trampling-related impacts to natural resources within and around the campgrounds. In addition, three of the campgrounds have recreational-vehicle dump stations that must be properly maintained so that sewage does enter groundwater or pollute neighboring water bodies. Furthermore, drainage ditches were constructed in the Big Meadows campground to drain water away from campsites located in the wetland. These drainage ditches may facilitate the movement of pollution (e.g., sewage, garbage, parking lot oil, and sediments) to the Big Meadows wetland and, ultimately, the surface water outlet at Hogcamp Branch or the groundwater outlet at Davids Spring.

Rock Climbing

Recreational rock climbing first occurred in SHEN in the late 1930s (Bair 1998). Rock climbing still occurs in SHEN, but primarily is concentrated at two locations within the park: Little Stony Man Cliffs and Old Rag Mountain (Bair 1998; Marion 2005b). Although rock climbing is not widespread in the park, this activity potentially affects the cliff and rock outcrops of SHEN which are some of the largest in the region and support rare animal and plant communities (Ludwig et al. 1993). Rock climbing is not regulated in the park and has several potential effects on these natural resources (Hilke 2002). These effects include (Bair 1998; Hilke 2002):

- Vegetation loss and soil erosion and compaction at the top and bottom of cliffs.
- Informal, visitor-created trails to climbing areas that impact sensitive or critical habitat for plant and animal species.
- The potential for gymnastic chalk used by climbers to change the chemical balance of soils and impact micro flora and fauna.
- Clearing of dirt, small plants, and lichens from natural cracks in rock faces.
- Alteration of cliff rock by motorized drills, chisels, hammers, and glue.

A cliff management project was initiated at SHEN in 2005 to determine the effects of rock climbing (and other recreational activities) to natural resources associated with cliffs and rock outcrops at SHEN. This 3-year project will assess biological and geological resources and visitor impact and use of cliffs in SHEN. Preliminary results from the recreational impacts’ portion of the cliff project indicate that most site impacts were due to day hikers and campers and impacts from rock climbing primarily were limited to cliffs at Little Stony Man Cliffs and Old Rag Mountain (Marion 2005b). The cliff management project will culminate in the development and implementation of a Cliff Management Plan that will direct management, mitigation, monitoring, and restoration efforts at cliff sites in the park. Such a plan should include outreach, climber education, and partnering with climber organizations to help limit the effects of rock climbing to natural resources of SHEN.

Fishing

SHEN's numerous mountain streams provide some of Virginia's finest native brook trout fishing (Bair 1998). Catch-and-release fishing is permitted parkwide, except for two streams designated as "closed to fishing". Twenty-two streams are designated as "regulated open for harvest fishing," from which fish may be kept subject to size and creel limitations (Bair 1998). Visitor-created hiking trails occur along popular fishing streams, and these trails and nearby campsites may contribute to sedimentation of streams in SHEN. Due to strict fishing restrictions that prohibit the use of live bait, the inadvertent introduction of nonnative bait species is not a problem at SHEN, as it is in other national parks.

Other Recreational Activities

Hang gliding and cross-country skiing are other recreational activities that occur in SHEN. However, their effects on natural resources are negligible. Hang gliding occurs at designated launch sites, requires a park-issued permit, and is an activity that occurs infrequently (Bair 1998). The effects of cross-country skiing on natural resources are limited due to the buffering effects of snow cover.

Collecting of seasonal forage for personal consumption may be considered another recreational activity in SHEN. Morel mushroom collecting during April/May is fairly popular, but the effects of this collecting on fungi populations in the park are unknown. Furthermore, medicinal plants such as American ginseng, black cohosh, and bloodroot are collected illegally in the park. The effects of collecting on plant populations are not entirely known, but the frequency of small size-classes of ginseng in the park indicate that plant poaching is having some negative effect on populations (Cass 2005).

Conclusions

SHEN supports a variety of natural resources that are intrinsically significant to the park. The globally significant natural resources found in SHEN include species and communities that can be seen nowhere else in the world. The High-Elevation Greenstone Barren plant alliance and the federally endangered Shenandoah salamander are endemic to the park and are globally-rare. Big Meadows contains a globally-rare wetland plant alliance, the Northern Blue Ridge Mafic Fen, that also is endemic to the park and is, perhaps, the only place in the country where a high-elevation grassland/shrub community has persisted for approximately 10,000 years.

Despite a history of disturbance, SHEN represents one of the nation's most diverse botanical reserves and is an outstanding example of the Northern Blue Ridge Forest, a globally significant resource (Braun 1950; NPS 1998). The federally endangered small whorled pogonia is found in this forest expanse. An abundance and diversity of breeding neotropical migratory birds also contribute to SHEN's globally significant natural resources. In addition, SHEN is one of the few places in the country where peregrine falcons can be observed nesting in their natural habitat. The native brook trout that inhabit the high-elevation streams also can be considered nationally significant, as they have been pursued by presidents and other leaders of our country, and SHEN still contains healthy populations of this fish that has declined dramatically throughout its range. Aside from providing valued fish habitat, the streams of SHEN form the cold, clear headwaters of three major river systems.

Regionally significant resources of the park are an abundance of black bears that may serve as a source population for the Blue Ridge Mountains; an abundance and diversity of streamside salamanders; and the presence of a variety of state plant and animal species of special concern that contribute to the local and state significance of the park.

The combination of high elevation, ancient geology, topographic variation, and natural- and human-caused disturbance regimes shaped the pre-European natural resource condition at SHEN. This historic condition consisted of large expanses of American chestnut and mixed-oak forests interspersed with stands of old-growth mesic forests and smaller barren, pine, hemlock, and riparian forest components. Early successional habitat consisted of forest openings created by periodic disturbances such as natural and native American caused fire, frequent ice storms, and periodic flood and hurricane disturbances.

European settlement, associated land clearing, limited industrialization, and introduced pests and pathogens completely transformed this landscape in the early- to mid-20th century so that today the large expanses of American chestnut are completely missing from SHEN's forests and even oak-hickory forests may be declining. Ecological succession has re-forested the northern Blue Ridge Mountains and many of the park's inherently significant resources, including diverse avian, salamander, and, floral communities, continue to thrive. For example, Big Meadows still supports wetland plant communities, provides breeding ground for amphibians, and contains populations of wetland birds, as it did for perhaps the last 10,000 years. A variety of rock outcrop communities support globally rare plant communities and provide opportunities for geologic study. Despite adverse effects by decades of acid deposition, the high-elevation streams at SHEN still support native fish communities in their pools and riffles.

Most of the threats to SHEN's natural resources are generated outside the park. For instance, nonnative insects such as the gypsy moth and the hemlock woolly adelgid threaten oak and hemlock forest communities, respectively. Hemlocks are all but extirpated from the park and the ecosystem effects of this loss are not well understood. Other nonnative pathogens such as dogwood anthracnose and beech bark disease further threaten the park's native trees. Herbaceous plants are most threatened by competition from nonnative plants, especially the invasive garlic mustard and nonnative honeysuckles. Acid deposition and ground-level ozone degrade water quality and affect the regionally significant scenic vistas that occur along the entire length of Skyline Drive. Finally, encroaching land development threatens the park's dark night skies and the expanse of its continuous forest matrix.

The nature of these threats requires natural resource managers at SHEN to cooperate with local, regional, and national officials and communities. For example, NPS resource managers and administrators need to work with state officials on their State Implementation Plans for air quality that must be submitted to the EPA. These plans will calculate the rate of progress needed to achieve specified attainment goals for each Class I air quality area in the country. In addition, natural resource managers should actively support Clean Air Act amendments that further reduce sulfate deposition in order to prevent further acidification in streams at SHEN. Specifically, for most streams to recover in the park, sulfate deposition should be reduced below 5 kg/ha/year, 40% of the current deposition amount.

Finally, the park must continue to steward its resources from within its boundaries. Recreational and cultural use of the park can be entirely compatible with good natural resource conservation. Proper planning will ensure that the intrinsically significant natural resources of SHEN are protected. For example, development in the park should be planned to minimize fragmentation of all large forest blocks and Wilderness Areas. An assessment of lighting within the park would determine the park's contribution to impairment of dark night skies, and the change to using high-efficiency, low-emissions vehicles sets an example of good resource stewardship.

Natural resource protection and stewardship will enable SHEN to remain an outstanding biological reserve for the next 80 years and beyond. In order to assist in the stewardship of this outstanding park, the findings of this natural resource assessment were used to generate a "report card" of natural resource condisions (Table 9). By providing a concise, color-coded overview of resource conditions, park managers may be better able to set conservation goals and prioritize management actions for SHEN.

Table 9. Status and trends in conditions of natural resources for Shenandoah National Park, Virginia. Trends reflect assessment of conditions over the past 10 years.

Air/Visability/Sound	Geology and Soil	Water	Plants	Terrestrial Vertebrates	Fish	Aquatic Invertebrates	Terrestrial Invertebrates
↔	↓	↔	↓	↔	↔	↔	**?**

Status	
	Significant concern
	Caution: may be a developing concern
	Good: resource in good condition
	Status unknown

Trend	
↑	Increasing
↔	Stable
↓	Declining
?	Unknown

Resource	Status	Trend	Evidence
Air Resources (overall)	Significant concern	Stable	
Ground-level ozone air pollutant levels	Significant concern	Declining; slight reduction in ground-level ozone over the past 10 years	SHEN is a Class 1 park and therefore is afforded the greatest degree of air quality protection under the Clean Air Act. However, air quality is of significant concern in the park. Based upon the SUM06 index, ozone concentrations averaged 46.9 ppm/hr during May–September 1990–2000. While there is no National Ambient Air Quality Standard (NAAQS) for SUM06, 46.9 ppm/hr far exceeds concentrations most experts believe can harm sensitive vegetation, i.e., 10–15 ppm/hr. Furthermore, there were periodic events when the ground-level ozone at Big Meadows exceeded the daily maximum NAAQS for ozone of 85 ppb. For example, an analysis of the Big Meadows monitoring data showed that the number of times per year daily maximum 8-hour ozone concentrations exceeded 85 ppb were 6, 22, and 15, respectively, during 1997, 1998, and 1999. SHEN has among the highest concentration of ground-level ozone of all national parks monitored, and in 2004 a portion of the park was designated by the state of Virginia and the EPA as a non-attainment area for ozone. However, in 2005, the park was re-designated as an attainment area of the ozone standard due to monitoring data showing improvement in ozone levels since 2002.
Acid deposition-sulfate and nitrate pollution	Significant concern	Declining; slight reduction in acid deposition over the past 10 years	Compared with other locations in the eastern United States, SHEN receives relatively high wet deposition of sulfate and moderately high wet deposition of nitrate. Among Class I national parks, SHEN and Great Smoky Mountains National Parks receive the highest sulfate and nitrate deposition—making acid deposition one of the greatest environmental problems facing the park. Over the approximately 20-year monitoring period at Big Meadows, wet deposition of sulfur averaged 6.7 kg/ha/year and total wet deposition of nitrogen averaged 4.6 kg/ha/year. Dry deposition of sulfur and nitrogen averaged 4.9 kg/ha/yr and 3.2 kg/ha/yr, respectively, at Big Meadows during the period 1991–1998. Despite high year-to-year variability, wet deposition of sulfate and nitrate has generally declined at SHEN, especially in the last five years. For example, statistically significant declines in SO_4^{2-} and NO^{3-} were recorded at SHEN from 1980–1993.
$PM_{2.5}$ - Fine mass particulate matter air pollutant levels	Caution	Increasing; fine mass particulates exceeds natural reference conditions	Fine mass particulate matter averaged 10.5 $\mu g/m^3$/yr at Big Meadows during the 12-year period of 1988–2000. Chemical components of the fine mass particulates included ammonium sulfate, ammonium nitrate, organics, light absorbing carbon, and fine soil. Current levels of fine mass particulate matter and its chemical components are five times greater than natural background (reference) conditions. The highest fine mass particulate concentration occurred during summer and most of the contribution was from ammonia sulfate.

Visibility	Significant concern	Declining; visibility is only 20% of natural visual range	The scenic vistas of the Shenandoah Valley and the Virginia Piedmont provided justification of park establishment and are, therefore, nationally significant. SHEN's estimated natural (background) visual range is approximately 185 km (115 mi). Visibility in the park has been severely degraded so that today the annual standard visible range (SVR) at SHEN averages 36.8 km (23 mi [only 20% of the park's natural visual range]). During summer, SVR decreases to an average of 20 km (12 mi), and increases to an average of 64 km (40 mi) during winter.
Dark night skies	Unknown	Unknown	The visual environment of dark night skies has not been studied at the park. However, the NPS is obligated to preserve, to the greatest extent possible, the natural landscape and dark night skies of parks, which are natural resources and values that exist in the absence of human-caused light. Aside from affecting the visibility of night skies, recent studies indicate that light pollution may adversely affect water quality, salamander foraging, bird migration, and turtle breeding.
Natural sounds	Unknown	Unknown	No research on the natural soundscape of SHEN has been conducted. However, noise from construction practices, traffic, and human aggregation all are potential threats to the natural sounds of SHEN.

Resource	Status	Trend	Evidence
Geologic Resources (overall)	Cautin	Declining	
Bedrock geology	Caution	Unknown	The Catoctin Formation rock type that is found at SHEN is one of the few places in the mid-Atlantic were volcanic rocks are found at the surface. These bedrock outcrops are numerous throughout the park; however, those present at overlooks along Skyline Drive and along hiking trails have the potential for overuse, including erosion created from repeated foot traffic and rock climbing. Vandalism is a problem in nearly all national parks, and graffiti is one of the larger threats that could impact the natural character of rock outcrops. Additionally, open fires constructed beneath rock ledges blacken the outcrops and pose an additional threat to interpreting the rock history.
Soils	Caution	Declining	Due to the steep slopes of the Blue Ridge Mountains and periodic flood disturbance regimes the soils at SHEN have severe erosion potential. In addition, soils that form from the siliciclastic rock type are adversely affected by acid deposition.
Surficial deposits	Caution	Unknown	Many locations throughout the park have boulders that are detached from bedrock outcrops and are perched or balanced in a quasi stable state. These locations have a high potential for dangerous rockfalls; particularly high foot traffic areas (Old Rag, Black Rock, and Bear Church Rock) have the greatest potential for hazards to park visitors. The flood of 1995 demonstrated the force of water and rock on the landscape within the park. The Rapidan River region received up to 76.2 cm (30 in) of rainfall in less than a day, resulting in numerous landslides and flooding of the Rapidan, Robinson, and Conway rivers and their tributaries. The park should consider these threats from surficial deposits when planning for future backcountry campsites or other permanent activities that may occur in the eastern flank lowlands. Although the probability of having additional debris flows in the affected basins in the near future is small, other areas of the park still remain at risk. Finally, the scoured tributaries impacted by the debris flows lack the capacity to slowly store and transmit rainwaters due to the full removal of the soils and rubble from the channels via the debris flows. These sediments act as a sponge; thereby, slowly releasing the captured rain water during precipitation events. This problem will continue until the impacted stream channels revegetate and develop the soil mantle.

Resource	Status	Trend	Evidence
Water Resources (overall)	Significant concern	Stable	
Streams	Significant concern	Increasing; slight improvement last 10 years	The clear and cold mountain streams of SHEN form the headwaters for three major rivers and contain nationally significant populations of native brook trout. Acid deposition, caused by sulfate and nitrate pollutants, is the major threat to water quality of SHEN's streams. Western and central Virginia consistently receive among the highest level of sulfate (acid-causing) deposition in the United States. SHEN, located in the northern region of the Blue Ridge Mountains, has the greatest known loading of sulfate of any national park in the U.S. Despite this threat, there may be some regional recovery occurring in SHEN streams. A variety of long-term studies conducted at SHEN, including the Shenandoah Watershed Study (SWAS), the Virginia Trout Stream Sensitivity Survey (VTSSS), and individual research projects, document decreasing trends in streamwater pH and ANC consistent with acidification of the streams due to acid deposition during the period 1980–1987. However, in 2004 a slight recovery in ANC and sulfate concentrations was noted in study streams. Despite this recovery in constituent solute values, water quality in SHEN streams is still degraded compared to historic levels. For example, sulfate concentrations in SHEN streams have increased 2.5–7.5 times from historic levels. In addition, the median historical loss of ANC in park streams has been estimated to be 20 ueq/l. Fecal coliform contamination has been noted at Pass Run and Hawksbill Creek in SHEN. The fecal coliform most likely originates from wildlife and human sources (recreational use) near streams.
Groundwater	Caution	Stable	Groundwater pumping at a well in Big Meadows (BM-3) contributed to water table decline in this portion of the park. This well was closed to all uses in 1992 and today most potable water for the Big Meadows campground is obtained from Lewis Spring. Additional wells were developed in 1989 to provide supplemental/backup water sources when flow from Lewis Spring is insufficient to meet demand at the Big Meadows campground in late summer. Groundwater pumping at these wells has the potential to contribute to water table declines in SHEN. A complete list of potential point and non-point groundwater contamination sources are provided in the Water Resources Scoping Report and include: Skyline Drive, sewage pollutants from campgrounds (pit toilets, tertiary sewage treatment plants) and visitor centers (which are all located near the largest springs in the park), underground gasoline tanks (associated with gasoline stations along Skyline Drive), gas lines, pesticide or other chemical spills at ranger stations and maintenance yards, landfills (12 known NPS sanctioned and CCC-era landfills are in SHEN), and chemical spills and road runoff (including deicing salts, heavy metals, and

			hydrocarbons) along any of the ten state roads found in the park (including routes 211 and 33). Wells near Lewis Spring potentially could be contaminated by pollutants leaking from an abandoned dump located 1.6 km (1 mi) away. Herbicides used to maintain power line rights-of-way could affect groundwater supplies at SHEN. Furthermore, bacteria from horse (used for trail riding) and human waste (from backcountry waste disposal and potential sewage leaks at developed facilities) may infiltrate groundwater supplies after storm events.

Resource	Status	Trend	Evidence
Plant Resources (overall)	Caution	Declining	
Unfragmented forest	Good	Stable	Due to the unfragmented and protected forests found in the park, SHEN contains a globally outstanding example of the Blue Ridge/Central Appalachian biome. Approximately 85% of the area within the park's boundary is contained within unfragmented blocks greater than 202 ha (500 ac). The construction of fragmenting features (such as visitor centers and roads) within large forested blocks that are not under wilderness protection is possible. In addition, the ecological value of the unfragmented forest blocks at SHEN are enhanced by forested areas that are adjacent to, but not owned by, the park. Therefore, road construction and land conversion from forest to residential and other land uses that is occurring outside the park have the potential to diminish the significance of the expansive, unfragmented nature of SHEN's forests.
Oak and oak-hickory forests	Caution	Declining	Forests that contain oak as a dominant component are the most commonly occurring forest types at SHEN. Some of the oak associate species, most notably flowering dogwood (*Cornus florida*), are threatened by pathogens at SHEN. The flowering dogwood has declined precipitously at SHEN and elsewhere in Virginia over the past two decades because of the prevalence of dogwood anthracnose, which causes mortality to dogwoods especially during dry years. A history of fire suppression probably has limited the regeneration of oak forests at SHEN. Although 90% of the fires that have been recorded in the park have been the result of human ignitions, natural fires occurred periodically throughout the Appalachians and played a role in shaping the plant communities that historically were present in the park. However, natural fires have not been permitted to burn in the park for over 78 years, resulting in conditions different from those that would have resulted if natural fire had been allowed to exert its influence on the landscape. Mesic species of trees have probably always been present to some extent on fertile, protected sites in the park, but they have increased in SHEN and throughout Virginia, perhaps due to fire suppression. Furthermore, rapid expansion of deer populations have greatly reduced the amount of oak regeneration at the same time that age, drought, and gypsy moth defoliation have removed much of the oak overstory. The species composition in many of Virginia's hardwood forests, therefore, is shifting away from oak towards more mesic species such as poplar and maple. Oak mortality caused by gypsy moths may have caused a decline in oak throughout the Appalachians. The ridges, south-facing aspects, and dry plateau areas with a significant oak component have the potential for being most affected by this nonnative pest. Nonnative plants, red maple, tuliptree, and other opportunistic species may invade gaps created by mortality of oaks. On the other hand, canopy

			gaps following gypsy moth infestation in some drier Virginia oak forests have also stimulated dense pulses of oak seedling germination. Sudden oak death caused by the pathogen, *Phytophthora ramorum*, potentially threatens oaks at SHEN. Sudden oak death was first reported in California in 1995 and no natural occurrence has been reported in the forests of the eastern U.S. However, there is significant risk that this pathogen could be introduced to eastern oak forests, as it was detected in nursery stock in Florida, North Carolina, and Georgia in 2004.
Mesic/rich cove forests	Caution	Increasing	Approximately 25% of the land cover at SHEN is in a mesic/rich cove forest vegetation association. Although the mesic forest associations appear to be regenerating at SHEN, threats to this forest type include competition from nonnative species, deer browsing, and fragmentation due to roadways, trails, and land use changes on the lower slopes along the park boundary. In addition, tree species most susceptible to damage by ozone are associated with mesic forests (e.g., tulip poplar, black cherry) and, therefore, air pollution threatens these forest alliances. The moist, usually fertile soils occupied by these communities make them especially vulnerable to massive invasions of the nonnative herbs garlic-mustard (*Alliaria petiolata*) and Japanese stilt-grass (*Microstegium vimineum*). In addition, beech bark disease may threaten the few mesic forest communities at SHEN where this species occurs. The disease results when bark, attacked and altered by the beech scale (*Cryptococcus fagisuga*), is invaded and killed by fungi, primarily *Nectria coccinea* var. *faginata* and sometimes *N. galligena.* The disease, although presently not found in SHEN, is present in northwestern Virginia and may arrive at the park and contribute to beech mortality.
Barrens, boulderfields, and exposed rock vegetation types	Caution	Declining	Due to the mountainous terrain at SHEN there are distinctive vegetation associations associated with exposed and/or loose rock, infertile, minimal soils, and low moisture gradients. The plant species that are found on these locations vary depending on elevation, substrate type, soil type, aspect, and degree of exposure, but tend to occur as stunted forests, shrublands, or herbaceous vegetation and are associated with diverse lichens and high (>50%) surface rock cover. The globally rare High-Elevation Greenstone Barren vegetation association is endemic to SHEN and is found mostly above 1,000 m (3,281 ft) on exposed metabasalt (greenstone) cliffs and ledges. Due to the harsh conditions and exposure, these vegetation types are slow-growing and vulnerable to disturbance. In addition, the exposed conditions associated with these communities make them popular destinations for hikers seeking scenic vistas and thereby threatening their persistence in the park. Invasive nonnative plants also threaten barren communities, especially on sites that have been disturbed by human activity.

Pine forests and woodlands	Significant concern	Declining	Pine forests and woodlands at SHEN are primarily composed of pitch pine, table mountain pine, scrub oaks, Virginia pine and, rarely, shortleaf pine (*Pinus echinata*). Pitch pine and table mountain pine are declining throughout their range because of the exclusion or suppression of fires. In addition, the older pine stands in the Appalachians are susceptible to southern pine beetle outbreak. At SHEN, a dramatic reduction in pine trees caused by these pine bark beetles has been documented. Furthermore, tree-of-heaven established itself at several former pine sites. White pines are threatened by the white pine blister rust (*Cronartium ribicola*), a fungal disease, and white pine weevil (*Pissodes strobi*), an insect that attacks and kills the uppermost shoots of the tree.
Eastern hemlock forests	Significant concern	Declining	The Eastern Hemlock Forest association has declined dramatically over the past 10 years at SHEN. Historically, it typically existed on shallow soils and in cool, deep ravines along waterways. Hemlocks are threatened throughout the mid-Atlantic by a nonnative insect pest, the hemlock wooly adelgid, that attacks and kills hemlock trees. The hemlock woolly adelgid has caused extensive mortality of hemlock in SHEN and this forest type is currently undergoing rapid change as canopy loss and related disturbance potentially affect moisture regimes and plant and nutrient dynamics. By 2004, 92% of these trees were classified as dead due to extensive feeding by the adelgid. As hemlocks continue to decline throughout the mid-Atlantic they most likely will be replaced by stands of oak, birch, and maple.
Black locust successional forest	Stable	Stable	The occurrence of the Black Locust Successional Forest association reflects past land use history at SHEN, especially the prevalence of small homesites now abandoned. This forest association covers 2,261 ha (5,587 ac [2.83%]) of the park and is often dominated by black locust and redbud (*Cercis canadensis*) in the forest canopy. This association will likely be replaced naturally by alliances containing white ash, tuliptree, and/or white pine, and eventually by red oak and a variety of hickories.
Wetland plant communities	Caution	Declining	Although wetland communities compose <2% of the land cover at SHEN, they do represent ecologically significant communities that add diversity to the landscape and provide critical habitat for rare plants, amphibians, and other animals. Six distinct wetland vegetation communities are found at SHEN. One community alliance, the globally rare Northern Blue Ridge Mafic Fen, is endemic to SHEN. Another rare wetland community, the Shenandoah Valley Sinkhole Pond, is endemic to a three-county area in Virginia's Shenandoah Valley. The mafic fen at Big Meadows is threatened by hydrologic alterations associated with a large well that formerly served the Big Meadows campground, deer browse pressure, invasive nonnative plants, and, perhaps, fire exclusion. Nonnative plants threaten native plant communities throughout the park and may be more likely to colonize wetland areas. At SHEN, small herbs such as Japanese stilt grass and long-bristled smart weed are threats in riparian areas. Furthermore, princess tree, tree-of-heaven, and oriental bittersweet are great threats in several riparian areas that suffered large landslides/soil slumps.

Old-growth forest	Significnat concern	Declining	Due to past land-use history, the old-growth (>200 years old) stands that still persist in SHEN are few and small in size. The Limberlost is perhaps the most famous and most frequently visited old-growth area in SHEN. Unfortunately, hemlock woolly adelgid has decimated old-growth hemlock trees in the park. Other tree pathogens, such as sudden oak death and beech bark disease, also potentially threaten old-growth specimens of those species in the park.
Plant species of special concern	Caution	Declining	Data collected by The Virginia Natural Heritage Program (VANHP) from various sources indicate that 92 vascular plant species and one non-vascular plant species of special concern in Virginia have been reliably reported from SHEN. A variety of threats at SHEN are affecting persistence of these plant species of special concern including disturbance suppression, competition from nonnative plants, hydrologic alteration, canopy defoliation, acid precipitation, illegal collecting, and herbivory by white-tailed deer.
Nonvascular plants, lichens, and fungi	Unknown	Unknown	Despite their importance to terrestrial and freshwater communities, little is known about the distribution and abundance of these species in SHEN. Approximately 100 species of lichens, 400 species of fungi, and 260 species of non-vascular plants are known from SHEN. Poor air quality may threaten nonvascular plants and fungi, especially at exposed, high-elevation sites. Furthermore, bryophytes may be especially sensitive to effects of acid deposition. Trampling by high visitation at rocky cliffs may threaten these species in the park. Collecting of edible fungi also may threaten fungi at SHEN.
Nonnative plants	Significant concern	Increasing (nonnative plants seem to be increasing at SHEN)	The invasion of nonnative plants may be the biggest threat to maintaining native forests and plant communities at SHEN because not all nonnatives can be controlled or removed. Nonnative plants penetrate an average of 75 m (246 ft) into the forests along Skyline Drive and about 102 m (335 ft) into the forests surrounding historic (and abandoned) developed areas. Garlic mustard and Japanese stiltgrass are the most problematic invasives, although mile-a-minute weed and oriental ladysthumb (*Polygonum caespitosum*) are recent serious concerns. The North District of the park contains more nonnative plant occurrences than the other two districts. In general, nonnative plants are more prevalent on the eastern slopes of the park than on the west. Skyline Drive, abandoned developed areas, and fire roads are associated with high numbers of nonnative plants; park boundaries are not. Tree-of-heaven is the most prevalent nonnative tree. Oriental bittersweet, multiflora rose (*Rosa multiflora*), wineberry (*Rubus phoenicolasius*), Japanese honeysuckle, and Japanese barberry (*Berberis thunbergii*) are the most common nonnative shrubs. Garlic mustard, Japanese stiltgrass, and long-bristled smartweed (*Polygonum caespitosum* var. *longisetum*) are the most common nonnative forbs in the park.

Resource	Status	Trend	Evidence
Terrestrial animals-including amphibians (overall)	Good	Stable	
White-tailed deer	Good	Increasing	Populations of white-tailed deer at SHEN are currently higher (25–30 deer/mi^2) than historic levels (8–20 deer/ mi^2). Deer densities are even higher in the front country where deer densities approach 200 deer/ mi^2 at Big Meadows. White-tailed deer are potentially threatened by chronic wasting disease (although this disease has not been detected in Virginia as of 2006).
Black bear	Good	Stable	There are approximately 300–800 black bears in SHEN. The SHEN population may be source population for the Blue Ridge Mountains. Black bears throughout the Appalachians are constantly threatened by poachers who illegally kill black bears in order to sell their gall bladders and paws on the international market. However, in SHEN, the illegal killing of black bears appears to be relatively inconsequential for population dynamics.
Allegheny woodrats	Caution	Stable	This species of special concern is declining throughout the Appalachians. Allegheny woodrats are known from nine sites within SHEN. Ensuring the continued persistence of these populations in the park will assist in the long-term conservation of this species.
Bats	Unknown	Unknown	The status of the bat community in SHEN is unknown. There have been no published studies of this vertebrate group in the park, and NPSpecies documents six species of bats (big brown bat [*Eptesicus fuscus*], little brown bat [*Myotis lucifugus*], silver-haired bat [*Lasionycteris noctivagens*], eastern red bat [*Lasiurus borealis*], hoary bat [*Lasiurus cinereus*], and eastern pipestrelle [*Pipistrellus subflavus*]) as being confirmed from SHEN. However, Virginia Gap predicts nine species of bats to occur in the park. Three of these predicted species, northern myotis (*Myotis septentrionalis*), eastern small-footed myotis, and evening bat (*Nycticeius humeralis*), have not been documented in the park and are not included in NPSpecies. In addition, two species (Indiana bat [*Myotis sodalis*] and Virginia big-eared bat [*Plecotus townsendii virginianus*]), both federally endangered, are known to occur on the west side of the Shenandoah Valley. Threats to the bat community in SHEN are unknown, although the conversion of nearby limestone caverns (e.g., Luray Caverns) to visitor attractions may have eliminated roosting and hibernation habitat.
Small mammals	Unknown	Unknown	The small mammal community has been little studied in SHEN. A species list published in 1985 suggests that 18 species of native mice, moles, voles, and shrews occur within the park. They include star-nosed mole (*Condylura cristata*), southeastern shrew (*Sorex longirostris*), pygmy shrew (*Sorex hoyi*), southern bog lemming (*Synaptomys cooperi*), white-footed mouse (*Peromyscus leucopus*), southern-flying squirrel (*Glaucomys volans*), and the rare Appalachian cottontail (*Sylvilagus obscurus*). In addition, the southern water shrew (*Sorex palustris*

			punctualatus) (endangered in Virginia) may occur in the park. Gypsy moth infestations and their effects on acorns have caused declines in native rodent populations in SHEN. Forest succession may contribute to declines in Appalachian cottontail.
Fur-bearing and other mammals	Unknown	Unknown	Fur-bearing mammals include beaver, bobcat, muskrat (*Ondatra zibethicus*), red fox (*Vulpes vulpes*), gray fox, raccoon, skunks (*Mephitis mephitis*, *Spilogale putorius*), woodchuck (*Marmota monax*), eastern cottontail (*Sylvilagus floridanus*), gray squirrel (*Sciurus carolinensis*), mink (*Mustela vision*), northern river otter, and weasels (*Mustela* spp.). Beaver and muskrat are only known from around the periphery of the park boundaries. Formal studies of these species populations in SHEN have not been conducted. The main threat to these animals is mortality due to vehicular traffic on Skyline Drive. Threats from disease are unknown although rabies could adversely affect these populations.
Neotropical migratory birds	Good	Stable	SHEN is globally significant in providing critical habitat for neotropical migratory birds, especially the wood warblers (Family *Parulidae*). Forest neotropical birds depend on the physical structure of the forest for survival. Some live in hardwoods with canopies, some along the edge, and some in forest gaps created by tree falls. This partitioning of the physical habitat supports the high diversity of forest birds in SHEN. Forest gaps contain early successional vegetation and sunlight, two environmental variables needed by several neotropical migrants. Threats to these birds in SHEN include modification of the park's hardwood forest structure due to loss of oaks from introduced gypsy moths, loss of hemlocks from the introduced hemlock woolly adelgid, lack of regeneration due to deer browsing, and disturbance suppression. Populations are also compromised by loss of forest habitat and fragmentation from developed sites in the park.
Waterbirds and waterfowl	Good	Unknown	Few waterfowl species occur in SHEN due to the small number of ponds and other open water bodies within park boundaries. However, several species, such as wood duck (*Aix sponsa*), green heron (*Butorides virescens*), great blue heron (*Ardea herodias*), and American bittern (*Botaurus lentiginosus*), use riparian corridors along mountain streams, especially at low elevations. The abundance of, and threats to these species within the park are unknown.
Raptors	Good	Stable	Hawks and falcons are frequent visitors to, and residents of SHEN. The spine of the Blue Ridge Mountains creates a pathway along which several species of raptors fly during fall migration periods, and at least ten species are known from SHEN. In addition, SHEN is one of the few places in the country where peregrine falcons can be observed nesting in their natural and historic habitat. Raptors are particularly susceptible to West Nile virus, but this pathogen has the potential to negatively affect various bird species.

Game birds	Good	Stable	Wild turkey, ruffed grouse, and American wookcock (*Scolopax minor*) occur in SHEN. Virginia turkey populations, estimated at about 120,000 statewide in 2005, appear to be stable, or declining slightly due to several years of low reproductive success. The current size of grouse and woodcock populations in Virginia are unknown, although grouse populations are low compared to levels prior to 2000. Woodcock have been declining at a rate of about two percent annually over the past two decades. Threats to these three game birds in SHEN are unknown, although American woodcock and ruffed grouse may be losing nesting habitat due to forest succession.
Turtles	Good	Stable	The only turtle that occurs throughout SHEN, is the eastern box turtle (*Terrapene carolina*). The wood turtle, a state-threatened species, may occur within the current SHEN boundary. Two other species, the painted turtle (*Chrysemys picta*) and the snapping turtle (*Chelydra serpentina*), may enter the park via streams from populations outside the park. Mortality by vehicles on Skyline Drive potentially is a major threat to box turtles and other turtle species that cross this road. Removal of individuals for pets is also a threat.
Lizards and snakes	Good	Stable	At least four species of lizard are known to occur within park boundaries: northern coal skink (*Eumeces anthracinus*), five-lined skink (*Eumeces fasciatus*), northern fence lizard (*Sceloporus undulates hyacinthinus*), and ground skink (*Scincella lateralis*). Most of the known locations are along the park's boundary and in the rock walls located along Skyline Drive. Of the 19 known snake species in the park , three are of conservation concern. Populations of timber rattlesnake are declining throughout the Northeast, and the northern pine snake (*Pituophis melanoleucus*) and the smooth greensnake (*Opheodrys vernalis*) have apparently declined dramatically in the Appalachians due to habitat loss, mortality on roads, and killing by humans. The northern pine snake is considered a species of special concern in Virginia. Road mortality on Skyline Drive and incidental killing constitute the main threats to snakes from humans. Some individuals are undoubtedly removed for the pet trade, but the incidences and threat level are unknown.
Salamanders	Good	Stable	The Shenandoah salamander is listed as federally endangered and is highly restricted to three talus areas in the northern section of SHEN. Primary habitat of several species of salamanders in SHEN is mountain streams and the springs and seeps that feed them. The abundance and diversity of streamside salamanders is regionally significant and depends entirely on this habitat type. Salamander populations in SHEN streams appear relatively secure at this time, but continued exposure to acid deposition and resulting stream and soil acidification eventually may adversely affect these populations.
Frogs and toads	Good	Stable	Little is known about the distribution and abundance of frogs and toads at SHEN; however, they are dependent on isolated vernal pools for breeding. At least two groups of isolated vernal pools are known to exist in SHEN. These pools, located at

			Big Meadows near the weather station and at Hogcamp Swamp, have been studied for several years by the USGS Amphibian Research and Monitoring Initiative (ARMI). Acid precipitation and alteration of the hydrological conditions of ponds constitute the primary threats to these amphibians. Draining and alteration (e.g., prescribed burning near these pools) of any part of the Big Meadows pools may cause several species (particularly Jefferson salamander) to become locally extinct within a short period of time. Many amphibians at SHEN migrate outside of the park boundary to breeding ponds on private lands. Any alterations to these ponds or barriers to migration pose a potentially serious threat to these boundary-line populations. Mortality by vehicles on Skyline Drive potentially is a significant source of mortality for some populations.

Resource	Status	Trend	Evidence
Fish (overall)	Good	Stable	
Brook trout	Good	Stable	The streams in SHEN offer one of the greatest concentrations of native brook trout in the eastern U.S., making native brook trout a nationally significant resource at the park. Acid deposition and resulting decreases in the ANC of SHEN's streams, and corresponding increases in toxic aluminum, threaten brook trout. In addition, the introduction of nonnative trout have disrupted native brook trout population in streams where they coexist. Maintaining groundwater levels and recharge rates at springs and seeps is also critical in protecting brook trout populations in the park. The cool water temperatures upon which trout depend may be adversely affected by the decline of the eastern hemlock that historically shaded headwater streams throughout the park. Although the effects of legal and illegal fishing pressure are difficult to quantify, illegal harvest should be considered a potential threat to the park's brook trout fishery. Streams located along the park boundary are particularly susceptible to illegal trout harvest. Salmonid whirling disease caused by a parasite (*Myxobolus cerebralis*) has not been detected in the park, but has the potential to negatively affect trout.
Fish communities (overall)	Good	Stable	Currently, NPSpecies (2005) lists 37 species (including one hybrid trout) of fish known from SHEN, and three of these, bluntnose minnow (*Pimephales notatus*), Potomac sculpin (*Cottus girardi*), and yellow bullhead (*Ameiurus natalis*), were first detected in the past two years by the fish monitoring program. Streams on the eastern slopes of the park contained higher trout and higher fish species diversity than streams on the western slopes due to greater invertebrate productivity, water flow, and pool formation. All populations of fish, regardless of species, are dynamic in the park (experience year-to-year population fluctuations) due to variations in water flow, acidity, and recruitment rates. Acidification of SHEN's streams threatens to reduce fish species richness by eliminating acid-sensitive species from fish communities. Aside from the effects of stream acidity, the principle short-term natural factors that have the most pronounced effect on the fishery resources of SHEN are drought and flood events. Fish pathogens, such as enteric redmouth disease caused by bacteria (*Yersinia ruckeri*), bacterial kidney disease caused by bacteria (*Renibacterium salmoninarum*), infectious pancreatic necrosis caused by a virus, and salmonid whirling disease caused by a parasite (*Myxobolus cerebralis*), have not been detected in SHEN, but are potential thtreats to fish in the park.

Resource	Status	Trend	Evidence
Aquatic invertebrates (overall)	Good	Stable	
Aquatic invertebrates- aquatic insects, crayfish, molluscs, and aquatic worms	Good	Stable	Most streams in SHEN contain macroinvertebrate assemblages that represent the best condition of streams in the Blue Ridge Mountains. However, acid deposition threatens the diversity of stream macroinvertebrate assemblages at SHEN. For example, streams with low ANC (primarily those found in the siliciclastic bedrock type) contain macroinvertebrate assemblages with lower species richness than streams with high ANC. These low-ANC streams may now possess less diverse macroinvertebrate communities than were present in pre-industrial times at SHEN. In addition, loss of eastern hemlocks may alter macroinvertebrate assemblages in streams that drain former hemlock stands. Little is known about the molluscs found in SHEN's streams.

Resource	Status	Trend	Evidence
Terrestrial invertebrates (overall)	Unknown	Unknown	
Insects and other terrestrial arthropods	Unknown	Unknown	Very little is known about the terrestrial invertebrates of SHEN. The most extensive survey of terrestrial invertebrates at SHEN was conducted at a hemlock (Limberlost) and a mixed deciduous forest stand (Matthews Arm) in 1997. In that study, 12,978 invertebrate specimens were collected. The hemlock forest contained more individuals in the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Psocoptera (book lice). However, the mixed deciduous forest had higher overall species diversity. Reflecting the potential high diversity of terrestrial invertebrates at the park, that limited study documented one new state record (*Actogeophilus fulvus*) and a new Madison County record (*Stimamia bidens*) for centipedes collected at Limberlost. In addition, a previously undescribed species in the order Homoptera and ten previously undescribed species in the order Diptera were documented. As part of the ongoing Rock Outcrop Management Project, geologists from the Virginia Department of Conservation and Recreation collected invertebrates during summer 2005 and 2006 using sweep nets and light traps at 21 rock outcrops in the park. Terrestrial invertebrates are threated by the application of pesticides by NPS personnel, concessioners, and adjacent landowners. In addition, invertebrates are potentially threatened as overstory forest tree species such as eastern hemlock decline and ecosystems dynamics are altered.

Literature Cited

Abrams, M. D. 1992. Fire and the development of oak forests. BioScience 42.

Åkerson, J. 2004. A nationally funded tactical exotics team gets started. Resource Management Newsletter, Shenandoah National Park, Luray, VA.

Åkerson, J. 2005. Abandoned developments exotic plant survey: 2004 preliminary results. Resource Management Newsletter, Shenandoah National Park, Luray, VA.

Altshuller, A. P., and A. S. LeFohn. 1996. Background ozone in the planetary boundary layer over the United States. J. Air Waste Mange. Assoc. 46:134-141.

Alvarez del Castillo, E. M., and D. L. Crawford. 2001. The value of dark skies and of high-quality night lighting – building public awareness. The George Wright Forum 18:20-24.

Anderson, R. L., J. L. Knighten, M. Windham, K. Langdon, F. Hedrix, and R. Roncardori. 1994. Dogwood anthracnose and its spread in the south. Forest Health Report, U.S. Department of Agriculture, Forest Service Southern Region.

Anonymous. 1988. Movement of black bears in park linked to gypsy moth infestation. August 9, The News-Virginian, Waynesboro, VA.

Argus, G. W., and D. J. White. 1984. *Panax quinquefolium*. In Atlas of the rare vascular plants of Ontario. Part 3. Edited by G.W. Argus and C.J. Keddy. National Museum of Natural Sciences.

Arritt, R. W. 1988. Numerical modeling of the effect of local source emissions on air quality in and around Shenandoah National Park. Final report. U.S. Department of the Interior, National Park Service, Air Quality Division, Denver, CO.

Arsenault, M., N. Fisichelli, C. Longmire, J. Åkerson, and R. Nemes. 2004. Shenandoah National Park boundary nonnative plant survey: 2003 preliminary results. Resource Management Newsletter, Shenandoah National Park, Luray, VA.

Atkinson, J. B. 2003. Shenandoah National Park Fisheries Monitoring Program Annual Report. Division of Natural and Cultural Resources, Shenandoah National Park, Luray, VA.

Atkinson, J. B. 2005. Fisheries project update. Resource Management Newsletter, Shenandoah National Park, Luray, VA.

Baedke, S. J., and L. S. Fichter. 2000. The geologic evolution of Virginia and the mid-Atlantic region: available online at http://csmres.jmu.edu/geollab/vageol/vahist/.

Bair, M. W. 2002. Forest health-gypsy moth update. Resource Management Newsletter. Shenandoah National Park. Luray, VA.

Bair, M. W. 2005. Hemlock woolly adelgid update. Resource Mangement Newsletter. Shenandoah National Park. Luray, VA.

Bair, S. 1998. Backcountry and wilderness management plan. U.S. Department of the Interior. National Park Service. Shenandoah National Park. Luray, VA.

Baker, J., D. Bernard, S. Christensen, M. Sale, J. Freda, K. Heltcher, D. Marmorek, L. Rowe, P. Scanlon, G. Suter, W. Warren-Hicks, and P. Welbourn. 1990. Biological effects of changes in surface water acid-base chemistry. SOS/T Report 13. Acid Precipitation Assessment Program. Washington, DC.

Balcom, B. J., and R. H. Yahner. 1996. Microhabitat and landscape characteristics associated with the threatened Allegheny woodrat. Conservation Biology 10.

Beck, J. P., and P. Grenfelt. 1994. Estimate of ozone production and destruction over northwestern Europe. Atmos. Environ. 28:129-140.

Bennett, J. P. 1984. Visible foliar injury to vegetation in Shenandoah National Parki, Virginia, caused by ozone. Final report to the Virginia Air Pollution Control Board. U.S. Department of the Interior. National Park Service. Air and Quality Division. Denver, CO.

Bennett, J. P. 1985. Effects of chronic air pollution on forests of Shenandoah National Park. Final report. U.S. Department of the Interior. National Park Service. Air Quality Division. Denver, CO.

Benzinger, J. 1994. Hemlock decline and breeding birds-I: Hemlock ecology. Records of New Jersey Birds 20:2-12.

Berg, L. Y., and R. B. Moore. 1941. Forest cover types of Shenandoah National Park, Virginia. U.S. Department of the Interior. National Park Service. Region One.

Bieri, R., and S. F. Anliot. 1965. The structure and floristic compostion of a virgin hemlock forest in West Virginia. Castanea 30:205-226.

Braun, E. L. 1950. Deciduous forests of eastern North America. The Blakiston Co. Philadelphia, PA.

Brinkman, W. A. 1975. Hurricane risk assessment. Program on Technology, Environment and Man, Monograph No. NSF-RA-E-75-007. Institute of Behavioral Science, The University of Colorado. Boulder, CO.

Brose, P., T. Schuler, D. Van Lear, and J. Berst. 2001. Bringing fire back: the changing regimes of the Appalachian mixed-oak forests. Journal of Forestry 99.

Brown, A. B. 1985. The bear necessities. Virginia Wildlife (July).

Brown, W. S. 1993. Biology, status, and management of the timber rattlesnake (*Crotalus horridus*): A guide for conservation. Society for the Study of Amphibians and Reptiles, Herpetological Circular 22.

Bruce, P. A. 1895. Economic history of Virginia in the seventeenth century; an inquiry into the material condition of the people, based upon original and contemporaneous records. P. Smith Inc. New York, NY.

Bulger, A., B. Cosby, C. Dolloff, K. Eshleman, J. Webb, and J. Galloway. 1999. The Shenandoah National Park: fish in sensitive habitats (SNP:FISH) project final report. An integrated assessment of fish community response to stream acidification. Shenandoah National Park. Luray, VA.

Bulger, A., C. Dolloff, B. Cosby, K. Eshleman, J. Webb, and J. Galloway. 1995. The Shenandoah National Park: fish in sensitive habitats (SNP:FISH) project. An integrated assessment of fish community response to stream acidification. Water, Air, and Soil Pollution 85:309-314.

Bunyak, J. 1993. Permit application guidance for new air pollution sources. NPS Natural Resources Report NPS/NRAQD/NRR-93/09.

Burns, C. E., K. M. Johnston, and O. J. Schmitz. 2003. Global climate change and mammalian species diversity in U.S. national parks. National Academy of Science, USA. 100.

Burns, D. A. 1989. Speciation and equilibrium relations of soluble aluminum in a headwater stream at base flow and during rain events. Water Resources Research 25:1653-1665.

Burton, T. M., and G. E. Likens. 1975. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, New Hampshire. Ecology 56:1068-1080.

Byrd, M. A., S. Padgett, and B. Watts. 2002. Peregrine falcone nesting and productivity. Yearly report to Virginia Game and Inland Fisheries. Richmond.

Camp, W. H. 1936. On Appalachian trails. Journal New York Botanical Garden 37:249-265.

Carey, C., A. P. Pessier, and A. D. Peace. 2003. Pathogens, infectious disease, and immune defenses. In R.D. Semlitsch (ed.), Amphibian Conservation. Smithsonian Institution Press. Washington, DC.

Carney, D., N. Garner, and M. Vaughan. 1987. Bear facts from Shenandoah National Park. Virginia Wildlife.

Cass, W. B. 1999. Big Meadows vegetation responds successfully to management. Resource Management Newsletter. Shenandoah National Park. Luray, VA.

Cass W. B. 2000. Pine Decline – Southern Pine Beetle Impacts to SNP Forests. Shenandoah National Park. Resource Management Newletter. pp. 11–12.

Cass, W. B. 2002. News from the ashes—forest regeneration and exotic species invasion after the Shenandoah complex fire. Shenandoah National Park. Resource Management Newsletter. Luray, VA.

Cass, W. B. 2005. Appalachian chain demonstration project: plants of economic importance – habitat model validation, plant marking, and covert plot installation. Final report. Shenandoah National Park. Luray, VA.

Cass W. B., and S. Bair. 2004. Rock Outcrop Management Project Detailed Implementation Plan. Unpublished Report. Shenandoah National Park. 40 pp.

Cass W. B, N. Fisichelli, and J. Hughes. 2006. Shenandoah National Park Long-Term Ecolgical Monitoring System Forest Monitoring Component - Standard Opperating Procedures 1–6 and 8–11. Unpublished Document. 129 pp. Shenandoah National Park. Luray, VA.

Castelle, A. J., and J. N. Galloway. 1990. Carbon dioxide dynamics in acid forest soil in Shenandoah National Park, Virginia. Soil Sci. Soc. Am. J. 54:252–257.

Chappelka, A. H., and B. I. Chevone. 1992. Tree response to ozone. Pp 271–324 *in* LeFohn, A. S. (ed.). Surface-level ozone exposures and their effects on vegetation. Lewis Publishers. Chelsea, MI.

Chestnut, L. G., and R. D. Rowe. 1990. Preservation values for visibility protection at the National Parks. Final report. Office of Air Quality Planning and Standards. U.S. Environmental Protection Agency. Washington, DC.

Cole, D. N., and J. L. Marion. 1988. Recreational impacts in some riparian forests of the eastern United States. Environ. Management 12:99-107.

Comiskey, J. A., K. K. Callahan, and C. M. Davis. 2005. Mid-Atlantic Network Vital Signs Monitoring Plan: Phase One. Inventory and Monitoring Program. USDI. NPS. Fredericksburg, MD.

Conners, J. A. 1988. Shenandoah National Park: an interpretive guide. The McDonald and Woodward Publishing Co. Blacksburg, VA.

Cooper, S. M., and D. L. Peterson. 2000. Tropospheric ozone distribution in western Washington. Eniron. Pollut. 107:339-347.

Cooper, S. M., and J. L. Moody. 2000. Meterological controls on ozone at an elevated eastern United States regional background monitoring site. J. Geophys. Res. 105:6855-6869.

Cosby, B. J., R. F. Wright, G. M. Hornberger, and J. N. Galloway. 1985. Modeling the effects of acid deposition: estimation of long-term water quality responses in a small forested catchment. Water Resources Research 21:1591-1601.

Cosby, B., P. Ryan, J. Webb, G. Hornberger, and J. Galloway. 1991. Mountains of West Virginia. Pages 297-318 in D. Charles, ed., Acidic deposition and aquatic ecosystems. Regional case studies. Springer-Verlag. New York, NY.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS 79/31. Washington, DC.

Crandall, H. 1975. Shenandoah: The story behind the scenery. KC Publishers. Las Vegas, NV.

Curtis, P. D., and K. L. Sullivan. 2001. Wildlife damage management fact sheet series: White-tailed deer. Cornell Cooperative Extension. Ithaca, NY.

DeKay, R. H. 1972. Development of ground-water supplies in Shenandoah National Park, Virginia. Mineral Resources Report 10. Virginia Division of Mineral Resources.

Demarest, D. 2005. Near stream recovery after the flood of 1995. Resource Management Newsletter. Shenandoah National Park. Luray, VA.

Dennis, T. E., and A. J. Bulger. 1995. Condition factor and whole-body sodium concentrations in a freshwater fish: evidence for acidification stress and possible ion regulatory over-compensation. Water, Air, and Soil Pollution 85:377-382.

DeSante, D. F., P. Pyle, and D. R. Kaschube. 2004. The 2003 annual report of the Monitoring Avian Productivity and Survivorship (MAPS) Program in Shenandoah National Park. Report to Shenandoah National Park. Luray, VA.

Deviney, F. A., Jr., and J. R. Webb. 2005. Water quality monitoring in the mid-Atlantic network of the National Park Service. University of Virginia. Charlottesville.

Diefenbach, D. R. 2001a. Estimates of statistical power to detect population trends fro black-nose dace and brook trout in Shenandoah National Park. Informal report. Pennsylvania Cooperative Fish and Wildlife Research Unit. U.S. Geological Survey, Biological Resources Division. University Park, PA.

Diefenbach, D. R. 2001b. Statistical evaluation of the vegetation inventory and monitoring program at Shenandoah National Park. Final report. U.S. Department of Interior. National Park Service. Cooperative Agreement 4000-8-9028.

Diefenbach, D. R., and C. G. Mahan. 2002. Setting realistic objectives: vegetation inventory and monitoring at Shenandoah National Park. Technical Report NPS/PHSO/NRTR-02/087. National Park Service. Northeast Region. Philadelphia Support Office. Philadelphia, PA.

Diefenbach, D. R., and J. K. Vreeland. 2003. A revised sampling design for vegetation inventory and monitoring at Shenandoah National Park. Final report. U.S. Department of Interior. National Park Service. Cooperative Agreement 4000-08-9028.

Dorazio, R. M., H. L. Jelkes, and F. Jordan. 2005. Improving removal-based estimates of abundance by sampling a population of spatially distinct subpopulations. Biometrics 61:1093-1101.

Dougherty, P. A dendroecological study of eastern hemlock decline in the Shenandoah National Park. PhD Dissertation. George Mason University. Fairfax, VA.

Duchelle, S. F., J. M. Skelly, and B. I. Chevone. 1982. Oxidant effects on forest tree seedling growth in the Appalachian Mountains. Water Air Soil Pollut. 18:363-373.

Duriscoe, D. 2001. Preserving pristine night skies in National Parks and the wilderness ethic. The George Wright Forum 18:30-36.

Eastern Brook Trout Joint Venture. 2005. Conserving the eastern brook trout: an overview of status, threats, and trends. Conservation Strategy Work Group, Eastern Brook Trout Joint Venture, International Association of Fish and Wildlife Agencies. Washington, DC.

Eaton, L. S., G. F. Wieczorek, B. A. Morgan. 2001b. Weathering characteristics and ages of debris-flow deposits at Graves Mill, VA. GSA Abstracts with Programs. Vol.33, No.2.

Eaton, L. S., T. M. Yanosky, and G. F. Wieczorek. 2003c. Use of dendrochronology for determining the chronology of landslide activity along Meadow Run, Shenandoah Valley, Virginia, USA. Eos Trans. AGU 84(46).

Eaton, L. S., and J. P. McGeehin. 1997. Frequency of debris flows and their role in the long-term landscape evolution in the central Blue Ridge (abstr.). Geological Society of America. Abstracts with Programs. Vol. 219, No. 6. p. 410.

Eaton, L. S., B. A. Morgan, R. C. Kochel, and A. D. Howard. 2003a. Quaternary deposits and landscape evolution of the central Blue Ridge of Virginia. *Geomorphology*. Vol. 56. p. 139–154.

Eaton, L. S., B. A. Morgan, and J. L. Blair. 2001a. Surficial geology of the Fletcher, Madison, Stanardsville, and Swift Run Gap, 7.5-minute quadrangles, Madison, Greene, Albemarle, Rockingham, and Page Counties, Virginia. U.S. Geol. Surv. OFR 01-92.

Eaton, L. S., B. A. Morgan, R. C. Kochel, and A. D. Howard. 2003b. Role of debris flows in long-term landscape denudation in the central Appalachians of Virginia. *Geology*. Vol. 31. p. 339–342.

Engquist, D. B. 2001. A dialogue on the natural resource challenge. The George Wright Forum.

Environment Canada. 1998. National ambient air quality objectives for particulate matter. Bureau of Chemical Hazards. Ottawa, Ontario.

Eshleman, K. N., L. M. Miller-Marshall, and J. R. Webb. 1995. Long-term changes in episodic acidification of streams in Shenandoah National Park, Virginia (U.S.A.). Water, Air, and Soil Pollution 85:517–522.

Eshleman, K., J. Moody, K. Hyer, and F. Deviney. 1999. Episodic acidification of streams in Shenandoah National Park, Virginia. Final report. U.S. Department of the Interior. National Park Service. Mid-Atlantic Region. Philadelphia, PA.

Eshleman, K. N., D. A. Fiscus, N. M. Castro, J. R. Webb, and F. A. Deviney, Jr. 2001. Computation and visualization of regional-scale forest disturbance and associated dissolved nitrogren export from Shenandoah National Park, Virginia. *In* Optimizing Nitrogen Management in Food and Energy Production and Environmental Protection: Proceedings of the 2nd International Nitrogen Conference on Science and Policy. TheScientificWorld 1.

Espenshade, G. H. 1970. Geology of the northern part of the Blue Ridge anticlinorium. *in* G. W. Fisher et al. eds. Appalachian geology: New York, Interscience Publishers. pp 199–211.

Feldman, R., and E. Conner. 1992. The relationship between pH and community structure of invertebrates in streams of the Shenandoah National Park, Virginia, USA. Freshwater Biology 27:261–276.

Ferman, M. A., G. T. Wolff, and N. A. Kelly. 1981. The nature and sources of haze in the Shenandoah Valley/Blue Ridge Mountains area. Research Publication. General Motors Research Laboratories. Warren, MI.

Fievet, D. J., M. L. Allen, and J. R. Webb. 2003. Documentation of landuse and distrubance history in fourteen intensively studies watersheds in Shenandoah National Park, Virginia. Final Report. Shenandoah Watershed Study. Department of Environmental Sciences, University of Virginia, Charlottesville.

Fleming, G. P. 2002. Ecological communities of the Bull Run Mountains, Virginia: baseline vegetation and floristic data for conservation planning and natural area stewardship. Natural Heritage Technical Report 02-12. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Richmond. 274 pp.

Fleming, G. P., and N. E. Van Alstine. 1999. Plant communities and floristic features of sinkhole ponds and seepage wetlands in southeastern Augusta County, Virginia. Banisteria 13:76–94.

Fleming, G. P., and W. H. Moorhead. 2000. Plant communities and ecological land units of the Peters Mountain area, James River Ranger District, George Washington and Jefferson National Forests, Virginia. Natural Heritage Technical Report 00-07. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Richmond. 195 pp.

Flenniken, D. 2006. Lichens Identified from Four Sites in the Shenandoah National Park for the Rock Outcrop Management Project. Unpublished Report. Wooster, OH. 6 pp.

Forman, R., and H. Sierk. 1970. Bryophytes and lichens of the Shenandoah National Park, Virginia, collected on the 1966 foray of the American Bryological Society. Bryologist 73: 82–92.

Fosberg, F. R. 1946. Observations on Virginia Plants. III. Castanea 11:66–70.

Fosberg, F. R. 1947. Observations on Virginia Plants. IV. Castanea 12:59–62.

Fosberg, F. R. 1955. Observations on Virginia Plants. V. Castanea 20:58–61.

Fosberg, F. R. 1959. Notes on the Shenandoah National Park flora. Castanea 24:135–143.

Fosberg, F. R., and E. H. Walker. 1941. A preliminary checklist of plants in the Shenandoah National Park, Virginia. Castanea 6:89–136.

Fosberg, F. R., and E. H. Walker. 1943. First supplement to a preliminary checklist of plants in the Shenandoah National Park, Virginia. Castanea 8:109–115.

Fosberg, F. R., and E. H. Walker. 1948. Second supplement to a preliminary checklist of plants in the Shenandoah National Park. Castanea 13:84–92.

Fosberg, F. R., and E. H. Walker. 1955. Third supplement to a preliminary checklist of plants in the Shenandoah National Park. Castanea 20:61–70.

Fosberg, F. R., and P. M. Mazzeo. 1965. Further notes on Shenandoah National Park plants. Castanea 30:191–205.

Frisbie, M. P., and R. L. Wyman. 1991. The effects of soil pH on sodium balance in the red-backed salamander, *Plethodon cinereus*, and three other terrestrial salamanders. Physiological Zoology 64(4):1050–1068.

Galloway, J., R. Deviney, and J. Webb. 1999. Shenandoah Watershed Study Data Assessment: 1980–1993. Project Final Report. Shenandoah National Park. Luray, VA.

Galloway, J., S. Norton, and M. Church. 1993. Freshwater acidification from atmospheric deposition of sulfuric acid: a conceptual model. Environmental Science and Technology 17:454A–541A.

Garner, N. 1987. Black bear – human interactions in Shenandoah National Park, Virginia. Research/Resources/Management Report to SHEN. Virginia Tech. Luray, VA.

Gathright, T. M. 1976. Geology of the Shenandoah National Park, Virginia: Virginia Division of Mineral Resources. Bulletin 86. 93 pp.

Gibbs, J. P. 1998. Integrating monitoring objectives with sound sampling design: a pilot review of selected monitoring programs at Shenandoah National Park. Final report. U.S.

Department of Interior. National Park Service. Northeast Region. Philadelphia Support Office. Philadelphia, PA.

Grant, E. H. C., R. E. Jung, and K. C. Rice. 2005. Stream salamander species richness and abundance in relation to environmental factors in Shenandoah National Park, Virginia. American Midland Naturalist 153:348–356.

Greenberg, C. H., D. E. McLeod, and D. Loftis. 1997. An old-growth definition for western and mixed-mesophytic forests. U.S. Department of Agriculture. Forest Service. Gen. Tech. Report SRS-16.

Griffis, M. R. 1993. Competitive exclusion of the endangered Shenandoah Salamander: Field and laboratory tests of the hypothesis. Master's Thesis. University of Louisiana, Lafayette.

Gubler, R. 2004. White-tailed deer spotlight counts in the Big Meadows area. Annual Report for 2003 to Shenandoah National Park, Luray, VA.

Gubler, R. 2005. Peregrine Falcon restoration and tracking project. Annual Report for 2004 to Shenandoah National Park, Luray, VA.

Hallingbäck, T. 1992. The effect of air pollution on mosses in southern Sweden. Biol. Conserv. 59:163–170

Hammitt, W. E., and D. N. Cole. 1998. Wildland recreation: Ecology and management. 2nded. Wiley and Sons. NY.

Harder, B. 2004. Degraded darkness. Conservation Biology in Practice 5.

Harris, R. 2006. Preliminary List of the Crustose Lichens of Shenandoah National Park. April 2006. Unpublished Report. New York Botanical Garden. NY. 6 pp.

Heffernan, K. E. 1999. Rare natural communities management guidelines, rare plant summary information, and rare plant species matrix for Shenandoah National Park, Virginia. Natural Heritage Technical Report 99-12. VA Department of Conservation and Recreation, Division of Natural Heritage. Richmond.

Hendrey, G. R., J. N. Galloway, S. A. Norton, C. L. Schofield, P. W. Shaffer, and D. A. Burns. 1980. Geological and hydrochemical sensitivity of the eastern United States to acid precipitation. EPA-600/3-80-024, U.S. Environmental Protection Agency, Washington D.C.

Herlihy, A. T., P. R. Kaufmann, M. R. Church, P. J. Wigington, Jr., J. R. Webb, and M. J. Sale. 1993. The effects of acidic deposition on streams in the Appalachian Mountain and Piedmont Region of the Mid-Atlantic United States. Water Resources Research 29:2687–2703.

Hildebrand, E., J. M. Skelly, and T. S. Fredericksen. 1996. Foliar response of ozone-sensitive hardwood tree species from 1991–1993 in Shenandoah National Park, Virginia. Can. J. For. Res. 658-669.

Horsely, S. B., S. L. Stout, and D. S. DeCalests. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 13.

Houston, D. R., and J. T. O'Brien. 1983. Beechbark disease. Forest Insect and Disease Leaflet. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. Hamden, CT.

Hudy, M., T. M. Thieling, N. Gilliespie, and E. P. Smith. 2006. Distribution, status, and threats to brook trout within the eastern United States. Final Report. Eastern Brook Trout Joint Venture. National Fish and Wildlife Foundation. Washington, DC.

Hyer, K. E., Jr., J. R. Webb, and K. N. Eshleman. 1995. Episodic acidification of three streams in Shenandoah National Park, Virginia, USA. Water, Air, and Soil Pollution 85:523–528.

Jacob, D. J., L. Horowitz, J. W. Munger, B. G. Heikes, R. R. Dickerson, R. S. Artz, and W. C. Keene. 1995. Seasonal transition from NOx to hydrocarbon-limited conditions for ozone production over the eastern United States in September. J. Geophys. Res. 100:9315–9324.

Jacobson, R. B., A. J. Miller, and J. A. Smith. 1989. The rate of catastrophic geomorphic events in central Appalachian landscape evolution. Geomorphology 2:257–284.

Jaeger, R. H. 1972. Food as a limited resource in competition between two species of terrestrial salamanders. Ecology 53.

Jewell, M. C. 2001. An assessment of trail conditions in Shenandoah National Park. M.S. Thesis. Clemson University. Clemson, SC.

Jewell, M. C., and W.E. Hammitt. 2000. Assessing Soil Erosion on Trails : A Comparison of Techniques. *In* Proceedings: Wilderness Science in a Time of Change; Vol 5: Wilderness Ecosystems, Threats, and Management. May 23-27, 1999. D. N. Cole and others, eds. pp. 133–140. Missoula, MT. Proceedings RMRS-P-15-Vol-5. Ogden, UT. USDA Forest Service, Rocky Mountain Research Station.

Johnson, G. G., and S. Ware. 1982. Post-chestnut forests in the central Blue Ridge of Virginia. Castanea 47: 329–343.

Johnson, Z., and C. Snyder. 2002. Recovery of aquatic macroinvertebrate communities following a 500+ year flood event in the Shenandoah National Park. U.S. Geological Survey, Leetown Science Center. Kearneysville, WV.

Johnston, D. W. (Compiler). 1997. A Birder's Guide to Virginia. American Birding Association. Colorado Springs, CO.

Jung, R. E., S. Droge, J. R. Sauer, and R. B. Landy. 2000. Evaluation of terrestrial and streamside salamander monitoring techniques at Shenandoah National Park. Environmental Monitoring and Assessment 63.

Jung, R. E., J. A. Royle, J. R. Sauer, C. Addison, R. D. Rau, J. L. Shirk, and J. C. Whissel. 2005. Estimation of stream salamander (Plethodontidae, Desmognathinae, and Plethodontinae) populations in Shenandoah National Park, Virginia, U.S.A. Alytes 22:72-84.

Kallman, H. 1987. Restoring America’s Wildlife 1937–1987. U.S. Fish and Wildlife Service. Washington, DC.

Karish, J., T. Blount, and B. Krumenaker (eds.). 1997. Resource assessment of the June 27 and 28, 1995 floods and debris flows in Shenandoah National Park. Natural Resources Report NPS/SHEN/NRR-97/001. Luray, VA.

Kasbohm, J. W. 1994. Response of black bears to gypsy moth infestation in Shenandoah National Park, Virginia. PhD Dissertation. Virginia Polytechnic Institute and State University. Blacksburg.

Kasbohm, J. W, M. R. Vaughan, and J. G. Kraus. 1994. Black bear harvest and nuisance behavior in response to gypsy moth infestation. Proceedings of the Annual Conference of SE Association of Fish and Wildlife Agencies 48.

Keene, W. C., D. J. Jacob, R. W. Talbot, and J. W. Munger. 1995. Shenandoah cloud and photochemistry experiment (SCAPE): overview. J. Geophysical Res. 100:9313–9314.

Lambert, D. 1989. The undying past of Shenandoah National Park. Roberts Rinehart, Inc. Boulder, CO.

Lee, T. R. and G. M. Hornberger. 2006. Inferred bimodality in the distribution of soil moisture at Big Meadows, Shenandoah National Park, Virginia. Geophysical Research Letters 33.

Lennon, R. E. 1961. The trout fishery in Shenandoah National Park. Special Scientific Report No. 395. U.S. Department of the Interior. U.S. Fish and Wildlife Service, Fish Control Laboratory. La Crosse, WI.

Lindsay, T., and P. Lindsay. 1997. Birds of Shenandoah National Park, A Naturalist's View. Shenandoah Natural History Association. Luray, VA.

Linzey, D. W. 1998. The Mammals of Virginia. McDonald & Woodward Publication Co. Blacksburg,VA.

Lipford, M. L. 1984. The effect of aspect and elevation on forest community composition in intermediate age successional stands in Shenandoah National Park, Virginia. M.S. Thesis. James Madison University. Harrisonburg, VA.

Litwin, R. J., B. A. Morgan, L. S. Eaton, and G. F. Wieczorek. 2004. Assessment of Late Pleistocene to recent climate-induced vegetation changes in and near the Shenandoah National Park (Blue Ridge Province, VA). USGS Open File Report 2004-1351.

Ludwig, J. C., G. P. Fleming, C. A. Pague, T. J. Rawinski. 1993. A natural heritage inventory of mid-Atlantic region National Parks in Virginia: Shenandoah National Park. Virginia Department of Conservation and Recreation Natural Heritage Technical Report No. 93-5.

Lynch, D. D. 1987. Hydrologic conditions and trends in Sheanandoah National Park, Virginia, 1983–1984. U.S. Geological Survey. Water Resources Investigations Report 87-4131. Richmond, VA. 115 pp.

MacAvoy, S. E., and A. J. Bulger. 1995. Survival of brook trout embryos and fry in streams of different acid sensitivity in Shenandoah National Park, USA. Water, Air, and Soil Pollution 85:445–450.

Mahan, C. G., K. L. Sullivan, B. Black, K. C. Kim, and R. H. Yahner. 2004. Overstory tree composition of eastern hemlock stands threatened by the hemlock woolly adelgid at Delaware Water Gap National Recreation Area. Castanea 69.

Manville, R. H. 1956. The Mammals of Shenandoah National Park. Shenandoah Natural History Association. Luray, VA.

Marion, J. L. 2005a. Guidance for managing informal trails. Research report. Cooperative Park Studies Unit. U. S. Department of the Interior. Virginia Tech. Blacksburg, VA.

Marion, J. L. 2005b. Recreation impacts to Shenandoah National Park cliffs: progress report and preliminary results. Cooperative Parks Unit. Virginia Tech. Blacksburg, VA.

Marion, J. L., and D. Haskell. 1988. An analysis of visitor impacts and rehabilitation methods for backcountry campsites at Shenandoah National Park. Res./Resources Management Report. U.S. Department of the Interior. National Park Service. Mid-Atlantic Region. Philadelphia, PA.

Marion, J. L., J. W. Roggenbuck, and R. Manning. 1993. Problems and practices in backcountry recreation management: a survey of National Park Service managers. Natural Resource Report NPS/NRVT/NRR-93/12. U.S. Department of the Interior. National Park Service.

Martin, L. 2002. Drinking water source protection plan, Big Meadows Area, Shenandoah National Park. National Park Service Water Resources Division. Fort Collins, CO.

Martin, W. H. 1992. Phenology of the timber rattlesnake (*Crotalus horridus*) in an unglaciated section of the Appalachian Mountains. Pp. 259–277 *in* J. A. Campbell and E. D. Brodie, Jr. (eds). Biology of the Pitvipers. Selva. Tyler, TX.

Martin, W. H. 1993. Reproduction of the timber rattlesnake (*Crotalus horridus*) in the Appalachian Mountains. Journal of Herpetology 27

Massey, A. B. 1968. Notes relative to plant ecology in Virginia. Castanea 33:161–162.

Matthiessen, P. 1987. Wildlife in America. Viking Penguin, Inc. NY.

Mazzeo, P. 1981. Ferns and fern allies of Shenandoah National Park. 2nd Edition. Shenandoah Natural History Association. Luray, VA.

Mazzeo, P. M. 1966a. Native and exotic ornamentals in the Shenandoah National Park. American Horticulture Magazine 45:419–421.

Mazzeo, P. M. 1966b. Notes on the conifers of the Shenandoah National Park. Castanea 31:240–247.

Mazzeo, P. M. 1966c. New additions to the Shenandoah National Park flora. Castanea 31:236–240.

Mazzeo, P. M. 1967. New additions and notes to the Shenandoah National Park flora. Castanea 32:177–183.

Mazzeo, P. M. 1968. Trees of Shenandoah National Park. Shenandoah Natural History Association. Luray, VA. 55 pp.

Mazzeo, P. M. 1972. Further notes on the flora of the Shenandoah National Park, Virginia. Castanea 37:168–178.

McClure, M. S. 1991. Density-dependent feedback and population cycles in *Adelges tsugae* (Homoptera: Adelgidae) on Tsuga Canadensis. Environmental Entomology 20.

McQuaid-Cook, J. 1978. Effects of hikers and horses on mountain trails. J. Environ. Manage. 6:209–212.

McShea, W. J. 2000. The influence of acorn crops on annual variation in rodent and bird populations. Ecology 81.

McShea, W. J., and G. Schwede. 1993. Variable acorn crops: the response of white-tailed deer and the other mast consumers. Journal of Mammalogy 74.

McShea, W. J., and J. H. Rappole. 1992a. Managing the abundance and diversity of breeding bird populations through manipulation of deer populations. Conservation Biology 14.

McShea, W. J., and J. H. Rappole. 1992b. White-tailed deer as keystone species within forest habitats of Virginia. Virginia Journal of Science 43.

McShea, W. J., and J. H. Rappole. 1997. Herbivores and the ecology of forest understory birds. Pp. 298–309 *in* W. J. McShea, H. B. Underwood, and J.H. Rappole (eds.). The Science of Overabundance, Deer Ecology and Population Management. Smithsonian Institution Press. Washington, DC.

Mengak, M. T. 2000. Analysis and summary of eleven years of Allegheny woodrat trapping data in southwest Virginia, 1990–2000. Virginia Department of Game and Inland Fisheries. Richmond, VA.

Mielke, M. E., C. Haynes, and W. L. MacDonald. 1982. Beech scales and *Nectria galligena* on beech in the Monongahela National Forest, West Virginia. Plant Disease Reporter 66(9):851–852.

Mielke, M. E., D. B. Houston, and D. R. Houston. 1985. First report of *Cryptococcus fagisuga*, initiator of beech bark disease, in Virginia and Ohio. (Disease Note) Plant Disease 69:905.

Mills, J. N., J. M. Johnson, and 15 other authors. 1998. A survey of hantavirus antibody in small mammal populations in selected United States National Parks. American Journal of Tropical Medicine and Hygiene 58.

Mitchell, J. C. 1994. The Reptiles of Virginia. Smithsonian Institution Press. Washington, DC.

Mitchell, J. C. 1998. Amphibian decline in the mid-Atlantic region: Monitoring and management of a sensitive resource. Final Report. Legacy Resource Management Program, U.S. Department of Defense.

Mitchell, J. C. 2000. Amphibian Monitoring Methods & Field Guide. Smithsonian.

Mitchell, J. C., and K. Reay. 1999. Atlas of Amphibians and Reptiles in Virginia. Special Publication Number 1. Virginia Department of Game and Inland Fisheries. Richmond, VA.

Mitra, G., and M. T. Lukert. 1982. Geology of the Catoctin-Blue Ridge Anticlinorium in northern Virginia. *in* Central Appalachian Geology. American Geological Institute. NE-SE Geological Society of America 1982 Field Trip Guidebook. pp 83–108.

Moeykins, M., and J. Voshell. 2002. Studies of benthic macroinvertebrates for the Shenandoah Naitional Park long-term ecological monitoring system: statistical analysis of LTEMS aquatic dataset from 1986–2000 on water chemistry, habitat, and macroinvertebrates. Final report. Shenandoah National Park. Luray, VA.

Mohn, L., and P. Bugas. 1979. Virginia trout stream and environmental inventory, January 1, 1976–December 31, 1979. Dingell-Johnson Report F-32. Virginia Commission of Game and Inland Fisheries. Richmond, VA.

Montgomery, M. E., and W. E. Wallner. 1988. The gypsy moth, a westward migrant. Chapter 18 *in* A. A. Berryman (ed.). Dynamics of forest insect populations: patterns, causes, implications. Plenum Press. NY.

Moore, H. W. 2003. Shenandoah: views of our National Park. University of Virginia Press. Charlottesville.

Morgan, B. A., L. S. Eaton, and G. F. Wieczorek. 2004. Pleistocene and Holocene colluvial fans and terraces in the Blue Ridge region of Shenandoah National Park, Virginia. U. S. Geological Survey. Report: OF 03-0410. 25 pp.

Munger, J. W., D. J. Jacob, B. C. Daube, and L. W. Horowitz. 1995. Formaldehyde, glyoxal, and methylglyoxal in air and cloudwater at a rural mountain site in central Virginia. J. Geophysical Res. 100:9325–9333.

Murphy, P. A., and G. J. Nowacki. 1997. An old-growth definition for xeric pine and pine-oak woodlands. U.S. Department of Agriculture, Forest Service. Gen. Tech. Rep. SRS-7.

Musselman, R. C., and W. J. Massman. 1999. Ozone flux to vegetation and its relationship to plant response and ambient air quality standards. Atmospheric Environment 33:65–73.

National Highway Institute. 1994. Rockfall hazard rating system. NHI course no.130220 Federal Highway Administration. Washington, DC.

National Park Conservation Association (NPCA). 2003. Shenandoah National Park: A Resource Assessment. Washington, DC.

National Park Service (NPS). 1997. Fisheries Management Plan, Shenandoah National Park, Luray, Virginia.

National Park Service (NPS). September 1998. Resource Management Plan, Shenandoah National Park, Virginia.

National Park Service (NPS). 2000. Inventory and prototype monitoring of natural resources in selected National Park system units, 1998–1999. U.S. Department of the Interior. National Park Service. Natural Resource Information Division. Natural Resource Technical Report NPS/NRI&M/NRTR-2000/1.

National Park Service (NPS). 2001. Management policies 2001. U.S. Department of the Interior. National Park Service. Technical Document NPS D1416.

National Park Service (NPS). 2003. Assessment of air quality and related values in Shenandoah National Park. Technical Report NPS/NERCHAL/NRTR-03/090.

National Park Service (NPS). 2004. http://www2.nature.nps.gov/air/Pubs/pdf/03Risk/midnO3RiskOct04.pdf.

National Park Service (NPS). 2005a. Air resource management. Natural resource fact sheet. U.S. Department of the Interior. National Park Service. Shenandoah National Park. Luray, VA.

National Park Service (NPS). 2005b. Brook trout genetics. Natural resource fact sheet. Shenandoah National Park. Luray, VA.

National Park Service (NPS). 2005c. Forest vegetation monitoring. Natural resource fact sheet. U.S. Department of the Interior. National Park Service. Shenandoah National Park. Luray, VA.

National Park Service (NPS). 2005d. Landscape management. Natural resource fact sheet. U.S. Department of the Interior. National Park Service. Shenandoah National Park. Luray, VA.

National Park Service (NPS). 2005e. Draft Fire Management Plan. Shenandoah National Park. Virginia. Luray, VA.

National Park Service (NPS). 2005f. Cliff management project. Natural resource fact sheet. Shenandoah National Park. Luray, VA.

National Park Service (NPS). 2005g. Exotic plant control. Natural resource fact sheet. Shenandoah National Park. Luray, VA.

National Park Service (NPS). 2005h. Bird monitoring. Natural resource fact sheet. Shenandoah National Park. Luray, VA.

National Park Service (NPS). 2005i. Current status of the rock outcrop management project at Shenandoah National Park. Progress Summary. Edited by Eric Butler. Shenandoah National Park. Luray, VA.

Newman, K., and A. Dolloff. 1995. Reponses of blacknose dace and brook char to acidified water in a laboratory stream. Water, Air, and Soil Pollution 85:371–376.

Norris, S. J. 2002. Review of plant species lists for New River Gorge National River, Bluestone National Scenic River, and Gauley National Recreation Area. Final report. National Park Service. Inventory and Monitoring Program.

NPSpecies. 2005. National Park Service Biodiversity online database. http://science.nature.nps.gov/im/apps/npspp/.

Ockels, F. S., M. Mielke, and P. Bonello. 2004. Sudden oak death: monitoring Phytophthora ramorum in the north central United States. Ornamental Plants Annual Reports and Research Reviews. Special Circular 195. Agricultural Extension Program. Ohio State University. Columbus.

O'Connell, T., R. Brooks, M. Lanzone, and J. Bishop. 2003. A Bird Community Index for the Mid-Atlantic Piedmont and Coastal Plain. Final Report. National Park Service. Inventory and Monitoring Program. University Park, PA.

Olday, F. 2005. Bryophyte Checklist of Shenandoah National Park. Unpublished Report. February 8, 2005. 4 pp.

Onken, B., J. Quimby, R. Evans, and S. Hutchinson. 1994. Work plan for monitoring the impacts of hemlock woolly adelgid. U.S. Department of Agriculture, Forest Service. Morgantown, WV.

Patterson, P. M. 1955. Additions and corrections to the bryophyte flora of the Shenandoah National Park. Castanea 20:16-24.

Plummer, L. N., E. Busenberg, J. K. Bohlke, D. L. Nelms, R. L. Michel, and P. Schlosser. 2001. Ground water residence times in Shenandoah National Park, Blue Ridge Mountains, Virginia, USA – a multi-tracer approach. Chemical Geology 179:93–111.

Raphael, D. L. 1982. A hiking trail model for the Central District, Shenandoah National Park. Institute for Research on Land and Water. The Pennsylvania State University. University Park.

Ravlin, F. W., S. J. Fleischer, and S. L. Rutherford. 1990. Shenandoah National Park Long-term Ecological Monitoring System. Section IV. Gypsy Moth Component User Manaual. NPS/NRSHEN/NRTR-90/02.

Redding, J. 1995. History of deer population trends and forest cutting on the Allegheny National Forest. *in* K. W. Gottschalk and S. C. L. Fosbroke, editors. Proceedings of the 10th Central Hardwood Forest Conference. USDA Forest Service. General Technical Report NE-97. Northeastern Forest Experiment Station. Radnor, PA.

Regelbrugge, J. C., and D. W. Smith. 1994. Postfire tree mortality in relation to wildfire severity in mixed oak forests in the Blue Ridge of Virginia. N. Journal of Applied Forestry 11:90–97.

Reid, S. E., and J. L. Marion. 2004. Effectiveness of a confinement strategy for reducing campsite impacts in Shenandoah National Park. Environmental Conservation 31:274–282.

Richardson, G. M., M. Egyed, and D. J. Currie. 1995. Does acid rain increase human exposure to mercury? A review and analysis of recent literature. Environmental Toxicology and Chemistry 14:809–813.

Riitters, K. H., J. D. Wickham, R. V. O'Neill, K. B. Jones, E. R. Smith, J. W. Coulston, T. G. Wade, and J. H. Smith. 2002. Fragmentation of continental United States forests. Ecosystems 5:815–822.

Rosenberg, K. V., S. E. Barker, and R. W. Rohrbaugh. 2000. An atlas of cerulean warbler populations. Cornell Lab of Ornithology. Ithaca, NY.

Ryan, P., G. Hornberger, B. Cosby, J. Galloway, J. Webb, and E. Rastetter. 1989. Changes in the chemical composition of stream water in two catchments in the Shenandoah National Park, Virginia, in response to atmospheric deposition of sulfur. Water Resources Research 25:2091–2099.

Sanchini, P. J. 1988. Ozone injury on *Pinus strobus* in permanent plots at Shenandoah National Park: 1986 Survey Results. Final Report. Air Quality Division. U.S. Department of the Interior. National Park Service, Cooperative Agreement CX0001-4-0058.

Scanlon, J. J., and M. R. Vaughan. 1987. Population and behavioral ecology of white-tailed deer in Shenandoah National Park, VA. Department of Fisheries and Wildlife Sciences. Virginia Tech. Blacksburg.

Schnooberger, I., and F. E. Wynne. 1945. The bryophytes of Shenandoah National Park, Virginia. Bulletin of the Torrey Botanical Club 72:506–520.

Schuler, T. M., and W. R. McClain. 2003. Fire history of a ridge and valley oak forest. Research paper NE-724. U.S. Department of Agriculture, Forest Service, Northeastern Research Station. Newtown Square, PA.

Schweitzer, D. F. 2004. Gypsy Moth (Lymantria dispar): Impacts and options for biodiversity-oriented land managers. NatureServe: Arlington, VA.

Seton, E. T. 1909. Life histories of northern mammals. Volume I. Chas. Scribner's and Sons. NY.

Seton, E. T. 1929. Lives of game animals. Volume III. Doubleday Doran and Co. Inc. NY.

Simpson, M. B., Jr. 1992. Birds of the Blue Ridge Mountains. University of North Carolina Press. Chapel Hill.

Simpson, R. C. 1985. Macro-Fungi Checklist: Shenandoah National Park. Unpublished Report. Lord Fairfax Community College. Middletown, VA. 2 pp.

Skelly, J. M., and E. Hildebrand. 1992. Occurrence and severity of ozone injury on sensitive hardwood species in Shenandoah National Park. Final Report. Department of the Interior. National Park Service. Cooperative Agreement 4000-9-8004. The Pennsylvania State University. Environmental Resources Research Institute. University Park.

Skelly, J. M., D. D. Davis, K. C. Steiner, J. Zhang, M. Schaub, J. Ferdinand, J. E. Savage, and R. E. Stevenson. 2001. Impact of ambient ozone on physiological, visual, and growth responses of sensitive eastern hardwood tree species under natural and varying conditions. Assistance ID No. 825244-01-0. Final report. National Center for Environmental Research and Quality Assurance. U.S. EPA. Washington, DC.

Smith, D. W., and J. L. Torbert. 1990. Shenandoah National Park long-term ecological monitoring system. Section II. Forest components user manual. NPS/NRSHEN/NRTR-90/02.

Smith, J. A., M. L. Baeck, and M. Steiner. 1996. Catastrophic rainfall from an upslope thunderstorm in the central Appalachians: The Rapidan storm of June 27, 1995: Water Resources Research, v. 32, pp. 3099–3113.

Smith, W. H. 1990. Air pollution and forests: Interaction between air contaminants and forest ecosystems. Springer-Verlag. NY.

Smoot, J. P. 2004. Sedimentary characteristics of late Pleistocene periglacial stratified-slope deposits in the Blue Ridge of central Virginia Abstracts with Programs - Geological Society of America. vol. 36, no. 2. p.95.

Sneddon, L. A., and K. J. Metzler. 1992. Eastern Regional Community Classification, Organization Hierarchy, and Cross-Reference to State Heritage Community Classifications. The Nature Conservancy. Eastern Heritage Task Force. Boston, MA.

Snyder, C., J. Webb, J. Atkinson, and S. Spitzer. 2003. Effects of stream water chemistry on mercury concentration in brook trout in Shenandoah National Park. Research Proposal. U.S. Geological Survey. Leetown Science Center. Kearneysville, WV.

Snyder, C. D., J. A. Young, D. Smith, D. P. Lemarie, and D. R. Smith. 2002. Influence of eastern hemlock (Tsuga canadensis) forests on aquatic invertebrate assemblages in headwater streams. Canadian Journal of Fisheries and Aquatic Sciences 59(2): 262–275.

Southern Appalachian National Park Commission (SANPC). 1933. Shenandoah National Park Souvenir Book. Harrisonburg, VA.

Stankey, G. H., D. N. Cole, R. C. Lucas, M. E. Peterson, and S. S. Frissell. 1985. The limits of acceptable change (LAC) system for wilderness planning. Gen. Tech. Rep. INT-176. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Ogden, UT.

Stebbins, R. C., and N. W. Cohen. 1995. A Natural History of Amphibians. Princeton University Press. Princeton, NJ.

Stephenson, S. L. 1974. Ecological composition of some former oak-chestnut communities in West Virginia. Castanea 39:278–286.

Stephenson, S. L. 1986. Changes in a former chestnut-dominated forest after a half-century of succession. American Midland Naturalist 116:173–179.

Stephenson, S. L., and H. S. Adams. 1989. The high-elevation red oak (*Quercus rubra*) community type in western Virginia. Castanea 54:217–229.

Stevenson, J. A. 1936. A preliminary checklist of the fungi of Shenandoah National Park. Claytonia 3:21–28.

Stevenson, J. A. 1937. A preliminary checklist of the fungi of Shenandoah National Park. Claytonia 3:31–35.

Sullivan, J., M. E. Patterson, and D. R. Williams. 1993. Shenandoah National Park: economic impacts and visitor perceptions, 1992. Technical Report NPS/MARSHEN/NRTR—93/055. U.S. Department of the Interior. National Park Service.

Sullivan, T. J., B. J. Cosby, J. A. Laurence, R. L. Dennis, K. Savig, J. R. Webb, A. J. Bulger, M. Scruggs, C. Gordon, J. Ray, E. H. Lee, W. E. Hogsett, H. Wayne, D. Miller, and J. S. Kern. 2003a. Assessment of air quality and related values in Shenandoah National Park. NPS/NERCHAL/NRTR-03/090. U.S. Department of the Interior. Philadelphia, PA.

Sullivan, T. J., B. J. Cosby, J. R. Webb, K. U. Snyder, A. T. Herlihy, A. J. Bulger, E. H. Gilbert, and D. Moore. 2003b. Assessment of the effects of acidic deposition on aquatic resources in the Southern Appalachian Mountains. Final report. Southern Appalachian Mountains Initiative (SAMI). E&S Environmental Chemistry, Inc. Covallis, OR.

Teetor, A. 1988. Identification and mapping of vegetation communities in Shenandoah National Park, Virginia. Final Report. MAR-34. Shenandoah National Park. Luray, VA.

Terwilliger, K., and J. R. Tate. 1995. A Guide to Endangered and Threatened Species in Virginia. McDonald & Woodward Publishing Co. Blacksburg, VA.

Thomas, S. H. 1987. Birds of Shenandoah National Park. Shenandoah Natural History Association. Luray, VA. (Brochure)

Tigner, T. 1998. Forest health versus forest change in Virginia: a primer. Virginia Forest Landowner Update 12(2).

Townsend, J. F. 2005. Natural Heritage Resources of Virginia: Rare Plants. Natural Heritage Technical Report 05-08. Virginia Department of Conservation and Recreation, Division of Natural Heritage. Richmond, VA. Unpublished report.

Treshow, M., and F. K. Anderson. 1989. Plant stress from air pollution. John Wiley and Sons. NY.

U.S. Census Bureau. 2005. Census 2000, 2004 data for the state of Virginia. http://www.census.gov/census2000/states/va.html.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service (USDA APHIS). 2003. Managing vulture damage. Pittstown, NJ.

U.S. Fish and Wildlife Service (USFWS). 1994. Shenandoah Salamander (*Plethodon shenandoah*). Recovery Plan. Hadley, MA.

U.S. Fish and Wildlife Service (USFWS). 1996. Small whorled pogonia in Endangered and Threatened Species of the southeastern United States. U.S. Fish and Wildlife Service, Division of Endangered Species. Asheville, NC.

U.S. Fish and Wildlife Service (USFWS). 1999. Partners in Flight Watchlist. USGS Patuxent Wildlife Research Center. Laurel, MD.

U. S. Fish and Wildlife Service (USFWS). 2002. National Wetland Inventory: a strategy for the 21st century. U.S. Department of Interior. Washington, DC.

U.S. Fish and Wildlife Service (USFWS). 2005. The American Eel status review. Progress Report. Washington, DC.

U.S. Forest Service (USFS). 2002. Pest alert: Sudden Oak Death. USDA, US Forest Service. Northeastern Area. NA-PR-02-02.

U.S. Forest Service (USFS). 2003. 2003 Forest insect and disease conditions for the southern region. U.S. Department of Agriculture, U.S. Forest Service.

Underwood, M. K., and C. A. Dolloff. 1996. Basinwide estimation of habitat and fish populations in five Shenandoah National Park watersheds. U.S. Department of Agriculture, Forest Service Southern Research Station. Blacksburg, VA.

van Manen, F. T., J. A. Young, C. A. Thatcher, W. B. Cass, and C. Ulrey. 2005. Habitat models to assist plant protection efforts in Shenandoah National Park, Virginia, USA. Natural Areas Journal 25:339–350.

Vana-Miller, D. L., and D. P. Weeks. 2004. Shenandoah National Park, Virginia, Water resources scoping report. U.S. Department of the Interior. National Park Service. Technical Report NPS/NRWRS/NRTR-2004/320.

Vaughan, M. R. 1983. Seasonal habitat use and home range of black bears in Shenandoah National Park. Report. Virginia Tech. Blacksburg, VA.

Vaughan, T.A. 1986. Mammalogy. Third edition. W. B. Saunders. Philadelphia, PA. 576 pp.

Virginia Department of Forestry. 2002. Virginia's fire history. Historical summary report of fire statistics. VA Department of Forestry. Richmond, VA.

Virginia Department of Game and Inland Fisheries (VDGIF). 1999. Deer Management Plan. Wildlife Information Publ. No. 99-1. VDGIF. Richmond, VA.

Virginia Department of Game and Inland Fisheries (VDGIF). 2005. Virginia Comprehensive Wildlife Strategy. Richmond, VA.

Virginia Gap Analysis Program (VA GAP). 2005. http://vafwis.org/WIS/asp/default.asp.

Voshell, J., and B. Marshall. 1994. Effects of gypsy moth defoliation on the aquatic biota of headwater streams in Shenandoah National Park. U.S. Department of the Interior. National Park Service. Shenandoah National Park. Luray, VA.

Watts, C. F. 2001. Cause versus trigger in rockfalls and rockslides; implications in cases of property damage and personal injury. GSA Abstracts with Programs. Vol. 33, No. 2. 15 pp.

Watts, B. M., and S. Padgett. 2002. VA FALCONS – The Center for Conservation Biology at the College of William and Mary. http://fsweb.wm.edu/ccb/.

Weaver, T., and D. Dale. 1978. Trampling effects of hikers, motorcycles and horses in meadows and forests. J. Appl. Ecol. 15:451–457.

Webb, J. R. 2004. Effects of acid deposition on aquatic resources in the Central Appalachian Mountains. University of Virginia. Charlottesville.

Webb, J. R. , B. J. Cosby, F. A. Deviney, Jr., J. N. Galloway, S. W. Maben, and A. J. Bulger. 2004. Are brook trout streams in western Virginia and Shenandoah National Park recovering from acidification? Environmental Science and Technology 38:4091–4096.

Webb, J. R., B. J. Cosby, F. A. Deviney, Jr., K. N. Eshleman, and J. N. Galloway. 1995. Change in the acid-base status of an Appalachian Mountain catchment following forest defoliation by the gypsy moth. Water, Air, and Soil Pollution 85:535–540.

Webb, J. R., F. A. Deviney, J. N. Galloway, C. A. Rinehart, P. A. Thompson, S. Wilson. 1994. The acid-base status of native brook trout streams in the mountains of Virginia: a regional assessment based on the Virginia Trout Stream Sensitivity Study. Final Report. Department of Environmental Sciences. University of Virginia. Charlottesville.

Webb, J. R., J. N. Galloway, and F. A. Deviney. 1993. Shenandoah watershed study program evaluation. Department of Environmental Sciences. University of Virginia. Charlottesville.

Webb, J., B. Cosby, J. Galloway, and G. Hornberger. 1989. Acidification of native brook trout streams in Virginia. Water Resources Research 25:1367–1377.

Webster, W. D., J. F. Parnell, and W. C. Biggs, Jr. 1985. Mammals of the Carolinas, Virginia, and Maryland. University of North Carolina Press. Chapel Hill.

Weidensaul, S. 1994. Mountains of the heart: a natural history of the Appalachians. Fulcrum Publishing. Golden, CO.

Welch, N. T., and T. A. Waldrop. 2001. Restoring table mountain pine communities with prescribed fire: an overview of current research. Castanea 66.

Wetmore, A. 1950. The list of birds of the Shenandoah National Park. Shenandoah Natural History Association. Luray, VA.

Whitaker, J. O., and W. J. Hamilton, Jr. 1998. Mammals of the Eastern United States. Cornell University Press. Ithaca, NY.

Whittaker, P. L. 1978. Comparisons of surface impact by hiking and horseback riding in the Great Smoky Mountains National Park. NPS-SER Res./Research Management Report No. 24. U.S. Department of the Interior. National Park Service.

Wieczorek, G. F., B. A. Morgan, and R. H. Campbell. 2000. Debris-flow hazards in the Blue Ridge of Central Virginia. Environmental and Engineering Geoscience Vol. VI, No. l, Pp. 3–23.

Wigington, P. J., Jr., J. P. Baker, D. R. DeWalle, W. A. Krester, P. S. Murdoch, H. A. Simonin, J. Van Sickle, M. K. McDowell, D. V. Peck, and W. R. Barchet. 1993. Episodic acidification of streams in the northeastern United States: chemical and biological results of the Episodic Response Project. EPA/600/R-63/190. U.S. Environmental Protection Agency. Corvallis, OR. 337 pp.

Wilhelm, E. J., Jr. 1966. Birds of Shenandoah National Park. Shenandoah Natural History Association. Luray, VA. (Brochure)

Wilhelm, E. J., Jr. 1969. Historical Ecology of Big Meadows Shenandoah National Park. Final Research Report 69-1, NPS RSP:SHEN-N-5. Department of Geography, University of Virginia. Charlottesville.

Williams, C. E. 1991. Maintenance of the disturbance-dependent Appalachian endemic, *Pinus pungens*, under low disturbance regimes. Natural Areas Journal 11:169–170.

Williams, P. B., and J. L. Marion. 1995. Assessing campsite conditions for limits of acceptable change management in Shenandoah National Park. Technical Report NPS/MARSHEN/NRTR-95/07. U.S. Department of the Interior. National Park Service. Philadelphia, PA.

Wilson, J. P., and J. P. Seney. 1994. Erosional impacts of hikers, horses, motorcycles, and off-road bicycles on mountain trails in Montana. Mountain Research and Development 14:77–88.

Winner, W. E., A. S. Lefohn, I. S. Cotter, C. S. Greitner, J. Nellessen, L. R. McEvoy, Jr., R. L. Olson, C. J. Atkinson, and L. D. Moore. 1989. Plant responses to elevational gradients of ozone exposures in Virginia. Proceedings National Academy of Sciences 86:8828–8832.

Winstead, R. 1995. Old-growth report: Shenandoah National Park. Working document. Shenandoah National Park. Luray, VA.

Wisdom, H. W., and T. G. Hudspeth. 1978. Virginia’s forest products industry. School of Forestry and Wildlife Resources. Virginia Tech. Blacksburg.

Witt, W. L. 1993. Annotated checklist of the amphibians and reptiles of Shenandoah National Park, Virginia. Catesbeiana 13.

Wrobel, D. J., W. F. Gergits, and R. G. Jaeger. 1980. An experimental study of interference competition among terrestrial salamanders. Ecology 61.

Young, J. A. 2005. Roadless block analysis for Shenandoah National Park. Final Report. U.S. Geological Survey, Leetown Science Center. Kearneysville, WV.

Young, J. A., F. T. van Manen, and C. A. Thatcher. 2003. Habitat modeling for protection of illegally harvested plants in National Parks of the Blue Ridge Mountains. National Park Service report. U.S. Geological Survey, Leetown Science Center. Kearnseyville, WV.

Young, J. A., G. Fleming, P. Townsend, and J. Foster. 2005. Vegetation of Shenandoah National Park in relation to environmental gradients. Draft final report. U.S. Geological Survey, Leetown Science Center. Kearneysville, WV.

Zobel, D. B. 1969. Factors affecting the distribution of Pinus pungens, an Appalachian endemic. Ecological Monographs 39:304–333.

Appendix A. Suggested desired conditions and management prescriptions for intrinsically significant biotic and abiotic components of aquatic habitats, mammalian resources, avian resources, herpetofaunal resources, and geologic resources at Shenandoah National Park.

The following desired conditions and management prescriptions were formulated for intrinsically significant resources at Shenandoah National Park during two workshops held in February and March of 2005. These workshops were attended by research scientists, technicians, and SHEN resource managers who are familiar with the intrinsically significant resources at the park. These conditions and prescriptions (recommendations) are strictly the collective opinions of the workshop attendees.

Biotic and Abiotic Components of Aquatic Habitats

1. <u>Native aquatic fauna desired condition</u>: Prevent loss from current (2005) level of native diversity (species richness and population density) of macroinvertebrates and fish.

    Management prescriptions:

    a. Quantify faunal diversity (species richness and population density) and productivity (reproduction and biomass) of aquatic habitats with a particular emphasis on macroinvertebrate and fish assemblages in headwater habitats to determine natural fluctuations in population levels.

    b. Conduct parkwide watershed analysis to establish hydrogeomorphic setting of water resources in the park (e.g., describe geology, forest composition, LULC, dispersal barriers, terrain within watersheds) to determine current and natural fluctuations in water resources.

    c. If changes are detected that deviate from natural fluctuations in aquatic resources (biotic and/or abiotic), try to determine causes and ameliorate, if possible. For example, if macroinvertebrate populations are declining due to increased stream sedimentation, stabilize stream banks (via re-vegetation), relocate streamside trails, and/or limit recreational use of the area to reduce soil disturbances.

2. <u>Watershed component connectivity desired condition</u>: Lateral and longitudinal connectivity among watershed components will be maintained at current (2005) levels.

    Management prescriptions:

    a. Identify potential barriers to dispersal of native aquatic fauna.

    b. Remove or modify nonnatural dispersal barriers. For example, at stream road crossings culverts should be kept cleared of debris so that aquatic vertebrates and invertebrates can disperse throughout the waterway.

3. <u>Water quantity and quality desired condition</u>: Water quantity and water quality will be maintained and, in some cases, improved from current (2005) levels. For example, acid precipitation is a potential threat to water quality in the park. However, the acid-neutralizing capacity of streams has prevented acid precipitation from degrading in-stream water quality. Water quality must be continually monitored because this situation could change.

Management prescriptions:

a. Determine the extent to which existing water quality/quantity data represents conditions parkwide and reflects natural fluctuations. Water quality data is currently available for 15 streams in Shenandoah National Park.

b. Develop a list of streams with degraded water quality and/or quantity (if any) and determine causes of degradation.

c. Develop and implement remedial solutions (e.g., increase acid-neutralizing capacity of stream via liming, reduce park water removal if water quantity declines) to restore degraded streams.

4. <u>In-stream habitat desired condition</u>: Natural in-stream habitat components will be maintained and artificial habitat components (e.g., damaging stream crossings, human-made stream pools) will be removed.

Management prescriptions:

a. Determine if specific park management activities (such as fire suppression and trail maintenance) disrupt natural processes of in-stream habitat formation and maintenance. For example, woody debris in streams may increase or decrease due to the type of vegetation removal along streams.

b. Ensure that park management activities do not disrupt natural processes of in-stream habitat formation and maintenance.

c. Do not remove or disturb naturally occurring in-stream woody debris unless it is causing impediments to fish movement or threatening property by damming the watercourse.

5. <u>Exotic and invasive species in aquatic systems desired condition</u>: Aquatic systems will be free of nonnative species.

Management prescriptions:

a. Identify nonnative species populations, map their locations, determine their points of entry, and their effects on native aquatic assemblages.

b. Evaluate potential threat of exotic pathogens and diseases to native aquatic assemblages.

c. Remove nonnative species of fish and macroinvertebrates (e.g., nonnative crayfish species) from watersheds if and when they are detected and prevent further introduction or reintroduction of nonnative species (e.g., do not allow nonnative species to be used as bait).

Mammalian Resources

1. White-tailed deer populations and natural communities desired condition: White-tailed deer populations will reflect high herd health (as measured by parasite/malnutrition index) and will not prevent native vegetation regeneration. Based on data collected by the Virginia Department of Game and Inland Fisheries, the average deer density in SHEN is probably 25–45 deer/mi^2 (2004). Historically, SHEN probably supported 12–15 deer/mi^2. Therefore, there are twice as many deer in SHEN today as compared to initial European settlement.

   Management prescriptions:

   a. Quantify deer herd health using indices taken on incidental road-killed deer.

   b. Determine regeneration of native vegetation by initiating deer exclosure studies parkwide.

   c. Determine the threshold deer population that will promote high herd health and that natural communities can sustain without appreciable degradation.

   d. Initiate hunting or in-park chase activities (if necessary).

2. Native mammalian diversity desired condition: Native mammalian diversity representative of the Blue Ridge ecosystem will be maintained at current (2005) levels. However, as research and management warrant, native mammalian components of the Blue Ridge ecosystem may be restored via re-introduction (e.g., Allegheny woodrat, Appalachian cottontail, spotted skunk, eastern elk).

   Management prescriptions:

   a. Determine composition, distribution, abundance, habitat use, interspecific interactions, and diseases of carnivore populations in the park.

   b. Monitor, map, and protect (e.g., reduce visitor disturbance) woodrat populations in the park.

   c. Determine size of Appalachian cottontail populations in the park.

   d. Determine small mammal assemblage (insectivores, lagomorphs, rodentia) and distribution within the park.

   e. Determine bat assemblage, distribution, and habitat use in the park

   f. Identify and determine distribution of, and provide protection for, rocky outcrops, boreal forests, vernal pools, hibernacula, and early successional habitats in the park.

   g. Construct a chronology of mammalian assemblages and distribution in the park based on on available historical accounts and scientific surveys.

h. Restore, via re-introduction, those mammal species native to the Blue Ridge Mountains that have been extirpated from SHEN, if research and management warrants.

Avian Resources

1. <u>High elevation bird communities desired condition</u>: High elevation bird communities will be maintained at current (2005) levels.

   Management prescriptions:

   a. Inventory, monitor, and map distribution of breeding population of red-breasted nuthatch (*Sitta Canadensis*) and winter wren (*Troglodytes troglodytes*) in park.

   b. If breeding populations decline, restore red spruce as replacement species for lost hemlocks at high elevations in the park.

2. <u>Neotropical migratory bird communities desired condition</u>: Neotropical migratory bird communities will be maintained at current (2005) levels.

   Management prescriptions:

   a. Continue breeding bird surveys in the park.

   b. Re-initiate MAPS program and determine population trends of breeding neotropical migratory species in the park in a local, regional, and national context.

   c. Conduct point counts for cerulean warblers throughout the park (including southern half) and determine number of breeding pairs in the park.

   d. Conduct point counts for veery (*Catharus fuscescens*) throughout the park and determine number of breeding pairs in the park.

   e. Conduct point counts for neotropical migratory birds in areas of forest change (e.g., former hemlock stands [Limberlost, Camp Hoover], post-burn areas).

   f. If point count data suggests decline of species in park, formulate and initiate management actions (e.g., restore red spruce in the park as surrogate for hemlock, reduce fragmenting features of the landscape).

3. Peregrine falcon desired condition: Two or three pairs of peregrine falcons will nest annually in the mountains of Virginia.

   Management prescriptions:

   a. Continue peregrine restoration program until park has two successful nesting pairs annually. Monitor successfully nesting pairs and re-instate restoration program if necessary.

   b. Reduce visitor impacts at current and potential peregrine nesting sites.

4. Hemlock bird communities desired condition: Bird communities that declined or were lost due to mortality of eastern hemlock forests will be restored.

   Management prescriptions:

   a. Encourage red spruce expansion at Limberlost.

   b. Provide assistance to researchers attempting to develop and/or implement controls of hemlock woolly adelgid. If adelgid is successfully controlled, re-establish eastern hemlock in the park.

Herpetofaunal Resources

1. Shenandoah salamander desired condition: Shenandoah salamander populations will be maintained at or above current (2005) levels.

   Management prescriptions:

   a. Monitor Shenandoah salamander populations in park.

   b. Determine population boundaries of Shenandoah salamander populations (e.g., are they dynamic?)

   c. If population declines are found, formulate and initiate management actions (e.g., maintain connectivity among populations, identify and restore critical habitat components).

2. Big Meadows swamp desired condition: Big Meadows swamp habitat will be maintained and/or restored to ensure persistence of herpetofaunal species.

   Management prescriptions:

   a. Study and determine hydrology of Big Meadows swamp.

   b. Identify factors that may be altering hydrology of Big Meadows swamp.

c. Restore hydrology, if necessary, by eliminating or minimizing effects of factors that are altering it.

3. Native herpetofaunal diversity desired condition: Diverse and productive assemblages of native herpetofaunal diversity representative of the Blue Ridge ecosystem will be maintained and/or restored.

Management prescriptions:

a. Identify and map all vernal pools and seepages in the park.

b. Determine amphibian species using vernal pools and seepages in the park.

c. Determine annual variation and turnover in amphibian species that use vernal pools and seepages in the park.

d. Identify and map rock outcrops, talus/scree slopes, xeric ridges, and glades in the park and inventory herpetofaunal communities at these habitats.

e. Identify, map, and maintain all timber rattlesnake dens in the park.

f. Determine effects of Skyline Drive on timber rattlesnake populations that are located near to versus far from this road.

g. Determine the effects of Skyline Drive, habitat alteration, and poaching on herpetofaunal communities of the park.

h. Determine occurrence and extent of herpetofaunal diseases in the park (e.g., chytrid fungus, *Perkinsus* parasite, upper respiratory tract disease in box turtles).

i. Determine the effects of hemlock loss on herpetofaunal presence, use of newly formed gaps, and behavior (e.g., do the newly formed gaps caused by dead hemlocks attract rattlesnakes?).

j. Conduct a parkwide inventory for pine snake, smooth green snake (*Opheodrys vernalis*), rough green snake (*O. aestivus*), corn snake (*Elaphe guttata*), eastern king snake (*Lampropeltis getula*), coal skink, wood turtle, painted turtle, and spotted turtle (*Clemmys guttata*).

Geologic Resources

1. Geologic hazards desired condition: By 2010, identify and limit the effects of recognized geologic hazards (rockfalls, debris flows).

    Management prescriptions:

    a. Identify and map visitor use areas (roads, trails, campgrounds, etc) with susceptibility to geologic hazards.

    b. Communicate information to the public by appropriate educational outlets (e.g., signs posted along Skyline Drive, at cliff faces, along trails).

2. Geologic research desired condition: World class interdisciplinary scientific research/understanding will broaden and continue at SHEN. Interdisciplinary/entire ecosystem level of cooperation and research is high at SHEN and will be highlighted and put on the global "radar." Park currently is destination for world-class geologic research.

    Management prescriptions:

    a. Research will be accessible to scientists, public, and resource mangers/interpreters via the development and implementation of annual reports, conferences, public outreach, and Web sites.

    b. Continue geologic research cooperation with the Geologic Resources Division of the NPS.

    c. Identify, map, and promote with scientists, the outstanding geological research and educational locations within the park.

    d. Prevent theft and vandalism of geologic resources in the park by alerting park law enforcement of their locations and value.

3. Cliff communities desired condition: Ninty-five percent of cliffs (>35 degree slope) are maintained in pristine condition where "pristine" is defined as a cliff that contains a continuous mat of vegetation and lichen with <2% exposed soil, and is located >0.5 mi from a trail/road.

    Management prescriptions:

    a. Identify cliff faces that meet pristine condition and implement management actions to protect them, such as: area closures (limiting climbing on certain cliff faces, for example), visitor education, require and enforce "leave no trace" climbing techniques, restore social trails (remove informal trails), remove illegal campsites, periodically patrol pristine cliffs to enforce regulations.

    b. Create a climbing guide to direct visitors to "sacrificial" cliff areas for climbing and other recreation.

Air Resources

A separate workshop was not held to define suggested desired conditions for air quality. Suggested desired conditions for air quality could be developed based upon the suggested management recommendations listed in the air resources section of this report. Additionally, suggested desired conditions could be developed based upon the management recommendations described in Sullivan et al. (2003).

Appendix B. Names, areas of expertise, and affiliations for professionals with knowledge of the natural resources of Shenandoah National Park.

Name	Area of expertise	Affiliation
DeSante, David	Ornithologist	The Institute for Bird Populations, Point Reyes Station, CA
DeViney, Frank	Aquatic Ecologist	University of Virginia, Charlottesville, VA
Diefenbach, Duane	Ecologist	The Pennsylvania State University, University Park, PA
Dolloff, Andy	Fisheries Biologist	Virginia Tech, Blacksburg, VA
Eaton, L. Scott	Geologist	James Madison University, Harrisonburg, VA
Fleming, Gary	Plant Ecologist	VA Natural Heritage Program, Richmond, VA
Heffernan, Kevin	Plant Ecologist	VA Natural Heritage Program, Richmond, VA
Jung, Robin	Herpetologist	U.S. Geological Survey, Laurel, MD
Kim, K. C.	Entomologist	The Pennsylvania State University, University Park, PA
Knox, Matt	Vertebrate Ecologist/Deer Biologist	VA Department of Game and Inland Fisheries, Richmond, VA
Lafon, Nelson	Vertebrate Ecologist/Deer Biologist	VA Department of Game and Inland Fisheries, Richmond, VA
Marion, Jeffrey	Recreation Specialist	Virginia Tech, Blacksburg, VA
Martin, Denny	Vertebrate Ecologist/Bear Biologist	VA Department Conservation and Inland Fisheries, Richmond, VA
Mengak, Mike	Vertebrate Ecologist	University of Georgia, Athens, GA
Mitchell, Joseph	Vertebrate Ecologist/Herpetologist	University of Richmond, Richmond, VA
Mohn, Larry	Vertebrate Ecologist	VA Department of Game and Inland Fisheries, Richmond, VA
Nott, Philip	Ornithologist	The Institute for Bird Populations, Point Reyes Station, CA
Snyder, Craig	Aquatic Ecologist	U.S. Geological Survey, Kearneyville, WV
Southworth, C. Scott	Geologist	U.S. Geological Survey, Reston, VA
Tollo, Richard	Geologist	George Washington University, Washington, DC
Vaughan, Mike	Vertebrate Ecologist	Virginia Tech, Blacksburg, VA
Watts, Bryan	Ornithologist	The College of William & Mary, Williamsburg, VA
Webb, Rick	Aquatic Ecologist	University of Virginia, Charlottesville, VA
Wilson, Mike	Ornithologist	The College of William & Mary, Williamsburg, VA
Young, John	G/S Specialist/Ecologist	U.S. Geological Survey, Kearneysville, WV

Appendix C. Synthesis Instructions.

1. Place “Synthesis Program Installation Disc” CD in CD drive and follow instructions on screen.
2. Remove “Synthesis Program Installation Disc” CD.
3. Place “Synthesis Data Disc” DVD in DVD drive.
4. Go to your Program Files and click on Synthesis.
5. Under “Select Site” click on MAHAN.
6. Document outline will appear. Click on subject material, e.g., Fish, and choose report to read. All reports are full-text searchable and most will open in Adobe Acrobat.
7. Some links (e.g. Water Resources) will direct your computer to a Web site. For example, when you click on Water Quality and then NPS-NatureNet Water Resources, you will be directed to a Web page. Click on Shenandoah National Park report found under Northeast Region. This will access the Water Resource Management Plan.
8. The Synthesis program will not run if it has no data to read, so make sure you have the Synthesis Data Disc DVD in your DVD drive.
9. For help and contact information: www.jmu.edu/synthesis/.

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-305 December 2006

National Park Service
U.S. Department of the Interior

Northeast Region
Natural Resource Stewardship and Science
200 Chestnut Street
Philadelphia, Pennsylvania 19106-2878

http://www.nps.gov/nero/science/