National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Blue Ridge Parkway

Natural Resource Report NPS/BLRI/NRR—2013/699

ON THE COVER
Blue Ridge Parkway
Photograph by: National Park Service

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This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Executive Summary

This report provides a comprehensive assessment of the state of natural resources at the Blue Ridge Parkway (BLRI or Parkway). It also addresses sets of stressors that threaten these resources and the biological integrity of habitats in the park. This assessment focuses on vital signs outlined by the Appalachian Highlands Network (APHN), as well as on attributes relevant to the park's natural resources. Assessed attributes are roughly organized into broad groups of resources as follows: air quality, atmospheric deposition, weather and climate, water quality and aquatic macroinvertebrates, exotic plants, significant flora, forest pests, animal communities, and landscape dynamics.

Data used in the assessment included inventory and monitoring (I&M) reports and bio-inventories, spatial information, park-commissioned reports, publicly-available data (EPAStoret, National Landcover Datasets), and personal communication with BLRI and APHN staff. No new field data were collected for this report. When available, published criteria were used to derive a condition assessment based on available data, and when appropriate, we identify opportunities for improved data collection to allow for stronger assessment in the future.

The Blue Ridge Parkway is unique among NPS units. The Parkway corridor traverses numerous habitat types and offers unparalleled views along the Southern Appalachian ridgeline. Spectacular leaf colors are a main attraction every fall. Some of the most sensitive and diverse high-elevation communities in the region are preserved along the Parkway, including mountain bogs, balds, outcrops, and spruce-fir forests. Although the Parkway includes much land immediately adjacent to the roadside, thousands of hectares of backcountry harbor additional diversity. In addition, the geological history of the Appalachians also leads to numerous soil types and varied topography along the Parkway, with elevations spanning 1700 m. These unparalleled natural offerings attract millions of visitors to the Parkway each year, making it the most visited National Park unit.

The Parkway supports a rich diversity of plants, invertebrates, and vertebrate species. Approximately 1,600 vascular plant species are found within park boundaries. Recent inventory efforts reported 82 fish species, including several of special conservation concern. No federal or state listed fish species were reported from the inventory. Recent inventory efforts reported 136 bird species from the park, including 16 species state listed as threatened, endangered, or of special concern. No federal threatened or endangered bird species were reported from BLRI in the recent bird inventory. A herpetofauna inventory reported 54 species of reptile and amphibians from BLRI, including 24 salamanders, a taxonomic group for which the region and the park are particularly rich. No federally listed herpetofauna species were reported from the inventory and one species of state special concern was reported. The recent mammal inventory reported 50 species, including a notably rich assemblage of small native rodents and shrews. Two federally endangered mammals, Virginia big-eared bat (*Corynorhinus townsendii*) and Carolina northern flying squirrel (*Glaucomys sobrinus coloratus*), were reported from the park, as well as seven species state listed as endangered or species of concern. A recent inventory of macroinvertebrate insects reported a nominal richness of 412 taxa, including many rare species, and several previously undescribed species. These species counts reflect the results of recent comprehensive efforts, and are conservative in terms of species present.

Overall, several broad classes of potential threats and stressors to natural resources are applicable to BLRI and are addressed in this report. They include:

- **Decreased air quality—**Ozone concentrations in particular are an issue at higher elevations in the Southern Appalachians, including at BLRI. Prevailing winds can lead ozone-causing pollution to areas along the Parkway, where high-elevation vegetation communities are especially vulnerable to foliar injury. At BLRI, monitoring shows that ozone concentrations appear to be decreasing, although they are still clearly in the range that can cause damage to plants. This is also supported by calculation of injury metrics.

- **Atmospheric pollutants—**Like ozone, other pollutants from outside the Parkway area can contribute to effects in the park, namely the deposition of nitrogen and sulfur. Again, the high elevation of the Southern Appalachians traps pollutants, which can lead to undesirable nutrient enrichment and acidic precipitation at BLRI. Park waters can contain high nitrate levels even though headwaters may be otherwise undisturbed within the park unit. Stations measuring depositional rates in and near BLRI show consistently high levels for both N and S, though fortunately, annual rates of deposition are declining. In addition to causing ecosystem damage, airborne pollutants in the form of particulate matter can also affect the aesthetic quality of the Parkway, resulting in one of the most conspicuous forms of natural resource impairment. Throughout the eastern US, average visibility ranges are dramatically decreased from natural levels as a result of airborne pollution. The Blue Ridge Parkway corridor is no exception. Although measured particulate matter concentrations are unmistakably decreasing, visibility along the Parkway as a whole is still affected.

- **Impaired water quality—**The high elevation of the Parkway means that many of the streams begin within or near the park boundary, though, as mentioned previously, it also places them at greater risk for effects from atmospheric deposition. This effect is complicated by low neutralizing capacity in many streams due to parent material. Ultimately, high deposition rates and low pH can result in impaired aquatic communities. Acidification of aquatic environments can reduce abundance and cause changes in the diversity of fishes and macroinvertebrates.

- **Exotic plants—**As unwanted species of plants invade areas along the Parkway, scenic vistas can become obscured. The other main threat posed by these species is competition with native plant and animal communities, wherein it can exclude sensitive species or alter habitat types. Management of these plant pests is an ongoing issue at the Parkway. One of the most useful techniques for combating infestations will be to immediately combat new occurrences to prevent further spread and help protect unaffected habitat areas.

- **Plant poaching—**Plant collecting has long been a traditional practice in the Southern Appalachians, though pressure from overharvesting may eventually lead to loss of populations. Collecting on Parkway lands is illegal, though still tempting to poachers due to the accessibility of most of the Parkway and the high number of commercially valuable plants. Common targets include trillium (*Trillium* spp.), bloodroot (*Sanguinaria canadensis*), black cohosh (*Cimicifuga racemosa*), galax (*Galax urceolata*), Gray's lily, sphagnum moss (*Sphagnum* spp.) and American ginseng (*Panax quinquefolia*).

- **Forest Pests—**Irreversible damage has already occurred in forest ecosystems throughout the Southern Appalachians due to introductions of foreign pests. Most notably, chestnut blight (*Cryphonectria parasitica*) and balsam woolly adelgid (*Adelges piceae*) have permanently altered the roles of American chestnut (*Castanea dentata*) and Fraser fir (*Abies fraseri*) in eastern forests. Currently, the most urgent forest insect pests threatening the Parkway are hemlock woolly adelgid (*Adelges tsugae*) and gypsy moth (*Lymantria dispar*). These species are pervasive throughout the park, and many areas benefit from treatment and protection, either to protect valuable community types or to preserve scenic quality.

- **Non-native wildlife—**Non-native species are recognized as an important threat to the health and persistence of native wildlife populations. In this report, non-native vertebrate animals were defined to include species or strains intentionally or accidentally introduced outside their native ranges by humans, and species spontaneously expanding their distributions to include areas never previously occupied. Recent vertebrate inventories in BLRI reported eight species of fish, four birds, and two mammals that were non-native to the areas where they were collected. Generally, non-native vertebrates were not evidenced to be a particularly outstanding threat to BLRI animal communities, although the impacts of non-natives were not rigorously explored. One area of potential management concern is the impact of non-native salmonids. Competition with non-native brown (*Salmo trutta*) and rainbow trout (*Oncorhyncus mykiss*) limits the ability of native southern Appalachian brook trout (*Salvelinus fontinalis*) to reestablish successful populations in parts of its original range. Non-native salmonids require high-quality habitat and their presence is not an indication of habitat decline.

- **Wildlife disease—**Disease outbreaks and emerging diseases pose threats to wildlife populations. Data used in this report did not indicate the existence of large-scale disease outbreaks in BLRI vertebrates. However, several potential threats are noteworthy. White-nose syndrome (*Geomyces destructans*), a communicable fungal disease that affects cave-hibernating bats, is a serious and growing problem for bats in the region. Since its discovery in 2006, the disease has spread rapidly in the eastern US, and has been reported from the southern Appalachians in Virginia and North Carolina. Although BLRI does not possess significant cave hibernacula resources, cave hibernating species use park resources, and white-nose syndrome should be considered a threat to these bats. Viral and fungal pathogens pose potential threats to BLRI amphibians. *Ranavirus* and Chytrid fungus (*Batrachochytrium dendrobatidis*) have caused population level declines of frogs and salamanders in the U.S. *Ranavirus*, in particular, has caused high amphibian mortality at sites relatively near the BLRI. No evidence of negative impacts from these pathogens was seen in the data examined for this report. However, because BLRI and the surrounding region are globally important hotspots of amphibian diversity, these pathogens represent serious potential threats to park resources.

- **Landscape change** – An expansive category including negative impacts from development, human population increases, agricultural land uses, and habitat alteration and fragmentation.

The Blue Ridge Parkway is especially vulnerable because of its long linear pathway, with little interior area to protect from adjacent development influences.

Fifteen natural resource attributes were discussed and assessed for this report. Assessed attributes were within four broad categories: air and climate (four attributes), water quality (one attribute), biological integrity (nine attributes), and landscape (one attribute). The water quality attribute and the fish assemblage attribute were assessed and assigned condition ranks for multiple reporting areas within the park. Other attributes were assessed and assigned conditions at the park level. To include multi-reporting area attribute conditions in a park-wide summary, the proportion of each reporting area within each condition rank was added to the appropriate category. For the entire park 4.7 (31%) of the attributes were ranked as good, 7 (47%) were ranked as fair, one (7%) was ranked as poor, and 2.3 (15%) were not assigned a rank. The assigned trend was improving for three (20%), stable for two (15%), declining for three (20%), and not determined for seven (47%) of the attributes. Data quality was good for 11 (73%) of the attributes, fair for 3.6 (24%), poor for 0.4 (3%) of the assessed attributes.

Attribute Assessment Summary

Ozone

Due to its high-elevation course through the Appalachians, BLRI is susceptible to elevated ozone concentrations, which can affect both human health and vegetation. In recent years BLRI has conducted extensive ozone monitoring at several locations throughout the park, all of which have shown reductions in ozone concentration over the available monitoring period. A recent (2008) change in federal regulations resulted in an even more stringent ozone standard, resulting in violations of the National Ambient Air Quality Standard (NAAQS) for ozone concentration at two out of five stations that year. As a result this condition was assigned a rank of fair. In addition to decreasing trends observed at the stations, recent analysis of ozone concentrations at and around BLRI also support lower concentrations since monitoring began, and thus an improving trend is also assigned. The quality of the data used to make the assessment was good.

Foliar Injury

Certain plant species are more sensitive than others to high concentrations of ozone. At BLRI, 32 species were identified that are susceptible to injury. Using a combination of old interpolated metrics and more recent metrics derived from ozone concentrations measured at stations within the park, overall risks appear moderate to sensitive plants. Two metrics each showed a high and low growth reduction potential, while earlier data showed moderate growth reduction potential. As a result, a fair condition status is assigned. Over time, metrics show no appreciable change across time periods, and thus a stable trend is assigned. The quality of the data used to make the assessment was good.

Atmospheric Deposition

Anthropogenic sources of sulfur dioxide and nitrogen oxides facilitate the production of harmful atmospheric constituents which can affect ecosystems either via precipitation or particulate matter and direct contact. Nitrogen and sulfur deposition can result in saturation and acidification, which can affect vegetation and faunal communities. Monitoring for both wet and dry deposition has been conducted at several stations near the Parkway since 1989, during which most annual measurements exceeded recommended maximums by the NPS Air Resources

Division to prevent ecosystem damage. As a result, atmospheric deposition received a condition status of poor. Data from both wet and dry deposition monitoring at both N and S stations showed significantly decreasing trends, and thus an improving trend is additionally assigned. The quality of the data used to make the assessment was good.

Particulate Matter and Visibility

In addition to pollution resulting from atmospheric deposition, anthropogenic sources also contribute to impaired visibility. Ambient particulate pollution can also contribute to human respiratory issues. Particulate matter is federally regulated, and monitoring along the Parkway since as early as 1990 showed no violations for either coarse or fine particulates. Lead particulate monitoring told a similar story, while metrics used by NPS to track visibility at different points along the Parkway showed impeded views over recent 5-yr periods. Because of this mixture of low particulate matter and high visibility reduction, this category receives a condition status of fair. The majority of stations for both particulate matter and visibility also showed significantly decreasing values, and thus an improving trend is assigned. Because data was only available until 2005, a temporal data quality check is also withheld.

Weather and Climate

Monitoring long-term trends in weather and climate gives an idea of changing patterns, trends and differences among stations along the Parkway. Eight weather stations monitored basic climate parameters near BLRI since as early as 1889, all of which monitored precipitation and temperature. Although no apparent trends appear in precipitation over time, several stations showed increases in average annual maximum, minimum, and mean temperatures, while only a single station observed a decreasing trend for mean minimum temperatures. Most temperature data series, however, showed no trend at all. Because this attribute is provided mainly for reference, it is not assigned a condition, and the data quality used in this section was good.

Water Quality

Because the Parkway stays close to the ridgeline over its course, most of the streams passing through the park, comprising some 1200 segments, are small headwater streams. Several major rivers also cross the Parkway, including the French Broad, Swannanoa, Linville, and James Rivers. Despite their overall protection from upstream anthropogenic influences, high-elevation streams in BLRI are susceptible to atmospheric deposition, which can result in acidification and impaired aquatic resources. Available water quality information along the Parkway shows that many areas do suffer from depressed pH, which is consistent with effects from atmospheric deposition and low buffering capacity. Elevated microorganism concentrations were also observed, especially in urban-influenced areas like Roanoke. Overall, available data resulted in ranking eight cataloging units as good, three as fair, and four without a rank due to lack of data. For the reporting areas assessed, seven had fair data quality and four had poor data quality. The remaining four reporting areas lacked data altogether and were not assessed.

Macroinvertebrate Assemblages

BLRI contains a rich macroinvertebrate fauna. Recent work reported at least 412 taxa, of which less than half were identified to species level. Sampling occurred primarily in small streams, seeps, and springs, and excluded impoundments and the largest rivers in the park. Assemblage condition was explored by calculating six species richness metrics from individual macroinvertebrate samples and comparing results to published reference ranges. A conservation value score, provided by the author of the macroinvertebrate report, was also applied to individual samples. BLRI proved to have many rare and intolerant species. Around 40% of the samples scored in the highest category in at least five of the six metrics. Sample locations with high taxa richness and high conservation scores occurred along the length of the Parkway, although the southern portions of the park had more locations from each category. The condition of BLRI macroinvertebrate assemblages was ranked as good. No trend was assigned to this condition because the assessment was based primarily upon a single recent inventory. The quality of the data used to make the assessment was good.

Exotic Plants

Treatment of exotic plants along the Parkway remains an important management priority and receives significant attention. The unique assemblage of flora and fauna found along the Parkway faces a particular threat from infestations of exotic plants. Certain species such as garlic mustard, Oriental bittersweet, and Japanese honeysuckle can exclude other native species, and once established can be very difficult to remove. Other tree exotics such as tree-of-heaven or Princesstree are fast-growing pioneers that can quickly impede scenic quality of vistas. Many of the exotics found at BLRI are clustered around urban areas such as the Asheville Basin and Roanoke. The Parkway itself acts as a vector for infestations, and early detection and rapid response is one important technique used to manage new infestations before they have an opportunity to impact pristine areas, especially those with sensitive species. Despite tremendous efforts to combat exotic infestations, their impact appears to be worsening. Japanese knotweed and mile-a-minute weed are anticipated to have a major impact at BLRI in the near future. Exotic plants receive a condition status of fair with a degrading trend. The data quality used to make this assessment is good.

Significant Flora

The Parkway provides habitat for several sensitive plant species, including the federally-listed mountain avens, Heller’s blazing star, small-whorled pogonia, rock gnome lichen, and swamp pink. These species are being carefully monitored and in some cases propagated. In addition, several plant species are susceptible to poaching pressure, which is particularly strong along the Parkway due to the accessibility it provides. The most notable targeted species include ginseng and galax, the latter of which grows as a unique large-leaved genetic form, with a range limited to the southern Blue Ridge escarpment, anarea encompassing the Parkway. This galax form is highly desirable within the floral trade. Other poached species include bloodroot, black cohosh, and trillium spp. Monitoring plots have already shown tremendous poaching pressure at BLRI, including a reduction in reproductive-aged ginseng in all monitored populations and evidence of poaching at 93% of galax monitoring locations. Despite the pressures faced, the Parkway provides strong protection to these sensitive species due to continued monitoring, propagation, and poaching enforcement. Unfortunately, poaching pressure continues to increase, and habitat for sensitive species like the rock gnome lichen is decreasing due to introduced pests such as the hemlock woolly adelgid. Because of these factors, significant flora at BLRI receives a condition status of good with a decreasing trend. The data quality used to make this assessment is good.

Forest Pests and Disease

Because the Parkway traverses numerous vegetation types, it is susceptible to a variety of pests and diseases. Some pests such as balsam woolly adelgid and chestnut blight have already rendered tremendous ecosystem impacts. Balsam woolly adelgid eliminated most canopy Fraser fir trees at the highest elevations of the Parkway starting in the 1970's. Today, the pest is still present in the park, though the age and structure of Fraser fir forests has likely been permanently altered. The same is true for American chestnuts, which were once widespread but were wiped out by chestnut blight several decades ago. Regenerative stump sprouts are all that remain of this once dominant forest species, though these are mostly killed by the blight before they can reach age of reproduction. The most crucial forest pests at the park today are likely hemlock woolly adelgid and gypsy moth. The adelgid was discovered at BLRI in 1984 and has since spread throughout its length, where it infests both Eastern and Carolina hemlocks. Hemlocks serve an important role in riparian and hardwood communities, the loss of which would have tremendous ecosystem effects. In addition, Carolina hemlock is already in danger of being lost due to its regional rarity. Gypsy moth infestations vary each year and can impact multiple tree species. Originally only affecting the northern portion of the Parkway, the gypsy moth has spread to its entirety and is the focus of control efforts. Because of the threat posed by these species and the fundamental changes faced by hemlock communities, this attribute receives a condition status of fair with a degrading trend. The data quality used to make this assessment is good.

Fish Assemblages

A recent fish inventory reported 82 species of fish, including five species of concern and eight non-native species. BLRI fish habitat is largely characterized by high elevation headwater streams, although the James, Roanoke, and Linville Rivers are important larger rivers that cross the park and provide habitat for riverine species. Family Cyprinidae (minnows) dominated the fish richness of the park, and Catostomidae (suckers) and Percidae (darters) were the next richest taxa observed in the inventory. Brook trout, a popular game fish and species of management concern, were reported from 11 samples, and occurred with non-native or environmentally tolerant species in five of these samples. Brook trout populations occurring in and around BLRI include pure, genetically-distinct southern strain fish, northern strain fish descended from historical introductions, and hybrids of the two strains. Fish assemblages were assessed for three reporting areas: North, consisting of the James and Roanoke River drainages; Atlantic, consisting of the remaining Atlantic drainages; and South, consisting of Gulf of Mexico drainages. Fish were assessed using an adapted regional index of biotic integrity, as well as a qualitative assessment of individual brook trout populations. The North Reporting Area was not ranked, and both the Atlantic and South Reporting Areas were ranked as fair. No trend was assigned to any of the fish assemblage condition assessments because these assessments were based primarily upon data from a single comprehensive inventory. Data quality was fair for all reporting areas.

Bird Assemblages

BLRI contains rich assemblages of breeding migrant, temporary migrant, and permanent resident bird species. A 2003 – 2005 bird inventory reported 136 species from the park, including over 20 species of conservation concern. Observed bird assemblages were dominated by forest species and breeding season richness was higher than winter richness. Birds were assessed using an index of biotic integrity and subsets of the data were compared using scores designed to reflect the threats experienced by individual species. Data were summarized and compared among four districts following the reporting methods used by the authors of the bird inventory. However, because the districts were similar by the measures used for the assessment, condition was reported for the entire park. BLRI bird assemblage condition was ranked as good. No trend was assigned because the assessment was primarily based upon a single inventory. The quality of the data used to make the assessment was good.

Reptile and Amphibian Assemblages

Evidence from a recent herpetofauna survey suggests that BLRI has relatively high richness of herpetofaunal species. The Parkway occurs in a region that is particularly notable for salamander richness. A recent survey reported 54 amphibian and reptile species, including 24 salamanders. The authors of the inventory summarized their findings by four park districts and found that richness varied from 26 to 42 herptile species among the districts. Reptile and amphibian assemblages were assessed by comparing observed to expected species lists, and by comparing the results of the BLRI inventory to the results of other large-scale sampling efforts in the southern Appalachians. Around 60% of the roughly 90 expected species of reptiles and amphibians were noted. When area was controlled for, the richness of the park was similar to other parks, with greater salamander richness than the comparison parks. No condition or trend was assigned to BLRI herpetofaunal assemblages. This resulted because of the lack of a detailed and defensible expected species list. Such lists are difficult to compile for any taxa group, but are especially difficult for BLRI herpetofauna. In terms of herpetofauna, particularly salamanders, the park represents a very long transect through specialized habitat occupied by a rich variety of highly endemic and cryptic species. The quality of the data used was fair, reflecting the difficulty of assessing this complex group from a single inventory.

Mammal Assemblages

The Parkway supports a rich mammal assemblage. A recent mammal inventory reported 50 species of mammals, including 42 terrestrial mammals and eight bats. Several rare species and two federally listed species (Virginia big-eared bat and the Carolina northern flying squirrel) were reported. Six species of shrews were observed and shrews were among the most commonly sampled taxa. Mammal assemblages were assessed by comparing the inventory results to expected species richness results and to results from other studies in the southern Appalachians. About 80% of the expected richness was actually reported, and BLRI was found to have a greater number of native rats, mice, voles, and shrews than were observed in inventories of similar conservation areas. The condition of BLRI mammal assemblages was ranked as good. No trend was assigned to this ranking because the condition was determined primarily from a single inventory. The quality of the data used to make the assessment was fair. This resulted because the known effort expended in the mammal inventory was low relative to comparison studies and did not include camera sampling.

Landscape Change

BLRI is a unique park unit in that it traverses a narrow corridor, passing through large wilderness areas as well as developed areas that abut the Parkway. Although the Parkway affords important protection for organisms and other resources within its boundaries, these same resources are also influenced by adjacent land use and processes. The area immediately surrounding the park shows minimal anthropogenic alteration and high proportion forested area, while these effects are no longer observable at an even broader landscape scale, suggesting a positive association between the Parkway and the surrounding landscape. At the largest landscape scale however, development continues to increase, especially in proportion to the amount of protected area. These factors result in a vulnerable rating according to the conservation risk index, and thus this attribute was assigned a fair condition. Fortunately, landcover change analysis, also at the broadest landscape scale, showed minimal conversion during a five-year span, and thus a trend of stable is also assigned. The data quality used to make this assessment was good.

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Acronyms and Abbreviations

ANC - Acid Neutralizing Capacity
APHN – Appalachian Highlands Network
ARD - Air Resources Division (NPS)
AVIP - Avian Conservation Implementation Plan
BBS - Breeding Bird Survey
BCI - Bird Community Index
BI – Biotic Index
BISO – Big South Fork National River and Recreation Area
BLRI – Blue Ridge Parkway
BOD - Biochemical Oxygen Demand
BSF – Big South Fork of the Cumberland River
CAA – Clean Air Act
CASTNET - Clean Air Status and Trends Network
COOP - Cooperative Observer Program
CRI – Conservation Risk Index
CRMS - Center for Remote Sensing and Mapping Science (UGA Department of Geography)
CUGA - Cumberland Gap National Historical Park
CUPN – Cumberland Piedmont Monitoring Network
CWCS – Comprehensive Wildlife Conservation Strategies
DAQ – Division of Air Quality
DO - Dissolved Oxygen
DWS – Domestic Water Supply
EDRR – Early detection and rapid response
EMF - Ecological Monitoring Framework
EPA - Environmental Protection Agency
EPT – Ephemeroptera, Plecoptera, Trichoptera
ESA – Endangered Species Act
EVT – Existing Vegetation Type
GIS – Geographic information system
GRSM - Great Smoky Mountains National Park
HUC - Hydrologic Unit Code
HWA – Hemlock Woolly Adelgid
IBI – Index of Biotic Integrity
IMPROVE – Interagency Monitoring of Protected Visual Environments
I&M - Inventory and Monitoring
IUCN – International Union for Conservation of Nature
MDN – Mercury Deposition Network
MRDS – Mineral Resources Data System
MRLC - Multi-Resolution Land Characteristics Consortium
MSPA – Morphological Spatial Pattern Analysis
NAAQS - National Ambient Air Quality Standards
NADP – National Atmospheric Deposition Program
NCDENR – North Carolina Department of Environment and Natural Resources
NCIBI – North Carolina Index of Biotic Integrity

NHP – National Historical Park
NLCD - National Landcover Dataset
NPS - National Park Service
NRCA - Natural Resource Condition Assessment
NRCS - Natural Resource Conservation Service
NTU - Nephelometric Turbidity Unit
NWS - National Weather Service
ONRW – Outstanding Natural Resource Water
PAD – Protected Areas Database
PIF - Partners in Flight
POMS - Portable Ozone Monitoring Station
PPM - Parts per million
RAWS - Remote Automated Weather Station
RBP – Rapid bioassessment protocol
RNA – Research Natural Area
SDI – Simpson's Diversity Index
SHEN – Shenandoah National Park
SNA – State Natural Area
SSURGO – Soil Survey Geographic
TMDL – Total Maximum Daily Load
TWC – The Weather Channel
UGA - University of Georgia
USACE – U.S. Army Corps of Engineers
USFWS – U.S. Fish and Wildlife Service
USGS - United States Geological Survey
VDGIF – Virginia Department of Game and Inland Fisheries
VOC - Volatile Organic Compounds
WAQ – Warm Water Aquatic Habitat
WMA – Wildlife Management Area
WNS – White-nose syndrome

1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…
Credible condition reporting for a subset of important park natural resources and indicators
Useful condition summaries by broader resource categories or topics, and by park areas

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decisionmaking, planning, and partnership activities.

Important NRCA Success Factors

Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://nature.nps.gov/water/nrca/index.cfm

NRCA Reporting Products…
Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)
Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)
Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation and Park Significance

Plans for constructing the Blue Ridge Parkway were approved in 1933 to connect Shenandoah National Park (SHEN) in Virginia to Great Smoky Mountains National Park (GRSM) in North Carolina. After outlining the route, state land officers agreed to purchase land for the road if the federal government would fund the construction. Construction began in 1935 and the following year, the Blue Ridge Parkway was authorized under the National Park Service (NPS 2010a).

The Blue Ridge Parkway is unique in several ways. It is the most visited unit in the National Park Service system and connects two of the most visited National Parks. At 755 km (469 miles), it is one of the longest and narrowest NPS units, as well as highest and narrowest continuous route in the Appalachians. Thus, the Parkway is effectively a long transect through some of the most scenic, ecologically diverse, and culturally significant resources in America. Primary objectives of the BLRI are to preserve the outstanding scenic and recreational values as well as the natural and cultural resources of the Parkway (NPS 2011). Staff of the Parkway work to protect rare and endangered organisms and community types throughout the park unit, while sites such as the Blue Ridge Music Center celebrate some of the traditions associated with Appalachian culture. The combination of cultural, recreational, and biological resources on the Parkway make it an invaluable feature of the entire southeastern US.

2.1.2 Geographic Setting

The Blue Ridge Parkway (BLRI) is located along the central and southern Appalachian Mountains in the states of Virginia and North Carolina (Figure 1). Parkway lands include portions of 29 counties in these two states. It extends from Shenandoah National Park in Virginia to Great Smoky Mountains National Park in North Carolina. Park lands include approximately 34,000 ha (85,000 acres) of fee simple and scenic easement lands. From its Virginia terminus, the BLRI runs roughly southwest for about 571 km following the long ridges of the easternmost Blue Ridge Mountains and averaging around 900 m in elevation. Near Mount Mitchell, NC, the Parkway skirts the Black Mountains and the Craggies. South of Asheville, NC, the Parkway turns northwest and traverses the high peaks of the Balsams and the Plott Balsam Mountains before entering the Great Smoky Mountains and reaching its southern terminus. The BLRI traverses approximately 5 degrees longitude and 3 degrees of latitude and has an elevation range of 1740 m. Parkway lands are contiguous with four national forests: the George Washington and Jefferson in Virginia, and the Pisgah and Nantahala in North Carolina. Parkway lands also include 47 designated natural heritage areas and passes through 15 major urban areas, the largest of which is the city of Roanoke, VA (NPS 2010a).

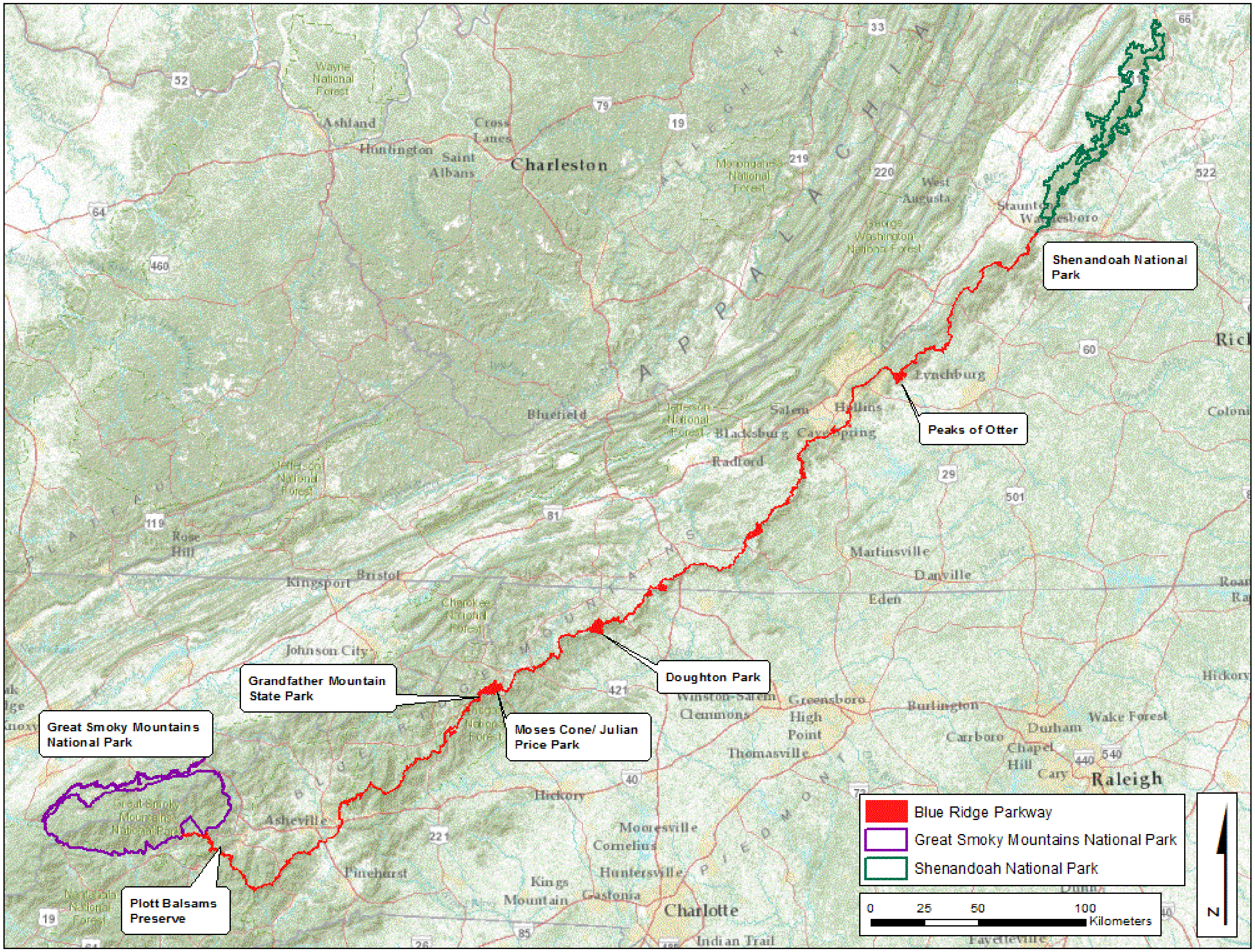

Figure 1**.** The Blue Ridge Parkway and surrounding areas in North Carolina. The Parkway is 469 miles (755 km) long, traverses 29 counties in North Carolina and Virginia, and is contiguous with two national parks and four national forests.

2.1.3 Park History

Construction began on the Blue Ridge Parkway in 1935 and was completed in sections, with the last section completed in North Carolina in 1987. The goal of the project was to provide a scenic tourist corridor between the existing Shenandoah National Park and Great Smoky Mountains National Park. Another immediate construction goal was to provide post-depression employment. The first phase of construction was authorized by the National Industrial Recovery Act during the Great Depression and was performed in large part by Civilian Conservation Corps workers. Aside from its own long construction history, the Parkway contains other important historical resources. Over 200 archaeological sites have been identified along the Parkway, and almost 700,000 artifacts are included in the park collection, many of which are on display at visitor centers. Fields originally cleared by Native Americans are visible from the roadway, and other historic structures such as Yankee Horse Railroad, and Harris Farm are also preserved along the route, representing a cross section of early Appalachian culture. Preservation of these historical resources is an important priority for the BLRI (NPS 2010a).

2.1.4 Geology, Landforms, and Soil

The Blue Ridge physiographic province consists of the eastern ranges of the Appalachian Mountains. This province is characterized by roughly parallel mountain ridges running from northeast to southwest. The Blue Ridge parallels the Ridge and Valley province of the Appalachians to the west and separates it from the Piedmont province to the east. The province was largely formed during the Paleozoic by tectonic shifting and faulting when the Blue Ridge was thrust to the northwest over the Ridge and Valley province (William and Mary Department of Geology 2008, McNab and Avers 1994). Many areas along the Parkway allow observers to see evidence of plate tectonic activity, including folds, joints, and faults in the Linville Falls region and multiple rock types in the Grandfather Mountain area, where the Iapetus Ocean existed 300 million years ago. In several places such as the Grandfather Mountain Window, older rocks formed 1.1 billion years ago have overthrusted younger rocks but gradually eroded away in areas, exposing a “window” to these younger rocks.

The Blue Ridge Mountains are generally rounded and forested. Elevations range from 300 to over 1800 meters with 46 peaks over 1820 m (McNab and Avers 1994). The Blue Ridge includes distinct northern and southern subprovinces. The northern subprovince, north of Roanoke, VA, is a narrow band of mountains characterized by steeper slopes and narrow ridges; the southern subprovince, south of Roanoke, is characterized by a broad upland plateau with more moderate slopes and peaks rising above the upland (William and Mary Department of Geology 2008). The ridges of the southern subprovince display less of the parallel structure typical of the northern region (McNab and Avers 1994).

The Parkway traverses both of these physiographic subprovinces. From its northern terminus to well into North Carolina, the Parkway remains close to the highest peaks of the eastern Blue Ridge with several deviations into the foothills to the east and the valleys to the west. Near Mount Mitchell in North Carolina, the Parkway skirts the Black Mountains, and south of Asheville, NC, the Parkway turns northwest and traverses the Balsam Mountains before entering the Great Smoky Mountains and reaching its southern terminus (NPS 2010a).

Parkway lands contain as many as 100 specific soil types (NPS 2010a). Broadly, Dystochrepts are found on steep slopes at lower elevations, Hapludults are found in lower foothills and broad valleys, and Haplumbrepts are found at high elevations and on foot slopes and mountain valleys (McNab and Avers 1994). Typical Blue Ridge soils have a mesic temperature regime (the mean annual temperature at a specific depth is between 8°C (46°F) and 15°C (59°F) and the difference between mean summer and winter temperatures is greater than 6°C (43°F), a udic moisture regime (typical of humid climates where stored moisture plus rainfall equals or exceeds evapotranspiration), and mixed mineralogy (McNab and Avers 1994). Changes in soil chemistry related to acid rain are a source of concern along the Parkway. Specifically, acid deposition may cause heavy nitrification of soils. This may decrease the availability of nutrients to forest plants, cause the release of toxic aluminum ions in soils, and cause harm to terrestrial and aquatic plants (NPS 2010b).

According to Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database, there are approximately 200 unique soil series, soil associations/consociations, complexes, and undifferentiated groups found along BLRI (NRCS 2012). The fifteen most common of these soil groups comprise roughly half the area of BLRI, though many of these soil types represent rock outcrop areas with little to no soil development (Table 1).

Table 1. Predominant soil types at BLRI (NRCS 2012).

Soil Series/Group	**Number of Areas**	**Total Area ---ha---**	**Prop. BLRI ---%---**
Unaka-Rock Outcrop Complex	312	1538	5.3
Porters	359	1406	4.8
Watauga	285	1304	4.5
Chestnut-Ashe Complex	121	1249	4.3
Chester	170	1232	4.2
Lew	38	881	3.0
Peaks-Rock Outcrop Complex	51	874	3.0
Stony/steep areas	66	743	2.5
Burton-Craggey-Rock Outcrop Complex	205	727	2.5
Wayah	91	656	2.2
Cullasaja	204	640	2.2
Chandler	120	630	2.2
Soco-Ditney Complex	137	623	2.1
Edneytown	145	616	2.1
Ashe-Cleveland-Rock Outcrop Complex	163	572	2.0
Total	**2467**	**13690**	**46.9**

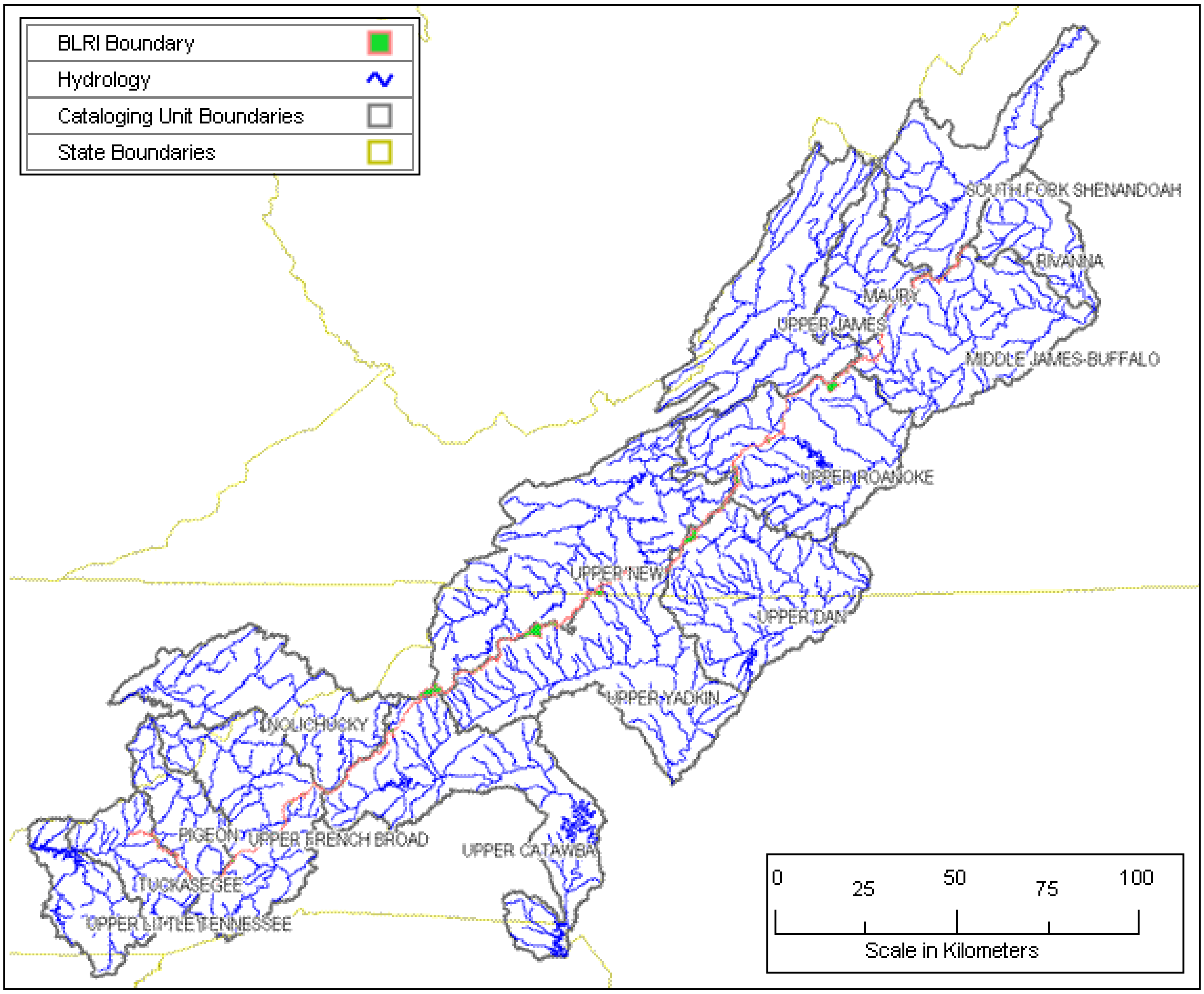

Figure 2. BLRI crosses 15 separate hydrologic cataloging units along its route from NC to VA.

2.1.5 Hydrology

The Blue Ridge Parkway intersects with over 1200 stream segments comprising 970km (600 miles) in length, of which around 150 are headwater streams. These streams drain into 15 separate HUC8 cataloging units before eventually reaching both the Atlantic and / or the Gulf of Mexico (Figure 2 and Table 2). There are seven stream segments classified as 303(d) in 2010, including two in NC and five in VA. Two of these streams originate inside the park unit. Several more streams listed as 303(d) pass within close proximity of the Parkway.

Table 2. List of cataloging units (HUC8) that the BLRI transverses.

Cataloging Unit	HUC8
South Fork Shenandoah	02070005
Upper James	02080201
Maury	02080202
Middle James-Buffalo	02080203
Rivanna	02080204
Upper Roanoke	03010101
Upper Dan	03010103
Upper Yadkin	03040101
Upper Catawba	03050101
Upper New	05050001
Upper French Broad	06010105
Pigeon	06010106
Nolichucky	06010108
Watauga	06010103
Tuckasegee	06010203

2.1.6 Visitation Statistics

The Blue Ridge Parkway is the most-visited NPS unit. In 2009, it attracted 15.9 million recreational visits, or almost 6% of the total NPS visitation. Great Smoky Mountains National Park, located at BLRI's southern terminus, received 9.5 million recreational visits—the third most of any NPS unit that year. Visitation at BLRI has steadily increased on average by 300,000 visitors per year to a peak of 21.5 million visitors in 2002 (Figure 3). After that, visitation has been steadily dropping to the most recent figures in 2009, which represent the lowest visitation since 1984.

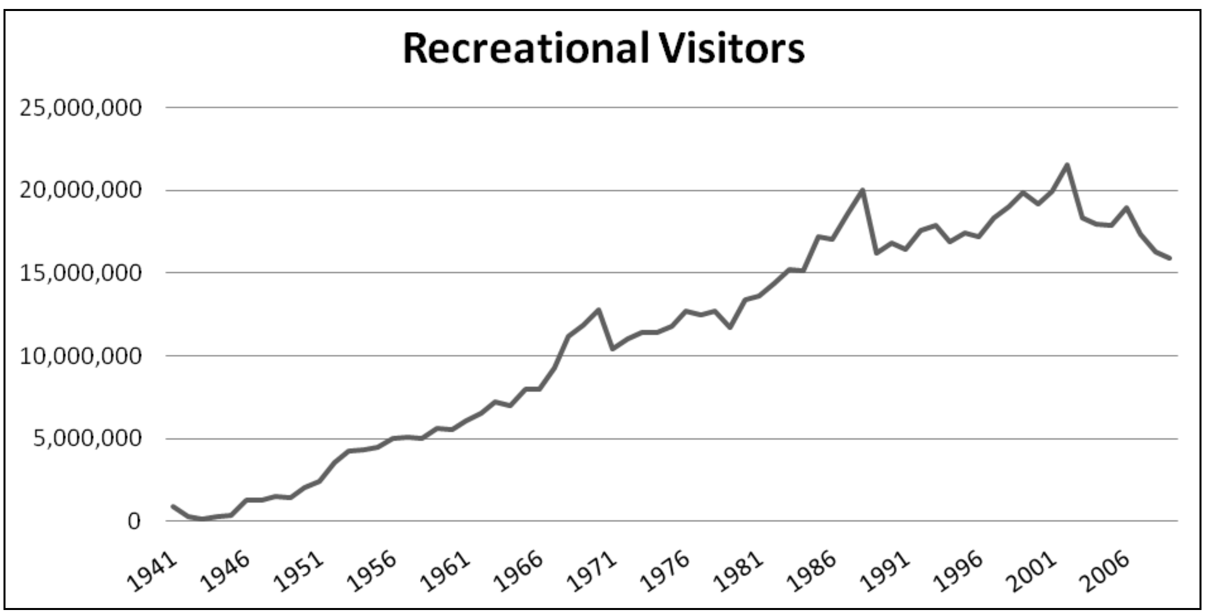

Figure 3. Visitor data for BLRI from 1941 to 2009 shows a steady increase until recent years.

2.2 Natural Resources

2.2.1 Resource Descriptions

Pursuant to its participation in the National Park Service Inventory and Monitoring program, the NPS has identified essential ecological vital signs for BLRI as part of the larger Appalachian Highlands Inventory and Monitoring Network (Emmott et al. 2005). These vital signs are a subset of all natural resources and are intended as indicators of the overall condition of the park unit. Because monitoring efforts by the APHN focus on these vital signs, they serve as a primary means of organizing resource assessments.

The Blue Ridge Parkway represents a large latitudinal transect across southern Appalachian highland ecosystems. Therefore it contains great physical and biological diversity. It lies at the heart of one of the most biologically diverse temperate areas on earth and harbors thousands of species. This diversity results from 200 million years of relative geological stability coupled with a great variety of landforms and climate. The region harbors over 1,600 vascular plant species, over 200 bird species, thousands of invertebrates, and the greatest diversity of salamanders on earth (NPS 2010b). The Parkway harbors at least five species of plants, one reptile, and two mammal species that are federally listed as threatened or endangered (Emmott et al. 2005). It also contains at least 81 species of biota designated by NatureServe as “vulnerable”, “imperiled”, or “critically imperiled” (Emmott et al. 2005). All of these species attest to the unique quality of the region and necessitate continued protection for their persistence.

<u>Water Quality</u>
Because BLRI water resources consist significantly of headwater streams, they are subject mainly to influences from within the park unit. These can include roadway and sewage runoff associated with the Parkway and its features, though the streams are largely free from pollutants associated with developed areas. BLRI also contains streams that originate outside the unit, and grazing has historically been permitted in some Parkway lands (NPS 2010a). Parkway managers are working to remove grazing as a source of pollution by fencing cattle out of riparian corridors and by converting grazing leases. Also, as previously discussed, acid deposition at high elevations can significantly acidify southern headwater Blue Ridge streams (Cook et al. 1994). This problem is compounded by the naturally low buffering capacities of some of the streams—a characteristic relating to their geologic origin and parent material. Water quality is also important for rare and unique seeps and bogs found along the Parkway. The NPS has identified the following objectives for water quality in BLRI (NPS 2010b):

1. Determine trends in: bacteria concentration, nutrients, sediment, metals, and physical parameters in streams, rivers, and wetlands.
2. Improve understanding of the relationship among water quality/quantity and park aquatic resources.

A detailed water quality monitoring protocol for the region is currently being finalized.

<u>Invasive Plants</u>
Because of its long, narrow configuration, and because it contains a roadway, the BLRI is particularly susceptible to invasion by exotic plant species. The Parkway contains many

thousands of disturbance habitats including “cut and fill” slopes, vista openings, and utility crossings. These provide ideal habitats for exotic plants to gain a foothold. Exotic plant species negatively impact the aesthetics of the Parkway, may reduce or eliminate native flora, and can disrupt the course of natural ecological succession. Exotic plants were found in 66% of 299 inventory plots along the BLRI (two to three times greater than proportions found at two nearby park units; NPS 2010b). Successful control of exotic plants requires long-term commitment. Many exotics can establish very rapidly and abandoning sites after simply removing plants may actually promote the establishment of future infestations. NPS staff have identified the management of exotic plant species as a top priority and are partnering with other groups to develop a monitoring protocol for BLRI. A successful approach must identify and control existing populations, as practical, but must also provide early warning of newly arriving infestations, and monitor for potential invasions that have not yet occurred. The NPS has identified the following objectives for control of exotic plant species in the BLRI (NPS 2010b).

1. Develop and update, at least every three years, a list of priority target species including species that are currently rare and species that do not occur in the park.
2. Develop a search model for target species based upon the natural history of the species.
3. Maintain early detection and rapid response (EDRR) efforts to control spread of invasives.

The NPS has used data from 299 established survey plots, and data from 1,000 additional plots on adjacent Forest Service land, to establish distribution maps of existing invasions and to begin developing search models for future invasions.

<u>Invasive Fauna and Fungi</u>
Several species of invasive fauna are known to present ecological problems in BLRI. European starlings (*Sturnus vulgaris*) compete with native eastern bluebirds (*Sialia sialis*) for nesting cavities. Brown trout (*Salmo trutta*) and rainbow trout (*Oncorhyncus mykiss*), although they represent a recreationally important managed fishery, have displaced native brook trout (*Salvelinus frontinalis*) from many streams, eliminating them or forcing them into higher-elevation habitats. Exotic earthworms and crayfish have been documented in the BLRI. Several exotic insect and fungi species have profoundly impacted native tree communities. These include the chestnut blight (*Cryphonectria parasitica*) which has effectively wiped out the American chestnut, and the balsam woolly aphid (*Adelges piceae*), which has destroyed high-elevation fir forests (NPS 2010a). The hemlock woolly adelgid (*Adelges tsugae*) was first found in the Parkway in 1984, and has since killed many of the native eastern hemlocks (*Tsuga canadensis*) and Carolina hemlocks (*Tsuga caroliniana*; NPS 2010c).

<u>Exploited Plants</u>
The BLRI contains many plant species of interest or potential interest to poachers, who illegally collect plants for commercial sale. Because the roadway provides relatively easy access to many desirable species, the BLRI is especially susceptible to plant poaching. Some target populations do not recover, or recover slowly, from species removal, and some of the most accessible of these populations are being eliminated along the Parkway. Species of particular interest include black cohosh (*Actaea racemosa*), bloodroot (*Sanguinaria canadensis*), trillium (*Trillium* spp.), and galax (*Galax urceolata*). The NPS has identified these species as suitable for monitoring and has established the following objectives for black cohosh, bloodroot, and trillium spp. (NPS 2010b):

1. Gain ability to detect a 30% decrease in overall abundance of black cohosh, trilliums, and bloodroot within the study areas.
2. Periodically collect/review presence/absence data for sample unit species for evidence of large-scale assemblage changes.

NPS staff have used predictive GIS modeling to identify potential sampling sites for these three species, have established some sampling sites, and have developed and implemented data collection methods to meet the objectives outlined above (NPS 2010b).

Galax is more widely distributed across general habitats than the three plants discussed above. Furthermore, the galax found along the southern Blue Ridge escarpment is a genetically distinct tetraploid form that, when mature, produces unusually large leaves that are especially desirable for floral arrangements. Therefore, the NPS has identified the following objectives for monitoring poaching impacts on galax in BLRI (NPS 2010b):

1. Gain ability to detect 30% decrease in galax cover in study area.
2. Gain ability to detect 30% decrease in ratio of large (>3.5 in; 8.9 cm) leaves to small leaves in study area.

NPS staff have sampled over 1,800 short transects along the BLRI for galax. From these, managers have established long-term monitoring plots designed to meet the stated objectives. These activities have already led to focused law enforcement activities resulting in several arrests for galax poaching (NPS 2010b).

Aquatic macroinvertebrates

Aquatic macroinvertebrates play an important role in forest ecosystems, because they play a key role in nutrient cycling and serve as food for other biota. Healthy macroinvertebrate assemblages include predators as well as herbivorous species. Their activities make primary production available to higher trophic levels, and play an integral role in breaking down stream litter. They form the base upon which many native stream fishes and amphibians depend. They are sensitive indicators of water quality and ecosystem health and are useful for assessment of these conditions. As such, invertebrate sampling presents a cost-effective tool of ecosystem assessment that can be used to establish reference conditions, detect and characterize impairment, identify impairment sources, and evaluate mitigation activities. Recent surveys of park water resources have identified several species of aquatic macroinvertebrates that are new to science, the region or the park and the potential exists for additional species to be found in future surveys. The NPS has established the following goals for the general Appalachian highlands area (NPS 2010b):

1. Determine trends in species assemblages and tolerance indices at index sites.
2. Correlate trends in assemblage changes with changes in habitat and water quality.

NPS staff has evaluated rapid bioassessment protocols (RBP) for southern Appalachian states and have decided to use the protocol used by the North Carolina Department of Environment, Health, and Natural Resources. This protocol has been successfully used in nearby parks, including Great Smoky Mountains National Park (NPS 2010b).

Landscape Changes

Many of the vital signs described above for BLRI interact with and respond to changes of the landscape within and surrounding the park, including exotic species introductions, water quality issues, and air quality problems. In some cases it is possible to link specific problems, like the reduction of a particular forest species, to particular landscape metrics, such as a decrease in the amount of core forested habitat, or an increase in levels of wildland-urban interface.

To investigate effects of landscape change in areas surrounding park units, NPS created a series of landscape dynamics data products called NPScape, whose goal was to create an organized protocol for landscape scale assessment for all park units in the US. To achieve that goal, NPScape divided the landscape analysis into five main categories: (1) landcover, (2) roads, (3) population and housing, (4) pattern, and (5) conservation status. Each of these categories has an associated set of data sources and data products that provide the foundation for further analysis. For each section, the NPScape interpretative guide provides a literature review, including lists of thresholds that can serve as metric guidelines.

Throughout the Southern Appalachians, the ongoing hemlock woolly adelgid infestation is changing vegetation cover and habitat availability on a large scale. With climate change, exotic infestations are expected to accelerate, making the need for this type of evaluation more pressing. Park Service staff have identified specific objectives for monitoring landscape change (NPS, 2010b):

1. Periodically determine status and trends in the aerial extent of land use and cover in lands bordering park lands.
2. Periodically determine status and trends of key landscape metrics in lands bordering the park.
3. Periodically document long-term changes in abundance, distribution and health of dominant vegetation types within the park.

2.2.2 Ecological Units

Wetland Communities

BLRI protects half of the remaining high elevation wetlands in North Carolina (Emmott et al. 2005). Parkway wetlands include Appalachian bogs, a rare ecosystem associated with unique and rare species of plants and animals. Appalachian bogs are open, acidic, seepage wetlands found along valley floors and headwater streams (Virginia Department of Conservation and Recreation 2006). These bogs support rare or locally rare plants including Gray's lily (*Lilium grayi*), large cranberry (*Vaccinium macrocarpon*), and Cuthbert's turtlehead (*Chelone cuthbertii*). The range of the bog turtle (*Glyptemys muhlenbergii*) overlaps significantly with Parkway lands and this species is of particular interest to Parkway biologists and other researchers. The bog turtle relies on upland wetlands such as bogs. The return of beavers (*Castor canadensis*) to Parkway lands is also important to the survival of the bog turtle and to the maintenance of quality wetlands generally. Beavers were removed from Blue Ridge by the end of the 19th century, but were reintroduced and began re-colonizing Parkway lands in the 1980s. Their return has been associated with increased wetland areas and with increased biodiversity (NPS 2010a). The watershed for many park wetlands includes lands outside the park's boundary and can be strongly influenced by the activities of these landowners. In order to help protect wetlands, NPS staff have identified two objectives to direct monitoring:

1. Determine status and trends in vegetation and hydrologic changes to park wetlands
2. Determine impacts of beavers as they move into new areas altering the site from wetland to ponds

Forest Communities

Different forest types exist in an elevation gradient along the Parkway, with the lowest areas dominated by a mixture of oak (*Quercus* spp.) and pine (*Pinus* spp.). Mesic areas support highly diverse cove forests, and in higher elevations (>1200 m), northern hardwood species are common, including American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), yellow buckeye (*Aesculus flava*), and yellow birch (*Betula alleghaniensis*). On higher ridgetops, cold-tolerant species such as Fraser fir (*Abies fraseri*) and red spruce (*Picea rubens*) are common, although forest structure of this community type has been altered due to the presence of balsam woolly adelgid (*Adelges piceae*). Trees killed by this pest also contribute to fuel loading, which can result in fires destructive to this type of community (Emmott et al. 2005).

Mountain Balds

Grassy and heath balds occupy many high-elevation sites along BLRI, many of which are highly susceptible to recreational impact and acidic deposition. Balds were historically dependent on large grazing animals such as elk (*Cervus canadensis*), which in turn allowed certain rare and endemic plants dependent on these open areas to persist. With the absence of these animals today, many of these plant populations are in danger of genetic inbreeding due to their isolation, or being lost altogether.

2.2.3 Resource Issues Overview

In addition to the specific resources outlined above, there are other factors that actively affect natural resources in the park unit and deserve continued monitoring and management attention. Fire management is an effective management practice that can result in several ecological benefits. In addition, the area around BLRI is especially sensitive to air quality factors due to high elevation and proximity of pollutive industrial activity. On a larger temporal scale, weather and climate as well as landscape change represent significant factors that can fundamentally alter the nature of the park unit. The last three are additionally listed as network vital signs and accordingly are the object of regular data collection and analysis.

Fire Management

The Parkway is divided into four fire management units: Ridge (milepost 0.0 to 106), Plateau (milepost 106 to 216.9), Highlands (milepost 216.9 to 305.1), and Pisgah (milepost 305.1 to 469.1). The northern two fire management units have been the most heavily impacted by tree mortality due to southern pine beetle, gypsy moth, and hemlock woolly adelgid. In addition, vegetation throughout the Parkway has been altered by a history of fire suppression, especially in higher elevation xeric pine communities. While the overall policy is to intercept and suppress wildfires in the park unit, the management plan also outlined the intention to conduct prescribed burns on areas totaling 220 ha over the course of five years, much of which is focused on restoring Table Mountain pine (*Pinus pungens*) and Montane oak-hickory communities (NPS

2004). Two main monitoring objectives help NPS staff direct fire management activities at BLRI:

1. Continue establishing and monitoring fire effects plots pre- and post-prescribed fires.
2. Assist with establishment of a prescribed fire program that benefits park natural resources.

Air Quality

Anthropogenic sources of pollution affect air quality along the Blue Ridge Parkway. Sources include fossil fuel burning power plants, industry, and automobiles. The Appalachian Mountains trap and concentrate wind-borne pollutants from a large geographical area. This has caused reductions in visibility by as much as 40% in winter and 80% in summer over the last 50 years. Because BLRI is specifically visited for its majestic views, this decrease in visibility is significant for park visitors. Air pollution also results in acid deposition in the region. Studies in Great Smoky Mountains National Park, the southern terminus of the Parkway, have shown that rainfall there is more acidic than national averages, measuring 5.0 to 5.6 on the pH scale, and ridge-top clouds can have a value as low as 2.0 (NPS 2010c). There is evidence that acid deposition is altering the soil chemistry of the Blue Ridge. Soils experience nitrogen saturation, causing calcium leaching and the release of toxic aluminum (NPS 2010b). This negatively affects plant growth and acidifies lakes and streams. Ozone is also concentrated by the Blue Ridge Mountains. Ozone levels at high elevations in the Smoky Mountains have been found to be twice as high as levels in Atlanta and Knoxville (NPS 2010a). Ozone poses a direct human health risk, and affects vegetation at high elevations. A risk assessment for BLRI has indicated that the risk of injury from ozone is high (NPS 2010b). The NPS has identified ozone, acid deposition, and visibility as greatest concern air quality issues for the Parkway. Air quality monitoring stations exist along the Parkway and specific monitoring objectives are (NPS 2010b):

1. Report trends in nitrogen and sulfur deposition.
2. Report trends in fine particle concentration.
3. Report trends in ozone concentration in metrics related to human health.

Weather and Climate

The purpose of weather monitoring within APHN is to develop a long-term record of local meteorological data, which may in turn be used to track changes in local weather station patterns, inform atmospheric models, advise visitors on park conditions, and help understand changes in plant and animal communities or other natural resources. The NPS has identified the following specific goals for monitoring weather and climate trends along the Parkway (NPS 2010b):

1. Maintain accurate information on weather stations within the park.
2. Analyze maximum/minimum temperature, wind speed, and precipitation trends.
3. Report unusual events.
4. Make weather summaries available.

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Chapter 3 Study Scoping and Design

3.1 Preliminary Scoping

During June 2010, an initial scoping meeting was held to discuss natural resource issues at BLRI (See Appendix A for list of attendees). The purpose of this meeting was to provide an introduction to the scope of the NRCA report and identify potential sources of data. Using the list of vital signs outlined by the APHN as a starting point, additional points of interest and important natural resource issues at the park unit were added as focal points to the assessment. Other discussion was devoted to how the report could maximize its utility at the park unit level while minimizing summary of existing reports and assessments.

3.2 Study Design

3.2.1 Indicator Framework

The ranking framework used for this natural resource condition assessments draws from the NPS ecological monitoring framework (EMF) (Fancy et al. 2009) (Table 3). Using the Environmental Protection Agency (EPA) ecological condition framework (Young and Sanzone 2002) as a model, the NPS framework divides monitoring into six general categories: air and climate, geology and soils, water, biological integrity, human use, and landscape pattern and processes. Each of these general categories, referred to as level-one, are further subdivided into level-two and level-three categories, with each park vital sign most closely associated with this fine-scale level-three division. Biological integrity, a level-one category for example, is divided into 4 level-two categories: exotic species, infestations and disease, focal species or communities, and at-risk biota. Exotic species, in turn, includes 2 level-three categories: invasive/exotic plants and invasive/exotic animals. Table 4 indicates the ecological attributes, key assessment measures, and primary sources of data used in this NRCA.

Table 3. NPS Ecological Monitoring Framework table used to organize and identify natural resource areas of interest at BLRI (Fancy et al. 2009). Blue highlighted categories represent relevant vital signs specifically selected for BLRI.

Level 1 Category	Level 2 Category	Level 3 Category	Specific Resource / Area of Interest
Air and Climate	Air Quality	Ozone	Atmospheric ozone concentration; damage to sensitive vegetation
		Wet and Dry Deposition	Wet & dry sulfate and nitrate deposition, concentration of nitrates
		Visibility and Particulate Matter	IMPROVE station data, change in visibility
		Air Contaminants	Hg
	Weather and Climate	Weather and Climate	Precipitation, temperature, wind speed/direction,
Geology and Soils	Geomorphology	Windblown Features and Processes	
		Glacial Features and Processes	
		Hillslope Features and Processes	
		Coastal/Oceanographic Features and Processes	
		Marine Features and Processes	
		Stream/River Channel Characteristics	
		Lake Features and Processes	
	Subsurface Geologic Processes	Geothermal Features and Processes	
		Cave/Karst Features and Processes	
		Volcanic Features and Processes	
		Seismic Activity	
	Soil Quality	Soil Function and Dynamics	
	Paleontology	Paleontology	
Water	Hydrology	Groundwater Dynamics	Quantity (especially in park wetlands)
		Surface Water Dynamics	Siltation; Flow
		Marine Hydrology	
	Water Quality	Water Chemistry	Temperature, specific conductivity, pH, DO, ANC
		Nutrient Dynamics	Heavy metals
		Toxics	
		Microorganisms	Fecal coliform, *E. coli*
		Aquatic Macroinvertebrates and Algae	*S*, *H'*, stream macroinvertebrate IBI, relative abundance

Table 3. (continued)

Level 1 Category	Level 2 Category	Level 3 Category	Specific Resource / Area of Interest
Biological Integrity	Exotic Species	Invasive/Exotic Plants	New invasions (early-warning emphasis); occurrence, distribution models
		Invasive/Exotic Animals	New invasions (early-warning emphasis); occurrence, distribution models
	Infestations and Disease	Insect Pests	Hemlock wooly adelgid, gypsy moth, balsam wooly adelgid, southern pine beetle
		Plant Diseases	Chestnut blight, beech-bark disease, dogwood anthracnose
		Animal Diseases	White-nose syndrome
	Focal Species or Communities	Marine Communities	
		Intertidal Communities	
		Estuarine Communities	
		Wetland Communities	Southern Appalachian bogs distribution/bog turtle habitat
		Riparian Communities	
		Freshwater Communities	
		Sparsely Vegetated Communities	
		Cave Communities	
		Desert Communities	
		Grassland/Herbaceous Communities	
		Shrubland Communities	
		Forest/Woodland Communities	Cliff/rock communities, grassy balds, spruce-fir forests, hemlock/cove forests
		Marine Invertebrates	
		Freshwater Invertebrates	Richness/diversity, rare species, species of conservation value
		Terrestrial Invertebrates	
		Fishes	Multimetric indices
		Amphibians and Reptiles	Rare species, expected vs. observed assemblages
		Birds	Multimetric community indices, conservation value indices, expected vs. observed assemblages

Table 3. (continued)

Level 1 Category	Level 2 Category	Level 3 Category	Specific Resource / Area of Interest
Biological Integrity (continued)	Focal Species or Communities (continued)	Mammals	Observed vs. expected
		Vegetation Complex (use sparingly)	
		Terrestrial Complex (use sparingly)	
	At-risk Biota	T&E Species and Communities	(plants) Heller's blazing star, spreading avens, small-whorled pogonia, swamp pink, rock gnome lichen
Human Use	Point Source Human Effects	Point Source Human Effects	
	Non-point Source Human Effects	Non-point Source Human Effects	
	Consumptive Use	Consumptive Use	Exploited Plants – trilliums, bloodroot, cohosh. Galax. Lilies, sphagnum
	Visitor and Recreation Use	Visitor Use	
	Cultural Landscapes	Cultural Landscapes	
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	Fire and Fuel Dynamics	Fire-dependent plants; effects/objectives of (prescribed) fires
	Landscape Dynamics	Land Cover and Use	NPScape components: landcover, housing, roads, population, pattern, and conservation status; 30 km and 3 km buffers
	Extreme Disturbance Events	Extreme Disturbance Events	
	Soundscape	Soundscape	
	Viewscape	Viewscape/Dark Night Sky	
	Nutrient Dynamics	Nutrient Dynamics	
	Energy Flow	Primary Production	

Table 4. Summary of ecological attributes, assessment measures, and data sources used in this Natural Resource Condition Assessment of Blue Ridge Parkway. Data source citations are found in the appropriate sections of Chapter 4.

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Ozone	4th highest maximum 8-hour average ozone concentration	Portable Ozone Monitoring Systems (POMS) in BLRI	Hourly measurements of ozone concentration within BLRI at 7 ozone monitoring sites	May-September, 2003-2005
	Foliar injury risk predictions (3-metric index)	NPS report for the Cumberland Piedmont Monitoring Network (NPS ARD 2004)	Kriged predictions extracted from US-wide ozone models	1995-2003
		Kohut (2007)	Description of foliar injury risks at each park unit	2007
Atmospheric Deposition	Wet and Dry Deposition	six monitoring stations in EPA Clean Air Status and Trends Network (CASTNET)	Wet deposition nitrate and sulfate concentrations; Dry deposition nitric acid, ammonium, nitrate, sulfur dioxide, and sulfate concentrations	1978-2008 (var.)
	Mercury Deposition	National Atmospheric Deposition Program (NADP) Mercury Deposition Program (MDP) station at Great Smoky Mountains National Park (GRSM)	Mercury deposition	1980-2008
Visibility	National Ambient Air Quality Standards (NAAQS) for particulate matter	Interagency Monitoring of Protected Visual Environments Program (IMPROVE) sites at GRSM, Shenandoah, James River Face Wilderness, Linville Gorge, and Shining Rock Wilderness	Fine ($PM_{2.5}$) and coarse (PM_{10}) particulate matter concentrations	1988-2004 (var.)
Weather and Climate	Deviation from normal conditions and frequency of extreme weather events	Two Remote Automated Weather Station (RAWS) in BLRI: Laurel Springs and Davidson River	Temperature, precipitation, wind speed/direction	2003-2006 (Laurel Springs); 2004-2006 (Davidson River)
		Six Cooperative Observer Program (COOP) sites in within/out the park boundary	*Same as above*	1893-present (var.)
		Flaherty (2010) climate summary for BLRI	Assessment of temperature, precipitation, and wind trends for 2007 using stations above	2007

Table 4. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Water Chemistry	Temperature (max, mean), pH (mean), specific conductance (mean), DO (mean), ANC (mean)	EPAStoret data for BLRI cataloging units	Raw water quality monitoring data from sampling at stations within 15 BLRI HUC8 cataloging units	No date
		Sullivan et al. (no date)	Streamwater Acid-Base chemistry and sulfur deposition	No date
		Smith et al. (2002)	Groundwater at Mt. Pisgah campground	2002
Microorganisms	E. coli (mean colonies/100mL), fecal	*Same sources as above*	--	--
Aquatic Macroinvertebrate Assemblages	Selected richness-based metrics, conservation index scores	David Lenat (2007)	Macroinvertebrate survey, narrative report and associated tabular data and appendices	2005-2007
Insect Pests/Plant Diseases	Treatment sites, infestation risk	NatureServe (2007) vegetation communities report	Description of major vegetation communities mapped at BLRI, as well as disturbance notes at each plot	2002
		NPS (2007)	HWA Control Strategies for BLRI	N/A
		Ohlsen (1991 & 1992)	BLRI Gypsy Moth defoliation	1990-1992
		Teague and Ohlsen (1991)	BLRI Pine sawfly distribution	1990-1991
		Teague et al. (1994)	BLRI Southern pine beetle distribution	1989-1993
		Witkosky, Kyle, Keith, and Sellers (1989-2002)	Gypsy moth outbreaks in Shenandoah National Park and BLRI	1988-2001
		Johnson and Ohlsen (1992)	Gypsy moth Integrated Pest management plan	N/A

Table 4. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Invasive/Exotic Plants	Presence, relative predominance, and invasibility of exotics	NatureServe (2007) vegetation communities report	Description of major vegetation communities mapped at BLRI, as well as disturbance notes at each plot	2002
		Southern Appalachian Man and the Biosphere Program (SAMAB)	Location of oriental bittersweet, Japanese honeysuckle, and purple loosestrife	2005
		BLRI Exotic Management Plan (2006)	Comparison of different management control techniques	2006
Vegetation Communities	Species composition, fire management, community structure, exotic predominance	NatureServe (2007) draft vegetation communities report	Description of major vegetation communities mapped at BLRI, as well as disturbance notes at each plot	2002
		Murrell et al. (2007) vegetation survey of developed areas along the BLRI	Describes and maps vegetation at picnic areas and campgrounds along the Parkway, including exotic vegetation and other disturbances	2000-2002
		Lance (2007) survey of hawthorn	Description of hawthorn species and their occurrence	2006
		Sutter et al. (2003)	Vegetation Changes after Elimination of Grazing in a Southern Blue Ridge Wetland	2003
		Heiman (1991)	Lichens of the Blue Ridge Parkway in North Carolina	1991
Fish Assemblages	Modified multimetric indices; status of brook trout community	Scott (2007)	Fish Survey narrative report and associated data in APHN fish sampling database	2004-2007
		Shull and Walker (1995)	Published report on electrophoretic genetic study of BLRI brook trout	1995
Bird Assemblages	Bird community index (BCI), conservation value index, richness, abundance	Pearson and Smith (2006)	Bird Inventory of BLRI including narrative report and database of raw data	2006

Table 4. (continued)

Attribute	Assessment Measure	Data Sources	Data Description	Data Period
Mammal Assemblages	Comparisons of reported vs. expected, presence of spp. of concern and exotic spp.	Britzke (2007)	Mammal Inventory	2003-2004
		Knowles et al. (1989)	Rare and endangered vertebrate survey of NC portion of BLRI, compiled from literature, interviews, and field work	1987-1989
Reptile and Amphibian Assemblages	Comparisons of reported vs. expected/similar studies	Howard (1985)	Reptile and Amphibian survey	1984-1985
		Hays and Hays (2006)	Inventory of the herpetofauna of BLRI	2003
T&E Species/ Communities	Protection status, abundance and rate of change	NPS Rare plants monitoring (2010)	Annual description of rare plant populations, poaching, and their overall health	2006-2009
Consumptive Use	Susceptibility, decline, and abundance of commonly exploited plants	NPS Rare plants monitoring (2010)	Annual description of rare plant populations, poaching, and their overall health	2006-2009
Landscape Dynamics	NPScape main categories: landcover, roads, population and housing, pattern, and conservation status	NPScape dataset	Suite of GIS layers and associated data for each of the main categories, as well as resulting spatial analysis data products	Varies
		Center for Remote Sensing and Mapping Sciences (CRMS) vegetation classification (2009)	Vegetation community map for BLRI	2003

3.2.2 Reporting Areas

With the exception of the condition assessments for water quality, fish assemblages, and landscape dynamics, each section of the report is scaled to the ecosystem or park level, depending on the data. Air quality attributes vary at a large scale, and at BLRI, observations are divided along its length to reflect latitudinal gradients associated with elevation and proximity to sources of pollution. The same is true for weather and climate, which is informed by data from some of the same stations. For water quality, data has been organized and ranked by watershed, though an overall ranking for the park unit is provided at the end of the section. Parameters are also individually summarized on a park-wide basis, and streams categorized as 303(d) are described separately. The exotic plants section lends itself to division by habitat unit, though a park-wide summary is also given. Lastly, the landscape dynamics section incorporates data from the entire region, including both 30 km and 3 km buffers around the park boundary. The condition status for this section is intended to reflect the influence of several large-scale factors on the park unit.

3.2.3 General Approach and Methods

Condition and Trend Status Ranking Methodology

Data collected as part of the NPS I&M program and park monitoring projects are usually intended to inform the condition of the vital sign at level 3, and therefore are summarized next to this level in the ranking status tables given at the beginning of each vital sign section. These tables represent a subset of the EMF tables and show only the complete division of the level 1 category to which the ecological attribute belongs. Individual attributes are assigned two individual rankings: condition and trend.

We used this hierarchical framework to inform our choice of assessment attributes and to organize the presentation of our results. We developed a list of ecological attributes suitable for condition assessment using: 1) level-three category attributes from the adapted EPA framework described above, 2) the inventory and monitoring goals for the Appalachian Highlands Network (APHN) (Emmott et al. 2005), and 3) input from NPS staff. We assessed the condition of each attribute using methods and reference criteria that are described in the appropriate sections of this report. When appropriate, we performed statistical comparisons using $a = 0.05$. We graphically presented the condition of each attribute as a colored circle where the color indicated condition on a four-tiered scoring system of excellent (dark green), good (light green), fair (yellow), or poor (red) (Table 5). It is important to note that condition rankings are relative for each condition, and that identical rankings for different attributes may hold separate meanings and implications. When possible, we used published metrics and established reference thresholds to assign rankings. But in cases where no quantitative metric or standard was found, we used our best judgment and expert opinion. For several attributes, a condition was not assigned because available data were insufficient or because we lacked a defensible ranking method. These attributes were indicated with a blue circle. When possible, we also assigned a trend to each condition ranking. We graphically presented condition trend with an arrow within the condition circle. Arrow orientation indicated improving condition (arrow points up), stable condition (arrow points right), or deteriorating condition (arrow points down). As with condition status, we did not assign a trend in cases where data were insufficient, or when we lacked a defensible method to determine a trend.

Data Quality

Adjacent to each vital sign condition and trend ranking in the EMF table subset, a data quality ranking is also given to provide context for the reliability of the rankings and help identify areas where insufficient data exist. This ranking is divided into three pass-fail categories—thematic, spatial, and temporal—and is adopted from the data quality ranking utilized by Dorr et al.'s 2008 NRCA report for Fort Pulaski National Monument. The first category, thematic, refers to the relevancy of the data used to make the assessment, such as whether a certain water quality parameter is measured directly or inferred from a secondary variable. In most cases, thematically relevant data for a particular attribute must be available before a condition assessment can even be assigned. For some attributes such as air quality, however, certain descriptors may meet this thematic requirement (e.g. ozone concentration) whereas others may not (e.g. foliar injury), resulting in a thematic data quality ranking that may not reflect all aspects of the data. The spatial category refers to whether there is a spatial component to the data, and if so, whether the available data is spatially relevant (e.g. inside the park unit). As in the ozone example, ozone concentration may be available from direct measurements (meeting the thematic requirement), but the monitoring station may not be inside the park boundary, therefore conditions at the park unit are inferred or interpolated. In such cases, the spatial requirement is not met. The third data quality category, temporal, is fulfilled if the data are less than five years old. To give an overall rank to the data quality, the number of requirements met are summed and translated into a good (3), fair (2), or poor (1) ranking and reported alongside the overall condition assessment (Table 5). Data that fulfill none of the three ranking categories are not used to assess vital sign conditions.

Because monitoring is relatively new for many aspects of natural resources in park units, several categories are missing criteria for data quality. However, as continued monitoring adds to the available data for future condition assessments, it is likely that these data quality rankings will improve. In addition, implementation and refinement of monitoring protocols for the various natural resource categories is still underway. Data collection methods will likely also change as monitoring needs are fine-tuned to specific metrics and aspects of vital signs at each park unit.

Table 5. Example condition assessments. Attribute condition is indicated by the color of the circle. Dark green = excellent, light green = good, yellow = fair, red = poor, blue = no condition assigned. Condition trend is indicated by the arrow within the circle. Pointing up = improving condition, pointing right = stable condition, pointing down = declining/deteriorating condition, no arrow = no trend assigned. Checkmarks indicate whether data were appropriately thematic, spatial, or temporal for assessments, as described in the text. Colored bar indicates data quality score. Light green = 3 of 3 possible checks, yellow = 2 of 3 possible checks, red = 1 of 3 possible checks.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal	Interpretation
Example 1:		✓	✓	✓	Condition: Excellent Trend: Improving Data Quality: Good
		3 of 3: Good			
Example 2:			✓	✓	Condition: Good Trend: Stable Data Quality: Fair
		2 of 3: Fair			
Example 3:		✓	✓		Condition: Fair Trend: Declining Data Quality: Fair
		2 of 3: Fair			
Example 4:				✓	Condition: Poor Trend: None assigned Data Quality: Poor
		1 of 3: Poor			
Example 5:		✓	✓	✓	Condition: None assigned Trend: None assigned Data Quality: Good
		3 of 3: Good			

3.3 Literature Cited

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Chapter 4 Natural Resource Conditions

4.1 Air Quality

As one of the recognized vital signs of the APHN, air quality is a major consideration at BLRI. Air quality is federally protected from degradation by the Clean Air Act (CAA) through a series of National Ambient Air Quality Standards (NAAQS), which are guidelines for certain airborne pollutants. Although there are six airborne pollutants for which NAAQS exist, the particularly important ones that are monitored at BLRI include ozone, particulate matter, and lead. The CAA classifies certain park units into two air quality classes which determine the level of focus on air quality as a natural resource. Throughout the US, there are 158 areas classified as Class-I, which includes 48 NPS units. These areas receive the highest level of management attention, though this designation is reserved for national parks greater than 5,000 acres and wilderness areas greater than 6,000 acres. Despite the tremendous importance of views at BLRI and their influence on visitation, the park unit is classified as Class-II because of this default classification scheme, which allows for higher levels of pollutants in the park before they are considered an issue under the CAA. Most of the time, these higher levels are designated in areas to allow for some development. An even more lenient Class-III designation exists, though no park units are currently classified with this category (NPS 2010).

In addition to the three air pollutants covered by NAAQS, there are other air quality related factors important at BLRI, including potential rates of foliar injury caused by ozone concentrations, atmospheric deposition, and visibility. In fact, in a report on visibility in national park units, the National Research Council (1993) indicated that average visibility in the eastern U.S. is about 30 km due to air pollution, whereas the natural visible range is fivefold that amount.

4.1.1 Ozone

Ozone is an atmospheric constituent produced from reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs). In humans, exposure to high levels of ozone can contribute to respiratory problems, inhibit lung capacity, and result in overall impairment of the immune system. High ozone levels are also harmful to plants, and can inhibit agricultural crops as well as natural communities (NPS ARD 2004). There are seven Portable Ozone Monitoring Station (POMS) sites located within the boundary of BLRI which have collected continuous monitoring data during the ozone season (April – October) for different periods since 2003. Each of the stations and their monitoring period is listed in Table 6 and shown in Figure 4. In addition, three passive ozone stations, which use a slightly different method of monitoring, collected data along BLRI near the state line.

Table 6. Data availability for each of the ozone monitoring stations at BLRI.

Station	Start	End	Total Years
7510 Blue Ridge Parkway	1998	2008	11
Barnet Knob Fire Tower	1999	2007	9
Unnamed	2003	2006	4
Frying Pan Mountain	1998	2008	11
Route 191	1998	2008	11
Ranger Station	2003	2008	6
East Vinton Elementary	2003	2008	6

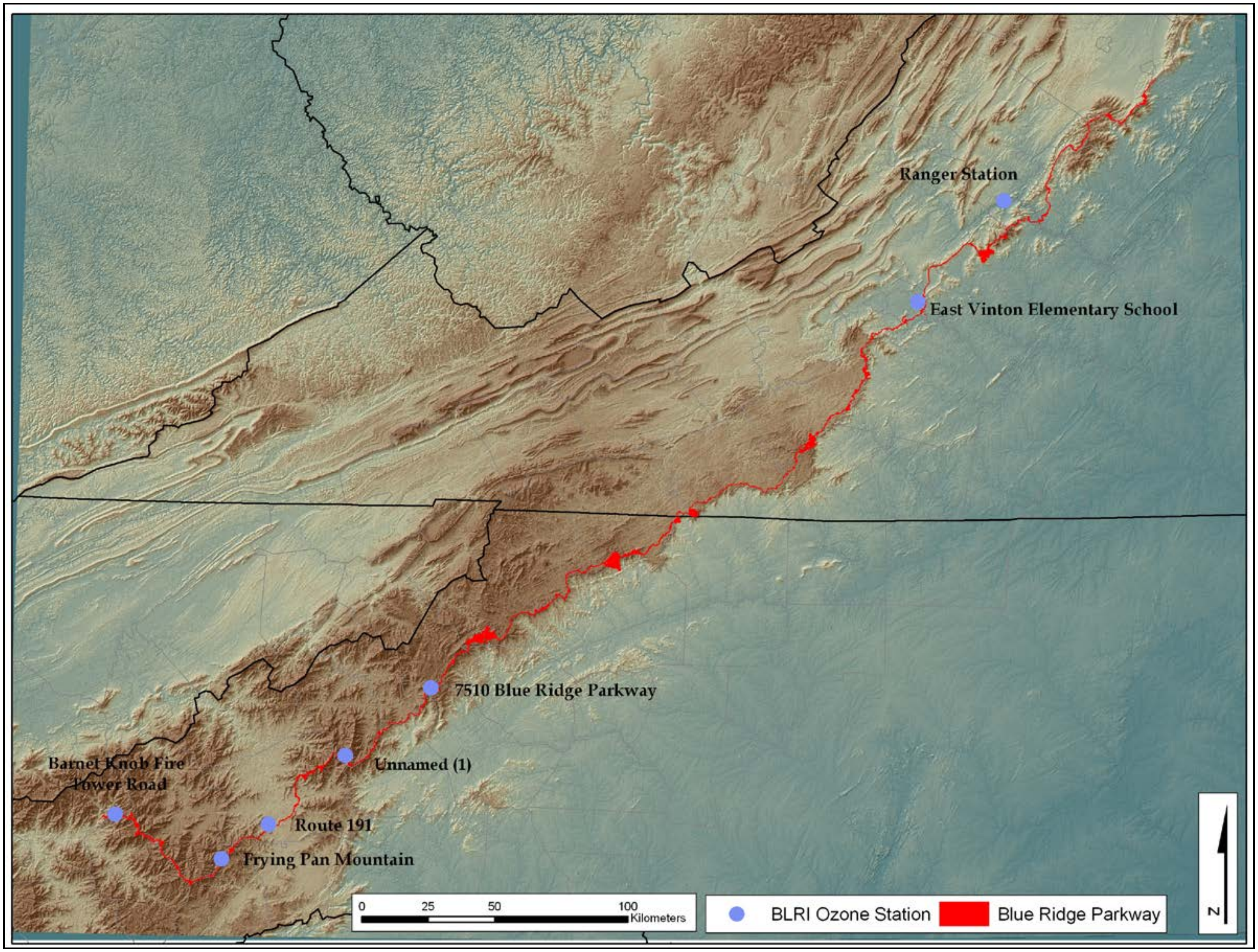

Figure 4. In the past, there have been seven Portable Ozone Monitoring Stations (POMS) and three passive ozone stations (not shown) along BLRI.

The National Ambient Air Quality Standards (NAAQS) set by the EPA include two thresholds for primary and secondary pollutant limits. For ozone, the NAAQS lowered primary and secondary standard concentrations on May 27, 2008 from 0.080 ppm to 0.075 ppm. As a result, standard violations are defined as 3-year averages of the 4th highest daily maximum 8-hour average ozone concentration (4th Hi Max 8-hr) that exceed 0.075 ppm after that period (NPS ARD 2007).

Direct ozone monitoring at BLRI began in 1995 with passive ozone monitoring stations at three locations. Measurements were collected for several months during the ozone seasons of 1995-1997. Concentrations averaged 0.045 ppm hr^{-1} in 1995 with a maximum observation of 0.065 ppm, 0.039 ppm hr^{-1} in 1996 with a maximum observation of 0.056, and 0.043 ppm hr^{-1} in 1997 with a maximum of 0.055 ppm hr^{-1}. Although the NAAQS 4th Hi Max 8-hr metric is not reported for the passive samplers during this time period, the NPS Air Resource Division interpolated estimates for several air quality parameters, including ozone, for park units throughout the U.S. and presented as an overall mean from 1995-1999. For BLRI, the predicted 4th Hi Max 8-hr metric during this period was 0.088 ppm, which well exceeds the NAAQS limit at that time. Although the ARD produced subsequent 5-yr interpolations for NPS units, none of these included BLRI.

Beginning in 1998, measurements collected at POMS are available online from the NPS Air Resources Division Gaseous Pollutant Monitoring Program and EPA AirData at seven sites. Data availability and results from these stations are shown in Table 6 and Figure 5, respectively.

Virtually all of the stations appeared to show decreasing trends over this time period, though significant decreases ($\alpha = 0.05$) occurred at ‘7510 Blue Ridge Parkway’ (-1.4 ppb yr^{-1}; $p = 0.01$), ‘Frying Pan Mountain’ (-2.0 ppb yr^{-1}; $p = 0.01$) and ‘Route 191’ (-1.9 ppb yr^{-1}; $p = 0.01$). Though the ‘Ranger Station’ site had less available data, it showed a trend of -2 ppb yr^{-1} at a significance of $p = 0.06$. Over the eleven-year monitoring period, four stations exceeded either the 0.08 ppm or 0.075 ppm threshold a total of eleven times, while the unnamed station, Ranger Station, and East Vinton Elementary sites remained below the threshold over their respective data periods. The majority of 4th Hi Max 8-hr metrics were above 0.070 ppm, and none of the stations reported a metric below 0.060 ppm.

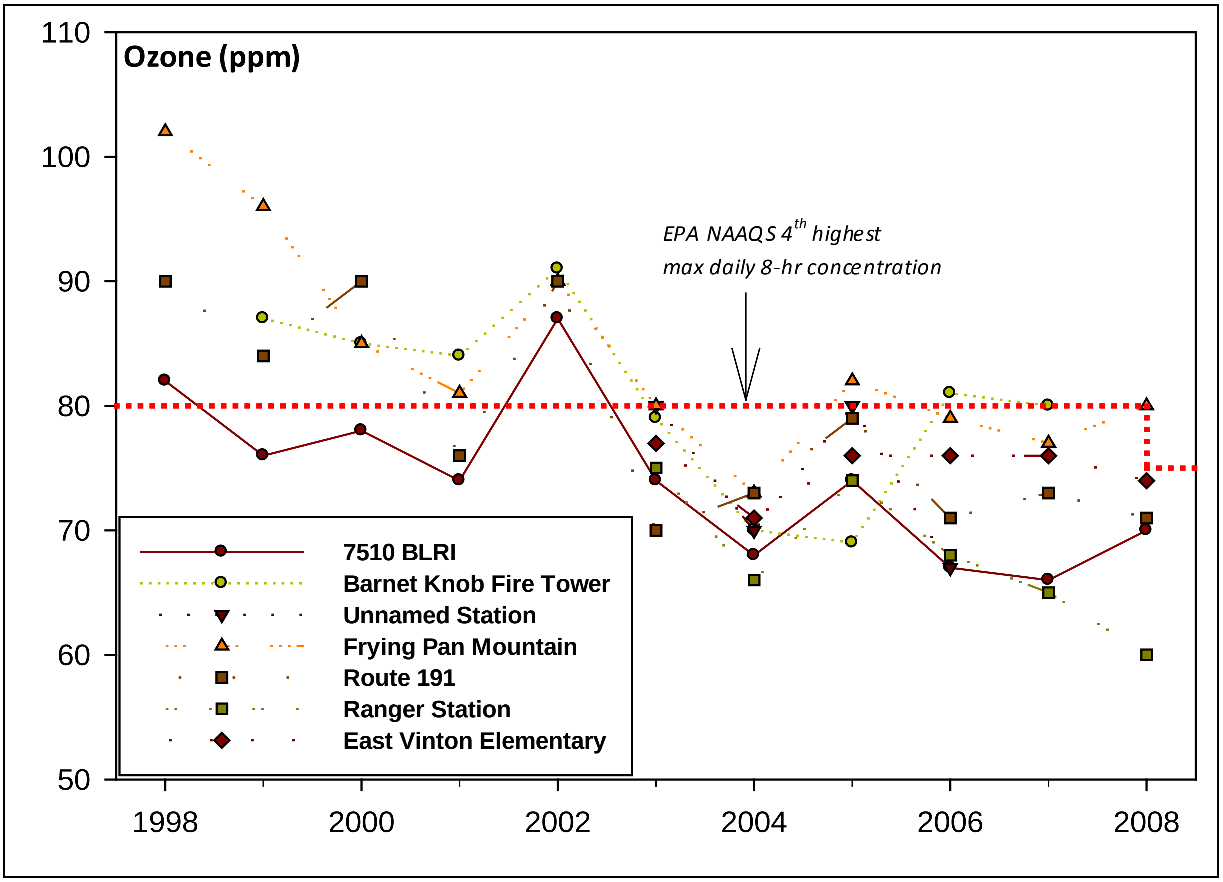

Figure 5. Data collected from seven POMS along BLRI showing annual 4th Hi Max 8-hr ozone concentrations over available data periods.

In order to determine attainment of the EPA NAAQS for ozone, the 4th Hi Max 8-hr metric is averaged over a three-year period, and concentrations exceeding the respective threshold are considered violations. These means are depicted in Figure 6 and show a clear distinction between past violations and lower concentrations later in the monitoring period. In fact, all four stations with eleven-year data periods showed significant decreasing trends over their three-year means: '7510 BLRI' showed a mean reduction of 1.5 ppb yr^{-1} (p = 0.001), 'Barnett Knob Fire Tower' a reduction of 2.3 ppb yr^{-1} (p = 0.01), 'Frying Pan Mountain' of 1.8 ppb yr^{-1} (p = 0.001), and 'Route 191' 2.0 ppb yr^{-1} (p = 0.001). For the three year means representing each of the years from 2000-2002, three stations showed NAAQS violations, and despite a strong decreasing trend over the monitoring period, 'Frying Pan Mountain' and 'East Vinton Elementary' recorded violations in 2008, in part because of the new lower standard that year.

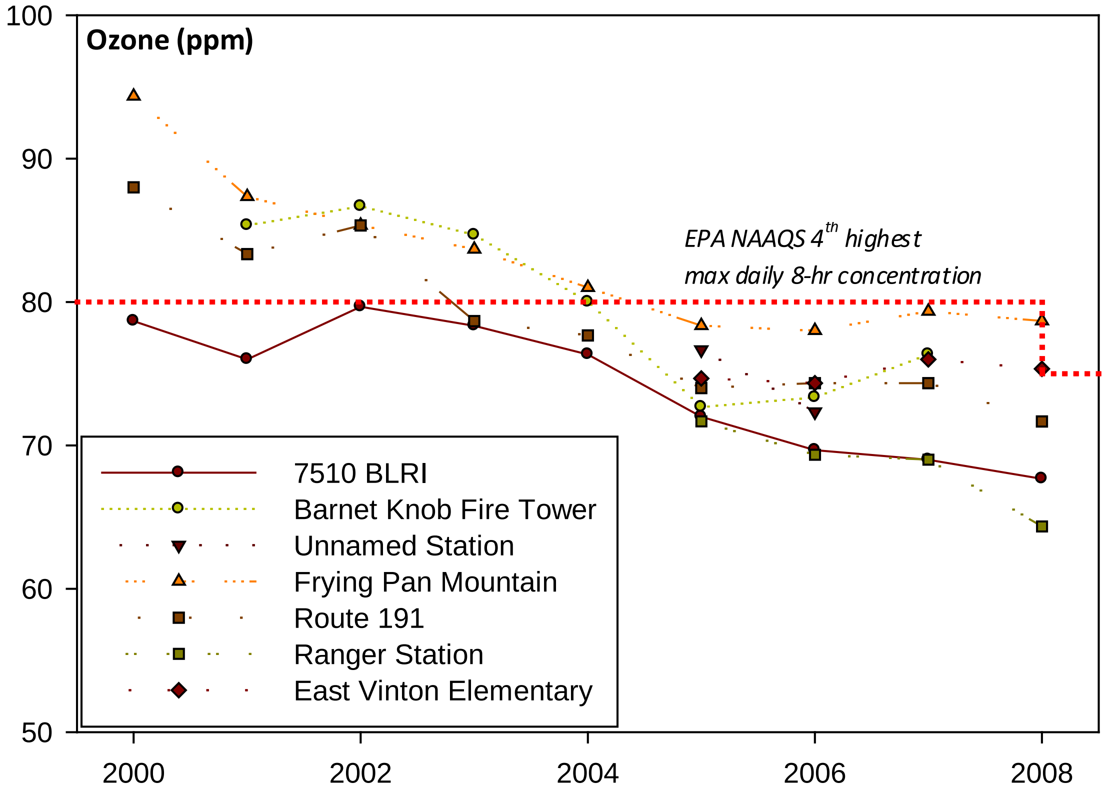

Figure 6. Three-year averages of 4th Hi Max 8-hr metrics for seven ozone monitoring stations along BLRI.

Overall, these ozone concentrations represent a significant concern along the BLRI. Two stations showed official non-attainment in 2008, and all stations recorded similarly marginal values close to the NAAQS threshold. Furthermore, the 2006 Annual Performance and Progress Report (APPR) on Air Quality in National Parks outlines assessment classes for different air quality parameters, and for ozone the classes are determined by 5-yr averages of the 4th Hi Max 8-hr metric. Mean concentrations over 0.084 ppm are classified as 'Condition Red' representing significant air quality concern—two stations each fall into this category during the periods 1998-2002 and 1999-2003. Twenty-five of the available 5-yr metrics fall into the 'Condition Yellow' category between 0.068 and 0.084 ppm representing moderate air quality condition. Only one metric falls into the 'Condition Blue' category, representing good air quality, while four are 'Condition Red', meaning they exceed 0.084 ppm. These classes are each adjusted downward in accordance with the new 2008 standards. Viewed together, all of these factors show that, despite the decreasing trends in ozone since 2000, concentrations are still at the threshold for NAAQS violations and may potentially represent threats to human health and natural ecosystems. Because of this, the condition status for ozone at BLRI receives a ranking of fair Table 7.

In addition to the data shown for the monitoring stations along BLRI, the 2008 APPR assessed general trends in ozone at BLRI over the period 1998-2007. Although the specific monitoring stations used for the assessment are not mentioned, monitors within 10 miles of the park are used in addition to those within the boundary. From this data, the report outlines an overall significant decrease ($p < 0.01$) in 3-yr 4th Hi Max 8-hr ozone concentration of 1.3 ppb yr^{-1} during the period 1998-2007. Because this report and the majority of the raw data from the monitoring stations show significant decreasing trends over the past few years, the trend for ozone at BLRI is designated as improving.

Table 7. The condition status for ozone at BLRI is fair with an improving trend. The data quality for this attribute is good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Ozone	⇧	✓	✓	✓
		3 of 3: Good		

4.1.2 Foliar Injury

Ozone concentrations have been linked with deleterious growth and physiological effects in certain sensitive plant species (Ollinger et al. 1997, Lefohn and Runeckles 1987). In a 2004 assessment of the overall foliar injury risk, the ARD assigned BLRI a low foliar injury risk rating, judging mainly that although concentrations sometimes exceed 0.080 ppm, this is uncommon. The report also noted that while the Sum06 metric generally exceeds the threshold for foliar injury, the W126 metric stays within a safe range. The metrics for BLRI are not measurements, but are actually kriged predictions extracted from ozone models for the entire U.S. by the NPS ARD. These metrics are available as yearly predictions from 1995-1999 as part of the 2004 foliar injury assessment report for the APHN (Table 8). In addition, the NPS ARD reported foliar injury metrics at individual monitoring stations in the 2007 Air Quality Progress Report (Ray 2008), which are shown in Table 9.

In order to describe potential foliar injury in park units, three biological indices with injury thresholds based on ozone concentrations were selected and applied to a representative group of ozone-susceptible plant species (NPS ARD 2003). The first metric, Sum06, is an index representing the cumulative sum of ozone concentrations ≥ 0.060 ppm between 8 AM and 8 PM over a moving 90-day period. The collection period usually occurs during the summer, when ozone concentrations are highest. The NPS ARD classifies 8 cumulative ppm-hours as the threshold for foliar injury, with the potential for growth reduction starting at 10 cumulative ppm-hr (NPS ARD 2004). At BLRI, Sum06 prediction values averaged 13 cumulative hours > 0.060 ppm during the five-year prediction period, which is well past the threshold for foliar injury. In addition, they showed an average increasing trend over the interpolation period of 3.6 cumulative hours yr^{-1} ($p = 0.02$). For the data available from individual stations during 2007, Sum06 averaged 24.6 cumulative ppm hours, which places it in the highest level for foliar injury risk.

The second index, W126, is a twofold description which includes the sum of hourly concentrations during the peak ozone season from April through October, and also considers the number of hours where the concentration was ≥ 0.010 ppm for the same period (LeFohn et al. 1997). For the hourly sum, this index weights the values using a sigmoidal function according to the equation:

$$W_i = \frac{1}{1 + M * e^{-(A*C_i)}} \quad \text{(Eq. 1)}$$

where W_i is the weighing factor for concentration C_i in ppm, and M and A are constants representing 4403 ppm and 126 ppm, respectively. The constant A represents the ozone concentration of maximum weighting, and lends itself to the naming of the index. By using this index, higher ozone concentrations are weighted disproportionately greater since they present more of a threat for foliar injury (LeFohn and Runeckles 1987). For W126, highly-sensitive species are affected beginning at 5.9 cumulative ppm-hr, and moderately sensitive at 23.8 ppm-hr. Predictions at BLRI for this metric averaged 33.6 for 1995-1999, which places it between the threshold affecting moderately and marginally sensitive species. Monitoring data from 2007 for this metric resulted in an average value of 17.1 cumulative ppm hours, which places it in the lowest threat category for foliar injury risk.

The final index is an N-value which corresponds to the number of hours that exceed 0.060, 0.080, and 0.100 ppm. Although these thresholds are relatively arbitrary, ozone concentrations above 0.080 and 0.100 ppm are typically associated with risk for foliar injury (NPS ARD 2004). Like the W126 metric, this one is also separated into three categories for N100 based on plant sensitivity: highly sensitive—6 cumulative hrs, moderately sensitive—51 cumulative hrs, and marginally sensitive—135 cumulative hrs. The average predicted N100 index during the five-year period was 1 cumulative hr, but this is because the prediction was zero for all but one of the years (Table 8). Overall this metric indicates no risk for foliar injury.

It is also possible to predict the severity of foliar injury risk in the park unit based on the species composition in the park. To that end, the NPS and the U.S. Fish and Wildlife developed a list of ozone sensitive plant species, defined as species that "exhibit foliar injury at or near ambient ozone concentrations in fumigation chambers AND/OR are species for which ozone foliar symptoms…have been documented." In addition, a subset of bioindicator species was developed, defined as a subset of sensitive species that best serve as indicators of ozone injury, due to easy identification of both the species and injury symptoms (NPS ARD 2003). From that overall list, 34 sensitive and bioindicator species are recognized at BLRI (Table 10).

Table 8. Foliar injury indices interpolated by the NPS ARD at BLRI, 1995-1999 (NPS ARD 2004).

	BLRI Ozone Foliar Injury Indices				
	Sum06	W126	N60	N80	N100
	--ppm-hr--		--hrs--		
1995	7	22.6	235	8	0
1996	8	33.7	544	20	0
1997	12	23.9	340	5	0
1998	20	38.9	736	21	3
1999	19	33.9	576	16	0
1995-1999 Mean	**13**	**33.6**	**586**	**14**	**1**

Sum06 (ppm-hr): 0-7 (no risk), 8-10 (low risk), 11-15 (mid risk), 16+ (high risk)
W126 (ppm-hr): 0-5.8 (no risk), 5.9-23.7 (low risk), 23.8-66.5 (mid risk), 66.6+ (high risk)
N100 (hr): 0-5 (no risk), 6-50 (low risk), 51-134 (mid risk), 135+ (high risk)

Table 9. Foliar injury indices monitored at BLRI in 2007, by station (NPS ARD 2004).

Station	W126	Sum06
	ppm hr^{-1}	
7510 BLRI	10.5	13.8
Barnet Knob Fire Tower	21.2	34.4
Frying Pan Mountain	32.2	52.4
Route 191	14.7	18.8
Ranger Station	8.1	8.9
East Vinton Elementary	15.8	19.4
Mean	**17.1**	**24.6**

W126 (ppm-hr): 5.9-23.7 (low), 23.8-66.5 (mid), 66.6+ (high)
Sum06 (ppm-hr): 8-10 (low risk), 11-15 (mid risk), 16+ (high risk)

Table 10. Thirty-four species at BLRI were identified as bioindicators of ozone based on ease of identification of both species and injury symptoms (NPS ARD 2003). These species were crosswalked with NPSpecies for BLRI.

Species	Common Name
Ailanthus altissima	Tree-of-heaven
Apios americana	Indian potato
Apocynum androsaemifolium	Spreading dogbane
Apocynum cannabinum	Indianhemp
Asclepias exaltata	Poke milkweed
Asclepias incarnata	Swamp milkweed
Asclepias syriaca	Common milkweed
Cercis canadensis	Redbud
Clematis virginiana	Virgin's bower
Corylus americana	American hazelnut
Eupatorium rugosum	White snakeroot
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green ash
Gaylussacia baccata	Black huckleberry
Krigia montana	Mountain dwarfdandelion
Liriodendron tulipifera	Tuliptree
Lyonia ligustrina	Maleberry
Parthenocissus quinquefolia	Virginia creeper
Pinus rigida	Pitch pine
Pinus virginiana	Virginia pine
Platanus occidentalis	Sycamore
Populus tremuloides	Quaking aspen
Prunus serotina	Black cherry
Prunus virginiana	Choke cherry
Rhus copallina	Winged sumac
Robinia pseudoacacia	Black locust
Rubus allegheniensis	Allegheny blackberry
Rubus canadensis	Smooth blackberry
Rudbeckia laciniata	Cutleaf coneflower
Sambucus canadensis	Elderberry
Sassafras albidum	Sassafras
Solidago altissima	Canada goldenrod
Verbesina occidentalis	Yellow crownbeard
Vitis labrusca	Fox grape

Soil Moisture

In addition to these exposure indices, soil moisture conditions play a large role in mitigating or exacerbating the potential for foliar injury. During periods of higher soil moisture, injury risk is typically reduced as leaf stomates close, thus reducing ozone uptake (Kohut 2007). Often, the danger of ozone to plants is less than what may be apparent from ozone conditions alone, as environmental conditions that facilitate the production of ozone such as a clear sky, high temperatures, and high UV levels also tend to reduce atmospheric gas exchange in plants. The Palmer Z index (Palmer 1965) attempts to describe soil moisture and its departure from long-term averages for a given month and location by assigning a number in the range ±4.0 based on temperature, precipitation, and available soil water content, with ±0.9 representing the typical range for soil moisture (NPS 2004, Wager 2003). This method was used to calculate drought indices for the same time periods used to calculate both the Sum06 and W126 metrics (Table 11 and Table 12) from 1995-1999.

As the 2004 foliar injury report for the APHN points out, there is little association between the Sum06 metric and levels of soil moisture at BLRI. While the Sum06 metrics generally increased over the five-year period, soil drought conditions also were the most severe in the later years, which might have served to mitigate the foliar injury threat to vegetation. Soil moisture conditions over the W126 period were fairly evenly mixed, though the majority of the drier months occurred in the later years like they did for the Sum06 metric. There were not extended periods of wet conditions, which may contribute to foliar injury susceptibility.

Summary

Overall, the NPS ARD estimates for 1995-1999 and the single year of monitoring in 2007 provide very little on which to base an assessment for foliar injury. For the most part, both the W126 and N100 prediction metrics consistently fell into the same respective threshold region of foliar injury for each year of the prediction period. The single year of monitoring in 2007 showed elevated metrics for Sum06, but low risk metrics for W126. The Sum06 metric was more variable, showing a significant increase over the period. If the mean Sum06 metric among stations in 2007 is included in a regression with the earlier predicted metrics, the mean increase is 1.4 cumulative ppm hours yr^{-1} (p = 0.03). Additional foliar injury data and Palmer-Z indices, especially those based on actual measurements at BLRI, would help in determining how foliar risk has changed since 2007.

Based on these existing data sources, foliar injury at BLRI receives a condition status of fair, and although the Sum06 shows a significant increasing trend, the W126 and N100 metrics show no significant change over their respective monitoring periods, and thus a stable trend is assigned (Table 13). In addition, each of the three data quality attributes is fulfilled, although recent monitoring data is limited to a single season.

Table 11. Palmer Z indices for Sum06 at BLRI (NPS ARD 2004).

Sum06	Month 1	Month 2	Month 3
1995	-0.22	+3.12	-1.62
1996	-0.70	+0.26	-0.32
1997	+2.84	-1.17	-3.35
1998	-2.57	-2.52	-3.01
1999	+1.24	-0.91	-2.64

Palmer Z index: -1.00 to -1.99 (mild), -2.00 to -2.99 (moderate), -3.00 and below (severe)
+1.00 to +1.99 (low wetness), +2.00 to +2.99 (mid wetness), +3.00 and above (high wetness)

Table 12. Palmer Z indices for W126 at BLRI (NPS ARD 2004).

W126	A	M	J	J	A	S	O
1995	-2.81	-0.22	+3.12	-1.62	+1.98	-0.16	+3.09
1996	+0.22	-0.70	+0.26	-0.32	+1.36	+2.86	-1.80
1997	+2.05	-0.13	+2.84	-1.17	-3.35	+1.59	+0.65
1998	+3.84	-1.65	+0.73	-2.57	-2.52	-3.01	-1.32
1999	-0.96	-0.39	+1.24	-0.91	-2.64	-1.75	-0.37

Palmer Z drought index: -1.00 to -1.99 (mild), -2.00 to -2.99 (moderate), -3.00 and below (severe)
+1.00 to +1.99 (low wetness), +2.00 to +2.99 (mid wetness), +3.00 and above (high wetness)

Table 13. The condition status for foliar injury at BLRI is fair with a stable trend. The data quality for this attribute is good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Foliar injury		✓	✓	✓
		3 of 3: Good		

4.1.3 Atmospheric Deposition

In addition to ozone exposure and foliar injury, another issue of air quality relevant to BLRI is atmospheric deposition. Airborne constituents can affect ecological systems through acidification, soil fertilization, and surface water loading. Deposition resulting from the production of nitrogen oxides (NO_x) and sulfur dioxides (SO_2) are particularly an issue at higher elevations. In particular, anthropogenic sources of sulfur dioxide and nitrogen oxides are issues in the Southern Appalachian region, where they become trapped by the physical structure of the mountains (NPS 2010). These pollutants are typically divided into wet (e.g. precipitation, condensation) and dry (e.g. adsorption, particulate, direct contact) sources, which can debilitate growing conditions for biota, among other effects.

Anthropogenic sources of sulfur dioxides typically include power plants, vehicle emissions, and other industrial sources, while natural sources may include volcanoes, organism emissions, and decaying organic material. The U.S. Clean Air Act, originally passed in 1970, was amended in 1990 to include further controls on atmospheric deposition rates. As a result, during the 18 years from 1990 to 2007, total nitrogen and sulfur deposition in the U.S. decreased by 17 and 34 percent, respectively (MACTEC 2008). Sulfur dioxide emissions at reference sites in the eastern U.S. dropped by 40% over the same 18-yr period. A large portion of the sulfur reduction included sulfur dioxide emissions from coal-fired power plants in the Ohio River Valley Region, which includes BLRI. Sulfur dioxide can react in the atmosphere to form sulfuric acid (H_2SO_4) and ammonium sulfate [$(NH_4)_2SO_4$], the latter of which is a significant constituent of potentially harmful fine particulate matter ($PM_{2.5}$). Despite considerable reductions in sulfur dioxide emissions since 1990, the Ohio River Valley Region north of BLRI still emits, by far, the highest concentrations in the U.S. (MACTEC 2008).

Particulate sulfate (SO_4^{2-}) is a resultant product of sulfur dioxide that often takes the form of ammonium sulfate [$(NH_4)_2SO_4$]. Patterns of sulfate distribution in the U.S. closely match those of sulfur dioxide, albeit with a more southerly skew. Like sulfur dioxide, sulfate concentrations are greatly elevated in the Ohio River Valley Region, and concentrations of sulfate at the eastern reference sites show a 26% decline during the period from 1990 to 2007 (MACTEC 2008).

In addition to sulfur dioxide, nitrogen oxides also react in the atmosphere to produce other pollutants. Nitric acid (HNO_3), for example, is a contributing factor to acid rain while particulate nitrate (NO_3^-) can take the form of ammonium nitrate (NH_4NO_3), a fine particulate matter. Farm production of ammonia (NH_3) can also react with sulfate and nitrate particles to produce particulate ammonium (NH_4^+). Total nitrate (NO_3^- + HNO_3) was highest in 2007 in the Great Lakes Region and southern California, though concentrations were moderately high (~2-3 $\mu g/m^3$) in the BLRI region. Figure 7 shows a hierarchical format of atmospheric deposition and its constituents.

Ecosystem effects of Nitrogen & Sulfur

The mobilization of N and S plays a large role in determining the impacts of deposition on an ecosystem. In particular, large soil inputs of both nitrogen and sulfur can lead to eventual saturation and acidification, wherein nutrient limitations and cycling disruptions can inhibit plant growth or contribute to the mobilization of toxic cations like Al^+ (NPS 2010). Mobile aluminum can damage plants via root uptake or create health problems for aquatic biota upon entering surface waters (Lovett et al. 2009). Deposition of N and S can also acidify surface waters, which can kill or displace sensitive aquatic biota, including freshwater mussels (Lovett et al. 2009; see section *Water Quality*). Continued buildup of these elements may contribute to prolonged damage, even if deposition rates decrease over time.

Leaching of anion versions of N (primarily NO_3^-) are a primary contributor to deposition-related soil acidification. This process often results in less hospitable conditions for plants, and may lead to an eventual shift in species composition towards N-adapted species (Lovett et al. 2009). As soil continually becomes N-saturated, this can also increase the emission rate of nitrogenous greenhouse gases from the soil itself (Fenn et al. 1998). Soil microorganism communities are also susceptible to increases in N. Carreiro et al. (2000) showed that added N can slow decomposition rates in hardwood litter with high-lignin content.

Increased N concentrations have also been shown to predispose some plants to certain insect pests. Pontius et al. (2006), for example, showed that N concentration of eastern hemlock (*Tsuga canadensis*) stands correlated with infestation of hemlock woolly adelgid (HWA) (*Adelges tsugae*), leading to more severe dieback symptoms. McClure (1991) tested hemlock response to N-fertilization in Connecticut and found a fivefold increase in the number of HWA per area and over a twofold increase in survival and fecundity. In addition, results showed that residual effects on HWA populations persisted even 6 months after initial fertilization. A later study by McClure (1992) comments that the “degree to which adelgid performance was enhanced by fertilization is remarkable…,” and combined analysis showed that fertilization in the presence of pesticide application reduces its effectiveness.

Sulfur is the other main constituent of total deposition, and can also affect forest ecosystems in several ways. Sulfur differs from nitrogen in that it is not a biologically-limiting element, and concentrations of S from deposition can persist in soil for long periods of time. Sullivan et al. (2008) points out that over time, soils can reach adsorption capacity such that additional S can be leached into surface waters as SO_4^{2-}, even if sulfuric atmospheric deposition rates decrease. In areas with low base-cation concentrations, sulfate leaching can lead to depletions of calcium (Ca^{2+}) and magnesium (Mg^{2+}), which can in turn inhibit hardwoods such as sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), basswood (*Tilia americana*), and dogwood (*Cornus florida*) (Lovett et al. 2009).

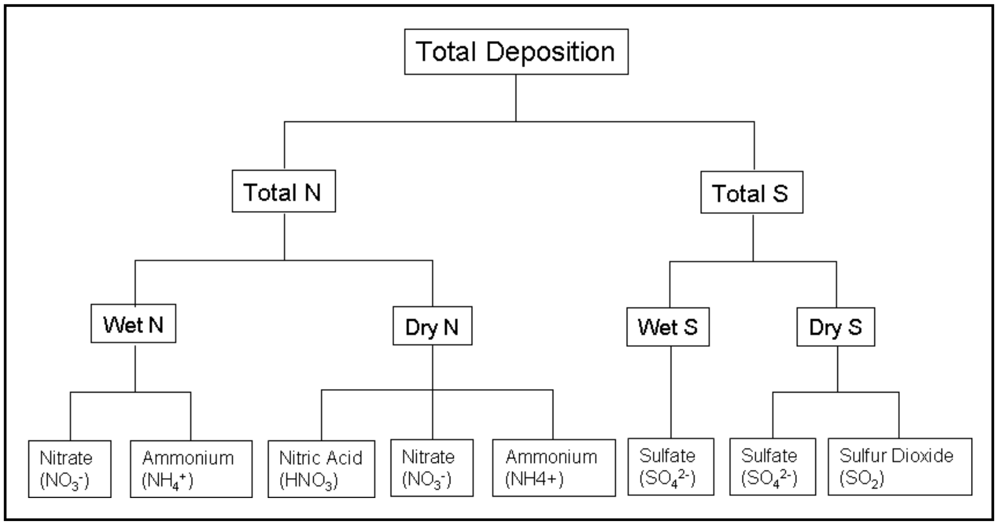

Figure 7. Total atmospheric deposition is typically divided into nitrogen (N) and sulfur (S) portions, each with wet and dry means of deposition.

Deposition Data

Sensitivity of APHN

Sullivan et al. (2011) conducted an assessment of the vulnerability of park units in the APHN to atmospheric deposition. Overall, the network was given a rank of high for pollutant exposure, and a rank of very high for ecosystem sensitivity. This latter ranking was based on the presence of sugar maple (*Acer saccharum*) and red spruce (*Picea rubens*), species considered highly sensitive to acidification, and was assessed to have the highest relative risk of acidification of any national I&M network. Both species are negatively affected by base cation depletion associated with acidification (Sullivan et al. 2011). Acid deposition can affect nutrient balance in the needles of red spruce, resulting in greater risk of freezing. In addition, aluminum concentrations can interfere with red spruce nutrient and water uptake (NPS 2010a). As an individual park unit, BLRI received the fourth highest pollutant exposure ranking, the highest ecosystem sensitivity ranking, and the third highest overall summary ranking relative to other units to which it was compared. Only SHEN and GRSM received higher summary risk ratings.

Deposition Monitoring

There are six sites near BLRI that collect wet deposition data either as part of the EPA Clean Air Status and Trends Network (CASTNET) or the National Atmospheric Deposition Program (NADP) (Figure 8). The four CASTNET stations are divided into wet and dry deposition for both N and S. Three of these stations—Look Rock in GRSM, Shenandoah, and Horton's Station—collected data over the period 1989-2009, while the Mt. Mitchell station collected data only over the period 1999-2009. Figure 9 and Figure 10 show wet and dry deposition for S and N for the BLRI CASTNET stations. Natural Bridge and Charlottesville, the two NADP stations, collected over 2003-2009 and 1985-2009, respectively. Figure 11 and Figure 12 show wet N and S deposition for the Natural Bridge and Charlottesville NAPD stations. Common years and parameters show relative agreement among stations. Table 14 shows all Pearson correlation coefficients between stations over common data periods. These comparisons show that dry deposition generally corresponded better than wet deposition, and S rates of deposition generally corresponded better than those for N. Among the CASTNET sites, data generally correspond better cross-network than within-network, while data between the two NADP sites seemed to correspond particularly well.

Table 14. Pearson correlation coefficients for wet and dry N and S deposition among six monitoring stations.

	CASTNET				NADP	
Wet S	GRS420	PNF126	SHN418	VPI120	Natural Bridge	Charlottesville
GRS420	-	-	-	-	-	-
PNF126	0.65	-	-	-	-	-
SHN418	0.61	0.58	-	-	-	-
VPI120	0.59	0.42	0.68	-	-	-
Natural Bridge	0.80	0.91	0.88	0.71	-	-
Charlottesville	0.65	0.68	0.87	0.65	0.93	-
Mean	**0.71**					-
Dry S						-
GRS420	-	-	-	-	-	-
PNF126	0.91	-	-	-	-	-
SHN418	0.89	0.86	-	-	-	-
VPI120	0.75	0.73	0.87	-	-	-
Mean	**0.84**					-
Wet N						-
GRS420	-	-	-	-	-	-
PNF126	0.60	-	-	-	-	-
SHN418	0.33	0.29	-	-	-	-
VPI120	0.42	0.28	0.49	-	-	-
Natural Bridge	0.58	0.71	0.74	0.39	-	-
Charlottesville	0.51	0.46	0.80	0.40	0.92	-
Mean	**0.53**					-
Dry N						-
GRS420	-	-	-	-	-	-
PNF126	0.91	-	-	-	-	-
SHN418	0.94	0.94	-	-	-	-
VPI120	0.97	0.65	0.49	-	-	-
Mean	**0.82**					-

Another notable aspect of the data is that most of the depositional parameters show decreasing linear trends, as shown in Table 15. This would support the reduction in annual deposition rates observed after the Clean Air Act, which started around 1990. Wet depositional values for both N and S at GRS420 and VPI120 were the only decreasing linear trends that were not significant ($\alpha = 0.05$).

Table 15. Slopes and p-values for deposition trends. Bold trends show significance (α = 0.05).

	S (Wet)	S (Dry)	N (Wet)	N (Dry)	n
		-----kg ha^{-1} yr^{-1}-------			---yrs---
CASTNET					
GRS420	-0.193 (p = 0.10)	**-0.167 (p < 0.01)**	-0.075 (p = 0.37)	**-0.239 (p < 0.01)**	11
PNF126	**-0.202 (p < 0.01)**	**-0.119 (p < 0.01)**	**-0.079 (p < 0.01)**	**-0.101 (p < 0.01)**	21
SHN418	**-0.187 (p < 0.01)**	**-0.148 (p < 0.01)**	**-0.083 (p < 0.01)**	**-0.074 (p < 0.01)**	21
VPI120	-0.076 (p = 0.08)	**-0.065 (p < 0.01)**	-0.011 (p = 0.68)	**-0.068 (p < 0.01)**	21
NADP					
Charlottesville	**-0.202 (p < 0.01)**	--	**-0.073 (p = 0.01)**	--	25
Natural Bridge	**-0.440 (p < 0.01)**	--	**-0.239 (p = 0.05)**	--	7

Like the ozone estimates used to approximate values for individual park units, the NPS ARD also created deposition estimates for wet N and S over the 1995-1999 period. These estimates utilize surrounding NADP stations for an interpolated surface, which is then averaged over the Parkway corridor and for the five year period. For NADP, this estimate is 2.78 kg ha^{-1} yr^{-1} total wet N and 3.55 kg ha^{-1} yr^{-1} for total wet S. These estimated values are slightly lower than observed values: 3.38 kg ha^{-1} yr^{-1} for wet N and 6.16 kg ha^{-1} yr^{-1} for wet S from the CASTNET stations of the available years, and 5.60 kg ha^{-1} yr^{-1} wet N and 7.00 kg ha^{-1} yr^{-1} wet S from the Charlottesville NADP. The NPS ARD also outlined an approach for assessing these values, noting that background wet deposition loading in the eastern U.S. is roughly 0.25 kg ha^{-1} yr^{-1} for both N and S (Ray 2009). To gauge condition, the ARD stipulates a threshold of 3 kg ha^{-1} yr^{-1} for total deposition, or about 1.5 kg ha^{-1} yr^{-1} for wet deposition.

The ARD mainly concentrates on wet deposition data rather than dry deposition to establish thresholds, mainly because dry deposition data is not as readily available. Between 2003 and 2006, sulfur dry deposition averaged between 11% and 60% of total deposition in the eastern U.S. (EPA 2007). Below 1 kg ha^{-1} yr^{-1}, wet deposition is not generally considered harmful to ecosystem function, while wet levels above 3 kg ha^{-1} yr^{-1} of either N or S are considered a significant threat. Other sources concentrating solely on N deposition suggest more lenient thresholds, such as Fenn et al.'s (2003) assessment that the lower limit of ecosystem effects from total N deposition ranges from 3 to 8 kg ha^{-1} yr^{-1} for sensitive species. Krupa (2002), on the other hand, suggests 5 to 10 kg ha^{-1} yr^{-1} total N as the critical range for sensitive terrestrial systems and values of up to 10 to 20 kg ha^{-1} yr^{-1} for forests. A USFS report by Pardo and Duarte (2007) examined deposition effects on forest types in GRSM, and generally found an acceptable limit of 3 kg ha^{-1} yr^{-1} for N deposition in low elevation mixed hardwood forests and 7 kg ha^{-1} yr^{-1} for higher elevation spruce-fir types. For the sites monitoring along BLRI, wet N deposition for the NADP sites was 5.01 kg ha^{-1} yr^{-1} (Charlottesville) and 3.09 kg ha^{-1} yr^{-1} (Natural Bridge), while CASTNET sites were 4.59 kg ha^{-1} yr^{-1} (GRS420), 4.83 kg ha^{-1} yr^{-1} (PNF126), 4.78 kg ha^{-1} yr^{-1} (SHN418), 3.96 (VPI120). While these are fairly consistent among sites, they are all above the ARD threshold of 3 kg ha^{-1} yr^{-1}.

While there are several references discussing critical thresholds for N deposition, less are available concerning rates of S deposition. In a description of developing critical loads for deposition, Porter et al. (2005) notes that S deposition has altered the acid neutralizing capacity (ANC) of aquatic resources in Shenandoah National Park. Based on modeling, a reduced range of S deposition rates, between 0 and 4 kg ha^{-1} yr^{-1}, would be necessary to even begin to restore

ANC values to pre-industrial levels. Over the period 1989-2009, total S deposition at the Shenandoah CASTNET station averaged 9.69 kg ha^{-1} yr^{-1}, while among all sites was 8.84 kg ha^{-1} yr^{-1}.

CASTNET Reference Sites

In the latest 2007 annual report on CASTNET stations (EPA 2008), the EPA aggregated concentration and depositional data from monitoring stations throughout the U.S. over the 18-year period from 1990-2007. A set of 34 stations became reference points for assessments regarding the eastern US. Park-specific deposition data were available from four CASTNET stations located along the Parkway. Using all the eastern stations as a reference, the eastern U.S. observed a 34% reduction in sulfur deposition—from 13.2 kg ha^{-1} during the 3-yr period from 1990-1992 to 8.7 kg ha^{-1} for the period 2005-2007 (EPA 2007). For available data at BLRI from the same time periods, sulfur depositions similarly decreased from 10.5 kg ha^{-1} yr^{-1} to 8.38 kg ha^{-1} yr^{-1}—a reduction of 20%. Total nitrogen across eastern CASTNET reference sites declined by 17% across the same time period, while data at BLRI shows a decrease from 6.89 kg ha^{-1} yr^{-1} to 6.64 kg ha^{-1} yr^{-1}—only a 4% reduction.

48

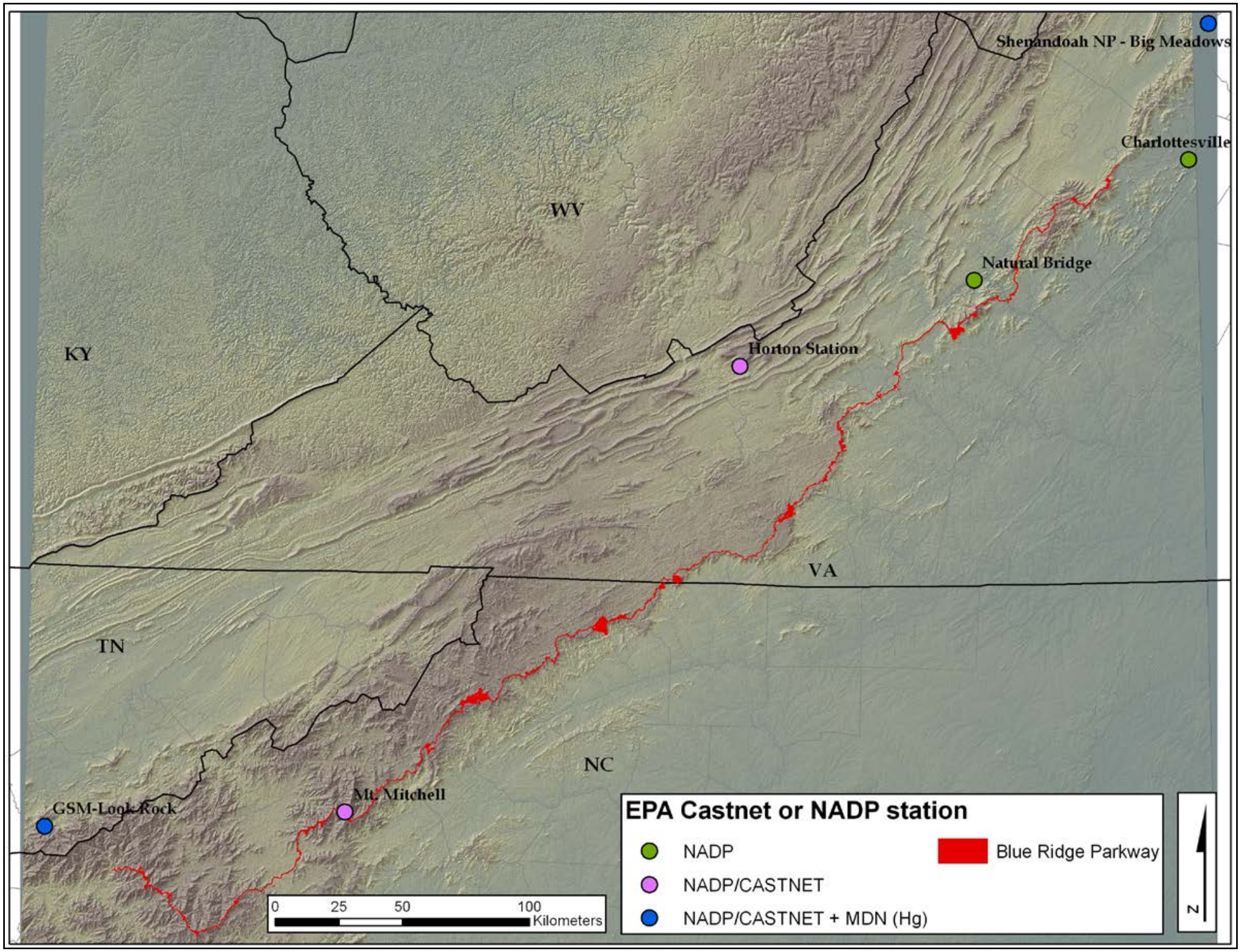

Figure 8. Six monitoring stations along the BLRI collect a combination of wet, dry, and mercury depositional data.

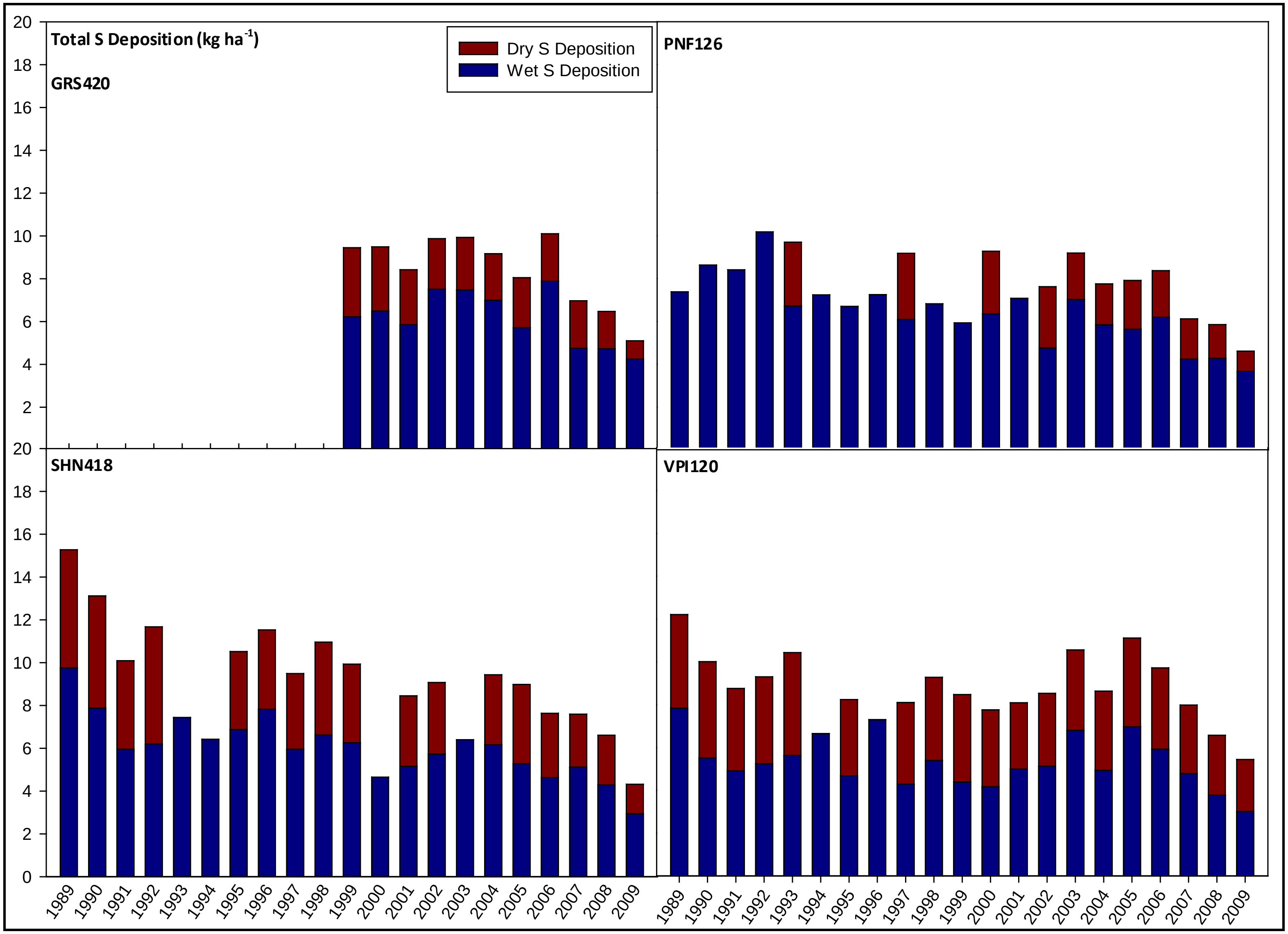

Figure 9. Annual wet and dry S deposition at four EPA CASTNET stations along the BLRI: Mt. Mitchell (GRS420; 1999-2009), Look Rock in GRSM (PNF126; 1989-2009), Shenandoah NP (SHN418; 1989-2009), and Horton's Station (VPI120; 1989-2009). Some years are missing values for dry deposition.

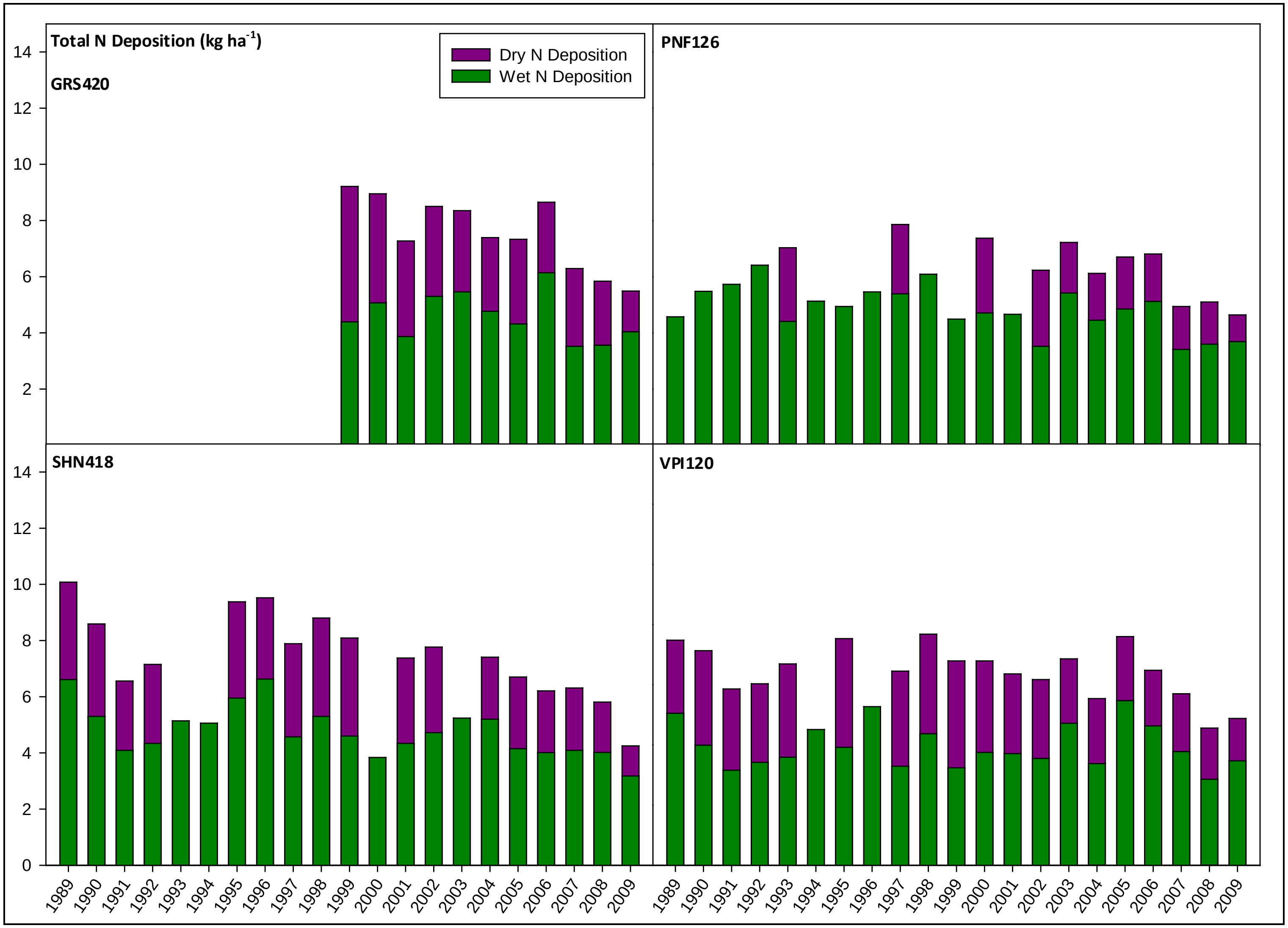

Figure 10. Annual wet and dry N deposition at four EPA CASTNET stations along the BLRI: Mt. Mitchell (GRS420; 1999-2009), Look Rock in GRSM (PNF126; 1989-2009), Shenandoah NP (SHN418; 1989-2009), and Horton's Station (VPI120; 1989-2009). Some years are missing values for dry deposition.

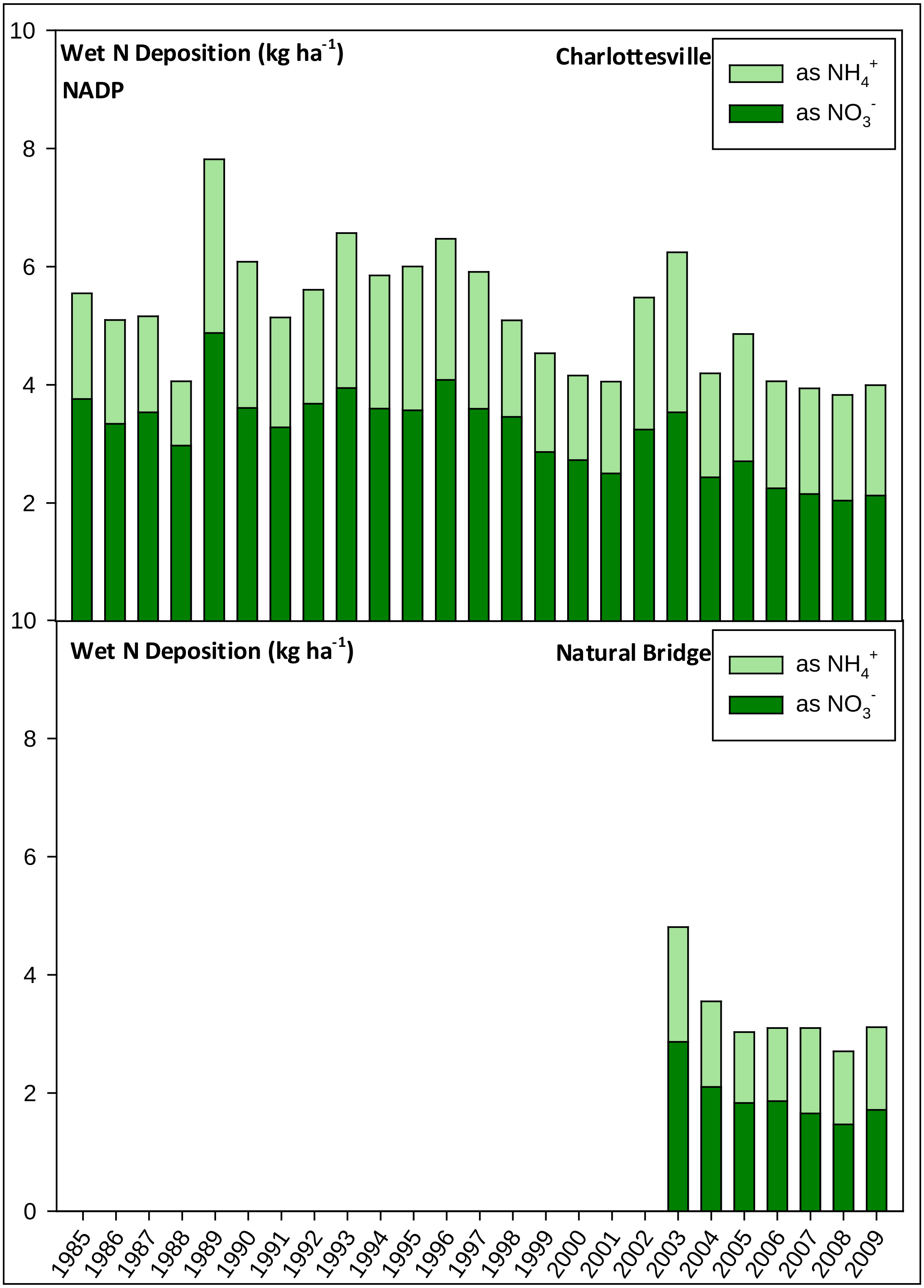

Figure 11. Annual wet N deposition values measured at the Charlottesville and Natural Bridge NADP stations.

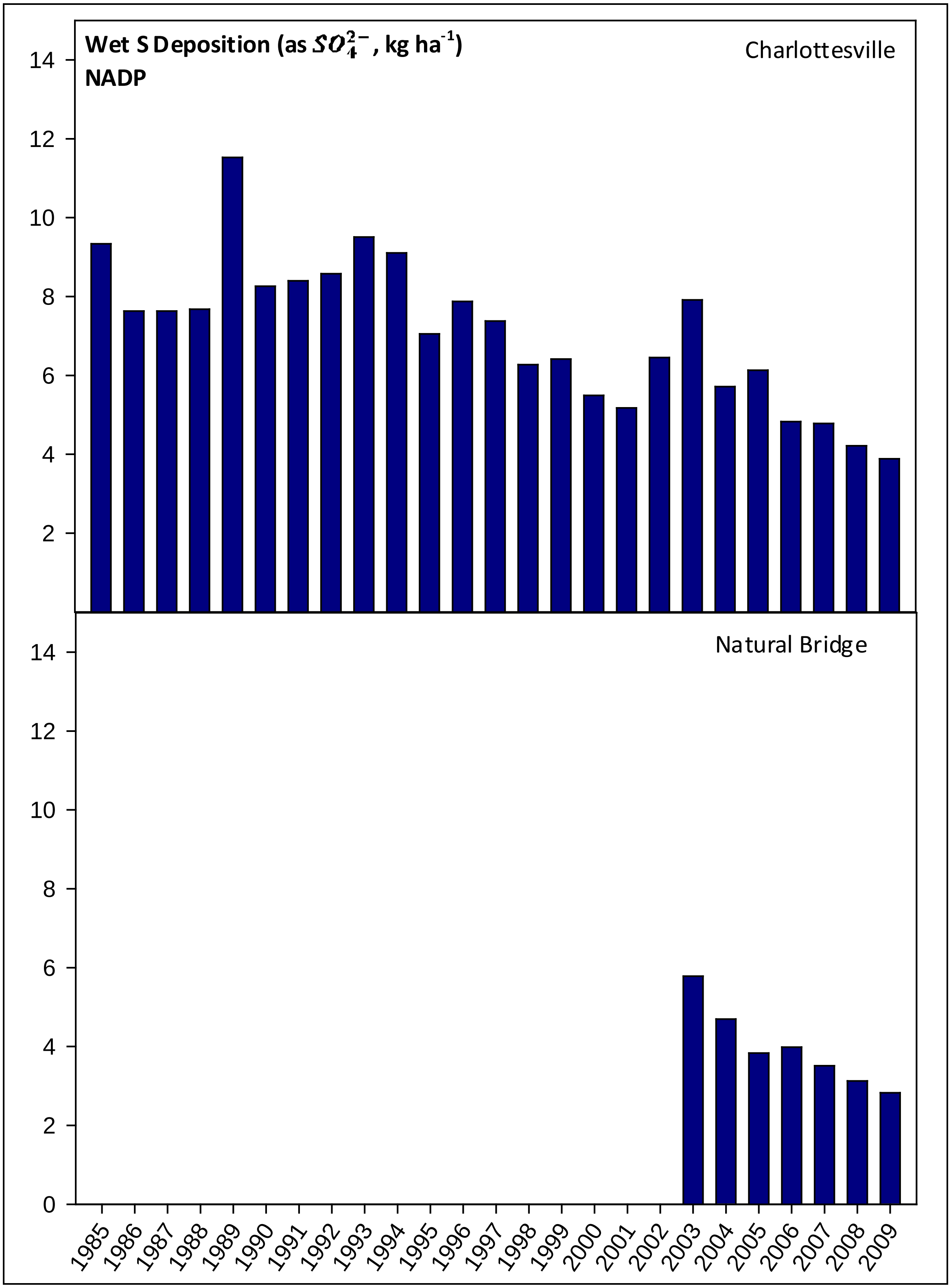

Figure 12. Annual wet S deposition values measured at the Charlottesville and Natural Bridge NADP stations.

Mercury Deposition

Mercury (Hg) finds its way into ecosystems via similar vectors as N and S. Concentrations of Hg may be transferred long distances in the atmosphere before deposition occurs. Like N and S, Hg may be deposited as either wet or dry mostly in elemental (Hg) or ionic (Hg^{2+}) versions (NADP 2011). Deposition of Hg is particularly a problem in forested areas, because forest canopies can act as a filter that traps dry particles, which are in turn either re-emitted or transported to the ground as throughfall. Terrestrial transport can also lead to contamination of aquatic systems, which can result in human health issues, though generally amounts of mercury transported as runoff are considered to be far less than that which is retained in the soil (EPA 1997a). Once Hg reaches aquatic environments, it can persist in the water column, be carried away, revolatize into the atmosphere, enter the sediment, or be taken up by biota, where it is converted to a different form known as methyl-mercury ($[CH_3Hg]^+$). This type of biotic accumulation, known as bioaccumulation, is particularly relevant in aquatic ecosystems, where organisms higher in the food chain (e.g. fish) can build up relatively high concentrations of mercury (NADP 2011). At BLRI, the James River was listed on the 2010 EPA list of 303(d) impaired waters due to high mercury concentrations (Table 21). Fortunately, effects of Hg deposition on vegetation are minimal because most plants do not uptake Hg, thereby limiting a similar bioaccumulative terrestrial pathway (EPA 1997a).

The NADP Mercury Deposition Network (MDN) monitors stations throughout the U.S. that collect weekly measurements of mercury wet deposition (Figure 13). Two of the CASTNET stations are also part of the NADP MDN: GRS420 at Look Rock and SHN418 at Big Meadows. The station at GRSM (640 m elevation) is located in Elkmont, TN and began collecting mercury data in January 2002, while the Shenandoah site (1074 m elevation) began collecting in October 2002. Figure 14 depicts weekly measurements at both sites, for which measurements at GRSM are overall a bit higher. Overall, average annual deposition at GRSM was 13.7 ng m^{-2} yr^{-1}, and 10.1 ng m^{-2} yr^{-1} at SHEN. Although no trend appears visible at either site, linear regression yields significantly decreasing mercury deposition on the order of 20.4 ng m^{-2} yr^{-1} ($p = 0.01$) at GRS420 Look Rock. There are no federal or state standards for deposition of Hg, although EPA ambient surface water criteria limits Hg concentrations to 0.012 µg/L (EPA 1997b) (see sec. *Water Quality*). It is important to note that although datasets are complete and extensive from the nearby MDN monitoring sites in GRSM and SHEN, data from these stations do not completely eliminate the possibility that regional variation may produce a different Hg depositional pattern along other parts of the BLRI. This is especially true of the southern portion of BLRI, because Hg deposition rates are consistently higher in the southeastern US, including western North Carolina. Direct monitoring at other locations along BLRI would ensure that park-specific Hg depositional patterns do not go undetected.

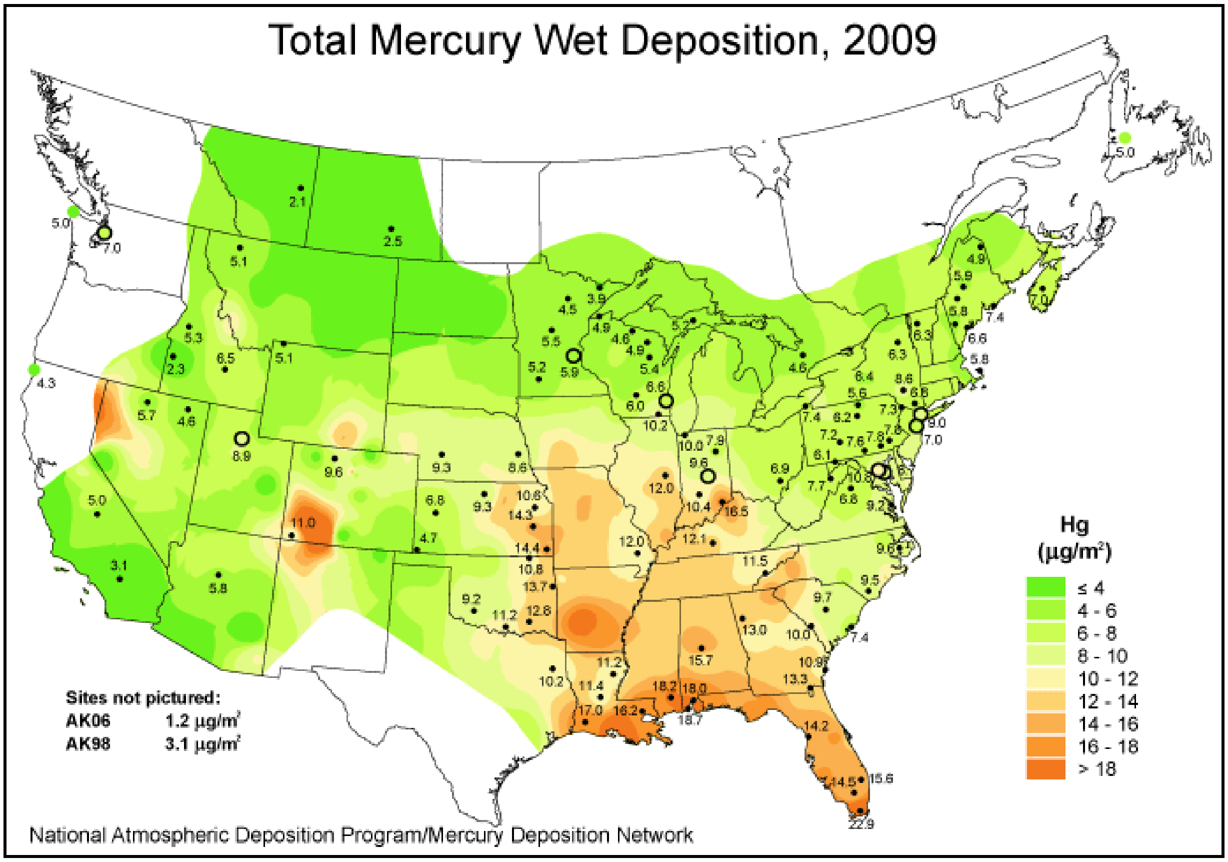

Figure 13. U.S. mercury wet deposition in 2009. [Source: http://nadp.sws.uiuc.edu/]

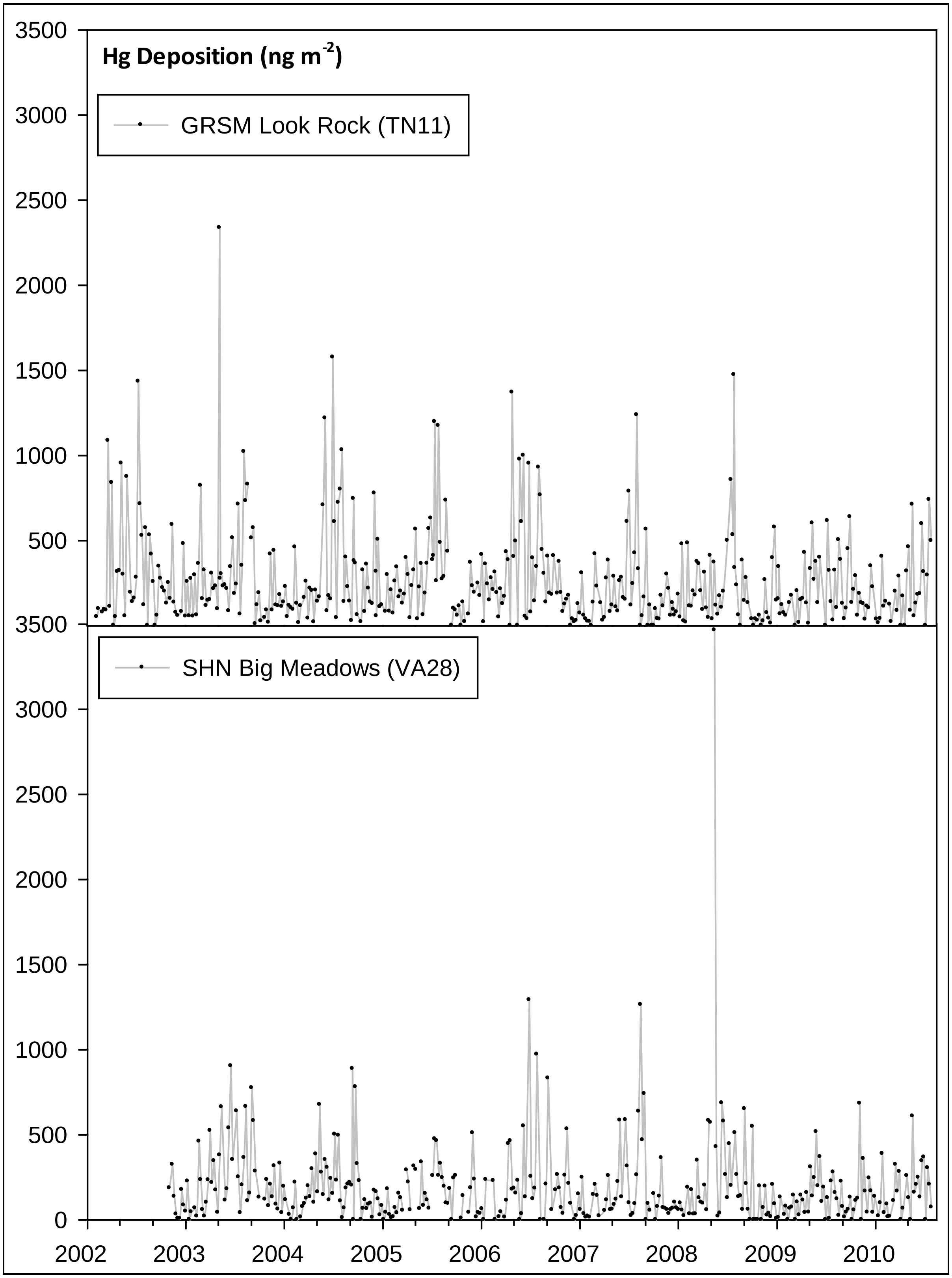

Figure 14. Total mercury weekly deposition measurements collected at GRSM Look Rock (top) and Shenandoah NP Big Meadows (bottom).

4.1.4 Summary

Overall, the EPA CASTNET and NADP stations provide a continuous and relatively complete data source for deposition throughout the region. Wet, dry, total, and mercury deposition rates show mostly significant decreasing trends over monitoring periods. However, the absolute amounts of reduction for total N and S at BLRI over the period 1990 to 2007 were less than the overall mean reductions for eastern EPA CASTNET reference sites. In addition, according to the NPS ARD wet deposition threshold of 3 kg ha^{-1} yr^{-1}, virtually all (98.1%) of the annual observations for N and S from the six NADP and CASTNET stations near BLRI represent a significant threat to ecosystem health. The recent assessment by Sullivan et al. (2011) also ranked the overall risk of acidification at BLRI as very high. Because of these factors, BLRI is assigned a condition status of poor for atmospheric deposition with an improving trend (Table 16). Although all data quality attributes are met, the spatial arrangement of the monitoring stations still leaves several areas with poor data coverage. This is especially true for the MDN stations, which lie outside the Parkway at either end, which leaves no official data source for the entire area in between, which is basically the route of the BLRI.

Table 16. The condition status for atmospheric deposition at BLRI was poor with an improving trend. The data quality for this attribute was good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Atmospheric deposition		✓	✓	✓
		3 of 3: Good		

4.2 Particulate Matter and Visibility

Throughout the southern Appalachians, anthropogenic sources of pollution have greatly impaired visibility (Figure 15). In eastern national parks, average visibility ranges have decreased from an unimpacted 150 km miles to ~30 km, and in some places, sunlight in the presence of airborne particles and humid conditions can reduce visibility even more (National Research Council 1993). In the eastern US, most visibility issues are caused by concentrations of SO_2 and SO_4^{2-}, the latter of which mostly exists in higher concentrations during the summer months.

Figure 15. Airborne constituents photos at the GRSM IMPROVE site showing conditions of decreased visibility range from 300 km (left), to 40 km (middle), to 13 km (right).

To monitor atmospheric constituents that may inhibit visibility, the Interagency Monitoring of Protected Visual Environments Program (IMPROVE) was formed in 1985, which established monitoring stations in 156 national parks and wilderness areas. Generally, particulates finer than 2.5 µm ($PM_{2.5}$) are the main cause of visibility issues, but they are also important to regulate because they contribute to human respiratory problems (Emmott et al. 2005). Most particles form via atmospheric chemical reactions involving sulfur dioxides and nitrogen oxides.

There are five IMPROVE stations that monitor visibility issues close to BLRI—one in each of GRSM and SHEN National Parks, and one each in the Shining Rock, Linville Gorge, and James River Face Wilderness Areas (Figure 16). The latter three are all located within 5 km of BLRI. Monitoring data for particulate matter and other airborne constituents is available from the collective sites over the period 1988-2004.

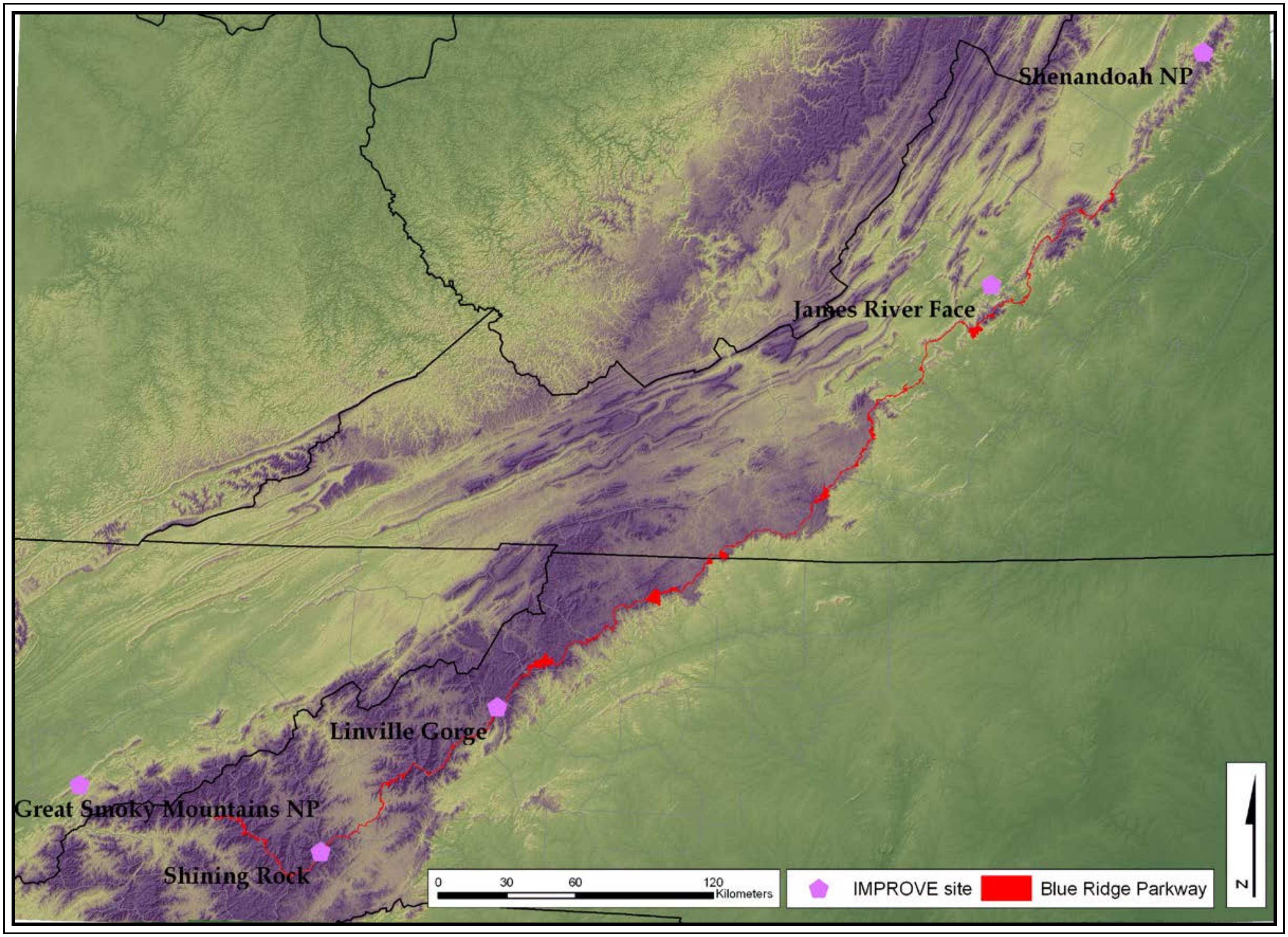

Figure 16. Five monitoring stations near BLRI are part of the Interagency Monitoring of Protected Visual Environments Program (IMPROVE).

The EPA regulates airborne particulate matter concentrations in two separate size classes. Particles between 2.5 and 10 µm are considered coarse particles (PM_{10}), for which the EPA poses a 24-hr primary standard of 150 µg m^{-3}, not to average more than one exceedance per year over the course of three years. None of the nearby monitoring stations exceeded this standard, though a single day in 1989 recorded a concentration of 409 µg m^{-3}, which is likely an anomaly or error. Figure 17 (bottom) shows 3-yr means for PM_{10} observations. For particles finer than 2.5 µm ($PM_{2.5}$), as opposed to the number of exceedances, NAAQS limits stipulate the 3-yr average of the weighted annual mean concentrations must not exceed 15 µg m^{-3}. Figure 17 (top) depicts 3-yr averages of annual mean concentrations for $PM_{2.5}$, for which none of the data points exceed the NAAQS. In addition, Table 17 shows the results of linear regression on 3-yr mean concentrations of both particulate matter classes. All stations show decreasing trends at both size classes, though only the three with the longest data periods are significant.

Table 17. Linear regression showing average amount of annual reduction in particulate matter and visibility at each IMPROVE station. Slopes shown in bold are significant at α = 0.05.

Stations	**Annual 3-yr Mean Concentrations** **$PM_{2.5}$**	**PM_{10}**	**Visibility**	**Data Period**
	----- µg m^{-3} yr^{-1}-------		**---deciviews (dv) yr^{-1}---**	**---yrs---**
GRSM	**-0.157 ($p < 0.01$)**	**-0.411 ($p < 0.01$)**	**-0.075 ($p = 0.01$)**	1990 - 2004
SHEN	**-0.215 ($p < 0.01$)**	**-0.446 ($p < 0.01$)**	**-0.005 ($p < 0.01$)**	1990 - 2004
James River Face WA	-0.697 ($p = 0.21$)	-1.059 ($p = 0.16$)	**-0.018 ($p < 0.01$)**	2000 - 2004
Linville Gorge WA	-0.793 ($p = 0.25$)	-1.140 ($p = 0.15$)	**-0.024 ($p < 0.01$)**	2000 - 2004
Shining Rock WA	**-0.265 ($p = 0.02$)**	**-0.963 ($p < 0.01$)**	**-0.006 ($p = 0.02$)**	1996 - 2004

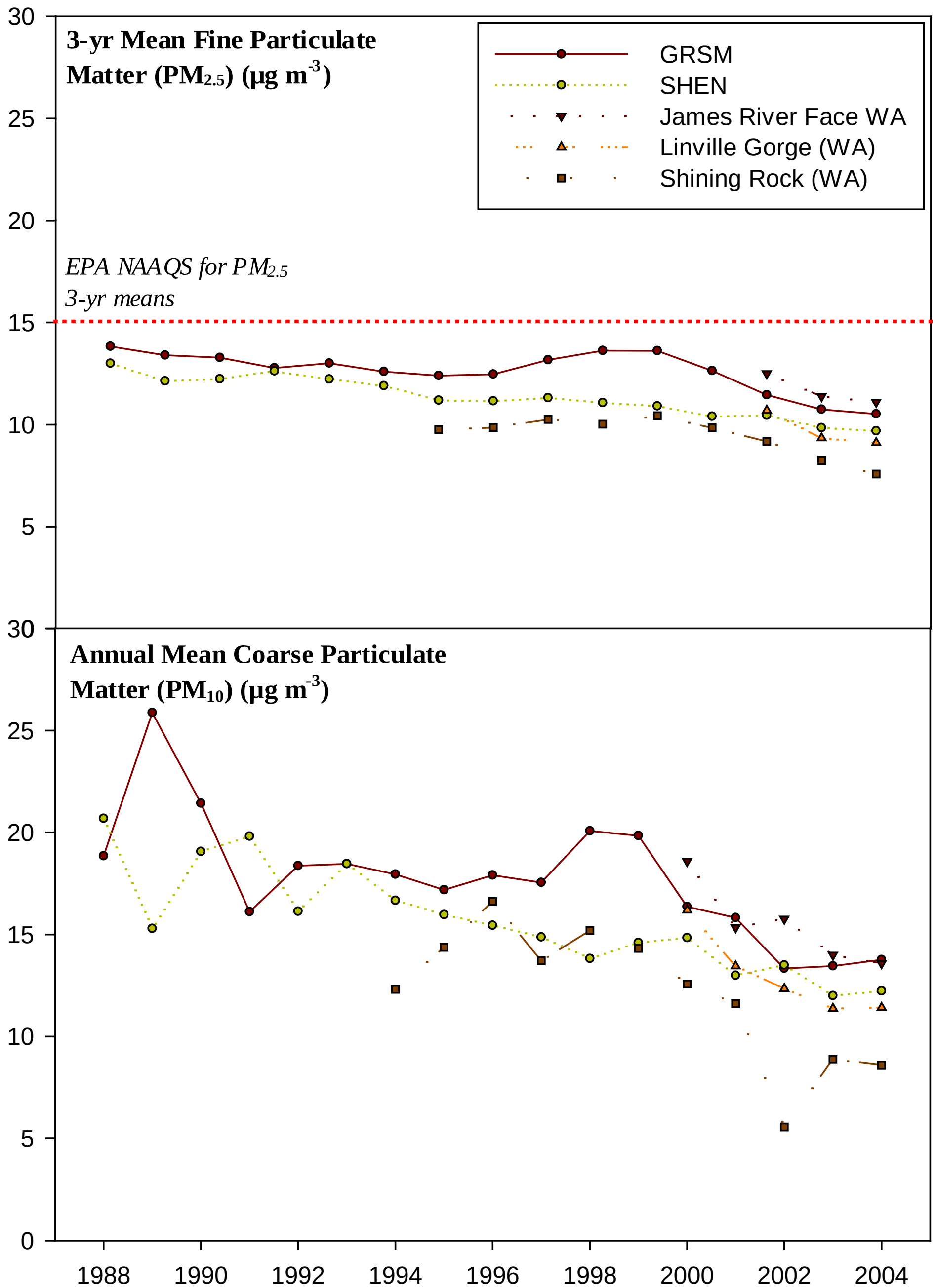

Figure 17. 3-yr mean concentrations of fine particulate matter at five IMPROVE monitoring stations near BLRI.

In addition to the particulate matter measurements, the NPS ARD models levels of visibility at park units across the US. Visibility, another air quality factor extremely important at BLRI, is rated by the NPS ARD using a metric called Group50, measured in deciviews (dv). As visibility decreases, the number of deciviews increases along a linear scale, with each unit corresponding to an equal reduction in visibility conditions. At each station, this metric is calculated as the difference between the mean of visibility conditions between the 40th and 60th percentile values for the past five years, and visibility under presumed natural conditions, which is estimated for each IMPROVE station (NPS ARD 2009). The NPS ARD specifies differences greater than 8 dv present significant concern, while values between 2 and 8 dv present only moderate concern. Using visibility data from the same set of five IMPROVE stations, it is possible to derive Group50 metrics for each station, shown in Figure 18. All five stations showed similarly elevated Group50 metrics in the range 11-13 dv for the latest 5-yr period. These values are consistent with the ARD predicted value at GRSM of 12.56 dv over the period 2003-2007. Table 17 shows trends at all stations monitoring deciviews were decreasing over data periods, meaning that visibility is improving.

4.2.1 Other Particulates

Lead (Pb) particulate is also monitored at each of the five IMPROVE stations, for which the EPA NAAQS stipulates concentration limits of 0.15 $\mu g\ m^{-3}$ over rolling 3-month averages and 1.5 $\mu g\ m^{-3}$ over quarterly averages. Concentrations for the IMPROVE sites around BLRI, however, were well below this standard, as none of the individual measurements exceeded 0.15 $\mu g\ m^{-3}$.

At the GRSM and SHEN stations, measurements of SO_2 were collected over the periods 1991-1999 and 1991-1996, respectively. The EPA NAAQS stipulates annual mean limits of 0.03 ppm and one-time limits of 0.14 ppm. The maximum annual mean between GRSM and SHEN was 0.0024 ppm, while the maximum one-time measurement was 0.0151 ppm, both well below their respective limits.

4.2.2 Summary

On the whole, the suite of five IMPROVE monitoring stations around BLRI provide a substantial amount of data pertaining to visibility and particulate matter, though unfortunately no site data is available past 2004. As a result, this attribute does not receive a ranking for temporal data quality.

For particulate matter concentrations, none of the IMPROVE stations exceeded the NAAQS 3-yr mean limit for fine and coarse particulate matter, and only a single day in 1989 at GRSM exceeded the one-time limit, though this likely could have been a data anomaly or measurement error. Three of the five improve stations also showed significantly decreasing particulate matter concentrations for both size classes.

Visibility data was also relatively consistent among the sites, though it did not support quite as positive a result. Latest five-year means from the stations showed consistently high Group50 metrics—all of which were 3 to 5 dv greater than the ARD threshold for significant ecosystem concern. These data are consistent with the poor visibility ranking assigned to BLRI in the 2008 ARD APPR. In addition, all IMPROVE stations showed a significantly decreasing trend in deciview observations, corresponding to an improvement in visibility conditions.

The generally good condition of particulate matter concentration and poorer visibility conditions result in an overall fair ranking at BLRI for both of these categories (Table 18). Measurements for both attributes consistently supported improving trends.

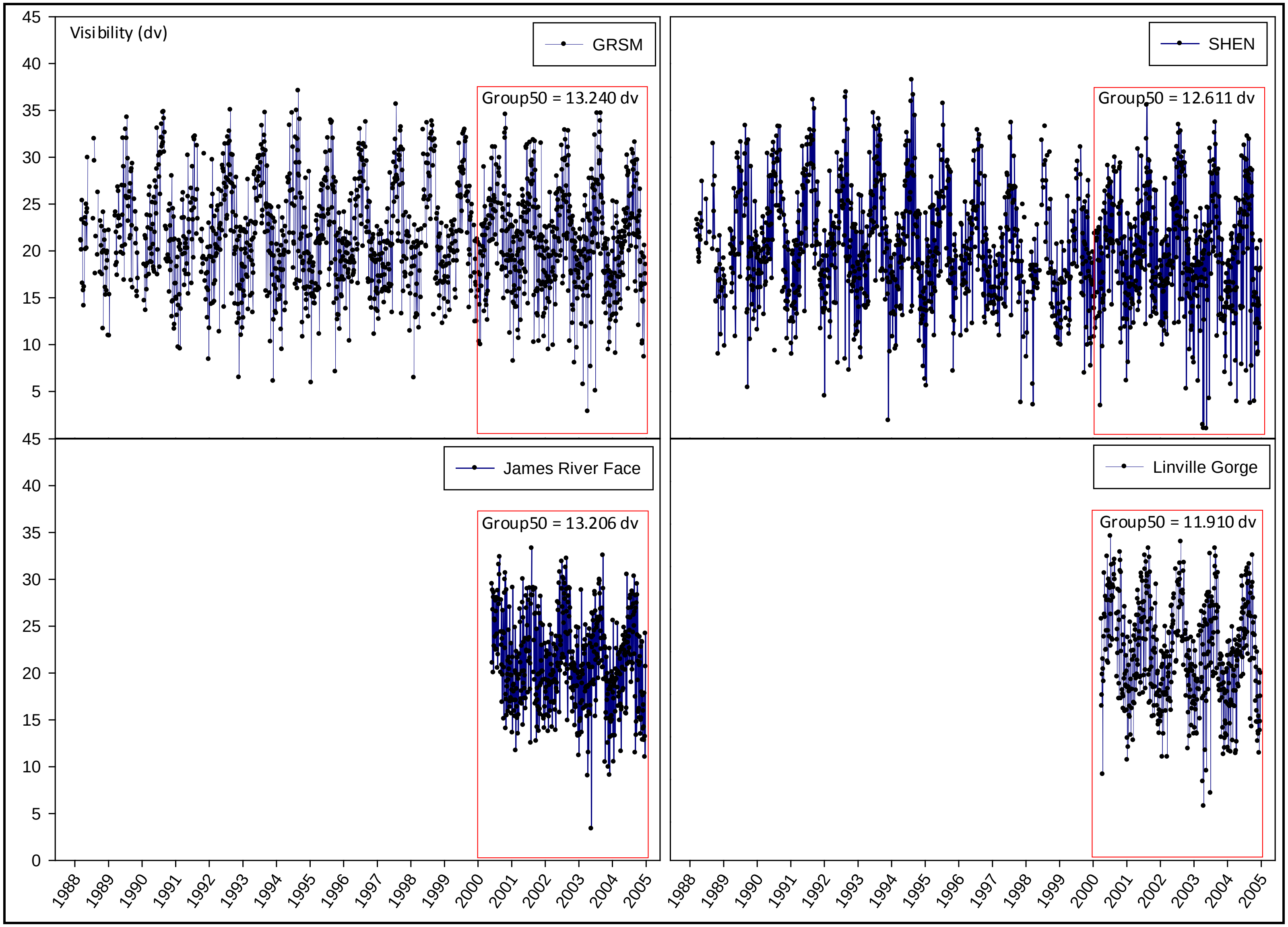

Figure 18. Visibility measurements from five IMPROVE stations, with Group50 metrics for the latest 5-yr data period.

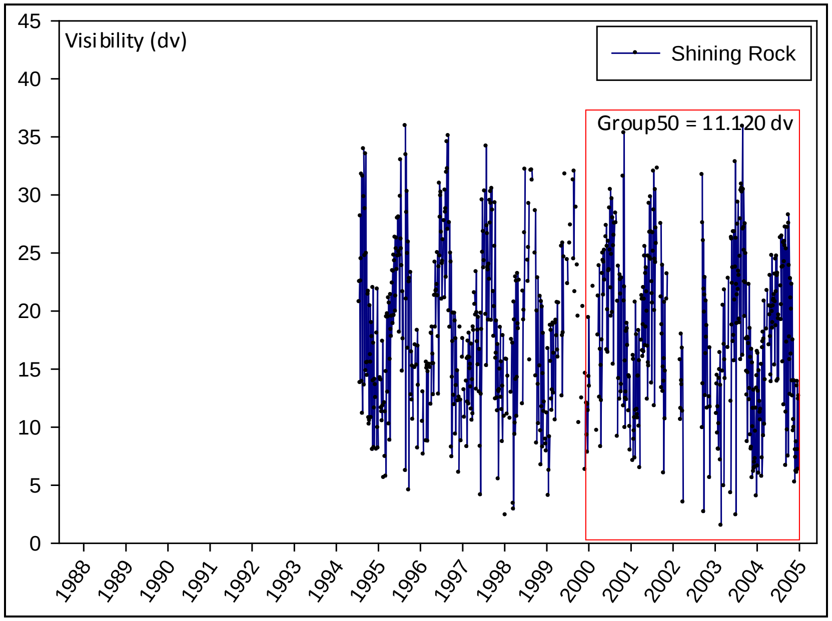

Figure 18. (continued)

Table 18. The Condition of visibility and particulate matter in BLRI was fair. The trend of this condition was improving. Data used to make the assessment was fair.

		Data Quality		
Attribute	Condition & Trend	Thematic	Spatial	Temporal
Visibility and Particulate Matter	⇧	✓	✓	
		2 of 3: Fair		

4.2.3 Literature Cited

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4.3 Weather & Climate

The APHN monitors long-term weather and climate patterns to help identify patterns, trends, and deviations for certain characteristics. Certain patterns can provide insight into natural resource phenomenon, such as the reproduction of certain species, forest insect pest and pathogen outbreaks, and spread and invasion of exotic species (Davey et al. 2007). For the purposes of monitoring, “weather” generally refers to present and short-term conditions, whereas “climate” is the long-term trend, or norm, representing the entire distribution of atmospheric activity and its associated set of statistical descriptors. Throughout the APHN, climate is closely tied to the presence of the Southern Appalachians. Precipitation varies with elevation, whereas temperature patterns depend on more localized topography. Both of these attributes can occur within quickly-changing gradients, resulting in unique microclimate areas over just short distances.

There are several weather monitoring stations in the vicinity of BLRI that provide observations of temperature, precipitation, wind, and humidity, among other observations. In his 2007 climate summary for BLRI, Flaherty outlines weather conditions at the park using data from seven nearby stations, including two Remote Automated Weather Stations (RAWS) and five National Weather Service (NWS) Cooperative Observer Program (COOP) stations. These stations were selected because they were relatively dispersed across the length of BLRI and they had relatively long data periods.

For the following analysis of weather and climate data at BLRI, data from five of those stations was used (Davidson River, Laurel Springs, Blowing Rock, Mt. Mitchell, and Roanoke Airport). Two of the stations used in Flaherty’s (2007) analysis were not used (Meadows of Dan and Holcombe Rock), and instead, three additional COOP stations were added to the analysis—Celo2S, Stuart 1 SSE, and Lexington based on extensive data histories. Table 19 shows details about each of the stations in this final selection, and Figure 19 shows their locations.

4.3.1 Implications of Weather and Climate Monitoring

Datasets collected through weather and climate monitoring represent a primary mode of detecting how meteorology affects ecosystem processes at BLRI. In the short-term, weather events drive multiple systems, including groundwater flow, species patterns, pollutant loads, and productivity (NPS, 2010a). Longer-term records can reveal gradual and more permanent changes in climate, which may in turn cause fundamental alterations in the environment of the southern Appalachians and the Blue Ridge region.

While impossible to outline the numerous effects of weather on the ecosystems of BLRI, it is more useful to report some of the potential long-term effects of climate change, with particular respect to changing temperature and precipitation regimes. An astounding amount of literature has been published regarding climate change effects in the southern Appalachians. Overall, an increase of 4.5°F (2.5°C) to 9.0°F (5.0°C) is predicted in the southeastern U.S. by the 2080s (Karl et al. 2009). Mulholland et al. (1997) outlined various consequences for aquatic ecosystems from these higher temperatures, including higher primary production rates and less cold water habitat available for sensitive fish and macroinvertebrate species. Xu et al. (2010) and Ries and

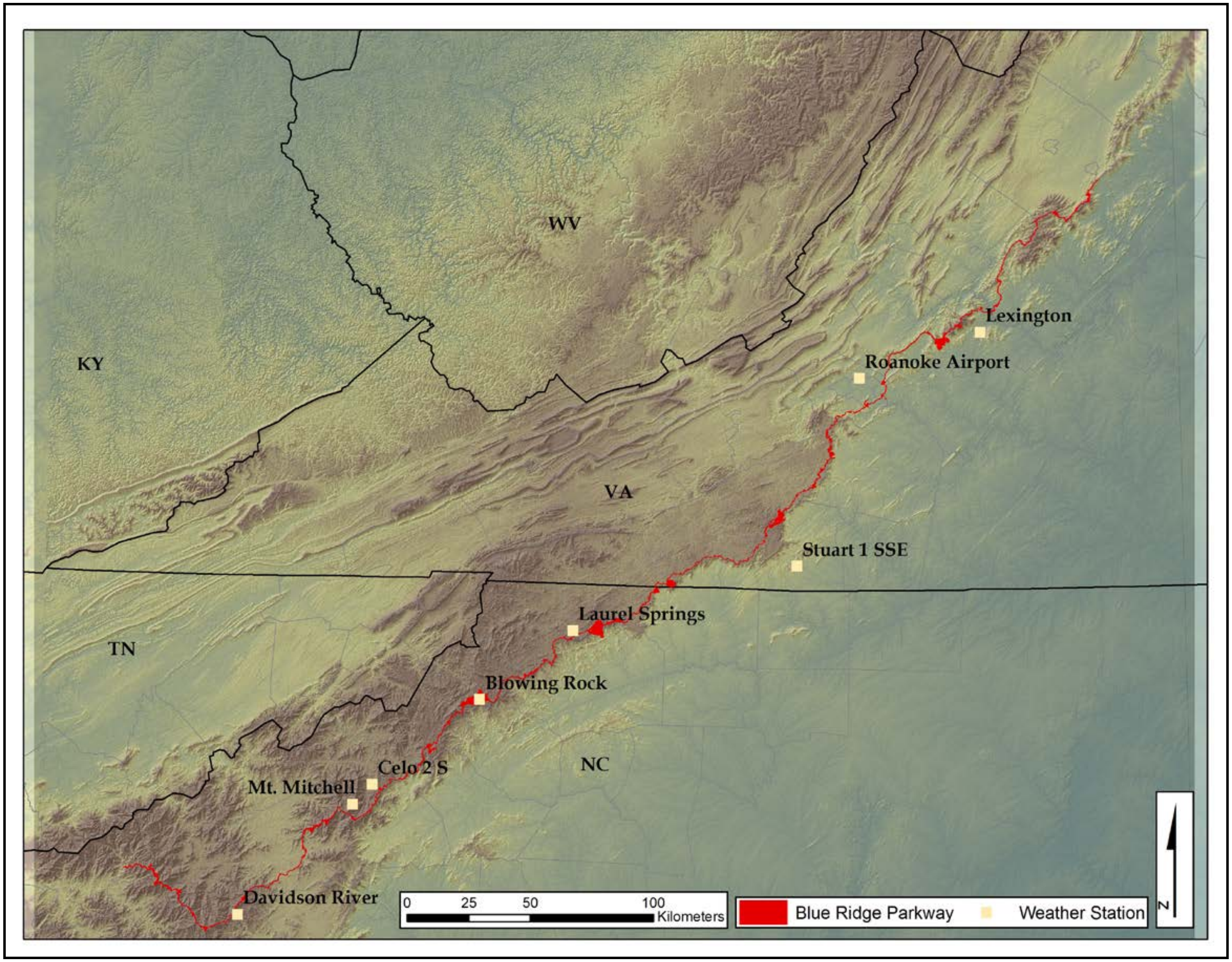

Figure 19. Locations of eight weather stations along BLRI used for analysis, including two RAWS and six COOP stations. All stations are located within 20 km of the park unit.

Table 19. Eight stations within 20 km of BLRI were selected for analysis due to their dispersed distance and extensive monitoring periods.

Station	Monitoring Period	Network	Complete Years† Temp/Precip.	Distance from BLRI --km--	Elevation --m--
Davidson River	2004 - present	RAWS	6/6	1.4	975
Blowing Rock	1893 - 2009	COOP	44/43	within	1141
Laurel Springs	2002 - present	RAWS	8/6	1.3	914
Lexington	1889 - present	COOP	114/98	7.7	242
Roanoke Airport	1949 - present	COOP	61/61	8.9	549
Stuart 1 SSE	1960 - present	COOP	37/37	16.3	445
Mt. Mitchell	1980 - present	COOP	25*/28	4.0	1902
Celo2S	1951 – present	COOP	57/56	3.2	820

†Complete years used for analysis are those with ≤2 days missing data for ≤3 months, and ≤1 months missing all days.
*Mt. Mitchell temp availability different among metrics—mean available years is given.

Perry (1995) both reported how increased temperatures can reduce growth rates for brook trout mainly due to reduced prey availability. Increasing temperatures are also expected to aggravate rates of photochemical smog, and, despite recent reductions in eastern U.S. NO_x emissions, increasing temperatures are predicted to potentially counteract anticipated air quality improvements due to the link with ozone concentrations (Bloomer et al. 2009). Rare mammal species found in BLRI such as southern red-backed vole (*Clethrionomys gapperi*), Carolina northern flying squirrel (*Glaucomys sobrinus coloratus*), and Allegheny woodrat (*Neotoma magister*) have also been shown to decline with increasing temperatures associated with climate change (Manjerovic et al. 2009, Myers et al. 2009).

Vegetation communities could also be affected, particularly elevation-restricted communities like the southern Appalachian spruce-fir forests. Fraser fir forests, which are restricted to only the highest elevations, are one of the most critically-imperiled vegetation communities, according to the Nature Conservancy, and 85% of their remaining habitat is encompassed in GRSM and BLRI. These areas remain constantly shrouded in fog and are extremely sensitive to temperature and precipitation, changes of which could slowly lead to their extirpation from lower elevation areas (Emmott 2010, NC DENR 2010). Blue Ridge also contains much of the remaining Southern Appalachian bog habitat, another imperiled ecosystem type. These areas are sustained by a constant flow of cold groundwater and could also be greatly impacted by changes in the climate.

4.3.2 Precipitation

The Southern Appalachian region generally receives the highest rates of precipitation in the eastern US. Precipitation is one of the most influential drivers for many ecosystem processes, through which it can affect fire regimes, primary production, stream flow, and pollutant deposition. In the latest Weather and Climate Inventory Report for the APHN, Davey et al. (2007) point out that, over the last century, precipitation has increased in some places in the APHN. The most recent 2007 climate summary for BLRI indicates that precipitation was well below average for that year (Flaherty 2010). Nationwide, seven months of the year experienced below-average rainfall, while NC reported its overall driest year on record. This pattern was also apparent at BLRI, where annual precipitation amounts at Mt. Mitchell and Blowing Rock were 23% and 34% below average for that year, respectively.

Annual precipitation levels at six COOP monitoring stations and two RAWS stations are available (Figure 20, Figure 21). Data are shown for the complete history at each station, with missing data points for years with one or more months of absent data, or three or more months with three or more missing days of data. Linear regression for each COOP station shows a single significant trend at the Lexington COOP. Since the latest APHN climate summary in 2007 (Flaherty et al. 2010), which reported unseasonably low rainfall for BLRI and the surrounding region, precipitation amounts increased in both 2008 and 2009.

4.3.3 Temperature

Long-term temperature monitoring in the APHN has also shown noticeable patterns over the past decades. Large-scale changes in temperature could be the result of climate change, as are changes in frequency of extreme weather events such as storms and droughts. These changes can also lead to ecosystem effects such as altered fire regimes and susceptibility to exotic species (Davey et al. 2007). The APHN Weather and Climate Inventory points out that temperatures were warmest during the 1940s and 1950s, but became suddenly cooler in the 1960s. Following that decade, temperatures began to show a warming trend that continues to this day (Davey et al. 2007). Flaherty (2010) reports that in 2007, Laurel Springs recorded an annual temperature 1.1 °F (0.6 °C) warmer than the mean of the 6-yr data period of the station, while Blowing Rock and Roanoke were respectively 1.3 °F (0.7 °C) and 3.0 °F (1.7 °C) warmer than the 30-yr norm over the period 1971-2000.

Figure 22 and Figure 23 show average daily, maximum, and minimum annual temperatures at the six COOP and two RAWS monitors. Years with insufficient data were not included in the plot. While data for the RAWS is relatively limited, the other COOP stations have data periods over considerable periods. Linear regression revealed significant trends for several of these longer datasets. Roanoke Airport, for which monitoring stretches unbroken from 1949 to 2009, shows significant increases in average annual mean temperature (p = 0.041) and average annual minimum temperature (p = 0.002) of 0.01 °C yr^{-1} (0.02 °F yr^{-1}) and 0.02 °C yr^{-1} (0.04 °F yr^{-1}), respectively. Monitoring for Celo 2S over roughly the same period also showed significant increases for the same metrics (respectively 0.03 °C yr^{-1} [0.05 °F yr^{-1}]; p < 0.001 and 0.05 °C yr^{-1} [0.09 °F yr^{-1}]; p < 0.001). Lexington offered the most continuous length of uninterrupted data, stretching over the period from 1890 to 2009 with only four missing years. Linear regression at this station depicted a significant linear increasing trend for both annual mean and maximum temperatures of 0.01 °C yr^{-1} (0.02 °F yr^{-1}) (p < 0.001). Finally, Stuart 1 SSE has a data period over the period from 1970 to 2009 and also shows significant linear increasing trends for mean and max temperatures (respectively 0.02 °C yr^{-1} [0.04 °F yr^{-1}]; p = 0.001 and 0.06 °C yr^{-1} [0.11 °F yr^{-1}]; p < 0.001). At Mt. Mitchell, the data period stretches from 1980 to 2009, where a significant decreasing linear trend of -0.03 °C yr^{-1} (0.06 °F yr^{-1}) (p = 0.03) was observed for the annual mean minimum temperature. It is important to note, however, that just as many temperature records among the stations showed no linear trend.

4.3.4 Growing Degree Days

Lastly, it is possible to track seasonal changes in temperature using the annual number of growing degree days (GDD) as a metric. Most simply, growing degree days correspond to the amount of time the temperature is above a certain baseline number of degrees. Often, 40 °F (4.4 °C) is used as a baseline, and temperatures above that threshold represent time plants can grow towards maturation.

After Dorr et al. (2009), we used monthly temperature means from each of the COOP and RAWS stations to calculate GDD according to the following equation:

$$GDD = (T_m - B)*D_m \qquad \text{(Eq. 2)}$$

where GDD is number of growing degree days, T_m is the monthly mean temperature, B is the baseline temperature (40°F in this case), and D_m is number of days in the current month. Results of this calculation for each of the eight stations are shown in Figure 24 and Figure 25. Linear regression shows several trends, all increasing, at four of the six COOP stations—Roanoke Airport (4.86 GDD yr^{-1}; $p = 0.05$), Lexington (2.30 GDD yr^{-1}; $p = 0.009$), Celo 2 S (12.45 GDD yr^{-1}; $p < 0.001$), and Stuart 1 SSE (9.64 GDD yr^{-1}; $p = 0.003$).

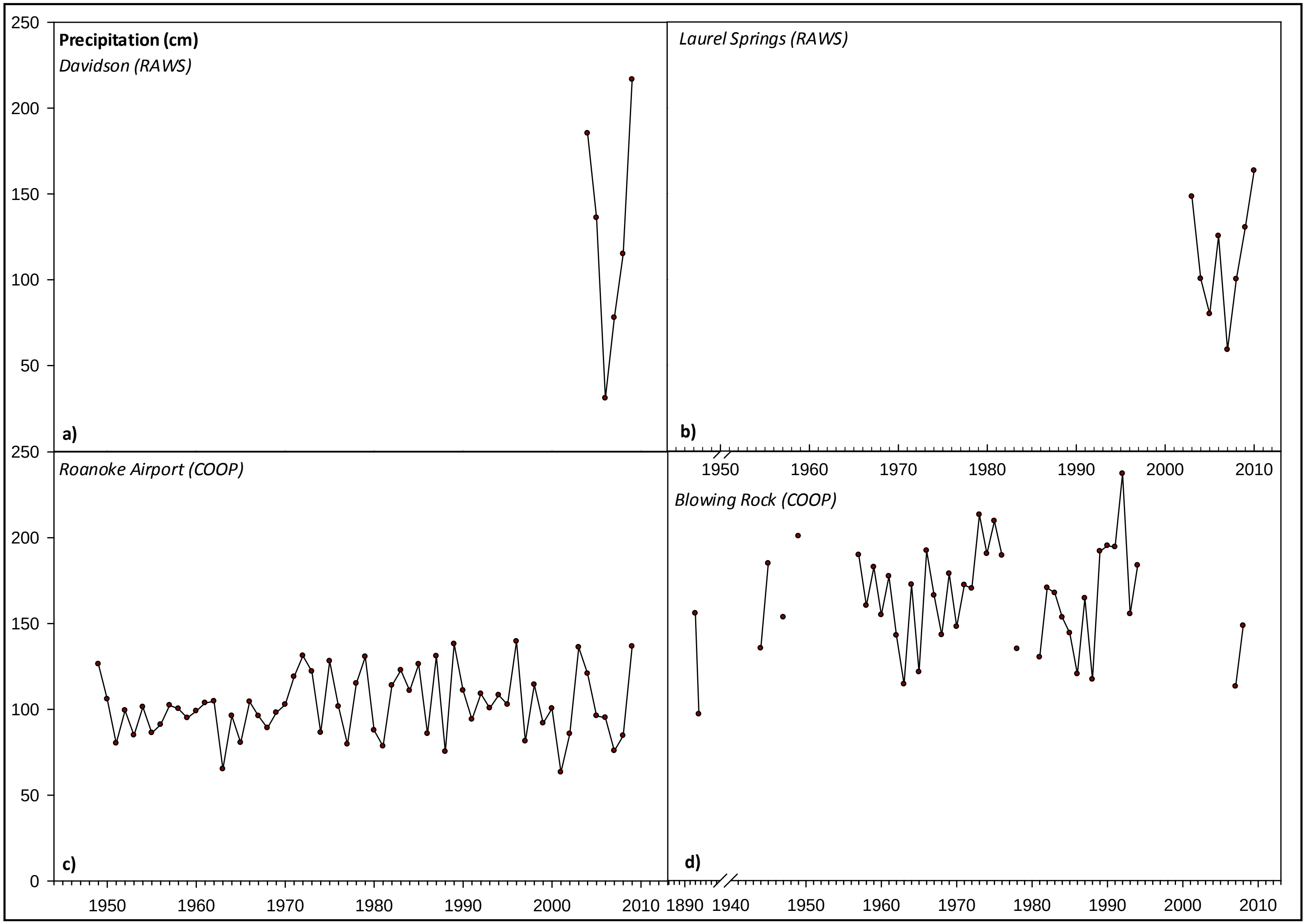

Figure 20. Average annual precipitation at BLRI at Davidson River (a), Laurel Springs (b), Roanoke Airport (c), and Blowing Rock stations (d). Years with at least one month of missing data are not included; significant linear trends are plotted with data.

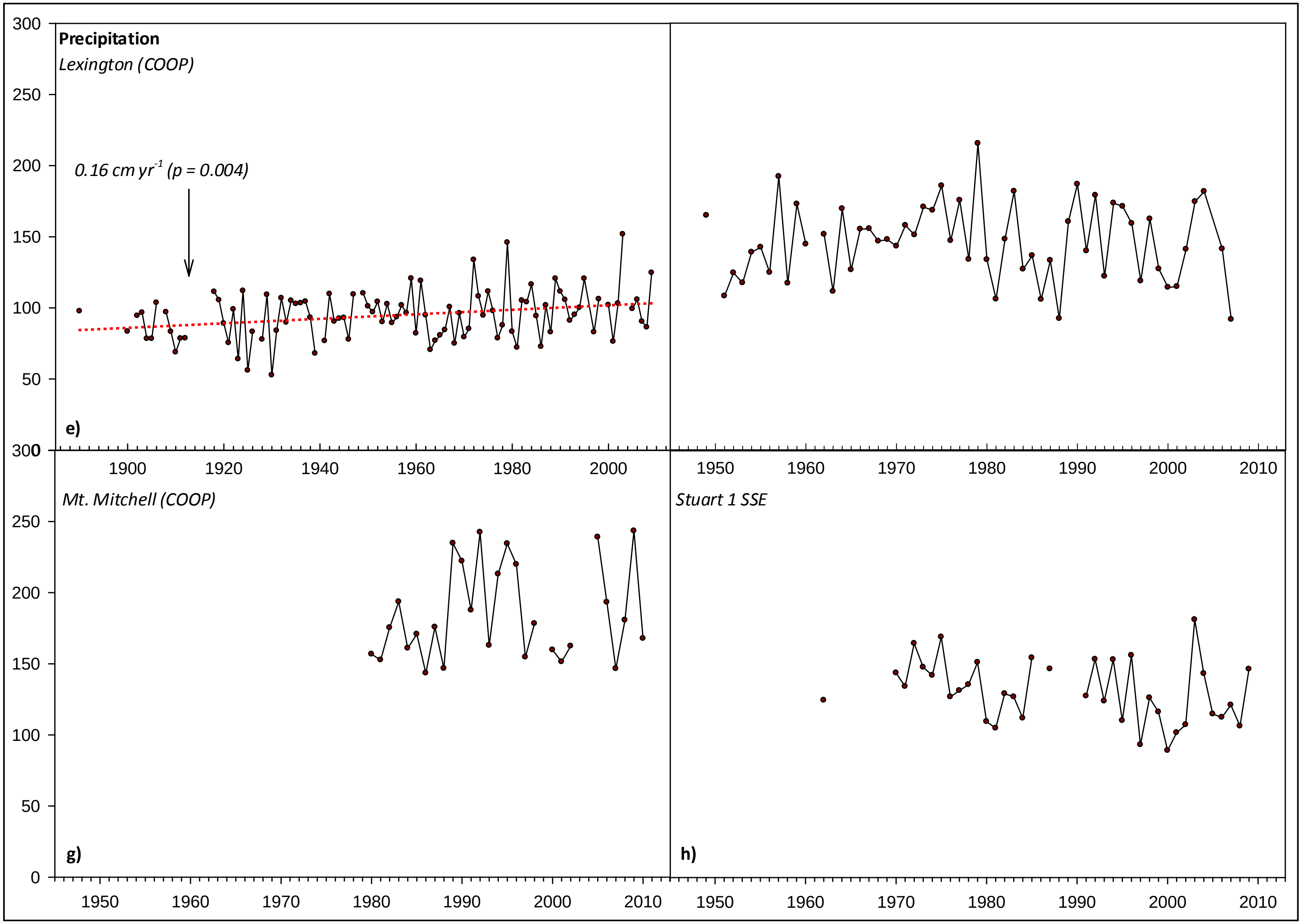

Figure 21. Average annual precipitation at BLRI at Lexington (e), Celo 2S (f), Mt. Mitchell (g), and Stuart 1 SSE stations (h). Years with at least one month of missing data are not included; significant linear trends are plotted with data.

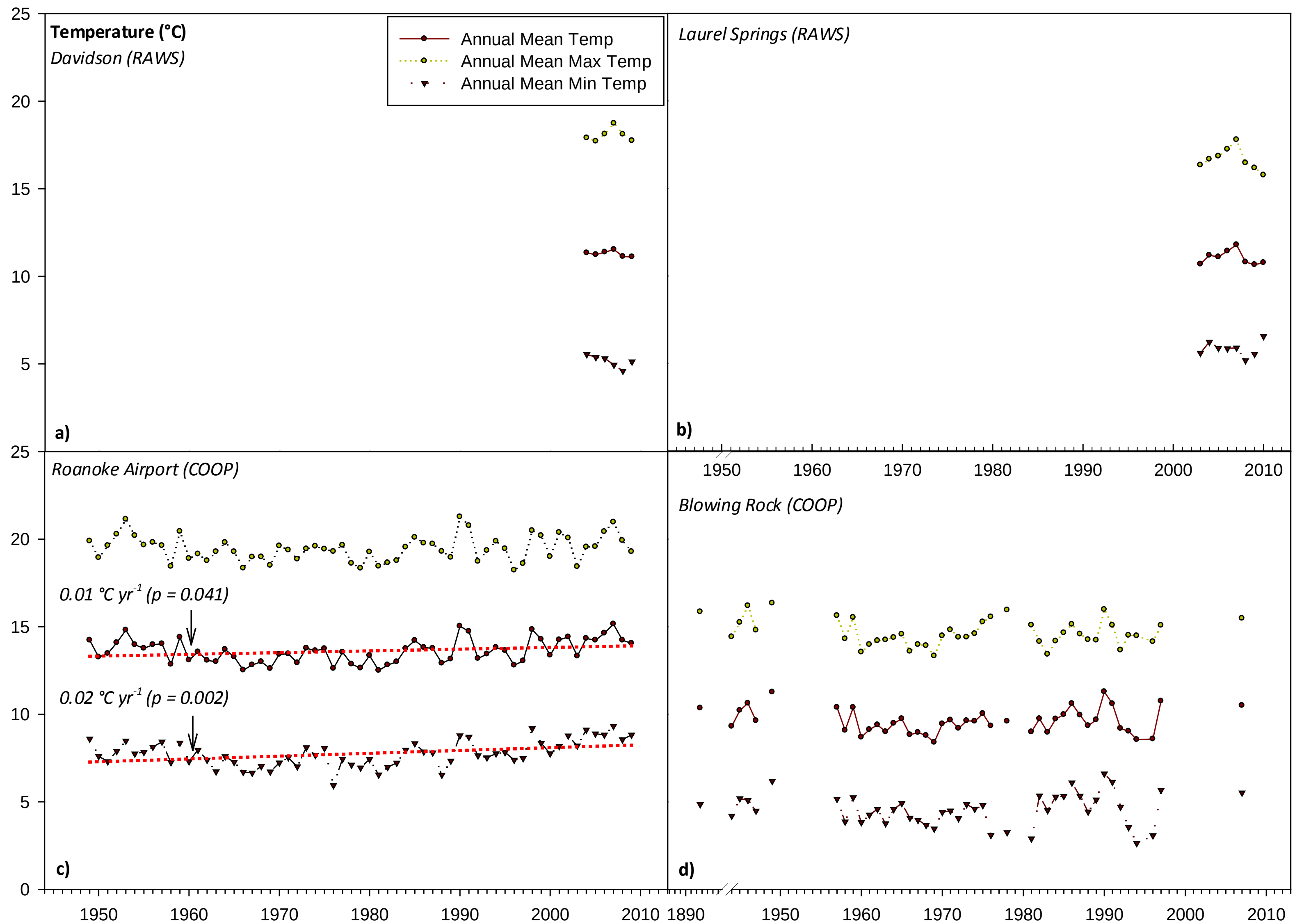

Figure 22. Average annual temperature at Davidson River (a), Laurel Springs (b), Roanoke Airport (c), and Blowing Rock stations (d). Years with at least one month of missing data are not included; significant linear trends are plotted with data.

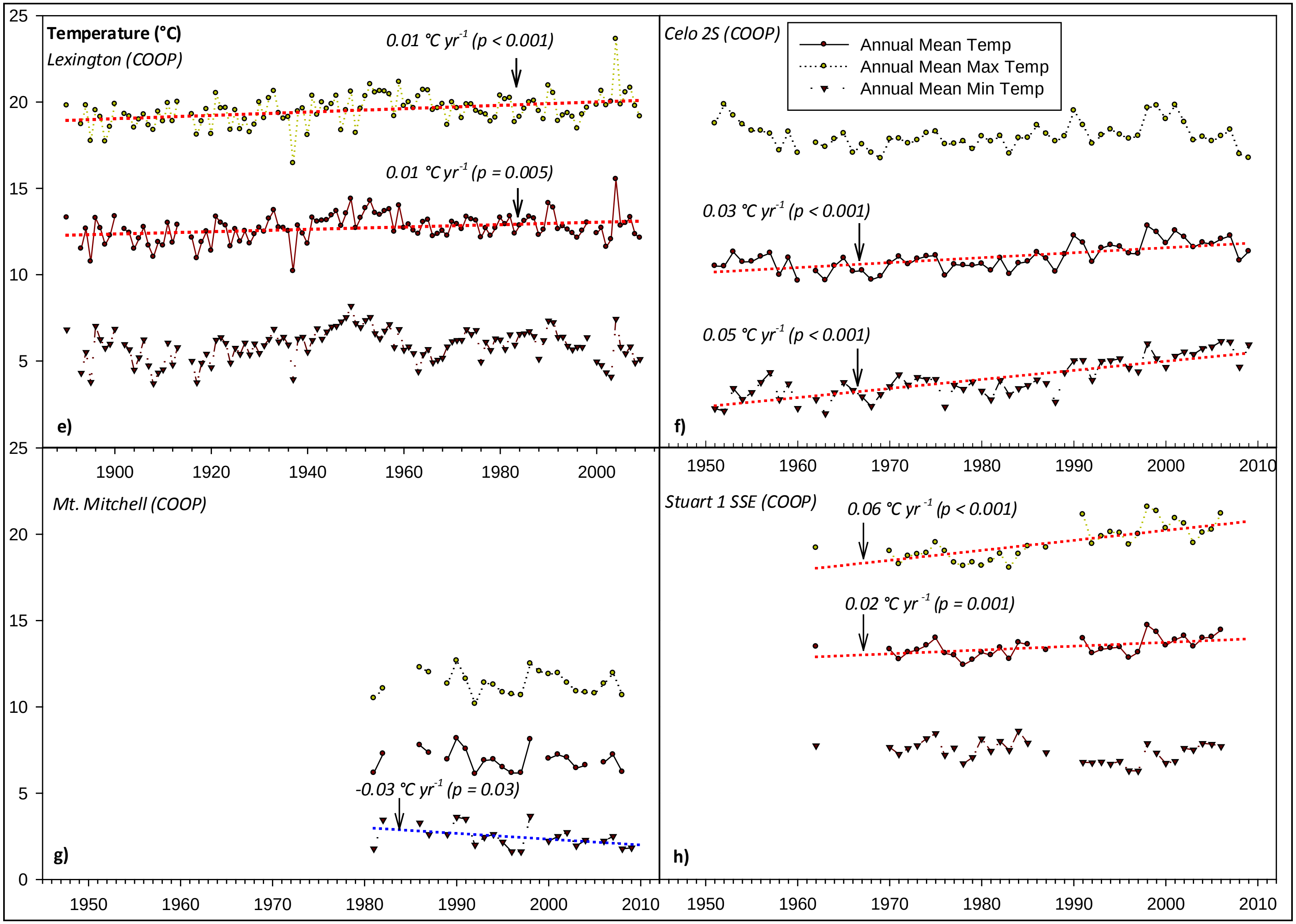

Figure 23. Average annual temperature at Lexington (e), Celo 2S (f), Mt. Mitchell (g), and Stuart 1 SSE stations (h). Years with at least one month of missing data are not included; significant linear trends are plotted with the data.

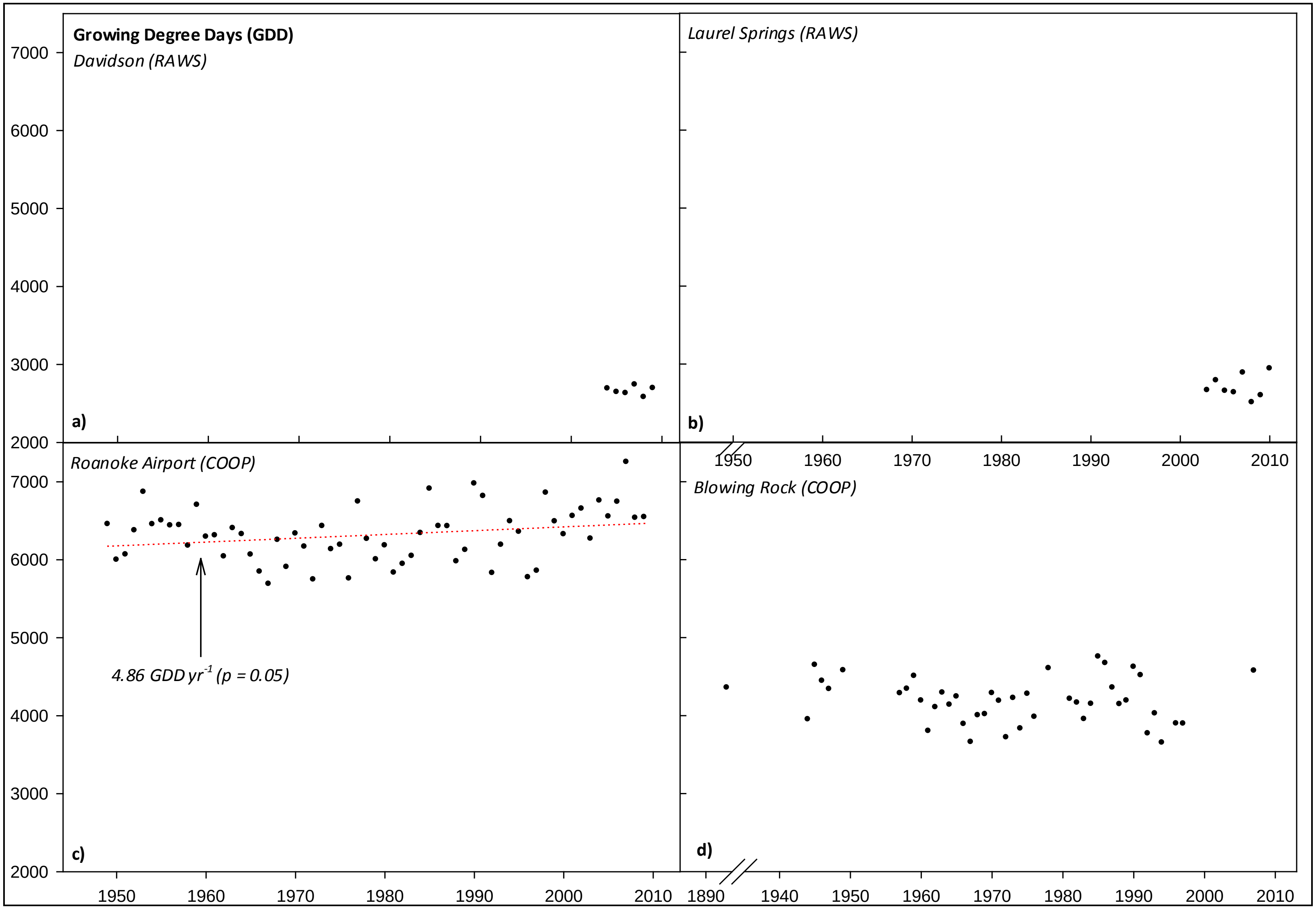

Figure 24. Mean monthly growing degree days (GDD), by year, for Davidson River (a), Laurel Springs (b), Roanoke Airport (c), and Blowing Rock (d). Only years with monitoring data for all 12 months are shown. Lines show significant trends for increasing (red) or decreasing (blue).

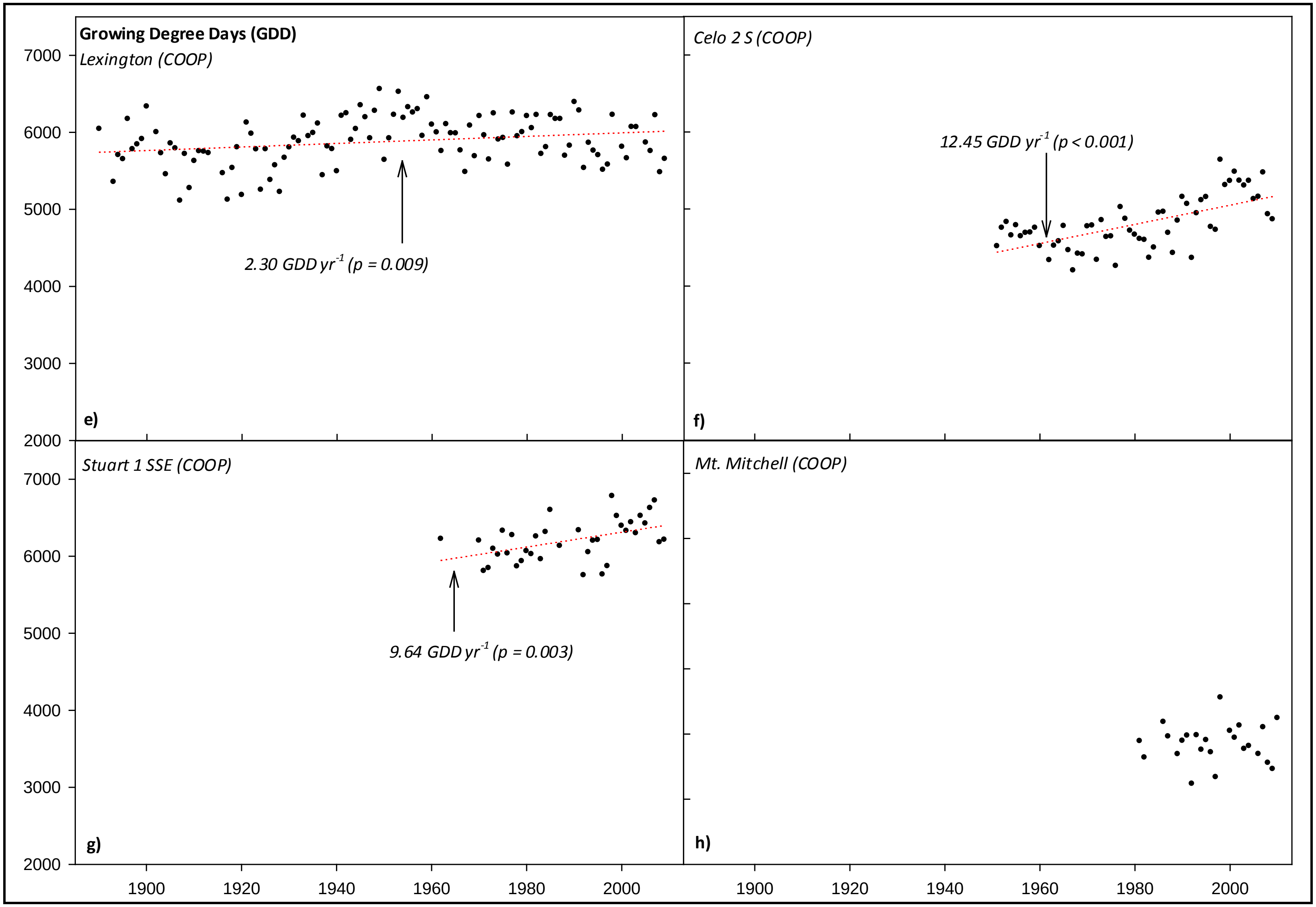

Figure 25. Mean monthly growing degree days (GDD), by year, for Lexington (e), Celo 2 S (f), Stuart 1 SSE (g), and Mt. Mitchell (h). Only years with monitoring data for all 12 months are shown. Lines show significant trends for increasing (red) or decreasing (blue).

4.3.5 Wind Speed and Direction

The RAWS at Davidson River and Laurel Springs also monitor wind speed and direction. Figure 26 shows a 16-point wind rose depicting cumulative wind speed and direction over the history of each monitoring station. At Davidson River, winds were calm (<1.3 m s^{-1}) approximately half the time, and predominant directions of wind origin are both SW and NE. At Laurel Springs, calm winds prevailed only about 14% of the time, with winds predominantly originating from the south and NW. Wind speed was also overall higher for Laurel Springs, falling mainly in the 3.6 to 5.9 m s^{-1} category, while at Davidson River, speeds were more reliably in the 1.8 to 3.6 m s^{-1} class.

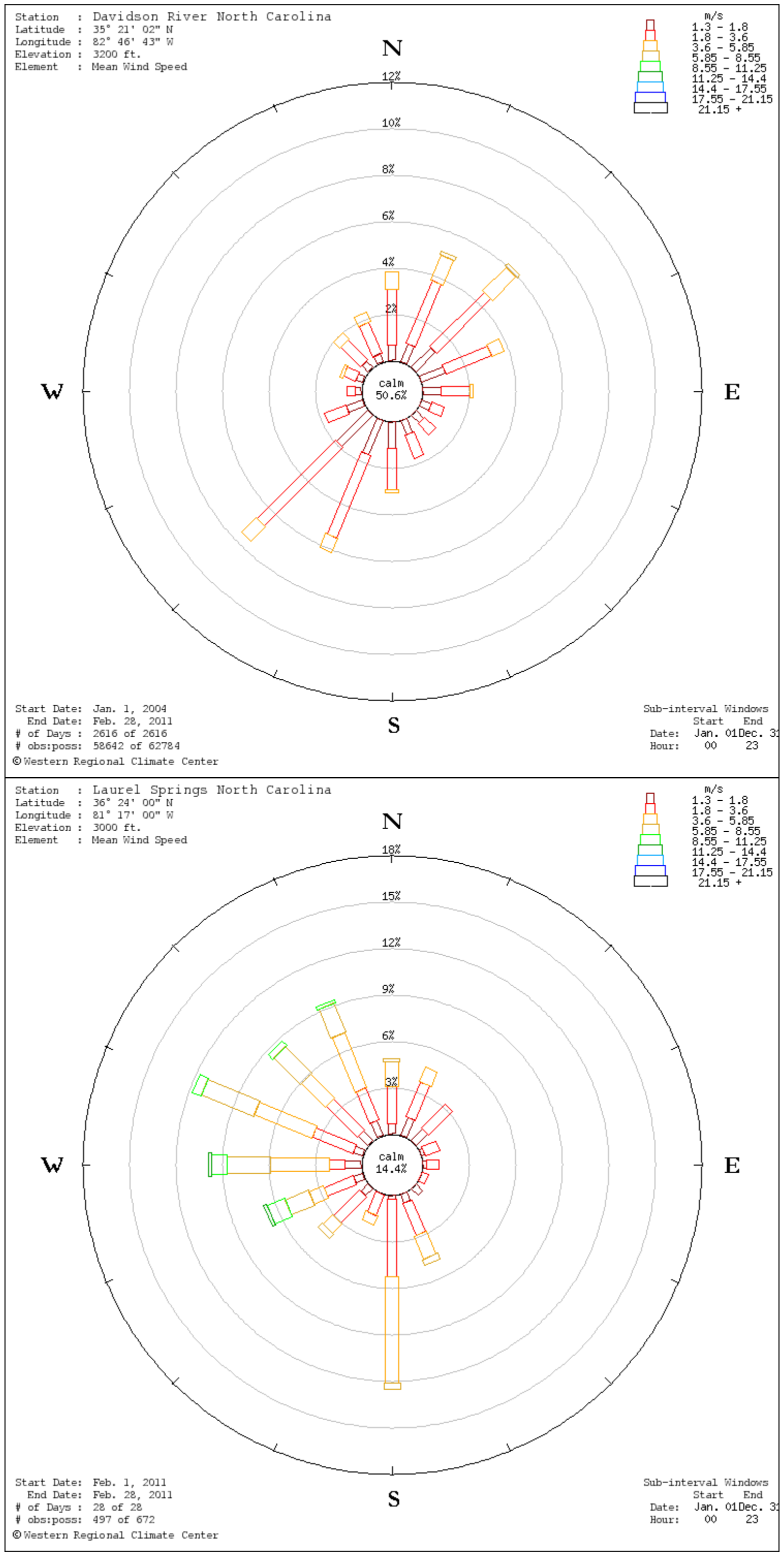

Figure 26. Directional wind roses for Davidson River (top) and Laurel Springs (bottom) RAWS monitors, over the periods 2004-present, and 2002-present, respectively. Colors represent wind speed, and length of individual colored bars represent proportion of wind in a given direction.

4.3.6 Summary

Overall, there are several data sources with reliable monitoring periods from which to make observations related to weather and climate at BLRI. Because the Blowing Rock COOP station is located within BLRI, the spatial quality criterion of the data quality for weather and climate is fulfilled, though the remaining seven stations are located close to, but not inside the park boundary. In addition, there are numerous trends apparent in the annual number of growing degree days and temperature metrics. The Lexington COOP was the only station to show a significantly increasing precipitation trend, and Mt. Mitchell showed a significantly decreasing annual minimum mean temperature of its data period. Most notably, perhaps, is that not only did the Lexington, Roanoke Airport, Stuart 1 SSE, and Celo 2 S COOP stations show significantly increasing temperature trends for two of the three temperature metrics over their respective data periods, but each of these stations also showed a significantly increasing number of growing degree days (GDD), as calculated from monthly mean temperatures. There are several qualifications to these observations, however, including the fact that the Blowing Rock, Davidson River, and Laurel Springs stations showed no significant trends, and in the case of Mt. Mitchell, a significant decrease was observed. Overall, however, this suite of trends observed at these eight weather stations supports a gradual but consistent change towards permanently warmer average temperatures and longer growing seasons from the available period of data. The resulting effects of these two parameters alone could have negative effects on the terrestrial and aquatic habitat at BLRI and the surrounding region, potentially displacing several important species like the native brook trout, or vegetation communities like the spruce-fir ecosystem. Despite these results, a valuation of weather and climate along BLRI is untenable, and as a result this condition is not ranked (Table 20).

Table 20. The condition status for weather and climate at BLRI was not assigned a rank or trend. The data quality for this attribute was good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Weather and Climate		✓	✓	✓
		3 of 3: Good		

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4.4 Hydrology and Water Quality

The area of the southern Appalachians that BLRI traverses includes a wealth of aquatic resources, including seeps and springs, wetlands, and upland coldwater trout streams (stocked and natural) (NPS 2010a). Because BLRI mainly follows the ridgeline of the southern Appalachians, much of its aquatic resources include streams with their headwaters situated inside the park boundary. As a result, precipitation is essentially the only source of flow for streams and groundwater in these areas, ensuring that the park is able to maintain downstream quality (Hopkins 1984). The vast majority of this groundwater is stored within the saprolitic surface layer of weathered rock overlying bedrock (Winner 1977). In other areas, however, stream corridors do enter the park unit from outside sources (NPS 2010b). Often, sources of runoff include adjacent agricultural lands where cattle grazing can degrade water quality (NPS 2010a). Some park lands are also grazed under specific use leases with the park unit in order to maintain a certain scenic character.

Throughout its 755 km course, BLRI traverses through four major hydrologic regions (HUC2), including seven subregions (HUC4), eight accounting units (HUC6), and 15 cataloging units (HUC8), also known as subbasins, and intersects with approximately 1200 stream segments (Figure 29). Of these, 150 streams originate inside the park unit. Major river intersections include the French Broad and Swannanoa rivers near Asheville, NC, the Linville River near Linville Falls, and the James River near Lynchburg, VA (Emmott et al. 2005).

The high-elevation of streams along the BLRI places them in a particularly susceptible position for atmospheric deposition. In a study at SHEN, Sullivan et al. (2008) point out that the park suffers from some of the highest deposition rates in the US, which severely impacts aquatic resources in the park. Sullivan et al. (2008) suggest that ANC values in streams at SHEN have gradually decreased since 1900 as a result of continued deposition, leaving them more susceptible to acidification loads. These effects are complicated by the natural geologic characteristics of the area, which include bedrock poor in base cations and poor S adsorption potential (Sullivan et al. 2008).

4.4.1 303(d) Streams and Outstanding Resource Waters

The Clean Water Act of 1972 requires each state to generate a list of its impaired waters bi-annually. Impaired waters are those which violate certain water quality parameters, which in turn depend on the use classification of the water body. Often, only certain sections are classified as impaired. In cases where the violation is due to a specific and identifiable pollutant, a Total Maximum Daily Load (TMDL) limit is assessed.

Within BLRI, seven stream segments were classified as 303(d) in 2010 (Figure 27). Of these, two are in NC and five are in VA, and two segments—Tom's Branch and W. Fork Dodd Creek—originate inside the park unit. Within a three-mile buffer of the park, however, 105 separate segments are classified as 303(d) streams in both VA and NC. Table 21 lists each listed stream passing through BLRI, as well as its cause of impairment.

Several stream segments occurring within Parkway lands were officially noted for exceptionally high quality. A single segment in VA, North Creek, was classified as an Outstanding National

Resource Water (Emmott et al. 2005). In addition, three stream segments were classified in NC as state-designated Outstanding Resource Waters: Andrews Creek, Linn Cove Branch, and Clear Branch (Figure 28). Wilson Creek is listed designated as a National Wild and Scenic River, in addition to being a State Outstanding Resource Water.

Table 21. Seven stream segments inside BLRI were included on the 2010 303(d) list of impaired waters in NC and VA (Figure 27). Total length refers to the complete 303(d) listed section, including length both within and outside BLRI boundaries.

Stream	Total Length (km)	Reason	Impaired Use
East Fork South Fork New River	3.7	Fair Benthos Ecological Integrity	Aquatic Use
Richland Creek	12.9	Fecal coliform	Recreation
Glade Creek	11.0	*E. coli*	Recreation
James River	14.8	Hg fish concentrations	Fish Consumption
Toms Branch	3.6	Macroinverterbrate Impairment from drought impacts	Aquatic Life
Roanoke River	5.1	Macroinverterbrate Impairment, *E. coli,* PCB fish and water concentrations	Recreation, Wildlife, Aquatic Life, Fish Consumption, Public Water System
West Fork Dodd Creek	8.5	Fecal coliform	Recreation

4.4.2 Past Monitoring and Parameter Criteria

To date, the most comprehensive analysis of water quality at BLRI was the 1996 baseline inventory conducted by the NPS Water Resources Division (WRD) for all NPS units. This inventory analyzed data available from the EPASTORET database over the period 1965 to 1995 for a study area encompassing three miles upstream and one mile downstream of the park boundary (NPS WRD 1996). Data included observations from 315 monitoring stations, 29 of which were located inside the park unit boundary. The majority of stations reflected short-term or one-time collections, though approximately one-third reflected longer monitoring periods, including four such stations within BLRI.

Overall, results of this inventory showed that some areas of the park unit were impacted by issues such as lack of dissolved oxygen, low pH, turbidity, high bacterial concentrations, and contaminants present in the water. The inventory offered general summary statistics for each parameter, and also identified possible anthropogenic influences including wastewater discharge and runoff from urban and agricultural sources (NPS WRD 1996).

<u>Dissolved Oxygen</u>
Dissolved oxygen (DO) is typically measured *in situ* using a sensor that adjusts for temperature and which is calibrated for atmospheric pressure at each site. The significance of this observation derives from its sensitivity to natural or anthropogenic alterations to the stream, as sensitive

aquatic plants are one of the main sources of oxygen, along with aeration and mixing of atmospheric O_2.

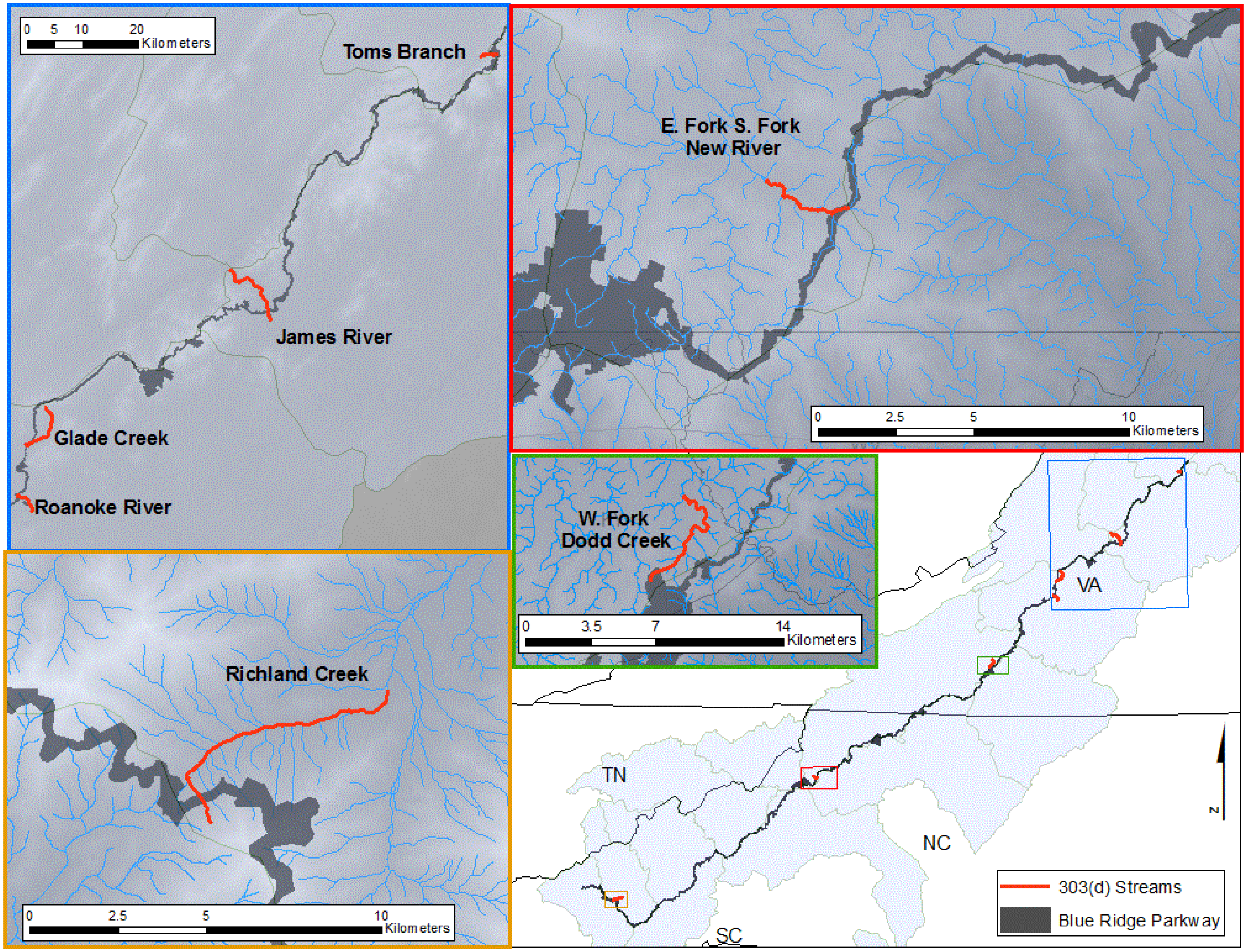

Figure 27. Seven streams along BLRI are classified as 303(d) due to impairment, while five streams are classified as either national or state outstanding natural resource waters.

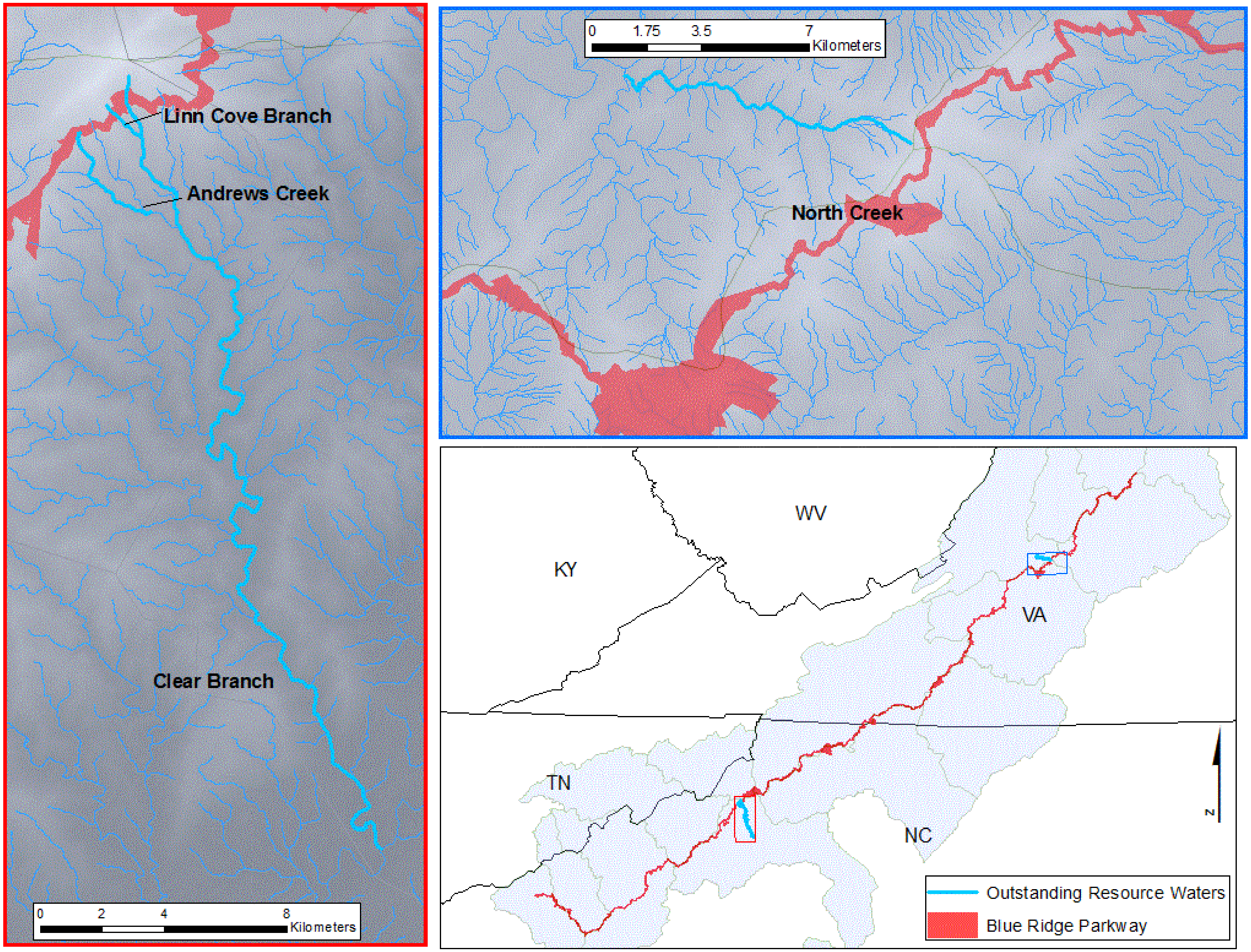

Figure 28. Four streams—three in North Carolina and one in Virginia—are classified as state or national outstanding resource waters.

Concentrations of DO are also important to the survival of essentially all aquatic species (Palmer et al. 1997). Several sources of runoff such as agriculture, urban areas, septic fields, or wastewater discharge can result in high biochemical oxygen demand (BOD) from microorganisms that break down their constituents, which can in turn deplete oxygen available to aquatic species (EPA 1997).

Dissolved oxygen criteria depend on the use classification of the water body, and absolute minimums for both NC and VA are 6.0 mg L^{-1} for natural trout waters. For freshwater aquatic life, NC specifies 5.0 mg L^{-1}, while VA specifies 4.0 mg L^{-1} for mountainous zone waters and 5.0 mg L^{-1} for stockable trout waters (VDEQ 2007, NCDEQ 2007). In its discussion of national water quality criteria, the EPA Goldbook (1986) establishes a coldwater minimum of 4 mg L^{-1}, though it indicates that certain coldwater fish species like salmonids require much higher concentrations, especially during early life stages. Concentrations up to 11 mg L^{-1} are recommended in salmonid waters during embryo and larval stages for no production impairment. Throughout the 30-yr monitoring period examined in the baseline inventory, DO was measured at 200 stations, wherein 98% of the observations were above the 4 mg L^{-1} threshold. Observations below this limit were recorded for 42, or 21% of all the stations.

<u>pH</u>

Measurements of pH are important to water quality because it affects multiple biological processes within aquatic ecosystems. Low levels of pH (i.e. acidic) can potentially increase the mobility of toxic elements, and in turn, their uptake by aquatic plants and animals (EPA 1997). Even at only slightly acidic levels (6.0-6.5), species richness of phytoplankton, zooplankton, and benthic invertebrates can be inhibited, while levels between 5.0 and 6.0 can result in mortality of several fish species. In addition, algal growth increases at these acidic levels, which translates into an increased risk of mortality for macroinvertebrate species. Levels of pH below 5.0 can result in the loss of most fish species, decreased rate of nutrient cycling and organic matter decomposition, and can result in reproductive failure of certain sensitive amphibians (Driscoll et al. 2003).

Both NC and VA stipulate pH values between 6.0 and 9.0 (VDEQ 2007, NCDEQ 2007), while the EPA Goldbook (1986) restricts the ideal range for freshwater aquatic life between 6.5 and 9.0. Although values below this range are not necessarily toxic to fish species, their combination with a high concentration of carbon dioxide (CO_2) can be harmful.

The baseline study analyzed pH values from 264 monitoring locations, of which 71% reported values outside the range of 6.5 to 9.0. In all, 22% of the observations fell outside of this range, of which the vast majority (84%) were due to acidity, though no map is shown in the inventory. The overall range of these values was 2.2 to 11.2.

<u>Turbidity</u>

Virginia does not outline limits for turbidity, measured in nephelometric turbidity units (NTU), though NC stipulates a limit of 50 NTUs for freshwater aquatic habitat, and a limit of 10 NTUs for trout waters (NCDEQ 2007). Thirty-eight out of 161 monitoring stations reported values exceeding the 50 NTU threshold, though these exceedances represented only 1% of the observations.

Acid-Neutralizing Capacity

Acid-neutralizing capacity (ANC) is measured to assess the relative ability of the water to buffer acidic loading resulting from precipitation or other sources. It is the most common measurement used to assess sensitivity to acid deposition, wherein lower ANC values generally correspond to higher levels of aluminum ion (Al^{n+}), as well as a greater level of toxicity to aquatic biota such as fish, invertebrates, and periphyton (Sullivan et al. 2011). Although calcium carbonate is used as an equivalent standard for ANC values, it reflects the concentration of all substances that would tend to raise the water pH above approximately 4.5 (EPA 1986). Higher values of ANC are particularly influenced by concentrations of carbonates (CO_3^{2-}), bicarbonates (HCO_3^-), phosphates (PO_4^{3-}), and hydroxides (OH^-). When referring to calcium carbonate concentrations, units of mg L^{-1} are used, while microequivalents per liter (µeq L^{-1}) are used to reflect concentrations of other compounds influencing alkalinity. Conversion between the two units is presented according to equation:

$$20 * ANC\,(\mu eq\, L^{-1}) = ANC\,(mg\, L^{-1}) \qquad \text{(Eq. 2)}$$

Acid-neutralizing capacity is similar to alkalinity, another common measure of buffering capacity, but differs in that it is tested using an unfiltered sample. Particulate matter removed from samples tested for alkalinity can affect buffering capacity, resulting in different measurements for each of these parameters (Radtke et al. 1998).

Low values of ANC are typical of the BLRI region because of the underlying geology. This is a particular concern at BLRI and the surrounding Southern Appalachians because of the constant threat of acid deposition and its impact of hydrologic resources. In an assessment of acidic deposition at Shenandoah National Park, Cosby et al. (2006) outlined four levels of ANC and their associated level of concern for adverse effects to the aquatic ecosystem (Table 22).

Table 22. Risks to aquatic ecosystem according to ANC value, according to Cosby et al. (2006).

Risk Level	**ANC Range (µeq L^{-1})**	**Effects**
Low	> 100	Generally none; fish and aquatic macroinvertebrates unaffected
Moderate	50 – 100	Fish species richness and macroinvertebrate diversity begins to decline
Elevated	0 – 50	Possible sub-lethal to lethal effects on brook trout populations; large reduction in fish species richness, macroinvertebrate communities; increase in acidophilic aquatic insects
Acute	< 0	Likely extirpation of all fish populations and very low diversity of macroinvertebrate communities and aquatic insects; robust populations of acidophilic aquatic insects

North Carolina and VA do not express standards for ANC, though the EPA Goldbook (1986) recommends values greater than 20 mg L^{-1} $CaCO_3$ for alkalinity to benefit aquatic life. Data for alkalinity at BLRI was only available at 25 stations between 1984 and 1986, during which two-thirds of the observations fell below the NPS ARD recommendation of 200 µeq L^{-1} (NPS WRD 1996).

Copper

Copper toxicity is related to water hardness, which refers to the concentration of polyvalent metallic ions such as Ca^{2+} and Mg^{2+}. With increasing concentrations, these ions generally alleviate the toxicity of copper and other heavy metals in water (EPA 1986). Thresholds are often described as a function of total hardness as $CaCO_3$, as in the case of VA, which specifies a 13 µg L^{-1} absolute limit and 9 µg L^{-1} chronic limit at 100 mg L^{-1} as $CaCO_3$. The standard for NC is 7 µg L^{-1}, which is not expressed as a function of hardness. EPA (1986) indicates that chronic toxicity values for copper span a large range for freshwater species, including concentrations as low as 3.87 µg L^{-1} for brook trout. The EPA Goldbook also outlines copper limits as a function of water hardness. Two limits are outlined—a 4-day average and a 1-hour average—neither of which are to be exceeded more than once every 3 years, which is determined to be the length of time from which a system will recover from a single exceedance of the standard. At 100 mg L^{-1} as $CaCO_3$, these respective limits are 12 and 18 µg L^{-1}. In an update on water quality criteria for copper, the EPA describes a biotic ligand model that provides more precise copper toxicity thresholds based on varying levels of pH, dissolved organic carbon, and water hardness (EPA 2007). At BLRI, copper concentration was measured at 120 stations over the period 1967 to 1995, out of which 9% of the observations at 53 stations reported values higher than 18 µg L^{-1}.

Microorganisms

Bacterial contamination in water is usually determined through measurements of total coliform, fecal coliform, or *Escherichia coli* concentrations. Total coliform bacteria are a group of bacteria that live in the intestines of warm and cold-blooded organisms, and typically are used as indicators of health risks presented by associated viruses and pathogens. Total coliform counts themselves, however, do not necessarily represent a health risk, as many types of coliform bacteria are harmless. Fecal coliform are a subset of total coliform bacteria that exist only in warm-blooded organisms, and may often originate in streams via wildlife feces. Because *E. coli* is a type of fecal coliform that is relatively easy to measure, it is commonly used to indicate fecal contamination.

Standards for different bacterial groups vary according to use, with more stringent values assigned to recreational waterbodies. At BLRI, total coliform was collected at 78 stations over the entire 30-yr period, out of which roughly half exceeded the Water Resources Division indicated threshold of 1,000 colony forming units (CFUs) 100 ml^{-1}. The EPA, VA, and NC do not stipulate criteria for total coliform concentrations. For fecal coliform, VA, NC, and the EPA Goldbook (1986) specify a maximum geometric mean value of 200 CFU 100 ml^{-1}. Virginia adds the additional criteria that, over a calendar month, this limit should not be exceeded more than twice, and that no more than 10% of samples exceed 400 CFU 100 ml^{-1}. Samples at BLRI were collected from 135 stations, of which 100 stations reported exceedances of 200 CFU 100 ml^{-1} for 36% of all observations.

Chloride

For chloride, both NC and VA specify a chloride concentration limit of 230 mg L^{-1} to benefit freshwater aquatic life, while VA additionally outlines a limit of 860 mg L^{-1} for acute conditions. The EPA National Water Quality Criteria (2009) also outline acute and chronic limits of 860 and 230 mg L^{-1}, respectively. Data available at BLRI included the period from 1929 to 1995, wherein measurements were collected at a total of 151 stations. Of these, only a single measurement in the Roanoke River near Roanoke, VA exceeded the EPA and lower state criteria.

Zinc

Like many other metals, the toxicity of zinc is influenced by other water quality parameters, most notably water hardness. As water hardness increases, zinc loses its ability to bind to biological tissues.

Criteria for zinc include a limit of 50 μg L^{-1} in NC, and a limit in VA expressed as a function of water hardness, which is 120 μg L^{-1} at 100 mg L^{-1} as $CaCO_3$,. The EPA National Water Quality Criteria (2009) also recommends chronic and acute zinc limits of 120 μg L^{-1} at 100 mg L^{-1} as $CaCO_3$. Zinc data for the baseline inventory was available from 120 locations over the period 1967 through 1995, of which only 4% of the measurements at 29 locations exceeded the VA freshwater limit of 120 μg L^{-1}.

Temperature

Temperature is an important factor for water quality because it interacts with other parameters. As temperature increases, breakdown of organic material generally accelerates, which can lead to elevated oxygen demand through microbial activity. This, combined with lower solubility of oxygen at warmer temperatures, can quickly lead to oxygen depleted water and reduced survival of sensitive organisms. Higher temperatures also correspond to greater toxicity rates of certain substances (EPA 1986). North Carolina regulates temperatures to a maximum of 29°C (84°F) for mountainous zones and 20°C (68°F) for trout waters, whereas Virginia stipulates three upper temperature limits of 20, 21, and 31°C (68, 70, and 88°F) for natural trout waters, stockable trout waters, and general mountainous zone waters, respectively (VDEQ 2007). Certain fish species, however, can depend on even lower temperatures for growth and survival. Brook trout, an important conservation species occurring in several small streams along BLRI, require temperatures at or below a weekly average of 9°C (48°F) during fall spawning, and short-term averages no higher than 13°C (55°F) to ensure embryo survival (EPA 1986). Although temperature was one of the most common parameters included in data from the baseline inventory, it was not presented as a summary among stations.

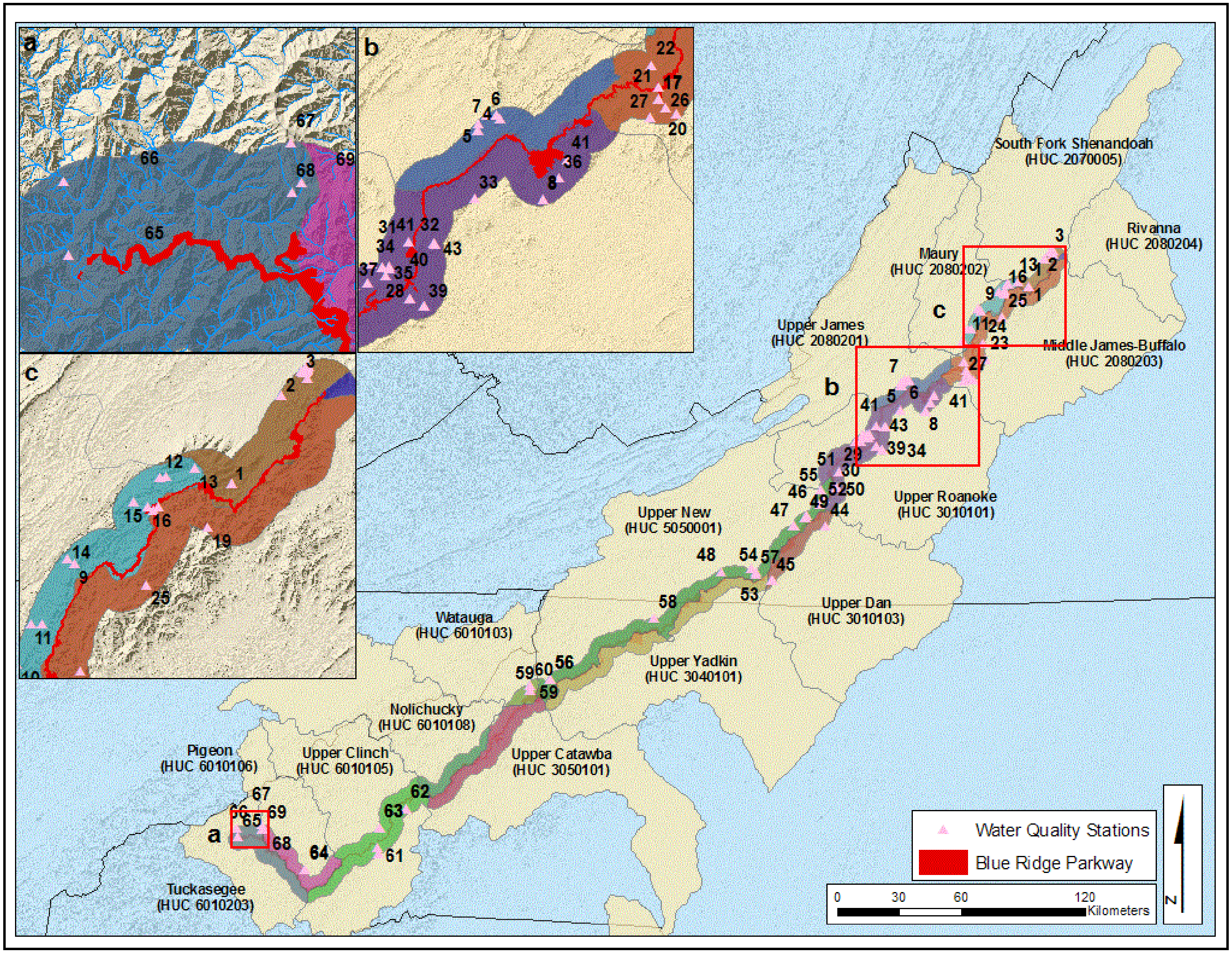

Figure 29. BLRI crosses 15 watersheds along its 755 km route. Within 3 miles of the park boundary, seventy-two sampling stations representing six separate agencies were analyzed using data between 1995 and 2009.

4.4.3 Recent Water Quality Monitoring

Although no data exists for analysis at the park scale, the water quality baseline inventory (NPS WRD 1996) summarized data available in EPA Storet until 1995. The inventory limited sampling data used in the analysis to stations occurring 3 miles (5 km) upstream and 1 mile (2 km) downstream. Since that time, numerous sampling stations have been established by different agencies to collect data within the vicinity of the park unit. Figure 29 shows their distribution along the park unit, where they appear in a clumped arrangement towards each end of the Parkway. Sites included data from six agencies: USFS, VA Dept. of Environmental Quality (VA DEQ), TN Dept. of Environment and Conservation Water Pollution Control Division (TDEC WPC), NC Dept. of Environment and Natural Resources (NC DENR), NPS WRD, and the EPA National Aquatic Resource Survey (NARS). The following section presents each sampling parameter and plot showing the latest data arranged by cataloging unit Table 23 shows IDs and location information for each sampling station. Some sampling locations, such as South River and Looney Creek, were aggregated to a single site ID because samples appeared to be replicates. At other stations the opposite was true, such as the French Broad River, wherein stations were listed with different location coordinates but the same site ID. These classifications were not altered. No attempt was made to place extra emphasis on sites close to the park boundary, either upstream or downstream.

Table 23. Water sampling data from EPAStoret represents 32 stations near BLRI between 1995 and 2009.

	Station ID	Organization	State	Waterbody	County	HUC	Class*
1	80501	USFS	VA	Sherando Lake/Back Creek	Augusta	2070005	-
2	1BBCK000.78	VA DEQ	VA	Back Creek	Augusta	2070005	-
3	1BSTH02-.--[†]	|	VA	South River	Waynesboro	2070005	-
4	2-BAC000.85	|	VA	Back Creek	Botetourt	2080201	-
5	2-ELS000.08	|	VA	Ellis Run	Botetourt	2080201	-
6	2-LMC00-.--[†]	|	VA	Looney Creek	Botetourt	2080201	-
7	2-MIA000.79	|	VA	Mill Creek	Botetourt	2080201	-
8	4ASEE003.16	|	VA	Sheep Creek	Bedford	3010101	-
9	2-ISH000.02	|	VA	Irish Creek	Rockbridge	2080202	-
10	2-MRY005.39	|	VA	Maury River	Rockbridge	2080202	-
11	2-MRY011.86	|	VA	Maury River	Buena Vista	2080202	-
12	2-SMR001.52	|	VA	St. Mary's River	Augusta	2080202	-
13	2-SMR004.80	|	VA	St. Mary's River	Augusta	2080202	-
14	2-STH006.54	|	VA	South River	Rockbridge	2080202	-
15	2-STH014.78	|	VA	South River	Rockbridge	2080202	-
16	VAEQ99-0433	|	VA	Little Mary's Creek	Rockbridge	2080202	-
17	2-HUO000.40	|	VA	Hunting Creek	Bedford	2080203	-
18	2-LIJ003.06	|	VA	Little Mary's Creek	Nelson	2080202	-
19	2BTYS000.85	|	VA	S. Fork Tye River	Nelson	2080203	-
20	2-JMS275.75	|	VA	James River	Amherst	2080203	-
21	2-JMS279.41	|	VA	James River	Amherst	2080203	-
22	2-JMS282.28	|	VA	James River	Amherst	2080203	-
23	2-POL008.53	|	VA	Pedlar River	Amherst	2080203	-
24	2-POL017.59	|	VA	Pedlar Reservoir	Amherst	2080203	-
25	2-PRS003.23	|	VA	S. Fork Piney River	Amherst	2080203	-
26	2-RED000.16	|	VA	Reed Creek	Bedford	2080203	-
27	VAEQ99-0489/2-RED003.65	|	VA	Reed Creek	Bedford	2080203	-
28	4ABAA002.61	|	VA	Back Creek	Roanoke	3010101	-

Table 23. (continued)

	Station ID	Organization	State	Waterbody	County	HUC	Class*
29	4ABNR009.36	|	VA	N. Fork Blackwater River	Franklin	3010101	-
30	4AGCR000.01	|	VA	Green Creek	Franklin	3010101	-
31	4AGLA000.20	|	VA	Glade Creek	Roanoke	3010101	-
32	4AGLA004.39	|	VA	Glade Creek	Roanoke	3010101	-
33	4AGSF002.60	|	VA	S. Fork Goose Creek	Bedford	3010101	-
34	4ALCK002.17	|	VA	Lick Run	Roanoke City	3010101	-
35	4ALCK000.38	|	VA	Unnamed	Roanoke City	3010101	-
36	4ALSA001.40	|	VA	Little Stony Creek	Bedford	3010101	-
37	4AMUR001.63	|	VA	Murray Run	Roanoke	3010101	-
38	4AORE000.19	|	VA	Ore Branch	Roanoke	3010101	-
39	4AROA196.05	|	VA	Smith Mountain Lake	Bedford	3010101	-
40	4AROA202.20	|	VA	Roanoke River	Roanoke City	3010101	-
41	4ATKR000.69	|	VA	Tinker Creek	Roanoke City	3010101	-
42	4ASCB004.58	|	VA	Stony Creek	Bedford	3010101	-
43	NLA06608-R318/4AXKD003.34	EPA NARS/VADEQ	VA	Beaver Dam Reservoir	Bedford	3010101	-
44	4ARBC005.44	|	VA	Rennet Bag Creek	Franklin	3010103	-
45	VAEQ99-0486	|	VA	Dan River	Patrick	3010103	-
46	9-DDD006.61	|	VA	Dodd Creek	Floyd	5050001	-
47	9-DDW000.02	|	VA	W. Fork Dodd Creek	Floyd	5050001	-
48	9-LEF005.25	|	VA	E. Fork Little Reed Island Creek	Carroll	5050001	-
49	9-LRI001.62	|	VA	Little Reed Island Creek	Pulaski	5050001	-
50	9-LRV065.57	|	VA	Little River	Floyd	5050001	-
51	9-LRV069.88	|	VA	Little River	Floyd	5050001	-
52	9-MDR00-.--[†]	|	VA	Meadow Run	Floyd	5050001	-
53	9-RICO49.29	|	VA	Big Reed Island Creek	Carroll	5050001	-
54	9-RICO51.80	|	VA	Big Reed Island Creek	Carroll	5050001	-
55	9-XDM002.81	|	VA	Little River	Floyd	5050001	-
56	K2100000	|	NC	S. Fork New River	Watauga	5050001	C; HQW

Table 23. (continued)

<table>
<tr><th></th><th>Station ID</th><th>Organization</th><th>State</th><th>Waterbody</th><th>County</th><th>HUC</th><th>Class*</th></tr>
<tr><td>57</td><td>VAEQ99-0447</td><td>|</td><td>VA</td><td>Big Reed Island</td><td>Carroll</td><td>5050001</td><td>-</td></tr>
<tr><td>58</td><td>CORN000.1JO</td><td>TDEC WPC</td><td>TN</td><td>Corn Creek</td><td>Johnson</td><td>5050001</td><td>-</td></tr>
<tr><td>59</td><td>L1700000</td><td>|</td><td>NC</td><td>Watauga River</td><td>Watauga</td><td>6010103</td><td>B; Tr:
HQW</td></tr>
<tr><td>60</td><td>L2000000</td><td>|</td><td>NC</td><td>Watauga River</td><td>Watauga</td><td>6010103</td><td>B; Tr:
HQW</td></tr>
<tr><td>61</td><td>E2730000</td><td>NCDENR-DWQ</td><td>NC</td><td>French Broad River</td><td>Buncombe</td><td>6010105</td><td>B</td></tr>
<tr><td>62</td><td>E4030000</td><td>|</td><td>NC</td><td>Beetree Creek</td><td>Buncombe</td><td>6010105</td><td>C</td></tr>
<tr><td>63</td><td>E4170000</td><td>|</td><td>NC</td><td>Swannanoa River</td><td>Buncombe</td><td>6010105</td><td>C</td></tr>
<tr><td>64</td><td>OWW04440-0542</td><td>EPA NARS</td><td>NC</td><td>W. Fork Pigeon River</td><td>Haywood</td><td>6010106</td><td>WS-III; Tr</td></tr>
<tr><td>65</td><td>GRSM_F_0266</td><td>NPS WRD</td><td>NC</td><td>Oconaluftee River</td><td>Swain</td><td>6010203</td><td>C; Tr;
HQW</td></tr>
<tr><td>66</td><td>GRSM_F_0268</td><td>|</td><td>NC</td><td>Oconaluftee River</td><td>Swain</td><td>6010203</td><td>C; Tr;
HQW</td></tr>
<tr><td>67</td><td>GRSM_F_0291</td><td>|</td><td>NC</td><td>Bunches Creek</td><td>Swain</td><td>6010203</td><td>C; Tr;
HQW</td></tr>
<tr><td>68</td><td>GRSM_F_0336</td><td>|</td><td>NC</td><td>Flat Creek</td><td>Swain</td><td>6010203</td><td>C; Tr;
HQW</td></tr>
<tr><td>69</td><td>GRSM_F_0337</td><td>|</td><td>NC</td><td>Bunches Creek</td><td>Swain</td><td>6010203</td><td>C; Tr;
HQW</td></tr>
<tr><td>70</td><td>2-TYE032.71</td><td>VA DEQ</td><td>VA</td><td>Tye River</td><td>Nelson</td><td>2080203</td><td>-</td></tr>
<tr><td>71</td><td>9-DDD006.27</td><td>|</td><td>VA</td><td>Dodd Creek</td><td>Floyd</td><td>5050001</td><td>-</td></tr>
<tr><td>72</td><td>4AXMQ000.07/
4ALOR026.73</td><td>|</td><td>VA</td><td>Little Otter Creek</td><td>Bedford</td><td>3010101</td><td>-</td></tr>
</table>

†Replicate sampling sites along South River, Looney Creek and Meadow Run were each aggregated to single site IDs.
*VA specifies no individual use designations, but instead universal requirements for recreation and aquatic life
Class C = Secondary Recreation, Fishing, Wildlife, Fish Consumption, Aquatic Life, Agriculture, and Fresh Water
Class B = Protected for Class C uses plus Primary Recreation
HQW = Special designation denoting waters with excellent biological and physical chemical characteristics
Tr = Stocked trout designation
WS-III = Water Supply III; Class C plus source of water supply for generally low to moderately developed areas

Acid neutralizing capacity

Samples for acid neutralizing capacity (μeq L^{-1}), were available from nine different stations among five separate cataloging units (Figure 30). Although there are no state standards for this measure in either NC or VA, Cosby et al. (2006) outlined several thresholds linking ANC levels to potential risks to aquatic ecosystems (Table 22). The most comprehensive sampling for this parameter was conducted in the Tuckasegee cataloging unit by stations in the GRSM. These stations conducted roughly bi- to tri-monthly observations from 1996 – 2003, while station #66 at Oconaluftee River collected through 2008. Three of the station means fell below the 100 μeq L^{-1} minimum recommendation for low aquatic risk, placing them in the category for moderate risk, while the other two stations averaged even lower, placing them in the region of elevated risk. At these low levels, populations of brook trout are especially sensitive to acidic stream deposition. The remaining samples available for ANC were collected in 2004 and 2007, though there was only one apiece for each station. These were well above 100 μeq L^{-1} with the exception of W. Fork Pigeon River, which recorded only 52 μeq L^{-1}. Overall, only 5% of the observations were greater than 100 μeq L^{-1}, while 40% fell into the 50 – 100 μeq L^{-1} range.

Alkalinity

As mentioned before, alkalinity is similar to acid neutralizing capacity, except for the difference in sample preparation; samples are filtered for alkalinity tests, but not for ANC. Figure 31 depicts total alkalinity for ten sampling stations in four cataloging units. All sampling histories were sparse, and with the exception of Corn Creek, samples were not available after 1998. The EPA Goldbook (1986) recommends a minimum of 20 mg L^{-1} as $CaCO_3$ to benefit freshwater aquatic life, and samples generally achieve this criterion, with the exception of Corn Creek and Back Creek.

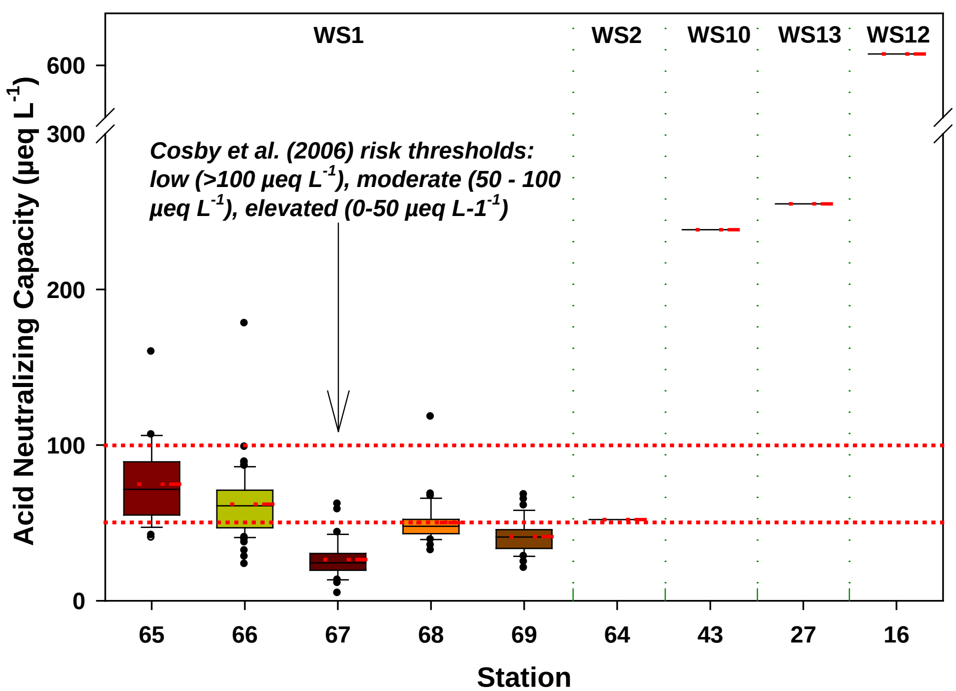

Figure 30. Water quality data summary for ANC at stations along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dashed lines are means.

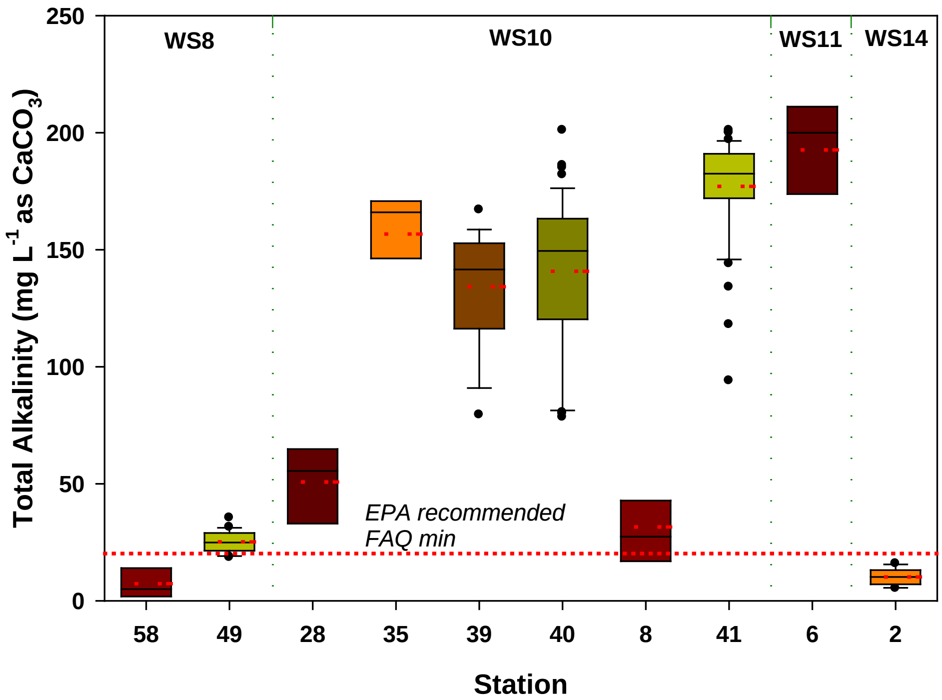

Figure 31. Water quality data summary for alkalinity at stations along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dashed lines are means.

Dissolved Oxygen (DO)

Samples for dissolved oxygen were available from 60 stations among eight separate cataloging units (Figure 32). Measurements were fairly consistent across watersheds, with means for stations typically falling between 8 and 12 mg L^{-1}, and virtually all individual samples falling above the 6 mg L^{-1} trout water NC and VA minimum standard. Sample periods were variable among stations, though stations usually either represented multiple years or just a handful (~10) of sampling points. The lowest station means, both 7.4 mg L^{-1}, were observed in VA at Little River and Stony Creek in Floyd and Bedford Counties respectively, though both were based on a single sample. Of repeated sampling (n = 8), the lowest was 8.1 mg L^{-1} at Pedlar Reservoir in Amherst County, VA, though without a single low measurement of 1.1 mg L^{-1}, the mean is 9.1 mg L^{-1}. Even these lowest mean concentrations, however, are still quite high, and they suggest no chronic issues with low DO at any of the sampling locations. Overall, fewer than 1% of the samples fell below each of the three minimum thresholds.

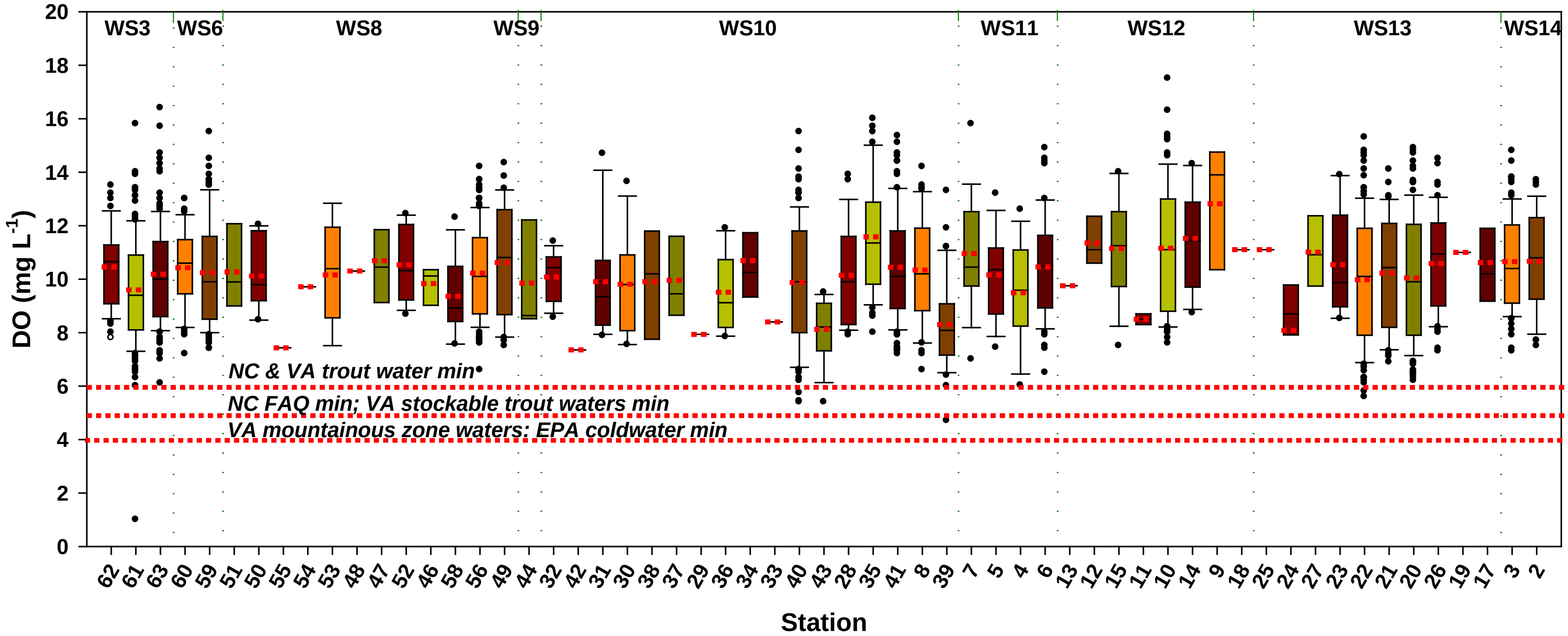

Figure 32. Water quality summary for dissolved oxygen along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dashed lines are means.

pH

Like dissolved oxygen, pH was one of the most thoroughly sampled water quality parameters and was an included measurement during most station visits. Data from 68 individual stations is available, and much again like dissolved oxygen, there is a large range of data periods represented by sampling. Both states specify minimum and maximum values for pH of 6 and 9, respectively, while EPA recommended a minimum of 6.5 to benefit freshwater aquatic life. Three stations recorded multiple samples below 6 SU, including Bunches Creek (#67) in GRSM, the French Broad River, and the Watauga River, though for each these observations only represent a small portion of the dataset. Overall, less than 1% of samples were above a pH of 9.0, 5% of samples fell below 6.5, and around 1% of samples were below 6.0.

Figure 33 depicts summarized pH data from this study as well as an earlier summary by the USGS, which analyzed data between 1945 and 2002. The plot depicting current data (top) is organized roughly linearly from south to north by watershed, while the older USGS data summary organizes stations exactly linearly from south to north. Despite their different data periods, a remarkably similar pattern of increasing pH from south to north is apparent in both plots, and in the current data appears to reach a maximum around 8 SU in the Upper Roanoke watershed in VA. This may likely be due to the changing geology types the Parkway crosses after it enters Virginia, eventually reaching the Rome and Elbrook Formations, which are large geologic striations that include limestone and dolomitic parent material. These formations encompass the northern portions of the Upper Roanoke cataloging unit (WS10), and may contribute to the higher pH values observed starting at that point.

Turbidity

Samples for turbidity were available only for data in the EPAStoret database, and thus represent only 20 stations. North Carolina specifies a limit of 50 NTUs for freshwater aquatic habitat, and a limit of 10 NTUs for trout waters (NCDEQ 2007), while Virginia does not specify a limit for turbidity. Mean turbidity measurements for eight stations exceeded the trout waters maximum, five of which were in the Upper Roanoke cataloging unit (Figure 34). There was also one in the Upper New cataloging unit, and two in the Upper Clinch cataloging unit. None of the station means exceeded the 50 NTU freshwater aquatic limit, though the two stations with high means in the Upper Clinch cataloging unit, both on Little Mary’s Creek, showed repeated samples well above 50 NTUs.

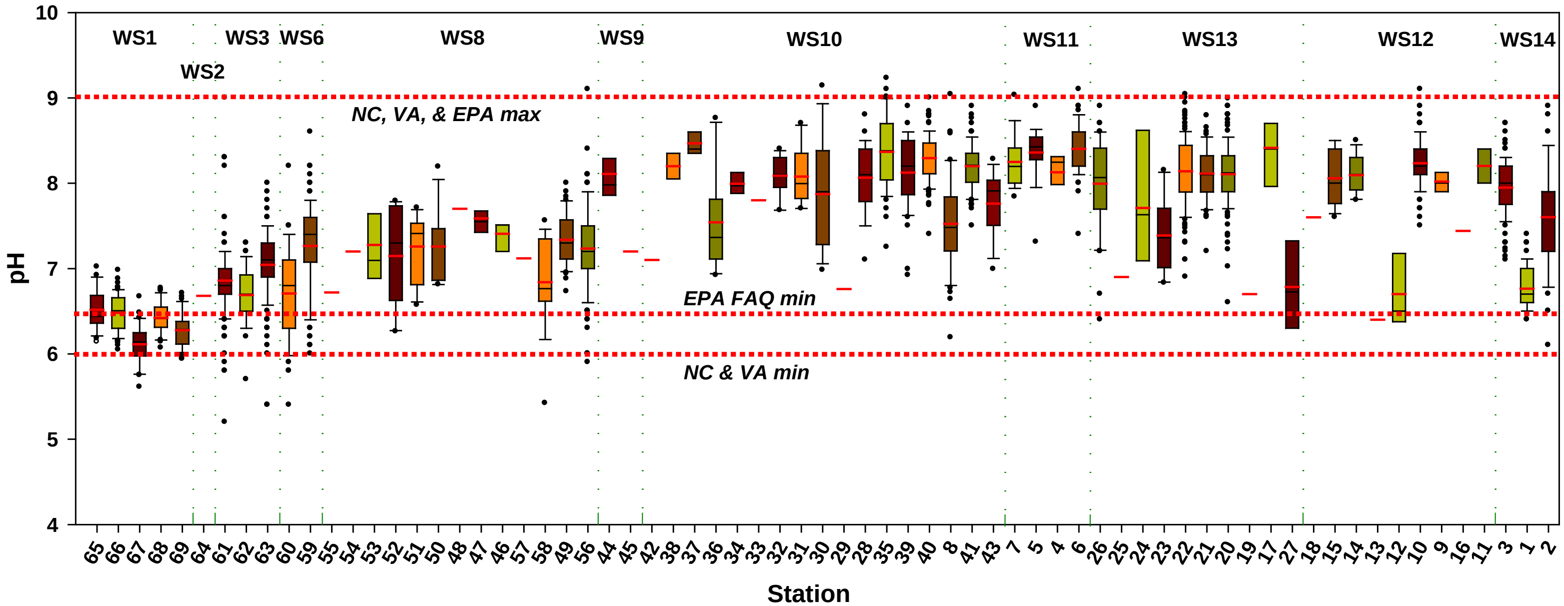

Figure 33. Water quality data for pH along BLRI after October 1995, sorted by HUC8 cataloging unit (top). Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red lines are means.

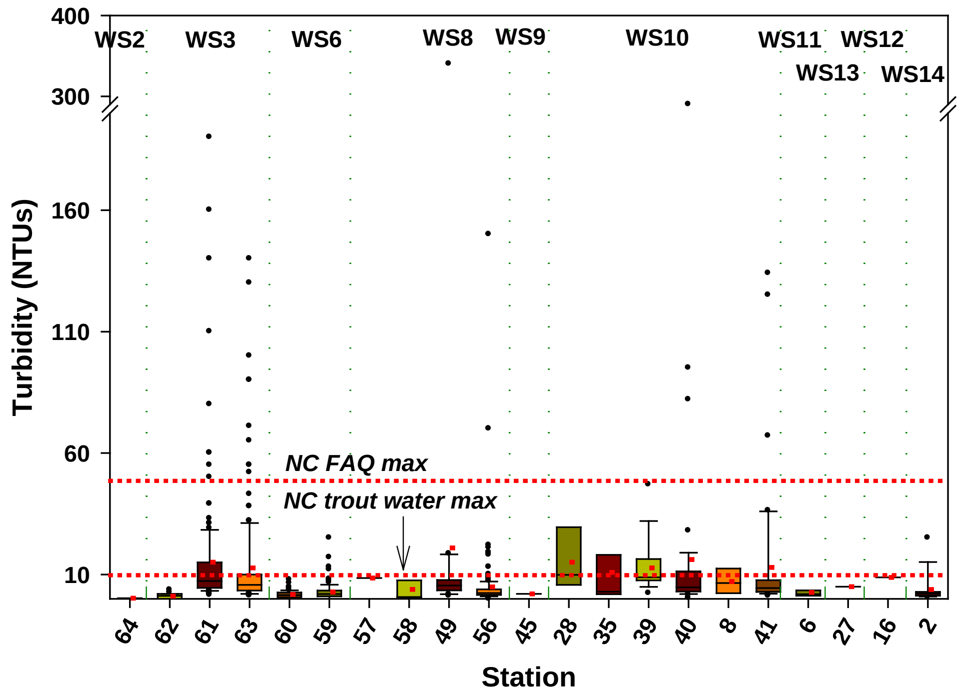

Figure 34. Water quality data for turbidity along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dashed lines are means.

<u>Copper</u>

Only a few samples were available for dissolved copper concentrations, with the most consistent sampling record at the NPS WRD stations in GRSM (Figure 35). As mentioned previously, concentrations of copper that produce toxicity are inversely related to water hardness levels, and as a result state and EPA thresholds are expressed as a function of a standard 100 mg L^{-1} water hardness. North Carolina is the only exception to this, which expresses a maximum concentration of 7 µg L^{-1}, referred to as an "Action Level," above which increased monitoring and mitigation efforts are undertaken by the discharger (NCDENR 2007). Recent EPA criteria updates, however, indicate that copper toxicity thresholds are more precisely determined as a function of alkalinity and dissolved organic carbon (DOC) concentrations instead of water hardness alone (EPA 2007).

Most of the sampling stations only included one or very few observations for dissolved copper, while long periods of sample data were only available for five stations. Three of these stations were in GRSM and averaged approximately 2 µg L^{-1}, though several individual observations were above various thresholds. Repeat sampling was also conducted on one of the two sampling stations along the Watauga River in the Watauga cataloging unit, which recorded several elevated copper concentrations. The highest concentration and overall mean, however, were observed at the S. Fork New River sampling station in the Upper New cataloging unit, based on sampling from 1995-2007. Overall, only 22 observations or 6%, exceeded the VA chronic max of 9 µg L^{-1}, while 32 samples or 8% exceeded the NC "Action Level" maximum.

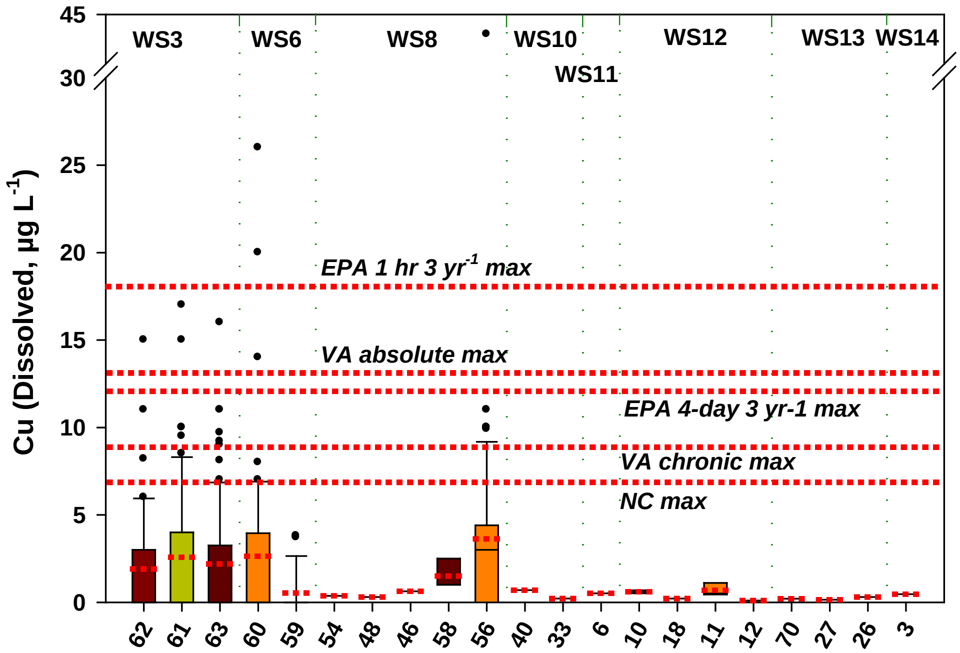

Figure 35. Water quality data for dissolved copper along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers; red dashed lines are means. All limits are expressed for 100 mg L^{-1} hardness with the exception of NC, which does not specify a hardness limit.

Microorganisms

Fecal Coliform

Measurements for fecal coliform were collected sporadically at 51 sampling stations after October 1995. Two assessment methods are commonly used to detect fecal coliform—multiple-tube fermentation (MTF) and membrane filtration (MF), the latter of which is a recently developed method and supposedly offers lower estimate variability (Gronwald and Wolpert 2008). Fecal coliform levels measured using the fermentation method are expressed as a most-probable-number (MPN), while membrane filtration measurements are expressed as colony forming units (CFUs), both per 100 mL. Virginia, North Carolina, and the EPA all specify a maximum geometric mean of 200 per 100 mL, while Virginia additionally stipulates a limit of 400 per 100 mL for 10% of all samples.

Samples are divided among eight cataloging units, with the most extensive set of records coming from the Upper Roanoke. There was no obvious association between sampling methods and minimum detection limits, which are shown in Figure 36. Although samples often were not repeated within a single month as Virginia's standards specify, 22 of the sampling stations with repeat measurements recorded observations above 400 per 100 mL for at least 10% of *all* observations, which included 12 of 18 stations in the Upper Roanoke cataloging unit. Furthermore, nine stations in the Upper Roanoke and 14 stations overall reported geometric mean fecal coliform concentrations greater than 200 per 100 mL. All of the stations showing high coliform concentrations in this unit are located within Roanoke, downstream of BLRI. The only exception was a station sampled by VA DEQ along Sheep Creek, which recorded an overall

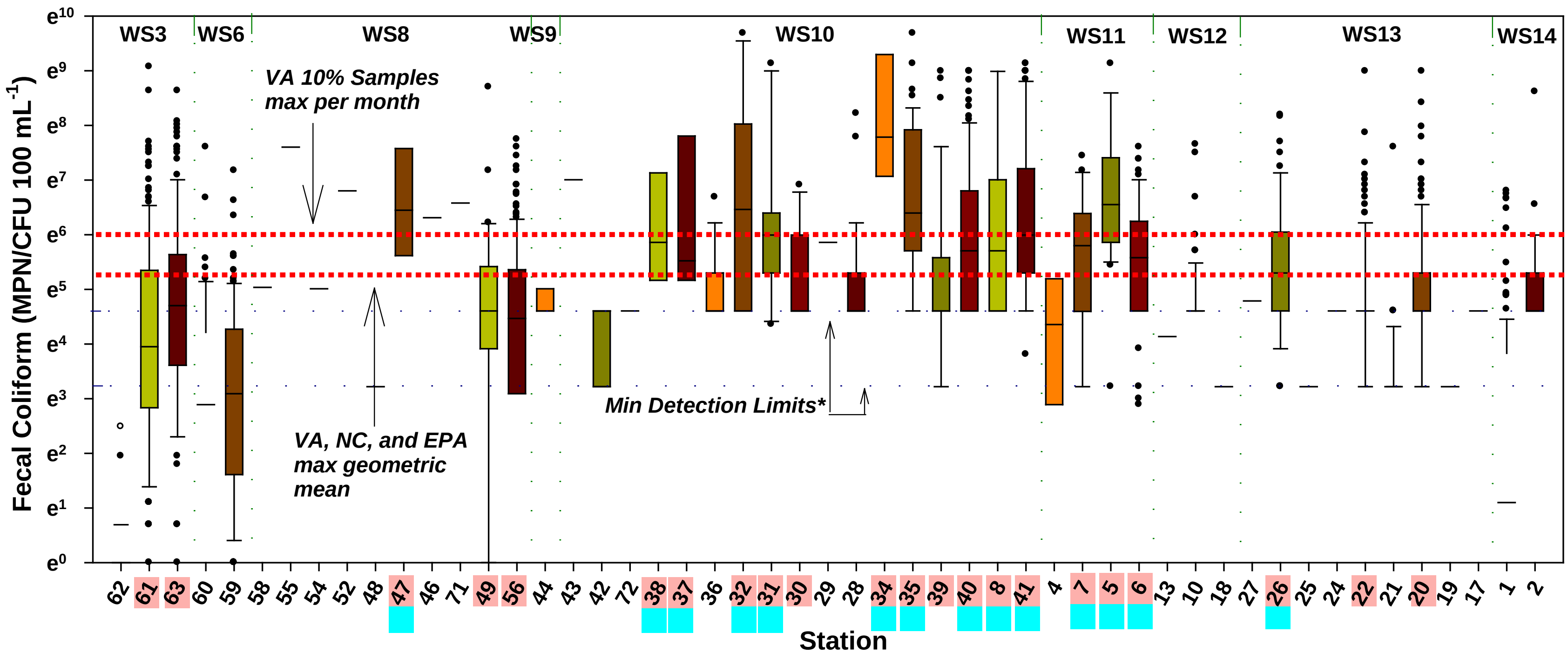

Figure 36. Log-transformed water quality data for fecal coliform along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers. All measurements at stations 52, 42, 18, 25, 24, 19, and 17 were at minimum detection limits and therefore not visible in the plot. Pink station highlights indicate stations with 10% of observations > 400 per 100 mL; blue highlights indicate stations with geometric means > 200 per 100 mL.

geometric mean of 413 per 100 mL with repeated high concentrations during initial years of the sampling period. Starting in 1999, there was a discernible decrease in concentrations at this site through the end of its monitoring period in 2003. Taken only during this latter period, the geometric mean is 161 per 100 mL.

In the Upper James watershed, three of the four sampling stations recorded geometric means above the state and EPA limits, and the same stations measured coliform concentrations above 400 per 100 mL for over 10% of all observations. Once again, each station is located in or around the developed area of Buchanan, VA, wherein instances of agricultural runoff are likely contributors to the elevated coliform concentrations.

Other stations showing histories with repeated elevated fecal coliform concentrations are typically located adjacent to agricultural areas. These include stations along the French Broad and Swannanoa Rivers in the Asheville, NC vicinity, the S. Fork New River near Boone, NC, and Little Reed Island Creek in a rural agricultural area. The Reed Creek station in the Middle James-Buffalo cataloging unit shows consistently elevated concentrations and is located at the intersection of the creek with State Highway 501, which is immediately adjacent to a Georgia-Pacific petroleum refinery in the small town of Big Island, VA. Virtually all of these instances occur well outside the boundary of BLRI, suggesting little influence, if any, of Parkway lands on elevated fecal coliform levels.

E. coli

A total of 38 sampling stations recorded measurements for *E. coli*, with observations typically separated by a period of two to three months. North Carolina does not specify *E. coli* as one of the bacterial water quality indicators, though for secondary contact recreation, VA specifies a geometric mean maximum of 630 per 100 mL for a minimum of two monthly samples, as well as a single sample maximum of 1173 per 100 mL. The EPA Goldbook (1986) specifies *E. coli* criteria only for waters designated for freshwater bathing—a designation inapplicable to waters in BLRI.

Samples for *E. coli* were limited by two pairs of minimum and maximum detection limits, shown in Figure 37. Geometric means calculated over the entire period of data resulted in no values greater than the 630 per 100 mL limit, and five stations reported a single sample exceeding the 1173 per 100 mL VA one-time limit.

<u>Chloride</u>

Chloride was sampled at 20 stations, with the most extensive record available from sites in GRSM (Figure 38). All samples fell below both the chronic and acute maximum criteria for VA, NC, and the EPA, except for the single sample of 378 mg L^{-1} on Little Mary's Creek in the Maury cataloging unit, which exceeded only the chronic maximum.

<u>Zinc</u>

Samples for zinc were collected from 27 stations, though data available for the majority of stations were only represented by a single or very few sampling dates (Figure 39). More extensive datasets were available from stations in the Upper Clinch and Watauga cataloging units. Although all available means for zinc concentrations were well below state and EPA

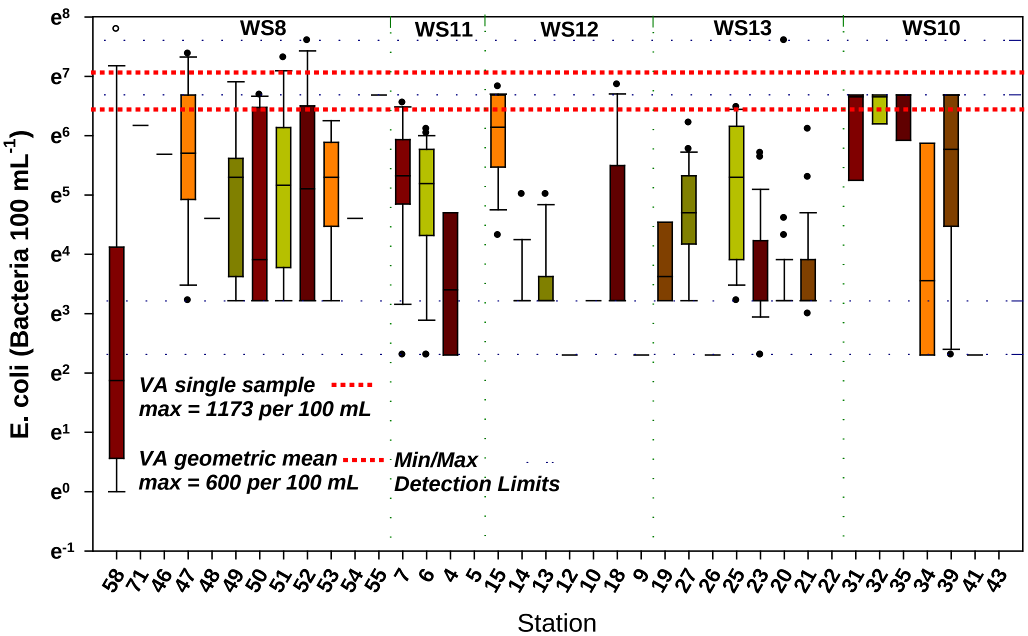

Figure 37. Log-transformed water quality data for *E. coli* along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers. All measurements at stations 13, 12, and 43 were at minimum detection limits and therefore not visible in the plot.

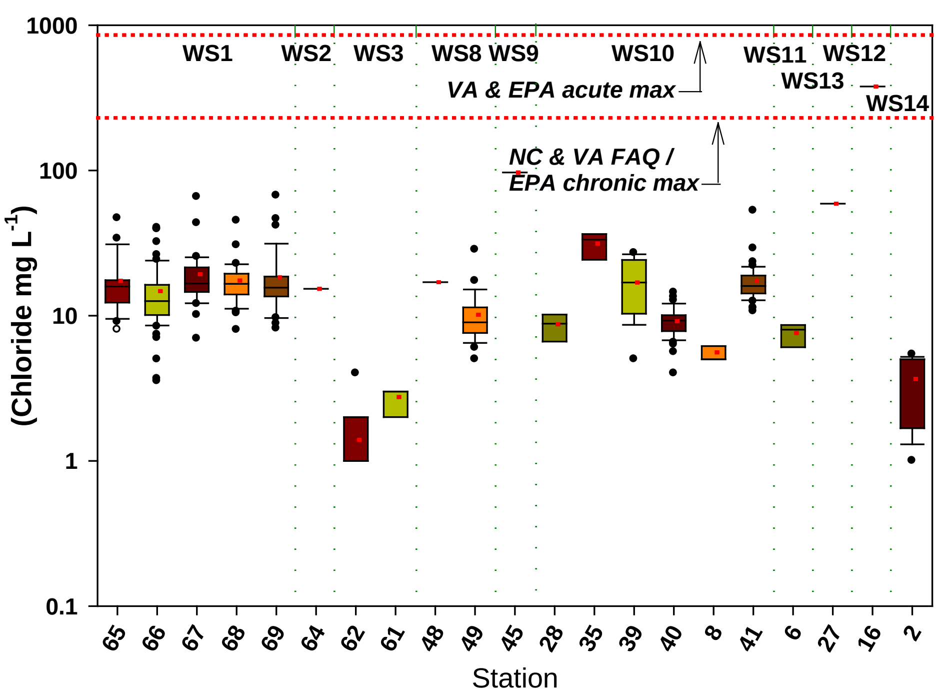

Figure 38. Log-transformed water quality data for chloride along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers.

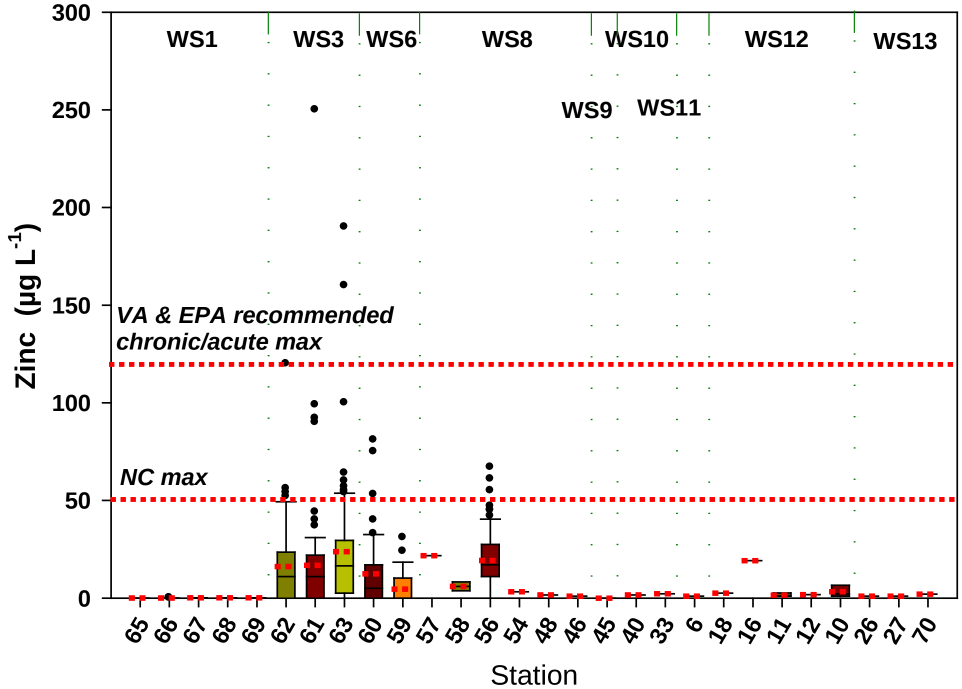

Figure 39. Water quality data for zinc along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers.

standards, stations in the Upper Clinch watershed around Asheville reported several samples above the NC standard. In the Upper French Broad cataloging unit, station means fell below the state and EPA maximum criteria, though each of the three stations recorded observations above both criteria levels. A station along the Watauga River and one on S. Fork New River in the Watauga and Upper New cataloging units, respectively, exceeded the 50 µg L^{-1} NC "Action Level". The VA and EPA criteria is expressed as a function of water hardness, with the 120 µg L^{-1} criterion provided as an example for 100 mg L^{-1} as $CaCO_3$. As a result, it is possible that a greater or fewer number of samples actually exceeded the VA and EPA criteria.

In the Upper New cataloging unit, only the site on the S. Fork New River recorded elevated zinc levels. The surrounding developed region may contribute to loading, especially due to the proximity of an industrial park immediately to the west and the county landfill to the east.
The three stations reporting the highest zinc concentrations in the Upper Clinch cataloging unit are all located in the greater Asheville, NC region. The two sampling stations along Bent Creek are located close to the Fletcher, NC airport and are respectively and immediately upstream and downstream from a Progress Energy coal power plant located on Lake Julian, which was among the top ten NC sources of point-source nitrogen oxide and sulfur dioxide pollution in 2002 (EPA 2011). This site recorded the highest zinc measurement (250 µg L^{-1}) among any of the water quality monitoring stations. The third station on Beetree Creek is located approximately 3 km south of the Craggy Gardens area of the Parkway, just above the Beetree Reservoir and the town of Swannanoa, NC. Although only a single sample exceeded the VA and EPA recommended max at this site, two others exceeded the NC "Action Level" of 50 µg L^{-1}. This site is unique to the others in the cataloging unit because it samples undeveloped headwaters of a mountain

drainage. Only the small Craggy Gardens parking lot and visitor's area is drained into the headwaters area.

Temperature

Temperature observations were common measurements and were available for 63 different stations in nine cataloging units (Figure 40). Although most were repeatedly sampled, only about half were sampled regularly for multiple years. Virginia specifies three maximum temperatures for mountainous zones, stockable trout waters, and natural trout waters, which are 31, 21, and 20°C (88, 70, 68°F), respectively. North Carolina also specifies different criteria for mountainous zones and natural trout waters, which are 29°C and 20°C (84 and 20°F), respectively.

No pattern is visible among the cataloging units or along the latitudinal gradient. Only nine samples exceeded the mountainous zones maximum temperatures, whereas roughly 19% and 24% of all observations were above the stockable trout and natural trout waters maximum, respectively. Of the eight sampling stations located in NC, only three are designated as trout waters, which are indicated in Figure 40. Two stations separated by 2 km on the Watauga River recorded repeated measurements above 20°C (68°F), averaging 15% of all samples between them. A construction aggregate quarry operated by Vulcan Materials Company located approximately 4 km upstream of the northern sampling location could play a role in these elevated temperatures. Quarry ponds are often a source of concern due to the possibility that warmed pit water could flow via groundwater and elevate temperature in cold water streams (Ontario Stone, Sand & Gravel Association 2010).

Specific Conductance

Specific conductance gives an estimate of the amount of dissolved inorganic solids that conduct electricity (EPA 1997). Parent material is one of the main influences on conductance, because bedrock types that do not contribute many dissolved materials, such as granite, can result in a much lower conductivity than materials that freely contribute ionized components, such as limestone (EPA 1997). However, anthropogenic factors such as sewage discharge can also affect conductivity, which may raise or lower conductance from natural levels. As a result, it is difficult to discern the potential for pollution from conductance values alone, and is perhaps more useful to compare measurements to a baseline value.

Conductance is measured as the reciprocal of resistance and expressed in micro-Siemens per cm (µS/cm). Although no state standards exist for this parameter, the EPA (1997) sampling methods manual identifies 50 to 1500 µS/cm as typical for waters in the US. It also outlines an ideal range of 150 to 500 µS/cm for "inland fresh waters…supporting good mixed fisheries," and furthermore suggests that "conductivity out of this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates."

Sampling data was available from 50 stations in six cataloging units, with some notable differences between cataloging units (Figure 41). Though data was available from ten stations in the Upper New cataloging unit, periods of record were consistently sparse. All station means, however, were below the EPA recommended minimum of 150 µS/cm, which may be due in part to the biotitic. Around half the stations in each of the Upper Roanoke, Middle James-Buffalo, and Maury cataloging units averaged in the recommended range, as did three of the four stations

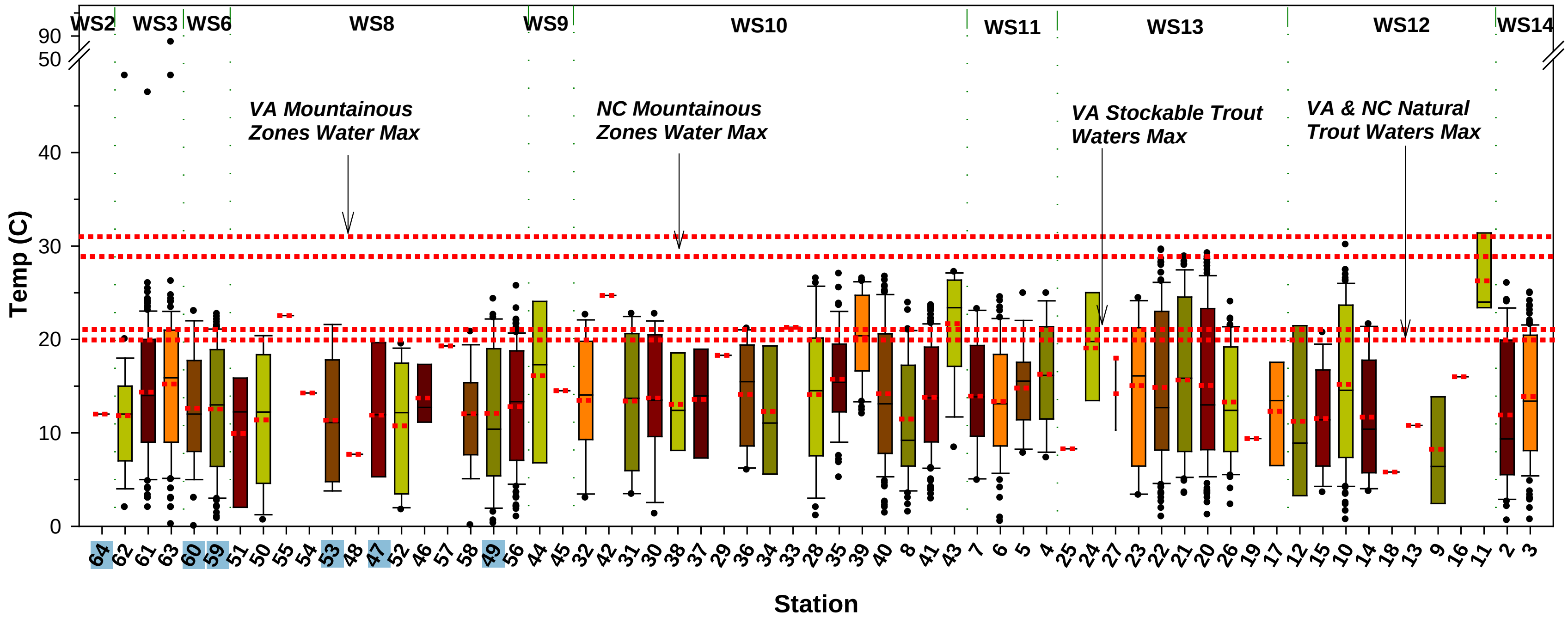

Figure 40. Water quality data for temperature along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers. Blue highlights indicate state trout water streams.

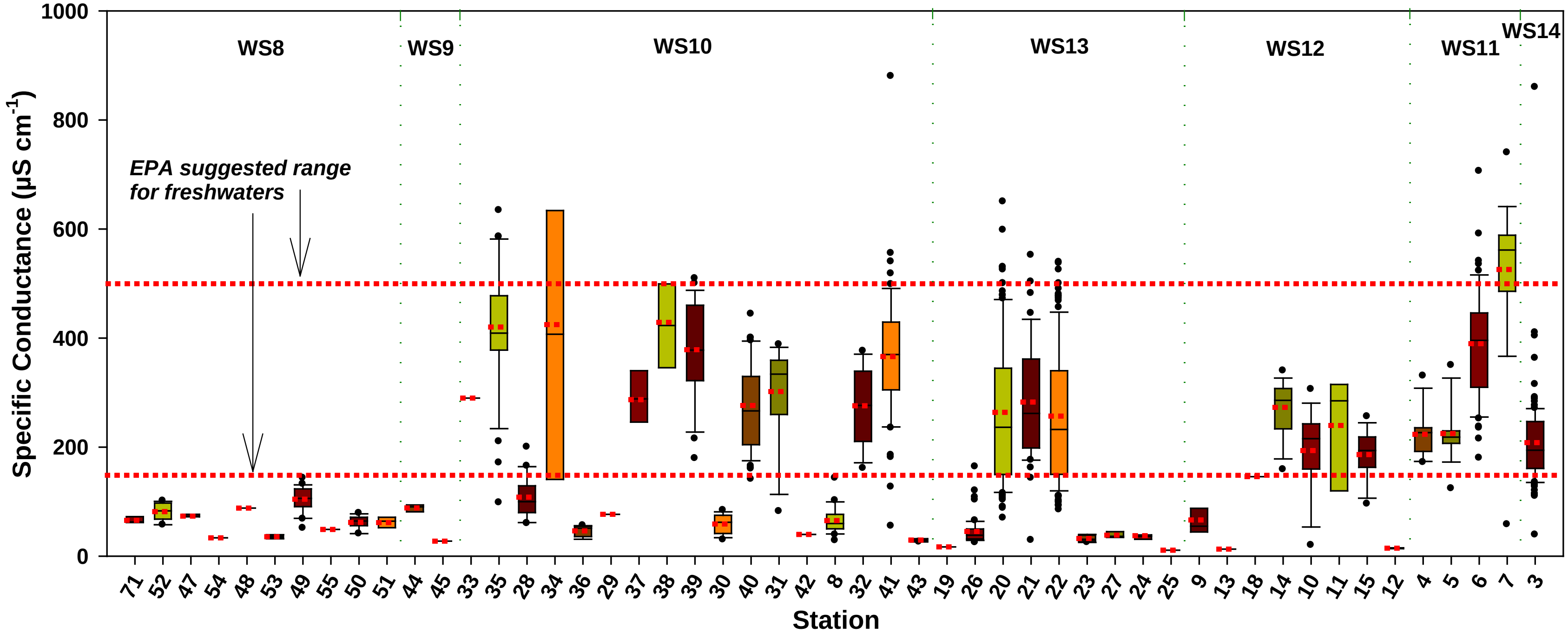

Figure 41. Water quality data for specific conductance along BLRI after October 1995, sorted by HUC8 cataloging unit. Numbered stations correspond to sampling locations as indicated in Table 23 and Figure 29. Boxes correspond to quartiles; whiskers correspond to 90 and 10 percentiles. Points represent outliers.

in the Upper James cataloging unit and the single station in the South Fork Shenandoah unit. The station on Mill Creek averaged 526 µS/cm over its three-year monitoring period and was the only station whose mean conductance exceeded the recommended range. Overall, roughly one-third of conductance observations fell below 50 µS/cm, while 5% exceeded 150 µS/cm.

4.4.4 Cataloging Unit Summary

Although BLRI crosses over portions of 15 separate cataloging units, sampling data available from EPAStoret and VADEQ were only available from 11 of the units. Sampling data from NCDENR did not include any stations within the 3-mile buffer for BLRI as it did for VADEQ. As a result, sampling stations are clumped in the northern half of the park in VA. A summary of available water quality information following the 1996 baseline inventory, along with a condition status, is presented for each cataloging unit. Because the Parkway mostly follows the ridgeline, sampling locations are often situated downstream, which also benefits park water quality by minimizing effects due to urban runoff and other contaminants.

<u>Tuckasegee - 06010203</u>
The southernmost cataloging unit includes the terminus of the Parkway at GRSM, including sampling from five stations within the national park. These stations sample the Oconaluftee River, Bunches Creek, and Flat Creek, all of which are classified as trout streams in NC. In a study on acidic deposition and fish populations in GRSM, Neff (2010) shows that the sampled stretch of the Oconaluftee River is home to both rainbow trout and brown trout, whereas the other two streams are classified solely as brook trout streams. Sampled parameters included pH, ANC, chloride, and zinc. Of note were the low observed pH values, which averaged the lowest among all 68 stations analyzed. Three of the five stations averaged pH values below the minimum EPA recommended value for freshwater aquatic life. The mean for the other two stations barely exceeded the minimum. These low values, along with the apparent gradation towards less acidic values in the northern section of the Parkway, suggest the influence of parent material on pH.

These five sites were the only ones with consistent ANC monitoring records, which showed relatively low mean values. These values fell within the range from moderate to elevated concern as outlined by Cosby et al. (2006), wherein they caution of repressed fish species richness and macroinvertebrate communities. Additional ANC samples by the USFS on Bunches Creek also showed moderate ANC levels (R. Emmott personal communication). Part of the description of the underlying geology for these sites, however, includes calcium-silicate rock, which, in sufficient amounts, would tend to raise conductance and ANC levels, and in turn the pH levels. It is possible these stations may occur on other geologic striations that do not include much calcium-silicate content, or it could be other factors, such as acidic deposition, that contribute to the higher observed acidity levels. As previously discussed, rates of acid deposition are high at GRSM and in the Southern Appalachians in general (Neff 2010).

Monitoring for the other parameters—chloride and zinc—showed consistently low and safe levels for each site according to EPA and state specifications. Based on the available monitoring data, the Tuckasegee cataloging unit receives a condition status of fair (Table 24) due mainly to the acidic nature of the waters. In addition, ANC values were relatively low, compounding the risk of acidic atmospheric deposition that already poses a risk in this region. The quality of the data used to make the assessment was fair (Table 24). The spatial category did not receive a checkmark because most sampling locations were outside park boundaries. No trend was assigned to water quality condition because data were insufficient to determine trend.

Table 24. The water quality condition of the Tuckaseegee cataloging unit (06010203) was fair. The quality of the data used to make the assessment was fair. No trend was assigned to water quality condition.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
06010203: Water Quality	Fair (yellow circle)	✓		✓
		2 of 3: Fair		

Pigeon – 06010106

Data available in the Pigeon cataloging unit consisted of samples for pH, turbidity, ANC, chloride, and temperature collected at a single site on a single sampling visit during fall 2004. Samples were collected on the W. Fork Pigeon River, which forms from the confluence of Buckeye Creek and Haywood Gap Stream about 1 km from the Parkway. Samples were collected at a site approximately 7 km downstream from this confluence. This section of river is classified by NCDENR as a trout stream as well as a high-quality water.

The sample for ANC placed it within the moderate risk threshold according to Cosby et al. (2006), whereas the measurements for pH, turbidity, chloride, and temperature all fell within state criteria and EPA recommended guidelines. Additional USFS sampling on West and East Fork Pigeon River has shown relatively low ANC values, especially in headwater areas (R. Emmott personal communication). Because we chose to assess water quality at the HUC8 level, the Pigeon cataloging unit receives a condition status of good (Table 25). It is highly impractical, however, to base the condition status for the cataloging unit on the results of a single site visit, and thus this ranking should be considered with caution. The condition of the data used to make the assessment was poor (Table 25), and interpretation of this assessment warrants particular caution. The thematic and spatial categories did not receive checks because the sampling location was located outside park boundaries and because the amount of relative data was very low.

Table 25. The water quality condition of the Pigeon cataloging unit (06010106) was good. The quality of the data used to make the assessment was poor. No trend was assigned to water quality condition. The asterisk indicates special caution when interpreting this condition because of the poor condition of the data quality.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
06010106: Water Quality	Good (green circle) *			✓
		1 of 3: Poor		

Upper Clinch – 06010105

Data in the Upper Clinch cataloging unit was collected at three sampling stations and included measurements for dissolved oxygen, pH, turbidity, copper, fecal coliform, chloride, zinc, and temperature. For the most part, sampling records consisted of reliable multi-year datasets. Samples were collected on the French Broad River, Swannanoa River, and Beetree Creek, the latter of which is classified as a state high quality water.

Dissolved oxygen appeared consistent among sites with a mean among all three stations close to 10 mg L^{-1}. Only a single sample fell below the three recommended EPA and state minima for mountainous and trout waters. Samples for pH were highly variable, averaging between 6.5 and 7.0 among sites, though a few samples fell below state standards, and roughly 10% fell below EPA recommended minimum. Turbidity data was more extensive for the French Broad and Swannanoa Rivers, where approximately 6% of collective samples exceeded the NC maximum for freshwater and aquatic life. Sample schedules were nearly identical for this pair of stations from 1995 to 2009, and roughly a third of exceedances occurred on common sampling dates between sites, suggesting storm events. The remaining exceedances may be due to local disturbances.

Virtually no indication of bacterial contamination was detected on Beetree Creek during four years of sampling, whereas fecal coliform concentrations were often elevated on the Swannanoa and French Broad Rivers from the period 1995-2009. Despite these high values, they did not exceed the state and EPA standard for maximum geometric mean.

Samples were similar at all three stations for copper, wherein roughly 9% exceeded the NC “Action Level” maximum. Chloride sampling was minimal, and no elevated values were observed on Beetree Creek between 1995 and 1999. Zinc monitoring was more extensive and included the period from 1995 to 2007 for the Swannanoa and French Broad Rivers and from 1995 to 1999 for Beetree Creek. For the longer datasets, zinc concentrations appear to decline from 1995 through 2000 and hold steady at minimal levels through 2007. Each station exceeded the NC “Action Level” a few times, though most often on the Swannanoa River. Frequencies of exceedance were 10%, 5%, and 11% for Beetree Creek, the French Broad River, and Swannanoa River, respectively. However, since 2000, only 3% of collective samples exceeded the limit.

Finally, temperature was recorded following the same schedule as fecal coliform. Mean temperatures were quite low among stations, with virtually no exceedances of the NC mountainous zones maximum temperature.

Overall, water quality in the Upper Clinch cataloging unit appears good (Table 26). Observations for temperature and dissolved oxygen, in particular, reflect relatively high quality waters. Though measurements demonstrate past issues with zinc and copper contamination, concentrations of these metals have decreased over time. A persistent issue, however, is the frequency of elevated coliform values on the two larger rivers, though no standards were violated. The quality of the data used to make the assessment was fair (Table 26). The spatial category did not receive a checkmark because most sampling locations were outside park boundaries. No trend was assigned to water quality condition because data were insufficient to determine trend.

Table 26. The water quality condition of the Upper Clinch cataloging unit (06010105) was good. The quality of the data used to make the assessment was fair. No trend was assigned to water quality condition.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
06010105: Water Quality	Good	✓		✓
		2 of 3: Fair		

Watauga – 06010103

Sampling data in the Watauga cataloging unit is informed by two stations located on the Watauga River, which is listed as both a trout water and high quality water in NC. The stations are downstream from Moody Mill Creek, Bee Tree Creek, and Boone Fork, all of which pass through the Julian Price and Moses H. Cone Memorial Park sections of the Parkway before feeding into the Watauga River. Available data includes samples for dissolved oxygen, pH, turbidity, copper, fecal coliform, zinc, and temperature. Sampling was not concomitant between stations, but instead ended at the downstream station in 2000 and resumed at the new site about 3 km upstream.

Samples for dissolved oxygen were very similar to each other, with no samples falling below state or EPA criteria. Although there was no overall apparent trend, there was an annual cyclical pattern likely associated with rainfall wherein dissolved oxygen was higher during winter months. Samples for pH averaged approximately neutral over the entire monitoring period, though roughly 18% of samples fell below the EPA minimum for freshwater aquatic life. Turbidity was also low, exceeding the state trout waters limit only four times from 1995 to 2009. Copper samples exceeded the NC standard only four times from 1995 to 2009.

Samples for fecal coliform had periodic highs, though overall they did not exceed maximums for state or EPA criteria. Zinc measurements exceeded the NC state standard for three consecutive monthly samples in 1997, suggesting the possibility of a single contamination event. After that period, no exceedances were recorded. Finally, though temperatures averaged well below state standards over the course of monitoring, most summer measurements, totaling 15% of all samples, exceeded the state criteria for trout waters. Overall, most samples generally adhered to state and EPA criteria, and thus the condition status of the cataloging unit is good (Table 27). The notable exception to this was pH, which fell below EPA criteria several times before 2003. However, like the Pigeon cataloging unit, the condition of this unit should be taken lightly due to the paucity of sampling stations. The condition of the data used to make the assessment was poor (Table 27), and interpretation of this assessment warrants particular caution. The thematic and spatial categories did not receive checks because the sampling location was located outside park boundaries and because the amount of relative data was very low.

Table 27. The water quality condition of the Watauga cataloging unit (06010103) was good. The quality of the data used to make the assessment was poor. No trend was assigned to water quality condition. The asterisk indicates special caution when interpreting this condition because of the poor condition of the data quality.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
06010103: Water Quality	Good *			✓
		1 of 3: Poor		

Upper New – 05050001

The Parkway shares its border with the Upper New longer than any other cataloging unit it passes through. It spans the NC-VA border, and is represented by 13 stations, most of which are clustered in the northern section. Stations on W. Fork Dodd Creek, Big Reed Island Creek, and Little Reed Island Creek are classified as state trout waters. Sampling data includes measurements for dissolved oxygen, pH, turbidity, copper, fecal coliform, *E. coli*, chloride, zinc, temperature, alkalinity, and specific conductance. Measurements fell mostly within range of state and EPA criteria at all stations for DO, pH, and chloride. One notable issue was high turbidity values on Little Reed Island Creek, which has more restrictive criteria due to its trout water classification. Though the site is located in VA, which does not specify criteria for turbidity, around 20% of observations exceeded the NC standard for trout waters. The S. Fork New River, located just outside Boone, NC recorded notably higher copper and zinc concentrations than other Upper New stations, which as mentioned earlier, might be due to its proximity to the industrial park and county landfill. These metal concentrations exceeded state standards 12% and 4% of the time, respectively. Both appear to be decreasing over the history of monitoring, though only zinc demonstrates a significant negative trend ($p = 0.0004$).

Fecal coliform was an issue at Little Reed Island Creek and W. Fork Dodd Creek, where both exceeded the state standard and the latter exceeded the EPA criterion. Measurements at Little Reed Island Creek also exceeded trout water temperature maximums for almost a quarter of the measurements, though these measurements were during summer months and likely reflect natural conditions. Alkalinity measurements were consistently above the EPA recommended minimum on Little Reed Island Creek, though minimal sampling on Corn Creek showed low values.

Low dissolved solids are pervasive throughout the Upper New cataloging unit, resulting in specific conductance values below the minimum EPA suggested range at all stations. Although all sampling records were relatively brief for this parameter, variability at each site was low.

Overall, Little Reed Island Creek showed the most issues, though its perhaps most substantial problem—high heavy metal concentrations—seems to have alleviated in recent years. Of concern, however, are the elevated fecal coliform concentrations and turbidity values. As a whole, the Upper New receives a condition status of good (Table 28). The quality of the data used to make the assessment was fair (Table 28). The spatial category did not receive a checkmark because most sampling locations were outside park boundaries. No trend was assigned to water quality condition because data were insufficient to determine trend.

Table 28. The water quality condition of the Upper New cataloging unit (05050001) was good. The quality of the data used to make the assessment was fair. No trend was assigned to water quality condition.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
05050001: Water Quality	Good (green circle)	✓		✓
		2 of 3: Fair		

Upper Dan – 03010103

The Upper Dan cataloging unit contains very little data, with only two sampling locations on Rennet Bag Creek and the Dan River, the latter of which was only sampled on a single date and the only one classified as a trout water. Rennet Bag Creek, however, is stocked by the Virginia Department of Game and Inland Fisheries (VDGIF) with rainbow and brown trout. Samples indicate normal values for most parameters sampled, including dissolved oxygen, pH, turbidity, fecal coliform, chloride, and zinc. Samples for temperature exceeded the VA stocked trout waters maximum on Rennet Bag Creek for two out of six samples over the course of two years. Both times were during summer months. All samples at both sites fell below the freshwater EPA recommended minimum for specific conductance. Despite these observations, however, the Upper Dan receives a condition status of good (Table 29), with a cautionary warning due to the scarcity of data. The condition of the data used to make the assessment was poor (Table 29), and interpretation of this assessment warrants particular caution. The thematic and spatial categories did not receive checks because the sampling location was located outside park boundaries and because the amount of relative data was very low.

Table 29. The water quality condition of the Upper Dan cataloging unit (03010103) was good. The quality of the data used to make the assessment was poor. No trend was assigned to water quality condition. The asterisk indicates special caution when interpreting this condition because of the poor condition of the data quality.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
03010103: Water Quality	Good (green circle) *			✓
		1 of 3: Poor		

Upper Roanoke – 03010101

Whereas BLRI follows the divide between cataloging units for the majority of its length, the Upper Roanoke cataloging unit is unique in that the Parkway bisects through its center, traveling through the valley around the city of Roanoke, VA. Much of the sampling data available in this unit was collected in and around Roanoke. Due to the lower elevation of the Parkway in this unit, many streams have more extensive upstream courses before passing through the park, which can lead to certain water quality issues. Although many sampling stations in this unit have short data records, the seventeen sampling sites provide the most extensive distribution of locations among cataloging units. Stations on N. Fork Blackwater River, Green Creek, Tinker Creek, and Glade Creek are listed as state trout waters.

Samples for dissolved oxygen averaged around 10 mg L^{-1} for most stations with repeat sampling, with the exception of Smith Mountain Lake and Beaver Dam Reservoir. These lower DO values are not unexpected of lentic waters. Samples for pH were somewhat variable among sampling locations, though all repeat sampled locations averaged alkaline values. Some of the consistently alkaline values were observed at an unnamed channelized tributary to Tinker Creek in urban Roanoke. The sampling station on Tinker Creek was the only station whose mean during four years of sampling exceeded turbidity criteria due to its status as a trout water. This is most certainly influenced by the urban setting of the creek.

Single measurements for copper and zinc at both the Roanoke River and S. Fork Goose Creek showed no issues of contamination. Minimal sampling for chloride at six sites also revealed consistently low levels.

Samples for fecal coliform were available from all locations in the cataloging unit, and outlined quite a number of problems at the majority of stations. Eleven and nine total stations respectively exceeded the state 10% maximum and maximum geometric mean standards (Figure 36). Stations exceeding the more stringent geometric mean standard are not surprisingly located in the city of Roanoke. The only exception is Sheep Creek in the northern section of the cataloging unit, which is fed by several upstream tributaries beginning in BLRI. Pastureland predominates in the valley area surrounding this station, which may contribute to the high coliform levels observed. Samples for *E. coli* mostly confirmed this pattern, with highest concentrations found inside the city. Though no stations exceeded state standards for *E. coli*, this was likely due a maximum detection limit that was barely higher than the state geometric mean maximum, and lower than the state single sample maximum. As a result, it is likely that actual *E. coli* concentrations were higher, and potentially exceeded both state standards on Glade Creek, Smith Mountain Lake, and the unnamed channel of Tinker Creek.

Although all observations for temperature fell below the VA state standard for mountainous zones, Glade Creek and Tinker Creek exceeded the lower trout water maximum temperatures. The mean at Tinker Creek was low, though samples regularly exceeded the trout water maximum during each year of from 1995 to 2003. Stations on Glade Creek located about 7km apart demonstrated the same pattern of summer exceedances, though data was only available for three years.

Alkalinity data was collected at six stations, all of which showed means above the EPA recommended minimum. Specific conductance was more of a mixed bag. Means at nine stations with repeat sampling fell into the EPA recommended range for freshwaters, while means at five stations showed low means with minimal variability.

Overall, the most concerning problem within this cataloging unit is the prevalence of elevated fecal coliform values. This is compounded by the fact that these sampling locations are on streams that ultimately flow into the Roanoke River, which passes through the park immediately adjacent to the city. As a result of these observations, the Upper Roanoke cataloging unit receives a condition ranking of fair (Table 30). The quality of the data used to make the assessment was fair (Table 30). The spatial category did not receive a checkmark because most sampling locations were outside park boundaries. No trend was assigned to water quality condition because data were insufficient to determine trend. Additional sampling where BLRI crosses the Roanoke River might be useful to determine the quality of water where it flows out of the city and enters the park.

Table 30. The water quality condition of the Upper Roanoke cataloging unit (03010101) was fair. The quality of the data used to make the assessment was fair. No trend was assigned to water quality condition.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
03010101: Water Quality	● (fair)	✓		✓
		2 of 3: Fair		

Upper James – 02080201

The Parkway skirts the Upper James cataloging unit just briefly before continuing into the Middle-James Buffalo unit. Sampling data comes from stations on four small runs around the town of Buchanan, VA, none of which are classified as trout waters. Parameters were fairly consistently among stations, though Looney Creek received additional attention. Data for DO, temperature, and pH fell within range of state and EPA criteria for all four stations. Specific conductance values were remarkably higher on Looney and Mill Creeks than the other two stations, with mean values on Mill Creek above the EPA recommended maximum. Sampling was also conducted at each station for fecal coliform, though very minimally at Back Creek. These results showed often elevated values at the other three sites, the geometric means of which all exceeded state and EPA criteria. Coliform levels were particularly high on Ellis Run, for which two-thirds of samples over three years of data exceeded 400 CFU per 100 mL. Virginia standards stipulate no more than 10% of samples should exceed this concentration. Some samples were also collected for *E. coli*, which revealed a range of values, though no stations exceeded state standards.

Other parameters with minimal sampling histories included turbidity, copper, chloride, and zinc, all of which fell within the range for state standards but were only sampled on Looney Creek. In the case of alkalinity, values over a year of sampling resulted in the highest mean of any station along the Parkway; all samples were well above the EPA recommended minimum for freshwater aquatic life. Recent sampling by USFS in upper reaches close to the Parkway also showed high ANC values (R. Emmott personal communication).

Overall, due to history of elevated coliform concentrations, the Upper James cataloging unit receives a condition status of fair (Table 31). Multiple years of sampling showed concentrations exceeding both VA standards and EPA criteria for three of the four sampling locations. Sites, however, were all located near one another and downstream from the Parkway. The quality of the data used to make the assessment was fair (Table 31). The spatial category did not receive a checkmark because most sampling locations were outside park boundaries. No trend was assigned to water quality condition because data were insufficient to determine trend.

Table 31. The water quality condition of the Upper James cataloging unit (02080201) was fair. The quality of the data used to make the assessment was fair. No trend was assigned to water quality condition.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
02080201: Water Quality	◯ (fair)	✓		✓
		2 of 3: Fair		

Maury – 02080202

The Maury cataloging unit is fairly well-represented by sampling data despite the small area the Parkway occupies within it. Two of the streams, Little Mary's Creek and St. Mary's River, are classified as state trout waters, while the South River is a stocked trout water.

Samples for DO and pH were within normal range for stations except on St. Mary's Creek, which were noticeably lower. Single samples at Little Mary's Creek for turbidity and ANC were normal. Periods of brief copper and zinc monitoring revealed no issues at five and four sites, respectively, and three sites sampled for fecal coliform also showed no issues, though repeat sampling on the Maury River recorded occasional elevated concentrations. Most samples at this site were recorded at the minimum detection limit, however, suggesting the absence of chronic contamination. Additional *E. coli* sampling also showed no issues. A single chloride sample at Little Mary's Creek was elevated, but it did not exceed the state/EPA acute maximum criteria.

Temperature data mostly fell within state regulated range, though stations on St. Mary's River and South River recorded some samples above the state trout waters limit. ANC values collected by USFS at several locations on St. Mary's River were also low (R. Emmott personal communication). Samples on the Maury River were the highest in the cataloging unit for temperature, though they only exceeded the state standard for one measurement.

The final parameter with data was specific conductance, and at stations with respectable collection histories, average values were within the EPA recommended range. Stations at St. Mary's River, Little Mary's Creek, and Irish Creek recorded lower values, below the recommended range.

Overall, water quality data available in this cataloging unit appears good (Table 32), with no evidence of chronic issues. As is the case with the other cataloging units, some stations were missing several parameters or were minimally sampled, leaving some uncertainty to the nature of the site. St. Mary's Creek, for example, though informed by two sampling locations, has a history of water quality issues, including impacts from intense mining and an experimental phase involving dichlorodiphenyltrichloroethane, commonly known as the controversial pesticide DDT. The creek is susceptible to acidic waters from atmospheric deposition, although the lithology of the area also contributes. Lime supplements were added in 1999 to help neutralize waters, though as mentioned earlier and as shown in Figure 33, the waters are demonstrably more acidic than others in the same cataloging unit (VA DGIF 2011). The quality of the data used to make the assessment was fair (Table 32). The spatial category did not receive a checkmark because most sampling locations were outside park boundaries. No trend was assigned to water quality condition because data were insufficient to determine trend.

Table 32. The water quality condition of the Maury cataloging unit (02080202) was good. The quality of the data used to make the assessment was fair. No trend was assigned to water quality condition.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
02080202: Water Quality	Good (green circle)	✓		✓
		2 of 3: Fair		

Middle James-Buffalo – 02080203

Sampling data in this cataloging unit is available at ten different stations on six different stream segments. State classified trout waters include the S. Fork Tye River and S. Fork Piney River. Data was fairly comprehensive for the core parameters of DO, pH, temperature, and specific conductance, though for other parameters was extremely sparse and most often only involving a single sample. Turbidity, chloride, copper, and zinc were all within range of state and EPA criteria though reflected only single samples. A single measure for ANC on the James River was quite high, while USFS measures for upstream tributaries of the Parkway were mixed but mostly relatively low. Fecal coliform samples were minimal at most sites with the exception of James River and Reed Creek, the latter of which exceeded the state and EPA maximum geometric mean standard, and both of which exceeded the less stringent state standard. Samples for *E. coli*, however, were overall low and did not exceed state standards. Finally, samples for specific conductance were consistently below the EPA recommended range at all sites except the James River, for which the three sampling stations showed fairly equivalent distributions over recent sampling.

The main water quality issue in this cataloging unit was the elevated fecal coliform concentrations observed at three sampling locations: two on the James River and one on Reed Creek. All stations were relatively close to one another, and James River drains a large area and could likely have been contaminated by urban areas upstream. Reed Creek, though not downstream of urbanized area, could have been affected by the adjacent Georgia Pacific manufacturing facility. As a whole, this cataloging unit displays minimal issues and therefore receives a condition status of good (Table 33). The quality of the data used to make the assessment was fair (Table 33). The spatial category did not receive a checkmark because most sampling locations were outside park boundaries. No trend was assigned to water quality condition because data were insufficient to determine trend.

Table 33. The water quality condition of the Middle-James Buffalo cataloging unit (02080203) was good. The quality of the data used to make the assessment was fair. No trend was assigned to water quality condition.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
02080203: Water Quality	Good (green circle)	✓		✓
		2 of 3: Fair		

South Fork Shenandoah – 02070005
The northernmost cataloging unit for which there was sampling data, the South Fork Shenandoah was sampled at three locations near BLRI. Two of these stations, Back Creek at Sherando Lake and South River, are classified as state trout waters. The other station on Back Creek is farther downstream from Sherando Lake and is not classified as a trout water at that point. Several proximate sampling sites along the South River were grouped into a single sampling location, but they were all located in the industrial area in the southern part of Waynesboro. This sampled area along the South River is also stocked annually.

Data for DO on Back Creek and South River showed high values that were consistently above state standards. Data for pH included regular sampling at all three stations, of which the lowest samples were observed at Sherando Lake. Minimal sampling for turbidity on Back Creek showed typical levels, as did sampling for chloride. Three years of alkalinity sampling also revealed low values on Back Creek that were below the EPA recommended minimum. Recent sampling by the USFS confirmed these low values at two locations near the sampling site (R. Emmott personal communication).

Two copper samples revealed low concentrations on South River, and six years of sampling for specific conductance revealed samples that averaged within the EPA suggested range, though roughly a fifth of samples fell below it.

Samples for fecal coliform were fairly extensive for Sherando Lake and Back Creek, neither of which exceeded the EPA or state criteria. Finally, temperature data were collected on Back Creek and South River, which showed a similar range of values. Because the South River is trout water, however, roughly a quarter of samples exceed the state criterion.

Overall, no real water quality issues are observed at these stations other than occasional high temperatures in the South River. These elevated values exceed the trout water standard, which seems an odd classification for the sampled region of the river given its urban setting. However, as a whole only three stations informed this cataloging unit, and data among those stations is extremely sparse and inconsistent. As a result, this cataloging unit receives a condition status of good (Table 34), though it is important to note the limits of the data. The condition of the data used to make the assessment was poor (Table 34), and interpretation of this assessment warrants particular caution. The thematic and spatial categories did not receive checks because the sampling location was located outside park boundaries and because the amount of relative data was very low.

Table 34. The water quality condition of the South Fork Shenandoah cataloging unit (020700085) was good. The quality of the data used to make the assessment was poor. No trend was assigned to water quality condition. The asterisk indicates special caution when interpreting this condition because of the poor condition of the data quality.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
02070005: Water Quality	*			✓
		1 of 3: Poor		

4.4.5 Summary

Of the 15 cataloging units through which BLRI passes, 11 were assigned a condition status based on sample data available from EPAStoret and VADEQ after October 1995, which was the end of the initial baseline inventory assessment period. These assigned conditions included eight good and three fair statuses, the latter of which were assessed due to depressed pH levels or bacterial contamination (Figure 42). Because of the irregular sampling schedule, no trend was assigned to individual cataloging units.

It is important to note that these assessments are organized by cataloging unit, but are only assessed using data available within a 3-mile buffer of BLRI. In addition, because the Parkway predominantly follows the ridgeline that forms the boundary between cataloging units, sampling stations typically occur downstream of the Parkway, often separated by several tributaries. The exceptions to this occur in the Upper Clinch, Middle James-Buffalo, and Upper Roanoke cataloging units, where the Parkway descends to pass through the middle of the units.

Data quality was ranked as fair or poor for all water reporting areas. Although significantly robust datasets were available for most cataloging units, most of these data were collected outside park boundaries. Therefore, the spatial category did not receive a check for any of the individual reporting area data quality conditions. Cataloging units with exceptionally small amounts of data, whether by few sampling stations or brief sampling periods, are indicated in their respective sections and in Figure 42 with asterisks.

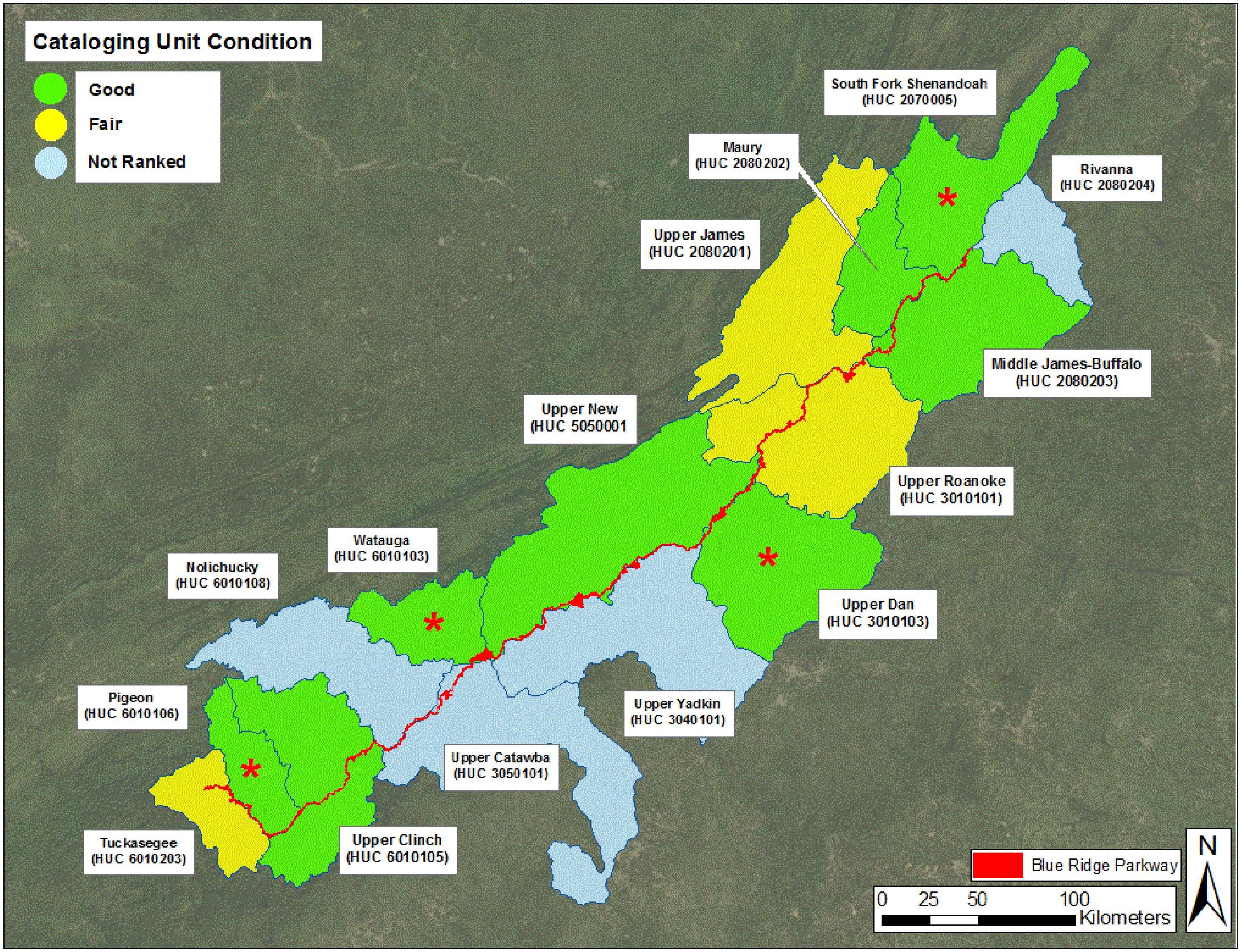

Figure 42. Condition status for 15 watershed cataloging units along BLRI. Asterisks indicate units for which data was notably sparse or reflected very few sampling locations.

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4.5 Aquatic Macroinvertebrates

4.5.1 Relevance and Context

Freshwater aquatic macroinvertebrates form diverse assemblages and perform a variety of important ecosystem roles (Wallace and Webster 1996). Streams of the southern Appalachians are physically and chemically unique, and possess a rich and highly endemic macroinvertebrate fauna (Morse et al. 1993). In North Carolina, the majority of known species of the Ephemeroptera, Plecoptera, and Trichoptera (EPT) orders occur in the Appalachians, and over 30% of these species occur only in the mountains (Morse et al. 1993). The richness, trophic diversity, and environmental sensitivity of these assemblages, as well as the relative ease with which they can be sampled, make them good indicators of biological integrity (Kerans and Karr 1994, Barbour et al. 1999, Burton and Gerritsen 2003). The BLRI contains many small streams, springs, seeps, and bogs that support a diverse and unique macroinvertebrate fauna. Many of the high-elevation aquatic micro-habitats found within the BLRI are relatively rare and are therefore valuable from a conservation perspective. Furthermore, these habitats have received little sampling and research effort, relative to larger streams and habitats, and are therefore valuable from an academic perspective. Intermittent streams, springs, seeps, and bogs are habitats small enough to occur entirely within park boundaries. Therefore, assemblages linked to these habitats can benefit significantly from the protection provided by the park. The shape and the elevation of the BLRI make it a long transect containing a large subsample of these specialized Appalachian habitats. Macroinvertebrate assemblages are an important resource in BLRI.

4.5.2 Resource Knowledge

Macroinvertebrates were extensively sampled in the park during a 2005-2007 inventory that focused on small streams, seeps, and springs (Lenat 2007). Other surveys have been conducted within the park, notably a region-wide effort involving multiple NPS units. That effort focused more on adult insects, and sampled in fewer locations. Selected results from that effort were included in the Lenat (2007) results.

For our analyses of BLRI macroinvertebrates, we relied upon the results reported by Lenat (2007). In this effort, samples were collected from 91 sites during June 2005, October 2006, and May 2007. Data from an earlier study were included where possible. Several locations were sampled multiple times. Most sampling was conducted in small streams, springs, and seeps. The large rivers in the northern watergap region (James and Roanoke Rivers) and the Linville River were not sampled, nor were the artificial impoundments located within the park. Kick nets, sweep nets, and other standard sampling methods were used at some of the larger streams sampled; other techniques such as aquarium dipnets, visual searching, and substrate washing were used to sample the very shallow waters of many springs and seeps (Lenat 2007). Lenat (2007) reported that 412 taxa have been identified from BLRI sites, and reported over 330 taxa from his own efforts combined with some data from a previous study. Taxa were sorted into abundance classes of rare, common, or abundant. Of the 2,598 records representing 96 sampling events analyzed from these results, 97% were identified to genus level, and 46% were identified to species level. Most of the taxa not identified to genus level were dipterans of the family Chironomidae. Around 48% of the taxa were from the orders of Ephemeroptera, Plecoptera, and Trichoptera (EPT), and 56% of these species were caddisflies (Trichopetera).

Lenat (2007) used personal knowledge, unpublished accounts from the North Carolina Natural Heritage Program, and a database of macroinvertebrate collections made by the NC Division of Environmental Management to identify rare taxa within his collections. He assigned a conservation score between one and four, with four being the rarest/possible new species (Lenat 2007). Over 80 rare taxa were identified, including new taxa and first state records (Lenat 2007). While acknowledging some subjectivity in the criteria used to determine rare taxa, Lenat (2007) concluded that there were “an extraordinarily high number of unusual taxa” within the park, and that many of these resided in seeps and springs.

4.5.3 Threats and Stressors

General threats to southern Appalachian aquatic macroinvertebrates include contamination of water with nutrients or chemicals, changes in pH, flow, oxygen, or temperature regimes, increased sediment, loss of woody debris, and changes in riparian flora assemblages (Morse et al. 1993). Historical forestry and land use practices certainly altered the original assemblages of the region, but historical assemblages are unknown (Morse et al. 1993). Threats specific to the BLRI assemblages include inputs from outside park boundaries for streams with reaches or catchment areas outside park boundaries. Within the park, the presence of the roadway and the management of roadside areas have the potential to impact macroinvertebrate assemblages, although specific cases of impairment are not known or reported here. Visitor use and traffic have the potential to impact these fauna. Acid rain, a significant issue for the BLRI, may be among the most important threats faced by macroinvertebrates, especially in the small micro-habitats that are otherwise highly protected by the existence of the park. Acidification can cause decreases in abundance and diversity of macroinvertebrate assemblages (Zischke et al. 1981).

4.5.4 Data

For our analysis dataset, we used the data presented by Lenat (2007).

4.5.5 Methods

Benthic macroinvertebrates assemblage data are widely used to assess biotic condition of aquatic resources and many regionally-specific multimetric indices of biotic integrity (IBIs) have been developed (Morse et al. 1993, Kerans and Karr 1994, Barbour et al. 1999, Burton and Gerritsen 2003). The collections from the BLRI are poorly suited for the application of these indices because much of the BLRI data were collected from seeps and springs, but most of the data used to develop the IBIs was collected in wadeable streams. Therefore, the empirically-derived reference standards based upon data collected from pristine wadeable streams may not be applicable for assessing the quality of these smaller microhabitats. Furthermore, the Lenat (2007) data did not include individual counts of each taxa and specific relative abundance metrics included in the IBIs could not be calculated. Despite these significant caveats, we calculated and summarized several richness metrics that are included in a Virginia regional macroinvertebrate IBI (Burton and Gerritsen 2003) and a Tennessee Valley regional IBI (Kerans and Karr 1993). These metrics provide useful descriptive accounts of the sampled assemblages, and present measurable baselines for future monitoring. Furthermore, under the general assumption that many of the taxa found in seeps and springs are similar to those found in wadeable streams, and respond similarly to environmental challenges, these findings can be suggestive of quality.

We calculated six taxa richness metrics for the BLRI macroinvertebrate dataset and summarized these findings at several levels. We calculated these metrics at the level of individual sampling events, where events were generally a single sample collected at single site. In some cases, events had additional data from other samples collected at the site. However, the event level represented the finest-scale of data summary available from our dataset. Following the Tennessee Valley IBI (Kerans and Karr 1993) we calculated total taxa richness, mayfly (Ephemeroptera) richness, caddisfly (Trichoptera) richness, and stonefly (Plecoptera) richness at the genus level. These counts were referenced to empirically-derived ranges to calculate a score of 1, 3, or 5, with 5 representing high-quality sites (Kerans and Karr 1993). Following the Virginia IBI (Burton and Gerritsen 2003) we calculated total taxa richness and EPT richness at the family level. These values were referenced to a standardized “best value” such that values near 100 represented high-quality sites.

We also calculated a “conservation score” based on the taxa scores determined by Lenat (2007). At the event and genus level, we summed the total score represented by the sample. There is no reference range for these scores, but they are useful for indicating areas with many rare taxa (Lenat 2007).

We summarized the event-level metrics at the “kilometer” level. For each sample, Lenat (2007) provided a specific mile-post reference indicating the distance from the northern end of the

Parkway. Many mile references included only a single sample, but some included repeated samples at the same site or several small sites referenced to the same mile-post. The 96 discreet events in our dataset condensed to 74 locations along the Parkway. For locations with multiple sampling events, we took the mean value of the metric, rounded to the nearest whole number. This was done primarily to facilitate graphical representation.

4.5.6 Condition and Trend

Among the 96 events analyzed, the mean taxa richness at the genus level was 27 (SD ± 15) and samples contained from two to 105 genera. The mean EPT genera richness was 16 (SD ± 11) and samples ranged from one to 66 genera. The mean conservation score was 6.6 (SD ± 4.7) and scores ranged from 0 to 22. Of the 96 events, 91 (95%) contained at least one rare species. We calculated six IBI metrics as described in the methods. Of 96 records, 21 (22%) scored in the highest possible category for all six metrics, 17 (18%) scored in the highest category in five of six metrics, and 14 (15%) scored high in none or a single metric.

We analyzed by Parkway kilometer location to facilitate graphic representation of the data. Locations with high taxa richness and locations with high conservation score values were distributed along the length of the parkway, although sites with high richness were often not the same location as sites with high conservation value (Figure 43). Lenat (2007) discussed several Parkway sections exhibiting high conservation scores. Among these, areas with highest scores included the Mabry Mill, Julian Price/Boone Fork, Wilson Creek/Grandfather Mountain, Mt. Mitchell/Craggy Gardens, and Devil’s Courthouse regions (Lenat 2007).

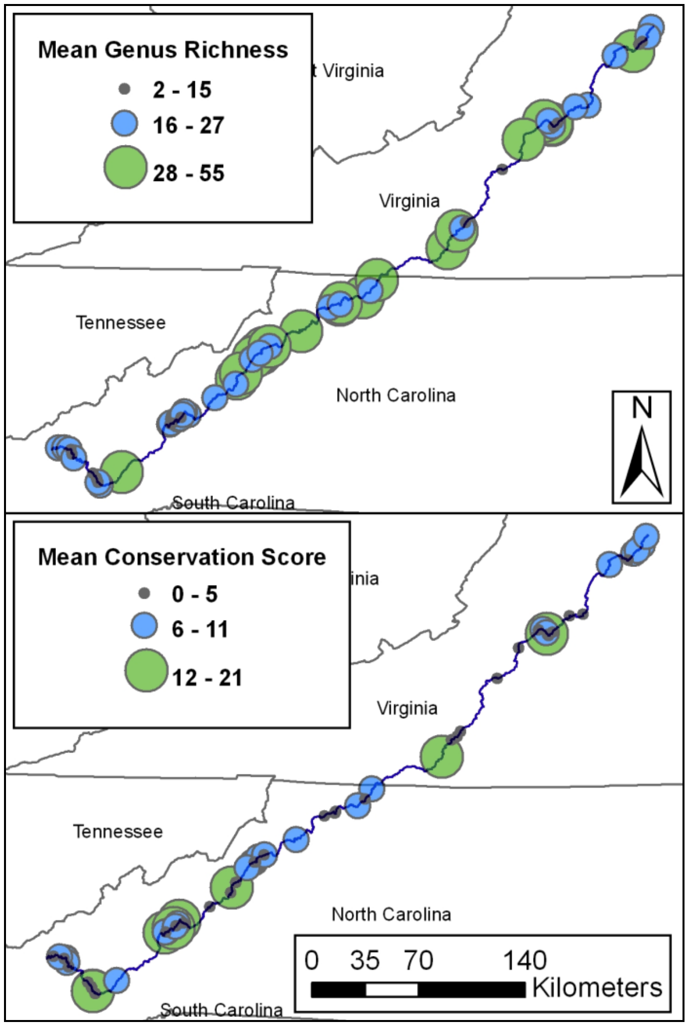

Figure 43. Macroinvertebrate mean genus richness and mean conservation score by kilometer for an inventory conducted on the BLRI by Lenat (2007). Most kilometers are represented by a single sample, but some summarize 2- 4 samples. Conservation score is mean summed score provided by Lenat (2007).

We ranked the quality of the BLRI macroinvertebrate assemblages as good (Table 35). This assessment is largely based upon qualitative factors and the comments of experienced regional researchers. The preponderance of rare species, the overall taxa richness, and the number of intolerant taxa (EPT) all suggest a diverse and healthy fauna. Although there are many caveats to interpreting the metrics we evaluated here, the results from these summaries are consistent with the hypothesis that many of the evaluated habitats are in good condition. We did not assign a trend to this condition because our assessment was based upon the findings of a single short-term study. The quality of the data was good. Although a single study of unique habitats is insufficient to establish condition with a high level of certainty, we feel the results are maximally useful in describing the present diversity and identifying areas of interest.

Table 35. The condition of BLRI macroinvertebrate assemblages was ranked as good. No trend was assigned to this condition. The quality of data used to make this decision was good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Macroinvertebrate Assemblages		✓	✓	✓
		3 of 3: Good		

Macroinvertebrate assemblages may be among the most important animal resources BLRI protects significantly within its borders. The sites sampled by Lenat (2007) are rare in that many of them are protected specialized high elevation seeps and springs. There are few datasets of this nature available for comparison. Therefore traditional tools such as IBIs have limited use in assessing this resource. However, the baseline established by the Lenat (2007) should be useful in ongoing monitoring.

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4.6 Exotic Plants

4.6.1 Problem Exotics

Exotic species represent a significant natural resource threat at BLRI. The linear nature of the Parkway makes it especially susceptible to early successional exotic species, which can quickly invade otherwise remote areas that provide habitat for rare and sensitive taxa. Exotic plants have the ability to alter natural landscapes by competing with native plant communities and degrading the aesthetic quality of an area. Dense growth of exotics in certain areas could obscure scenic views that attract so many visitors to the Parkway. At BLRI, park staff use a variety of measures to control exotic species, including mechanical, physical, chemical, cultural, and biological means of removal.

The most recent vascular plant inventory at BLRI was initiated in 2002 by NatureServe and continued through 2004. The assessment included the creation of 356 plots, including permanent and temporary locations, wherein plants were identified and vegetation communities were documented. These surveys identified 251 vascular plant species previously unknown to the park, representing a 20% increase in the number of taxa already known (Govus and White 2009). Of the currently documented 1590 species in the park, 252 (16%) are non-native, and exotics were present in two-thirds of the survey plots (NPS 2010a), mainly clustered around the Peaks of Otter, Roanoke, Humpback Rocks, and James River areas. Urban areas in particular can act as a source for exotic species. Oriental bittersweet, for example, was documented in 269 locations, most of which were around Asheville, with additional occurrences around the Cumberland Knob (~MM220), Rocky Knob (~MM170), and Linville Falls (~MM320) areas

Govus and White (2009) observed that, based on classification by Miller (2000), 37 of the exotics at BLRI are considered particularly aggressive with the ability to exclude the persistence of native species in the Southeast region. According to Govus and White (2009), areas with the greatest infestation include the Asheville Basin and the region surrounding Roanoke. Govus and White (2009) list several species that pose a particular problem in the Asheville Basin (Table 36).

In addition to the plant inventory conducted by NatureServe, researchers also classified different vegetation types encountered during the survey according to the National Vegetation Classification System (Grossman et al. 1998). Each of these types is associated with a unique Community Element Global identifier (CEGL) number. Of the 81 different vegetation associations sampled in the park, 13 were specifically noted by Govus and White (2009) for the presence of exotics (Table 37). The 2006 Exotic Plant Management Plan Environmental Assessment (EPMPEA) also outlined priority areas for exotics treatment along the Parkway according to the locations of high priority natural vegetation communities (Figure 44).

The EPMPEA (NPS 2006) also outlines specific problem exotics and the variety of habitats that are threatened by their adaptability. It notes that the Parkway also manages upwards of 2000 ha as rural farmland, which by its nature facilitates the invasion of exotics into adjacent forested fragments. Grazing contributes to the invasion of exotic species, as many were originally introduced as pasture feed (Sutter et al. 2003).

Table 36. Problem exotics specified by Govus and White (2009) and the EPMPEA (NPS 2006). Habitat and eradication methods from Smith (2008) and NatureServe (2011).

Growth Habit	Species		Susceptible Habitat	Recommended Control Methods
Herb	*Alliaria petiolata*	Garlic mustard	Roadsides, trail edges, floodplains, streambanks, forest edge/interior	Repeat cutting of flowering stem to prevent seed production; glyphosate foliar application
	Bromus tectorum	Cheatgrass	Fields, riparian areas, roadsides	Burning, tilling, herbicide, and reseeding in succession
	Cytisus scoparius	Scotchbroom	Grasslands, shrublands, forests	Integrated pest management; physical, manual, and mechanical methods
	Elymus repens	Quackgrass	Grasslands, woodlands, riparian areas	Tillage, herbicide, and reseeding combination; burning and herbicide alone prove ineffective
	Holcus lanatus	Common velvetgrass	Mesic disturbed areas; roadsides, pastures	Manual removal, mowing, grazing, herbicide
	Hypericum perforatum	Common St. Johnswort	Grasslands, woodlands, riverbanks, disturbed areas, roadsides	Manual removal, repeated herbicide; seedbank viable up to 10 years
	Iris pseudacorus	Yellowflag iris	Riparian habitats, wetlands	Rhizomatic--manual removal effective for small areas; leaf resin skin irritant; Cutting/glyphosate combination
	Lythrum salicaria	Purple loosestrife	Wetlands, riparian areas	Very difficult to control—containment often most feasible; glyphosate effective for small infestations before flowering; loosestrife beetles (*Galerucella* spp.) effective, as well as root-mining weevil
	Microstegium vimineum	Japanese stiltgrass	Closed forest interior; floodplains; disturbed areas	Mowing/pulling/glyphosate application before seed set
	Miscanthus sinensis	Chinese silvergrass	Roadsides, forest edges, open areas	Rhizomatic, hand-pulling generally ineffective; repeated herbicide effective—glyphosate solution applied before seed set
	Plantago lanceolata	Narrowleaf plantain	Open areas, pastures, grasslands, roadsides; prefers mesic sites	Grazing, mowing, herbicide (glyphosate)
	Poa compressa	Canada bluegrass	Roadsides, grasslands, pastures	Late spring burning; Removal of grazing pressure; Herbicide use may result in non-target mortality

Table 26. (continued)

Growth Habit	Species		Susceptible Habitat	Recommended Control Methods
Herb (cont.)	*Polygonum caespitosum*	Oriental lady's thumb	Disturbed areas, roadsides, pastures	--
	Centaurea biebersteinii	Spotted knapweed	Open areas, roadsides	Mowing after flower; spot herbicide; biological control possible
	Lythrum salicaria	Purple loosestrife	Wetlands	Seed containment; late summer glyphosate application; possible biological control; difficult to manage when > 3 acres
	Lespedeza cuneata	Chinese lespedeza	Open areas, marshes, roadsides, eroded and steep slopes	Mowing/burning combined with chemical treatment (triclopyr and clopyralid)
Tree	*Ailanthus altissima*	Tree-of-heaven	Urban areas, roadsides, fields	Targeting of fruiting trees, glyphosate or metsulfuron application; stump spray using triclopyr during summer to early fall, basal application for smaller trees; hand-pulling when young
	Paulownia tomentosa	Princess tree	Forests, stream banks, rocky slopes/exposed sites, roadsides	Similar to above; Hand-pulling or glyphosate application when young; stump spray with triclopyr during summer to early fall when older, basal application when young
	Albizia julibrissin	Mimosa	Roadsides, developed areas, stream banks	Similar to above; stump spray, trunk girdling (hack and squirt), or basal application before seed using triclopyr; glyphosate or triclopyr application for large thickets
	Morus alba	White mulberry	Forests, forest edges, grasslands, waste areas, roadsides	Pull young plants; Cut stump or girdling with Imazapyr or triclopyr herbicide application
	Populus alba			
Vine	*Celastrus orbiculatus*	Oriental bittersweet	Old homesites, forest edges, fields, roadsides, disturbed woodlands	Preemptive control before disturbance release is best; hand-pull small initial pops.; ground-cutting understory infestations early in growing season followed in one month by triclopyr; cut and immediate triclopyr application for canopy infestations
	Clematis terniflora	Sweet autumn clematis	Forest edges, rights of ways, riparian areas	--

Table 26. (continued)

Growth Habit	Species		Susceptible Habitat	Recommended Control Methods
Vine (cont.)	*Dioscorea oppositifolia*	Chinese yam	Homesites, roadsides, mesic forest edges, moist disturbed areas	Repeat cutting provides some control; foliar application of triclopyr or glyphosate, preferably between July and October; cut stems/triclopyr application
	Hedera helix	English ivy		
	Pueraria montana	Kudzu	Roadsides, old fields, forest edges, sunny disturbed areas	Weeding, mowing, grazing of small patches; cut with triclopyr for large vines; foliar glyphosate, triclopyr, or clopyralid application; central root crown application;
	Ampelopsis brevipedunculata	Porcelainberry	Riparian areas, forest edges	Triclopyr application to foliage, cut vine, or basal application
	Lonicera japonica	Japanese honeysuckle	Forests, fields, forest edges, disturbed areas	Hand-pulling small infestations; Cut and glyphosate or triclopyr application; foliar application for groundcover
	Lonicera maackii	Amur honeysuckle	Forests and forest edges	Clipping effective in forest areas, though in open areas must be accompanied by herbicide or burning; Cut and glyphosate applications twice a year for three to five years
	Wisteria sinensis	Chinese wisteria	Forest interiors and edges	Cutting and herbicide application
Shrub	*Rosa multiflora*	Multiflora rose	Roadsides, pastures, wetlands, disturbed areas	Glyphosate, triclopyr, or metsulfuron foliar application (spring to fall); cut stump with triclopyr
	Spiraea japonica	Japanese Spiraea	Water edges, forest edges/openings, old fields, roadsides	Controlled with repeat mowing/cutting; Killed with glyphosate or triclopyr foliar application before seed set; cut stump with triclopyr
	Rubus phoenicolasius	Wineberry	Fields, roadsides, edges	Hand-pulling when possible; cut stump with triclopyr or glyphosate
	Elaeagnus spp.	Russian, Autumn olive	Open areas, forested areas, roadsides, pastures, disturbed areas	Hand-pulling young plants; glyphosate or triclopyr foliar application (spring to fall), also metsulfuron for *E. umbellata*; triclopyr basal application; cut stump triclopyr application
	Euonymus alatus	Winged burning bush	Open woodlands, forests, forest edges, old fields, roadsides	Cut and herbicide (glyphosate); manual removal; foliar herbicide
	Berberis thunbergii	Japanese barberry	Forested areas, pastures, open areas; still relatively uncommon in NC	Hand-pulling; glyphosate application (early spring for identification); burning
	Ligustrum sinense	Chinese privet	Bottomlands, stream sides, disturbed areas, roadsides	Manual removal using leverage-pullers; glyphosate or triclopyr foliar application (late fall or early spring); cut stump with triclopyr

Table 37. BLRI vegetation associations threatened by exotic species (Govus and White 2009).

CEGL Code	**Vegetation Association**	**Specific Associated Exotics**
007944	Eastern White Pine Successional Forest	--
002591	Virginia Pine Successional Forest	--
006237	Sugar Maple – White Ash – American Basswood – Tuliptree/Black Cohosh Forest	Garlic mustard
008510	Central Appalachian Rich Cove Forest (Tuliptree – Northern Red Oak – Cucumber-tree Type)	Japanese honeysuckle, Tree-of-heaven
007221	Interior Mid- to Late-Successional Tuliptree – Hardwood Upland Forest (Acid Type)	Japanese honeysuckle, Oriental bittersweet, Japanese stiltgrass
007220	Successional Tuliptree Forest	Tree-of-heaven (*Ailanthus altissima*)
007219	Early Successional Appalachian Hardwood Forest	Japanese honeysuckle, Asian bittersweet, Japanese stiltgrass
007279	Black Locust Successional Forest	Japanese stiltgrass, Japanese honeysuckle, Oriental bittersweet
007312	River Birch Levee Forest	Chinese privet, Japanese honeysuckle, Japanese stiltgrass, Oriental bittersweet, Multiflora rose
007339	Montane Alluvial Forest (Cades Cove/Oconaluftee)	Japanese stiltgrass, Japanese honeysuckle, Multiflora rose
008533	High-Elevation Hemlock – Yellow Birch Seepage Swamp	Garlic mustard
004242	Grassy Bald (Southern Grass Type)	Timothy (*Phleum pratense*), Red clover (*Trifolium repens*), Wild leek (*Allium ampeloprasum*), Sheep sorrel (*Rumex acetosella*), Heal-all (*Prunella vulgaris*)
004991	Low-Elevation Basic Glade (Montane Type)	Oriental bittersweet

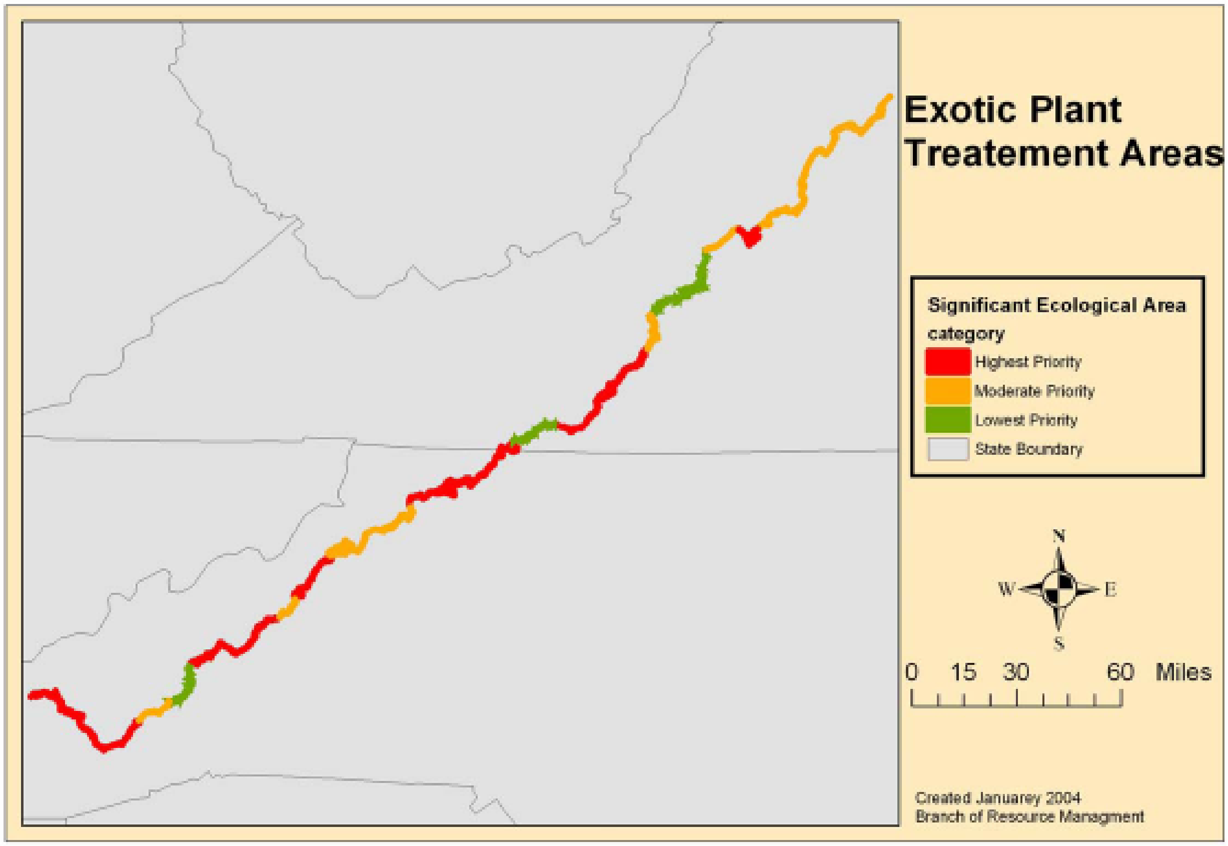

Figure 44. Priority of areas along BLRI for treatment of exotics. This figure was taken directly from the EPMPEA (NPS 2006).

4.6.2 Vulnerable Resources

Rare Plant Species

Exotic plant species can affect natural and aesthetic resources in several ways. Sensitive community types or rare plant species can be altered or outcompeted by aggressive exotics. This is a notable problem at BLRI, which provides important refugia for numerous species of rare plants, and which is in close proximity to adjacent developed land for much of its length. Roughly 3600 ha of vegetation communities at BLRI are considered imperiled or critically imperiled according to the NatureServe classification, overall encompassing 10% of the Parkway. Five federally-listed plant species are present along the Parkway (Table 38), along with many species of state-listed plants (Appendix B), of which approximately one-third are threatened by exotic species (NPS 2006).

Table 38. BLRI plant species with federal status (NPS 2006). Additional details provided in *Sec. 4.5 – Rare Plants.*

Species		Federal Status	State Status	
			NC	VA
Gymnoderma lineare	Rock gnome lichen	Endangered	S2	S1
Geum radiatum	Mountain avens	Endangered	S2	--
Liatris helleri	Heller's blazingstar	Threatened	S2	--
Helonias bullata	Swamp pink	Threatened	S2	S2
Isotria medeleoides	Small whorled pogonia	Threatened	S2	S2

A 2006 survey of hawthorn (*Crataegus* spp.) by Ron Lance revealed several uncommon species along the Parkway. Exotic species represent a threat to these populations, especially in the Bull Gap area where Oriental bittersweet threatens individuals of succulent hawthorn (*Crataegus succulenta*), as well as *C. boyntonii* and *C. pallens*.

Rare Animal Species

Exotic species can not only exclude native plant species but also animal species. The 2006 EPMPEA conducted at BLRI outlines several federally-listed species that may be particularly vulnerable to habitat alteration due to exotic plants. The Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*), for example, was not generally observed to have been affected by exotic species, though vines such as kudzu may affect trees used by the squirrels. Herbaceous exotics could restrict areas available for foraging, which could in turn impact the ability of squirrels to disperse fungi and microbial species—an important function in the forest habitat. Bog turtles (*Glyptemys muhlenbergii*) are threatened by encroachment of woody vegetation in wetland areas, though this often is due to native woody vegetation. Purple loosestrife (*Lythrum salicaria*), however, does invade wetland areas and could affect bog turtle habitat. The Indiana bat (*Myotis sodalis*) could also potentially be affected by exotic vines such as kudzu that overtake roost trees (NPS 2006). Other habitat specialists such as the Spruce-fir moss spider (*Microhexura montivaga*) (documented in GRSM) and Peaks of Otter salamander (*Plethodon hubrichti*) could be greatly impacted by encroachment of exotic species.

Aquatic Macroinvertebrate Communities

The EPMPEA also mentions the vulnerability of aquatic invertebrate fauna, citing the findings of Sweeney (1993), who discusses how exotic plants often exclude native trees in riparian areas to the detriment of stream macroinvertebrate communities. Other studies have found negative effects on aquatic macroinvertebrates of exotic leaf litter stream inputs (Going and Dudley 2008, Bailey et al. 2001).

Visual Resources

Vistas and other areas cleared as scenic overlooks are another threatened resource along the Parkway. These openings are particularly vulnerable to establishment of exotic species, and as a result, would benefit from early detection and rapid response control methods. At BLRI, adaptive management is currently used in vista areas that includes replanting of sites with species resistant to herbicide or that have the ability to outcompete exotics. These techniques aim to reduce the amount of management time devoted to individual sites (C. Furqueron personal communication)

One of the difficulties of maintaining these vistas areas is that activities such as clearing and trimming facilitate the proliferation of exotics such as tree-of-heaven (*Ailanthus altissima*), mimosa (*Albizia julibrissin*), and princess tree (*Paulownia tomentosa*). There are 960 vista areas along the Parkway that are regularly cut on three-year rotations, during which these weed trees can grow up to 4 to 5 m and impede viewsheds (NPS 2006).

A study by Burch and Zedaker (2003) indicated tree-of-heaven can ultimately reach heights of 15 to 24 m and cut stumps can resprout 3 to 4 m in the first-year alone, in addition to increasing the density of the tree. These latter facts bolster the necessity of killing the tree with herbicides to prevent regeneration. Burch and Zedaker (2003) compared eight different herbicide treatments with manual cutting on several infestations on Skyline Drive in SHEN and found that cut stumps resprouted 79% of the time while the same proportion of chemically treated stumps were killed. None of the herbicide stumps resprouted. They also noted that elimination of tree-of-heaven resulted in the return of native plant species such as Joe Pye Weed (*Eupatorium* spp.), Dutchman's pipe (*Aristolochia durior*) and jewelweed (*Impatiens capensis*) in herbaceous understory layers that had previously been dominated by garlic mustard (*Alliaria petiolata*) and bouncing bet (*Saponaria officinalis*), both exotics.

<u>Soil Resources</u>
The EPMPEA indicates that exotic plants represent a considerable risk to soil resources in the Parkway. Some plants, such as tree-of-heaven, are allelopathic, which means they produce chemicals that alter the suitability of soil for other plant species. In a similar fashion, exotic nitrogen-fixing species such as mimosa or kudzu can also alter soil conditions and decrease success of associated native species (NPS 2006).

<u>Migratory Birds</u>
Changes in vegetation structure could affect availability of habitat for migratory birds along the Parkway. Exotics that displace native plants could in turn decrease foraging and nesting opportunities, or alter rates of nest predation. As the EPMPEA points out, the BLRI provides a relatively secure area of habitat for birds in an overall landscape that is quickly being altered. In addition, birds also serve as a vector for exotic plants, often transporting seeds that facilitate their spread.

4.6.3 Treatment Priorities

The 2006 Exotic Plant Management Plan is an environmental assessment which outlines the feasibility and necessity of a treatment program for the Parkway (NPS 2006). Little attention has been devoted to the problem of exotic plants over the past 20 years, and, as a result, several areas of the park have become infested. Besides aggressive exotics, the report also mentions the predominance of kudzu (*Pueraria lobata*) and plume grass (*Miscanthus sinensis*). Plume grass is an emerging threat at BLRI, particularly along guard rails, where it can exacerbate fire issues (C. Furqueron personal communication).

Although treatment is not feasible in every location, Govus and White (2009) suggest natural communities and communities with rare plant associations that might benefit the most from targeted exotics control. These include mafic woodlands and glades, bogs, and ultra-mafic barrens. These areas are threatened in particular by Chinese privet, Oriental bittersweet, and Japanese honeysuckle. They also mention that the park is invaded by Oriental bittersweet in areas of the Montane Cedar – Hardwood Woodland (CEGL003752) and Low-Elevation Basic Glade (Montane Type, CEGL004991), where rare species of hawthorn (*Crataegus succulenta* and *Crataegus pallens*) might be vulnerable. Another area is the River Birch Levee Forest (CEGL007312), which occurs only on levees along the French Broad River and harbors plant species found only in that section of the Parkway. In 2008, the SEEPMT, along with staff at BLRI, focused on eradication of Oriental bittersweet, multiflora rose, and Japanese spiraea along the Parkway, particularly in the Craggy Gardens area and between the French Broad River and Mt. Pisgah. Total area treated that year is shown in Table 39. Of these, Oriental bittersweet is highlighted as a particularly important problem invasive along the Parkway (R. Emmott personal communication).

Table 39. Species and acreage of exotic plants treated at BLRI during 2008.

Species		**Acres Treated**
Ailanthus altissima	Tree-of-heaven	0.5
Celastrus orbiculatus	Oriental bittersweet	43.1
Dioscorea bulbifera	Chinese yam	0.1
Ligustrum spp.	Privet	23.8
Miscanthus sinensis	Japanese grass	2.3
Rosa multiflora	Multiflora rose	30.2
Rubus phoenicolasius	Wineberry	23.8
Spiraea japonica	Japanese spiraea	23
Verbascum thapsus	Common mullein	4.2
Wisteria sinensis	Japanese wisteria	8.1
Total		**159.1**

4.6.4 I-Rank

Morse et al. (2004) developed a methodology to quantify the threat posed by exotics to native species and ecosystems, called the I-rank. The overall I-rank consists of 20 questions that cover four main subranks: ecological impact, current distribution and abundance, trend in distribution and abundance, and management difficulty. These rankings are shown in Table 40 for 90 exotic plant species observed at BLRI, adapted from the list by Govus and White (2009). These species were selected because they had an overall I-Rank of medium or higher. Besides the I-Rank, threats were also included by the NC Native Plant Society, and include five plants listed as a severe threat, and three listed as significant threats. Five plants were listed with the highest I-Rank.

4.6.5 Summary

Overall, it is clear that exotic plants represent a serious threat to plant and animal communities along the Parkway and at vistas. The Parkway itself can easily serve as a vector for transferring exotics, which can quickly spread to surrounding areas and exclude native vegetation, compromise vistas, threaten aquatic ecosystems, degrade wildlife habitat, and alter soil quality. Compounding their impact is the collection of unique ecosystems found throughout the region, which together contain several habitat types endemic to the Southern Appalachians. Several species of rare and endangered plants also occur on Parkway lands, altogether providing a strong basis for the management of exotic plants.

Altogether, the condition status of exotic plants at BLRI receives a condition ranking of fair, with a degrading trend (Table 41). This moderate ranking is given because several species of exotics are present at BLRI that degrade sensitive habitats and threaten native plants and animals. However, infestations are mainly concentrated around developed areas, leaving more remote sections of the Parkway less or not at all impacted. Also, exotic infestations have been observed worsening, and will likely continue to do so based on the rapid rate of new exotic species entering the region. Japanese knotweed (*Fallopia japonica*) and mile-a-minute weed (*Persicaria perfoliata*), for example, are anticipated to have a major impact at BLRI (N. Fraley and C. Furqueron personal communication).

Because management of all instances of exotic populations is impractical at BLRI due to lack of funds, insufficient information, and complications involving the large size of infestations and the Parkway itself, prioritization of treatment areas is necessary. Prevention is also an important part of the equation - EDRR is an effective and efficient management approach. Landscape management practices could also potentially contribute to the spread of new infestations, whether via mowing height, ditch clearing, or soil movement (C. Furqueron personal communication). In addition, although infestations may not initially occur in sensitive areas, EDRR can help ensure that they do not reach them, which can reduce efforts of control in the long run (N. Fraley personal communication). As White and Govus (2009) also point out, exotics threatening particularly unique vegetation communities or individual species of rare plants also represent urgent targets for control (Table 37).

Table 40. I-Rank for 90 species of exotics observed in NatureServe plots, adapted from Govus and White (2009). Species listed as severe or significant threats are according to the NC Native Plant Society. Ranks do not reflect abundance within BLRI.

Species		I-Rank/Threat
Lespedeza cuneata	Chinese lespedeza	Severe Threat
Paulownia tomentosa	Princesstree	Severe Threat
Pueraria montana	Kudzu	Severe Threat
Rosa multiflora	Multiflora rose	Severe Threat
Wisteria sinensis	Chinese wisteria	Severe Threat
Clematis terniflora	Sweet autumn virginsbower	Significant Threat
Euonymus alata	Winged burning bush	Significant Threat
Polygonum caespitosum	Oriental ladysthumb	Significant Threat
Bromus tectorum	Cheatgrass	High
Coronilla varia	Purple crownvetch	High
Lonicera maackii	Amur honeysuckle	High
Lythrum salicaria	Purple loosestrife	High
Rubus phoenicolasius	Wine raspberry	High
Alliaria petiolata	Garlic mustard	High/Medium
Berberis thunbergii	Japanese barberry	High/Medium
Celastrus orbiculata	Asian bittersweet	High/Medium
Centaurea biebersteinii	Spotted knapweed	High/Medium
Cytisus scoparius	Scotchbroom	High/Medium
Elymus repens	Quackgrass	High/Medium
Frangula alnus	Glossy buckthorn	High/Medium
Hedera helix	English ivy	High/Medium
Holcus lanatus	Common velvetgrass	High/Medium
Hypericum perforatum	Common St. Johnswort	High/Medium
Iris pseudacorus	Paleyellow iris	High/Medium
Ligustrum sinense	Chinese privet	High/Medium
Lolium arundinaceum	Tall fescue	High/Medium
Lonicera japonica	Japanese honeysuckle	High/Medium
Lonicera morrowii	Morrow's honeysuckle	High/Medium
Microstegium vimineum	Nepalese browntop	High/Medium
Morus alba	White mulberry	High/Medium
Potentilla recta	Sulphur cinquefoil	High/Medium
Ranunculus repens	Creeping buttercup	High/Medium
Spiraea japonica	Japanese meadowsweet	High/Medium
Brassica nigra	Field mustard	High/Low
Datura stramonium	Jimsonweed	High/Low
Dioscorea oppositifolia	Chinese yam	High/Low
Hypochaeris radicata	Hairy catsear	High/Low
Linaria vulgaris	Butter and eggs	High/Low
Miscanthus sinensis	Chinese silvergrass	High/Low
Plantago lanceolata	Narrowleaf plantain	High/Low
Populus alba	White poplar	High/Low
Prunus avium	Sweet cherry	High/Low
Pyrus communis	Common pear	High/Low
Bromus inermis	Smooth brome	Medium
Lespedeza bicolor	Shrubby lespedeza	Medium
Lolium perenne	Perennial ryegrass	Medium
Phleum pratense	Timothy	Medium
Poa compressa	Canada bluegrass	Medium
Verbascum thapsus	Common mullein	Medium
Agrostis stolonifera	Creeping bentgrass	Medium/Low

Table 30. (continued)

Species		I-Rank/Threat
Arthraxon hispidus	Small carpgrass	Medium/Low
Bromus sterilis	Poverty brome	Medium/Low
Cannabis sativa	Marijuana	Medium/Low
Cirsium vulgare	Bull thistle	Medium/Low
Conium maculatum	Poison hemlock	Medium/Low
Cynodon dactylon	Bermudagrass	Medium/Low
Dipsacus fullonum	Fuller's teasel	Medium/Low
Eragrostis curvula	Weeping lovegrass	Medium/Low
Erodium cicutarium	Redstem stork's bill	Medium/Low
Hemerocallis fulva	Orange daylily	Medium/Low
Hesperis matronalis	Dams rocket	Medium/Low
HIeracium aurantiacum	Orange hawkweed	Medium/Low
Hieracium pilosella	Mouseear hawkweed	Medium/Low
Humulus japonicus	Japanese hop	Medium/Low
Leucanthemum vulgare	Oxeye daisy	Medium/Low
Ligustrum obtusifolium	Border privet	Medium/Low
Lysimachia nummularia	Creeping jenny	Medium/Low
Melilotus officinalis	Yellow sweetclover	Medium/Low
Poa trivialis	Rough bluegrass	Medium/Low
Rumex acetosella	Common sheep sorrel	Medium/Low
Tragopogon dublus	Yellow salsify	Medium/Low
Trifolium hybridum	Alsike clover	Medium/Low
Trifolium repens	White clover	Medium/Low
Marrubium vulgare	Horehound	Medium/Low
Medicago lupulina	Black medick	Medium Insignificant
Arctium minus	Lesser burdock	Medium/Insignificant
Artemisia annua	Sweet sagewort	Medium/Insignificant
Asparagus officinalis	Garden asparagus	Medium/Insignificant
Cichorium intybus	Chicory	Medium/Insignificant
Dactylis glomerata	Orchardgrass	Medium/Insignificant
Echinochloa crus-galli	Barnyardgrass	Medium/Insignificant
Festuca trachyphylla	Hard fescue	Medium/Insignificant
Glechoma hederacea	Ground ivy	Medium/Insignificant
Hieracium caespitosum	Meadow hawkweed	Medium/Insignificant
Hieracium piloselloides	Tall hawkweed	Medium/Insignificant
Malus pumila	Paradise apple	Medium/Insignificant
Malva neglecta	Common mallow	Medium/Insignificant
Melissa officinalis	Common balm	Medium/Insignificant
Poa annua	Annual bluegrass	Medium/insignificant
Prunus cerasus	Sour cherry	Medium/Insignificant

Table 41. The condition status for exotic plants at BLRI receives a ranking of fair with a degrading trend. The data quality of this ranking is good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Exotic Plants		✓	✓	✓
		3 of 3: Good		

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4.7 Significant Flora

4.7.1 Significant Vegetation Communities

Because of the high rainfall and variation in topography and geology, BLRI runs through one of the most florally diverse regions of the country. Throughout its course, it encompasses 14 major vegetation types and contains over 1600 vascular plant species. Along with the magnificent views of autumn foliage, along the Parkway, these natural features help attract millions of annual visitors. The portions of the Parkway at highest elevations support spruce-fir forests— relict glacial communities found in the southeast only in a narrow strip of habitat following the ridgeline. Appalachian balds, also found at BLRI, are unique mountain communities whose origin is still debated, though they support a variety of rare species. In addition, the variety of wetland types found at BLRI is also of note, which together contain more federally listed species than all other southeast wetland types (BLRI 2012).

Along with the general plant inventory conducted by Govus and White (2009) during 2002-2004, they also documented 81 vegetation associations classified according to the National Vegetation Classification System (NVCS) based on plot assessments. This classification system was developed by NatureServe, and is utilized by the USGS/NPS National Vegetation Mapping Program (Grossman et al. 1998). Of these communities, 38 were considered regionally vulnerable or rarer according to the global ranking provided by NatureServe (Table 42). Many of these globally rare communities occurred in small patches, such as grassy balds, rock outcrops, wetlands, and mafic glades. The most common vegetation types observed in BLRI include oak-hickory forest types, such as those shown in Table 43, which comprise thousands of acres along the Parkway. Govus and White (2009) report that these areas are generally of high quality and remain relatively unaffected by exotic species.

Table 42. List of regionally rare vegetation communities at BLRI ranked as G3 or rarer (Govus and White 2009).

Vegetation Community	G-Rank*	CEGL#[†]
Southern Appalachian Herb Bog (Low-Elevation Type)	G1	4156
Southern Appalachian Herb Bog (Typic Type)	G1	4158
Grassy Bald (Southern Grass Type)	G1	4242
Southern Appalachian Ultramafic Barren	G1	4999
Southern Appalachian Beech Gap (South Slope Sedge Type)	G1	6130
Red Spruce – Fraser Fir Forest (Evergreen Shrub Type)	G1	7130
Southern Appalachian Heath Bald	G1	7876
Southern Appalachian Shrub Bog (Typic Type)	G1G2	3915
Southern Appalachian Bog (Low-Elevation Type)	G1G2	3916
Carolina Hemlock Forest	G1G2	7138
Montane Cedar – Hardwood Woodland	G2	3752
Southern Appalachian High-Elevation Red Oak Forest	G2	4256
Blue Ridge Table Mountain Pine – Pitch Pine Woodland (High-Elevation Type)	G2	4985
Low-Elevation Basic Glade (Montane Type)	G2	4991
Red Spruce – Northern Hardwood Forest (Herb Type)	G2	6256
Red Spruce – Fraser Fir Forest (Deciduous Shrub Type)	G2	7131
High-Elevation Red Oak Forest (Tall Herb Type)	G2	7298
Southern Blue Ridge High-Elevation Seep (Sedge Type)	G2	7697
High-Elevation Hemlock – Yellow Birch Seepage Swamp	G2	8533
Red Spruce Forest (Protected Slope Type)	G2G3	6152
Southern Appalachian Boulderfield Forest (Currant and Rockcap Fern Type)	G2G3	6124
Southern Appalachian Mountain Laurel Bald	G2G3	3814
Appalachian Montane Oak-Hickory Forest (Low-Elevation Xeric Type)	G2G3	7691
Southern Appalachian Spikemoss Granitic Dome	G2G3	4283
Central Appalachian Small-Stream Montane Floodplain Forest	G3	8405
Montane Alluvial Forest (Small River Type)	G3	7143
Southern Appalachian Northern Hardwood Forest (Rich Type)	G3	4973
Appalachian Montane Oak-Hickory Forest (Rich Type)	G3	7692
Central Appalachian Montane Oak – Hickory Forest (Northern Red Oak – Red Hickory Type)	G3	8519
Central Appalachian Montane Oak – Hickory Forest (Basic Type)	G3	8518
Central Appalachian Basic Seepage Swamp	G3	8416
Blue Ridge Table Mountain Pine – Pitch Pine Woodland (Typic Type)	G3	7097
Central Appalachian Basic Boulderfield Forest (Montane Basswood – White Ash Type)	G3	8528
Central Appalachian Chestnut Oak / Catawba Rhododendron Forest	G3?	8524
Northern Red Oak Forest (Pennsylvania Sedge – Wavy Hairgrass Type)	G3?	8506
Southern Appalachian Red Oak Cove Forest	G3?	7878
Northern Red Oak Forest (Minniebush / Hay-scented Fern Type)	G3?	8505
Northern Blue Ridge Montane Alluvial Forest	G3?	6255

*Rounded NatureServe G-Ranks represent the relative imperilment of vegetation communities from a rangewide perspective. G1=Critically Imperiled, G2=Imperiled, G3=Vulnerable, G4=Apparently Secure, G5=Secure. Range ranks (e.g. G1G2) and inexact numeric ranks (e.g. G3?) are used to express uncertainty.

[†]Community Element Global identifier number

Table 43. Common oak-hickory vegetation types observed along BLRI (Govus and White 2009).

Vegetation Community	Ecological System Name
Appalachian Montane Oak Hickory Forest (Typic Acidic Type)	S. Appalachian Oak Forest
Appalachian Montane Oak - Hickory Forest (Red Oak Type)	S. Appalachian Oak Forest
Appalachian Montane Oak Hickory Forest (Chestnut Oak Type)	S. Appalachian Oak Forest
High-Elevation Red Oak Forest (Deciduous Shrub Type)	Central and Southern Appalachian Montane Oak Forest
High-Elevation Red Oak Forest (Evergreen Shrub Type)	Central and Southern Appalachian Montane Oak Forest

In a report of vegetation surrounding developed areas along the Parkway, Murrell et al. (undated) studied three areas with high visitor use that were notable for their unique species composition. The first is a wetland area near Rocky Knob Campground containing several unique species such as coralberry (*Symphoricarpos orbiculatus*), skunk cabbage (*Symphoricarpos foetidus*), and American golden saxifrage (*Chrysosplenium americanum*). A rocky outcrop near the Saddle overlook was identified as a significant area susceptible to hiking impact. The third site around the Smart View area was noted for its high plant diversity.

4.7.2 Rare Plants

Of the 1590 plants present at BLRI, five species are federally listed: mountain avens (*Geum radiatum*), Heller's blazing star (*Liatris helleri*), small-whorled pogonia (*Isotria medeoloides*), rock gnome lichen (*Gymnoderma lineare*) and swamp pink (*Helonias bullata*). Since at least 2005, all known locations of these species, along with Gray's Lily, another rare species, have undergone monitoring efforts to document growth and survival.

Mountain Avens

Mountain avens grows at high elevations (>1300m) and is typically found on exposed cliffs with a northwestern aspect. Besides its federal listing, this species is also listed as S2 (imperiled) in NC and S1 (critically imperiled) in TN. Main threats to this species include trampling and collecting (NatureServe 2011).

Monitoring for this rare species began in 2003. The latest rare plant monitoring report indicated that, at last count, there were 22 known sites, rangewide, that included 8700 individual plants. Seeds of this species are also currently collected for propagation and planting in the park.

Figure 45. Heller's blazing star (*Liatris helleri*). [K. Tripp, USFWS, fws.gov]

Heller's Blazing Star

This plant is only known from the Blue Ridge Mountains in NC, where it has a state conservation rank of S2 (imperiled) in addition to being listed as federally threatened. Like mountain avens, Heller's blazing star (Figure 45) occurs on cliffs and bare rock in high elevation areas. According to NatureServe Explorer, only 21 patches of this plant remain rangewide, 13 of which are protected by the NC Heritage Program. The main threat of this species is human disturbance, as their habitat on balds and outcrops often coincides with areas with the best overlooks.

At BLRI, monitoring of this species began in 2003, where sites are tracked and numbers of plants are recorded. During 2007-2008, drought stress inhibited reproduction and likely resulted in an increased mortality rate. In early 2007, a prescribed fire burned three of the six monitored sites, resulting in an increased flowering in these areas (Figure 47), though survivorship and recruitment was not altered. However, the report notes that prescribed fire does appear to benefit these plants, and that the particularly hot and dry year may have attenuated the apparent benefits of the burn. In addition, a total of 85 propagated seedlings have been reared and planted in 2007 at burned locations, though by 2009 only 24 were still alive.

Small-Whorled Pogonia

This species is unique for its terminal leaf whorl, lending to its common name (Figure 46). Its range stretches from Maine to Georgia, though overall occurrence is sporadic and total number of individuals is estimated to be less than 3000 (NatureServe 2011). This species has a state conservation rank of S2 (imperiled) in both VA and NC, in addition to being listed as federally threatened. This species is mainly vulnerable in its overall range to habitat destruction and logging operations, though in BLRI, deer herbivory is perhaps the largest threat. Damage from research activity has also been noted at BLRI.

There are two populations of small-whorled pogonia—one each in VA and NC. Populations in VA have been monitored since 2003, and in NC since 2002, though no plants have been observed at the NC site since that time. Plants in the VA population have been caged to prevent deer herbivory. The monitoring report (NPS undated) observes that both populations are susceptible to competition from encroachment from other vegetation.

Figure 46. Small-whorled pogonia (*Isotria medeoloides*). [N. Murdock, USFWS, fws.gov]

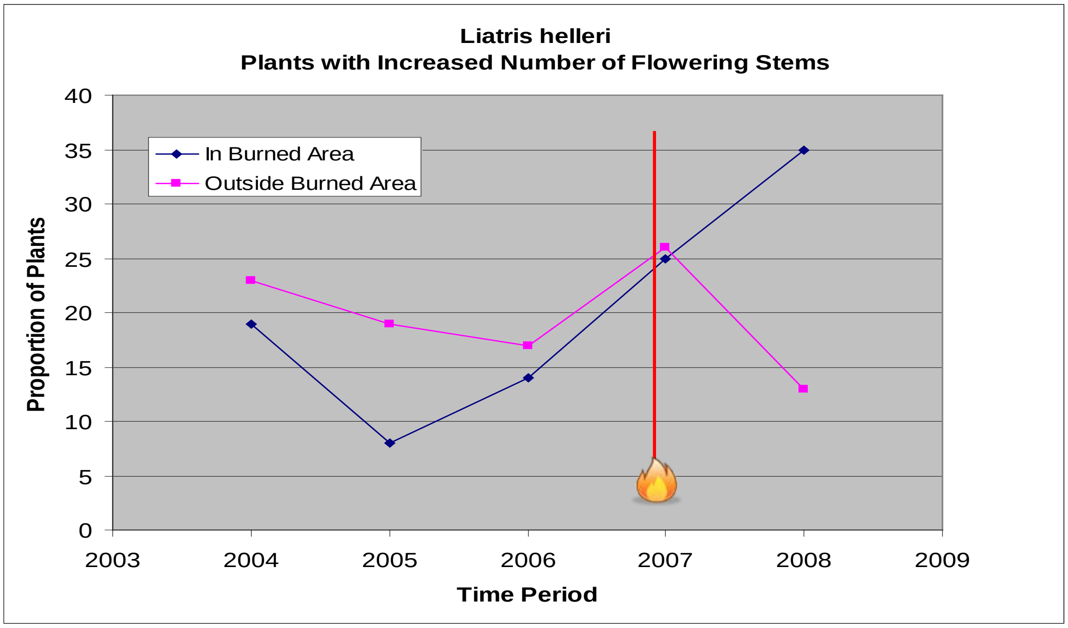

Figure 47. Burning at three sites in BLRI in 2007 stimulated increased flowering the following year. [taken from rare plants monitoring report (NPS 2009)]

Swamp Pink

This species (Figure 48) is limited to forested wetland habitat, and as a result, is sensitive to hydrological alteration and threats from development (Figure 48). It spreads slowly due to limited seed dispersal and flowering frequency, and as a result protection of existing sites is particularly important. Much of the original distribution of this plant has been lost, especially in its northernmost range in NY, though populations remain as far south as GA. It has a state conservation rank of S2 (imperiled) in NC and VA and is federally classified as threatened.

Figure 47. Swamp pink (*Helonias bullata*). [S. Croy, USDA Forest Service, fs.fed.us]

At BLRI, two populations exist—one in NC and one in VA. Like the small-whorled pogonia, swamp pink is vulnerable to deer browsing, and as a result protective cages have been constructed around flowering plants. It is also been observed that removal of competing skunk cabbage (*Symplocarpus foetidus*) may have also improved growth in this species. The VA site has many more individuals than NC, and as a result in 2010, propagated seedlings were to be introduced to the NC population in an effort to augment its numbers.

Gray's Lily
Although not federally-listed, Gray's lily has a state conservation rank of S3 (vulnerable) in NC and S2 (imperiled) in VA. It occurs only in the southern Appalachians and is threatened by commercial harvesting and hydrologic alteration. At BLRI, monitoring has been ongoing since 2006, and during 2008-2009 a decline in overall plant quality was observed, which may have been due to changes in moisture conditions. The rare plants monitoring report (NPS undated) suggests some canopy clearing may be necessary for this species to increase light availability.

Figure 48. Rock gnome lichen (*Cetradonia linearis*). [S. Sharnoff, lichen.com]

Rock Gnome Lichen
An extremely rare species, rock gnome lichen is listed as federally endangered and is restricted to the southern Appalachians. In addition, it has a state conservation rank of S2 (imperiled) and S1 (critically imperiled) in NC and VA, respectively. Rock gnome lichen is associated with Fraser-fir forests previously common to high-elevation sites along the Parkway, but has undergone recent severe declines in response to the loss of these forests to the balsam woolly adelgid. It also occurs in lower elevation gorges in hemlock communities, which are facing a current and ongoing threat from hemlock woolly adelgid. Both of these forest types provide shade required for this species. Its association with rocky outcrops also makes it vulnerable to trampling (NatureServe 2011).

A recovery plan developed by the USFWS (Murdock and Langdon 1997) indicated 33-35 known populations, with five known extirpations. All but 5 of these populations are under public ownership, with the largest current population at GRSM. In addition to threats from recreational use, air pollution, particularly sulfates, as well as acidic rainfall may also be influencing the decline of this species.

Other Rare Plants
Many other sensitive and rare plants are present at BLRI that NPS staff are not able to monitor regularly (Appendix B). Several of these species have state conservation ranks of imperiled or critically imperiled and were discovered at new locations within BLRI by the recent NatureServe (Govus and White 2009) vascular flora inventory (Table 44). The rare plants report (NPS undated) also mentions that monitoring has been conducted as part of an internship program that included three rare plants at BLRI—mountain catchfly (*Silene ovata*), shooting star (*Dodecatheon meadia* var. *meadia*), and creeping phlox (*Phlox subulata*). However, at the time of the report, these data had not been analyzed.

Table 44. Newly identified populations and occurrences of rare plants at BLRI identified by Govus and White at BLRI (2009).

Species		State Rank[1] NC	VA	Global Rank[2]
Adlumia fungosa	Climbing fumitory	S2		G4
Carex vesicaria	Inflated sedge		S1	G5
Clematis catesbyana	Satin-curls	S2		G4
Crataegus succulenta	Fleshy hawthorn	S1		G5
Dalibarda repens	Robin runaway		S1	G5
Pycnanthemum curvipes	Tennessee mountainmint	S1		G3
Euphorbia purpurea	Glade spurge	S2	S2	G3
Geum geniculatum	Bent avens	S2		G2
Glyceria nubigena	Smoky Mountain mannagrass	S2		G2
*Gymnoderma lineare**	Rock gnome lichen	S2		G2
Scutellaria saxatilis	Rock skullcap	S1	S3	G3
Taenidia Montana	Yellow pimpernel	S3	S5	G3

[1]Rounded NatureServe conservation status of a species from a state/province perspective, characterizing the relative imperilment of the species. S1=Critically Imperiled, S2=Imperiled, S3=Vulnerable, S4=Apparently Secure, S5=Secure, SH = Possibly Extirpated, H = Historic; Refer to <http://www.natureserve.org/explorer/nsranks.htm> for additional information on ranks.
[2]Rounded NatureServe conservation status from a global (i.e., rangewide) perspective, characterizing the relative imperilment of the species. G1=Critically Imperiled, G2=Imperiled, G3=Vulnerable, G4=Apparently Secure, G5=Secure. Refer to <http://www.natureserve.org/explorer/ranking.htm> for additional information on ranks.

4.7.3 Plant Exploitation

Although plant collecting in the Southern Appalachians has long been identified as a traditional activity, overharvesting, particularly at commercial scales, of plant populations can eventually lead to their loss. Many plants at BLRI are collected illegally due to their commercial value as herbal remedies or floral products. Plant poaching is particularly a problem at BLRI because of its high plant diversity, in addition to the relatively easy access to large areas of the park property from the roadway. Some of the poaching targets of greatest concern include trillium (*Trillium* spp.), bloodroot (*Sanguinaria canadensis*), black cohosh (*Actaea racemosa*), galax (*Galax urceolata*), Gray's lily, sphagnum (*Sphagnum* spp.) and other moss species, and American ginseng (*Panax quinquefolius*).

American Ginseng

Ginseng occurs in rich, mesic forests under moderately closed canopy where average populations can include dozens to hundreds of individual plants. Due to its high market price, up to $1,100 per dry pound ($2,425 per kg), wild-harvested ginseng roots are the most commonly exported native medicinal plant in the U.S. (Scott et al. 1995, Gabel 2009). The main threats to this species are illegal harvest, irresponsible harvest, herbivory by white-tailed deer (*Odocoileus virginianus*), and invasive plant species. Habitat loss and destruction also threaten the species in parts of its range (USFWS 2011). In some regions of its natural habitat, ginseng is under threat by invasive plants such as multiflora rose, garlic mustard, and Japanese barberry, and has been impacted largely in the past by periods of timber harvest and overall loss of forest habitat. Wixted and McGraw (2009a) observed an increased susceptibility of ginseng to invasive encroachment in harvested populations, as well as increased mortality of ginseng seedlings in the presence of garlic mustard. In addition, ginseng is susceptible to invasion by tree-of-heaven, which, like garlic mustard, produces allelopathic chemicals that can decrease chances of survival for ginseng seedlings (Wixted and McGraw 2009b). In a Virginia study plot, Wixted and McGraw (2009b) documented Japanese stiltgrass (*Microstegium vimineum*) and multiflora rose among a ginseng population during field assessments in 2006 and 2007. Wixted and McGraw (2009b) described the ability of multiflora rose to form dense thickets that eventually may exclude native species including ginseng. Ginseng is also slow-growing, not reaching reproductive status for a minimum of 7-9 years in the wild, sometimes taking much longer. Populations are particularly vulnerable to repeated, intensive poaching (Nantel, Gagnon, and Nault 1996; Gagnon 1999).

Efforts to determine minimum viable population (MVP) sizes have resulted in estimates ranging from 172 plants in Canada, 510 in Great Smoky Mountains National Park (GRSM), and up to 800 in West Virginia and other locations where populations are influenced by white-tailed deer (*Odocoileus virginianus*) predation (Furedi and McGraw 2004, McGraw and Furedi 2005, NatureServe 2011). The survey at GRSM observed that none of the populations there reached the 510 MVP level (NatureServe 2011), nor have any populations that large been found at BLRI. Methods to mark ginseng plants at GRSM have aided in prosecution of poachers by tracing confiscated roots to the park. As a result, similar monitoring methods have been adopted at BLRI, SHEN, and MACA (Rock 2001).

<u>Black Cohosh</u>
Another current poaching target at BLRI is black cohosh. Valuable as a medicinal herb, cohosh is commonly regarded as an anti-inflammatory, sedative, and diuretic, among other functions. It is also widely used as an alternative to hormone replacement therapy for treating menopausal symptoms (Predny et al. 2006). Dry black cohosh root is valued from $3 up to $5 per pound ($6.61 to $11.02 per kg) (NatureServe 2011). Although it is not state-listed in either NC or VA, it is in danger of decline, especially in public land areas where larger tracts of forest are available for collecting (NatureServe 2011).

<u>Trillium spp.</u>
Nine species of trillium have been documented at BLRI, including several rare species. Sweet white trillium (*T. simile*is listed as Threatened in North Carolina. , and southern nodding trillium (*T. rugelii*) and Barksdale trillium (*T. sulcatum*) are both listed as S3 (vulnerable) in NC. Nodding trillium (*T. cernuum*) is listed as S2 (imperiled) in VA.Generally, trilliums are taken for the floral trade, and may be shipped overseas as live plants to satisfy demand from collectors. In addition to poaching, trillium populations are vulnerable to many other threats including development, trampling, and encroachment of exotic species such as English ivy (*Hedera helix*), garlic mustard (*Alliaria petiolata*), Japanese honeysuckle, and kudzu (NatureServe 2011).

<u>Galax</u>
Galax represents a significant poaching target along the Parkway. The unique large genetic form of galax that is most desired by buyers occurs only along the Blue Ridge escarpment and the Blue Ridge Embayment, where the Parkway is situated. Populations may be slow or unable to recover depending on poaching pressure, as whole plants are removed as opposed to just foliage or flowers. Export estimates of galax reach up to three billion leaves a year (NPS 2010). Recently advertised wholesale prices, as of March 2012, have reached as high as $4.40 per leaf. A system of visible and concealed plant tagging has been used at BLRI to trace galax origins.

Bloodroot

Bloodroot is an herbaceous perennial native to eastern North America. Stems and rhizomes exude a bright red fluid when broken. Preferred habitat is rich, mesic to somewhat dry deciduous forests and coves with fertile soils and circumneutral to basic soil. In portions of its range, including the southern Appalachian Mountains, this species is often encountered with sugar maple. Occasionally, this species occurs in well-drained soils along ridge tops, from aspen/poplar woodlands in the northwest portion of its range to montane oak-hickory forests, high-elevation red oak forests and northern hardwoods in the southern Blue Ridge. (NatureServe 2012). The alkaloids in bloodroot have strong antibiotic and anti-inflammatory properties (Godowski 1989), and have been used for various medicinal purposes for centuries. Most recently, extracts of bloodroot have been used in toothpaste to prevent plaque formation and gum disease, and as a livestock feed additive in European countries where antibiotics have been banned.

In the early 1990's, the market demand for bloodroot, worldwide, was estimated at 2,000 tons. In 2002, retail prices were $3.35 per ounce of cut dried root, and $14 per ounce of liquid extract. In 2000, a single German company which uses bloodroot to produce livestock feed that fattens animals naturally, purchased 40 metric tons of bloodroot from the Southern Appalachians, which was less than a third of what they needed (Clark 2002). In 2003, the same company projected a need for 300,000 pounds of dried root per year. At present, there are probably fewer than 70 acres in bloodroot production in all of North America, which is a fraction of what would be needed to satisfy the increasing demand (Persons and Davis 2005). Because of concerns for increasing harvest pressure on wild populations, the United Plant Savers Organization lists bloodroot as an "At-Risk" species. (Predny and Chamberlain 2005).

Monitoring

As of 2012, permanent monitoring plots had been established at 34 sites on BLRI by the APHN to monitor relative declines of black cohosh, trilliums, bloodroot, and ginseng, with the specific goal of detecting a 30% decrease in abundance in the first three targets. Ginseng is found in much lower numbers than cohosh, trilliums or bloodroot, making detection of significant trends more difficult. The ultimate goal is to establish a total of 64 permanent plots across BLRI for monitoring changes in these species. Plots were located in areas of predicted habitat according to a model developed by the U.S. Forest Service and NatureServe that incorporates geology, precipitation, and landforms. Poached species will be monitored annually and a total inventory may be conducted every five-to-ten years to determine larger trends in plant composition. In the last 2 years, APHN field crews have visited 200 sites that were predicted to be suitable habitat for ginseng, trilliums, black cohosh and bloodroot. Ginseng was found at only 42 of these sites. Only one of the ginseng populations contained more than 30 plants, far short of the minimum number believed necessary for long-term survival. Age structure in all populations was skewed toward immature, non-reproducing plants; 30 percent of the populations had no reproductive plants left. The vast majority of the populations had less than a dozen ginseng plants remaining. This initial data is indicative of intensive, long-term poaching of ginseng at BLRI. Law enforcement rangers arrest an average of 6-12 ginseng poachers per year, and confiscate 500 ginseng roots in an average year, but apprehension is difficult. Although BLRI is best known for its roadway, the park also encompasses thousands of acres of rugged backcountry. APHN monitoring sites include plots in remote areas, as well as closer to the road. Disconcertingly, ginseng populations are showing the effects of long-term intensive poaching, even in those areas that are much more difficult to access.

APHN monitoring of galax poaching at BLRI involves a 2-pronged approach: 1) “quick plots” – are being monitored every year to detect evidence and intensity of poaching (approximately 100 populations); and 2) eight permanent long-term quantitative plots are being monitored for changes in density of galax cover and leaf size ratios (age class). Large leaves are 3.5 inches (9 cm) or larger in diameter, the size preferred by commercial buyers. Galax populations were systematically mapped during visits to 1,876 sites across the entire Parkway; 7% of the sites where galax was observed were considered “poachable” – a minimum of 50 square meters of galax with at least some leaves 3.5 inches or greater in diameter. During the winter of 2011-2012, 93% of the "quickplots" were poached. In the permanent quantitative plots, galax cover decreased in 4 of the 8 plots between 2010 and 2011, in spite of unusually heavy recruitment within the populations between monitoring events (possibly the result of heavy snowfall in the preceding winter). Based on U.S. Forest Service data, unharvested populations typically contain 30-40% large leaves. Only 3 of the 8 quantitatively monitored populations fell within that range in 2011. The other 5 populations had less than 15% large leaves, and 4 of the 5 had no large leaves remaining in the sampling transects. Based on the qualitative estimates taken in the quick plots, 62% of the populations had less than 25% large leaves, and 9% had virtually no large-leaved plants left anywhere within the population. Using data provided by APHN field crews, BLRI rangers have apprehended and arrested over 70 galax poachers since the monitoring began. Five poachers caught in 2008 were in possession of nearly 26,000 freshly harvested galax leaves. Three poachers caught in September 2011 were in possession of over 30,000 leaves. Monitoring will continue to be used to aid law enforcement efforts to reduce poaching.

4.7.4 Summary

Due to the wealth of plant diversity present at BLRI, issues such as plant exploitation and rare plant conservation remain constant management challenges. Fortunately, the Parkway serves as a refuge for these rare plant species, and efforts to collect seeds and propagate populations, such as are ongoing for Heller’s blazing star, mountain avens, and swamp pink, may assist long-term conservation efforts. At the same time, however, the accessibility provided by the Parkway risks bringing visitors in contact with these very same plants. Many rare species such as mountain avens and rock gnome lichen specialize in cliffline habitat and are therefore susceptible to trampling from unwary hikers.

Plant exploitation is particularly difficult to address due to the uncertainty involved in how much park populations are being affected. To this end, the Appalachian Highlands Inventory and Monitoring Network has conducted extensive baseline surveys to aid in the establishment of permanent monitoring plots. These long-term plots will gauge the impact of poaching over time and assist in focusing efforts to reduce poaching pressure.

Despite the pressures on multiple plant species at BLRI, efforts by the park on behalf of these species likely provide the best hope of their protection and persistence. On the other hand, the threats to these species are imminent and show signs of worsening. Ongoing habitat threats such as hemlock woolly adelgid continue to degrade habitat for the rock gnome lichen. Plant poaching pressure also continues to increase. Monitoring plots for rare species will eventually provide information on trends for these populations, but current available data remains inconclusive. As a result, the condition status of significant flora at BLRI receives a condition ranking of good with a declining trend (Table 45).

Table 45. The condition status for significant flora at BLRI is good with a declining trend. The data quality for this ranking is good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Significant Flora		✓	✓	✓
		3 of 3: Good		

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4.8 Forest Pests and Disease

4.8.1 Chestnut Blight

A host of pests and diseases threaten the health of vegetation communities at BLRI. One of the earliest impacts by exotics on forest ecosystems in this area was the introduction of the chestnut blight (*Cryphonectria parasitica*), a fungus that infects American chestnut (*Castanea dentata*) trees, eventually resulting in their death. Initially introduced in New York in 1904, the blight spread throughout the entire natural range of the chestnut in the Oak-Chestnut and Mixed Mesophytic Forest Regions, eventually killing an estimated 4 billion trees, which at the time may have comprised up to 25% of canopy trees (Griffin 2000). Today, large uniform stands of red oak occur partially as a result of the massive dieoff (Govus and White 2009). Although the American chestnut trees still exists as stump sprouts, they rarely survive long enough to reach sexual maturity before being killed by the blight. Currently, restoration efforts have focused on crossing Asian blight resistant species with naturally-resistant American chestnut. Initial reintroduction trials are ongoing, though none are located at BLRI.

4.8.2 Balsam Woolly Adelgid

In addition to the far-reaching impacts from chestnut blight, an impact more unique to the Blue Ridge Parkway was an infestation of the balsam wooly adelgid (*Adelges piceae*). The Parkway encompasses roughly 10% of the entire range of Fraser fir, the tree species impacted by the adelgid. Initial infestation of the southeastern U.S. began in the 1950's, eventually reaching BLRI by the 1970's (Figure 50). A small insect native to Europe, the balsam adelgid affects fir species (*Abies* spp.) in eastern and western US. At BLRI, the Red Spruce – Fraser Fir Forest (Evergreen and Deciduous Shrub Types) (CEGL7130) occurs at the highest elevations and was heavily affected by the adelgid, resulting in almost complete mortality of canopy fir trees (Govus and White 2009). Today, balsam adelgid populations persist in infected areas, though communities of Fraser firs are regenerating. Age class structure has likely been permanently altered, and through repeated cycles of mortality and regeneration, it is likely that overall number of trees will eventually decline. Young Fraser firs, in general, show less susceptibility than mature ones. Though many species of predatory insects have been released as an attempt at biocontrol, they have been largely ineffective (Ragenovich and Mitchell 2006).

Figure 49. Throughout its range, mature Fraser fir (*Abies fraseri*) forest has been decimated by balsam woolly adelgid (*Adelges piceae*). [R. Anderson, USDA Forest Service, bugwood.org]

4.8.3 Hemlock Woolly Adelgid

A related pest is the hemlock wooly adelgid (HWA) (Adelges tsugae), which recently began spreading throughout the range of hemlocks in the eastern U.S. after its initial discovery in Richmond, VA. Native to southern Japan, this species of adelgid preys upon species of eastern hemlock (Tsuga canadensis) and Carolina hemlock (Tsuga caroliniana), usually resulting in fatal damage to the tree within 3 to 10 years of infestation. In the northeastern US, hemlock mortality has been reported at levels up to 90%; in SHEN, mortality is reported to be 80% in some areas (NPS 2007). Hemlock woolly adelgid was discovered along the BLRI in VA in 1984.

Hemlock often functions as a keystone species, meaning that its role is essential to the function of the community as a whole. The recent environmental assessment on HWA treatment options (NPS 2007) points out the lack of shade tolerant evergreens that could fill the important ecological role of hemlock. Numerous studies predicted a multitude of effects on the structure and function of hemlock riparian and cove hardwood communities due to adelgid-induced decline, including transpiration rates, carbon cycling, vegetation dynamics, structural complexity, wildlife, and potential spread of exotic species (Ford and Vose 2007, Cleavitt et al. 2008, Nuckolls et al. 2009, Daley et al. 2007, Eschtruth et al. 2007). Native brook trout (*Salvelinus fontinalis*) prefer cooler water temperatures associated with hemlock ecosystems over warmer waters to which exotic brown trout and rainbow trout are adapted (NPS 2007). In addition, the rock gnome lichen (*Gymnoderma lineare*), an endangered high-elevation lichen that occurs at BLRI, could suffer a loss of shaded habitat areas as a result of hemlock decline. Besides these numerous ecosystem effects, loss of hemlocks would impact BLRI in other ways, including increasing amount of fuel loading, reducing aesthetic quality of overlooks and recreational areas, and causing safety concerns.

Several community types indicated by Govus and White (2009) are susceptible to impacts from HWA decline: Southern Appalachian Eastern Hemlock Forest (White Pine Type) (CEGL7102); Blue Ridge Hemlock – Northern Hardwood Forest (CEGL7861); Southern Appalachian Acid Cove Forest (Typic Type) (CEGL7543); Central Appalachian Acidic Cove Forest (CEGL8512); High-Elevation Hemlock – Yellow Birch Seepage Swamp; and Carolina Hemlock Forest (Mesic Type) (CEGL7138); Central Appalachian Acidic Cove Forest (White Pine – Hemlock – Mixed Hardwoods Type) (CEGL6304); Montane Alluvial Forest (Small River Type) (CEGL7143). Of these seven community types, the first four are included in the park's vegetation map, and comprise a total of 1548 ha. Although spread throughout the Parkway, these communities occur predominantly within the wider sections of the park. These include the Doughton Park, Cumberland Knob, Rocky Knob, and Julian Price/Moses Cone areas (Figure 51).

Although treatment of HWA often includes predatory beetle releases and insecticide application, they are expensive and labor intensive, necessitating that only specific areas can realistically be prioritized for treatment. One such potential area is the Carolina Hemlock Forest—an extremely rare community on the Parkway—which occupies a small area near Linville Falls. In North Carolina, this species is estimated to have fewer than 100 population occurrences remaining (NPS 2007). White and Govus suggest the Montane Alluvial Forest tract near Linville Falls would also be a potential target for control.

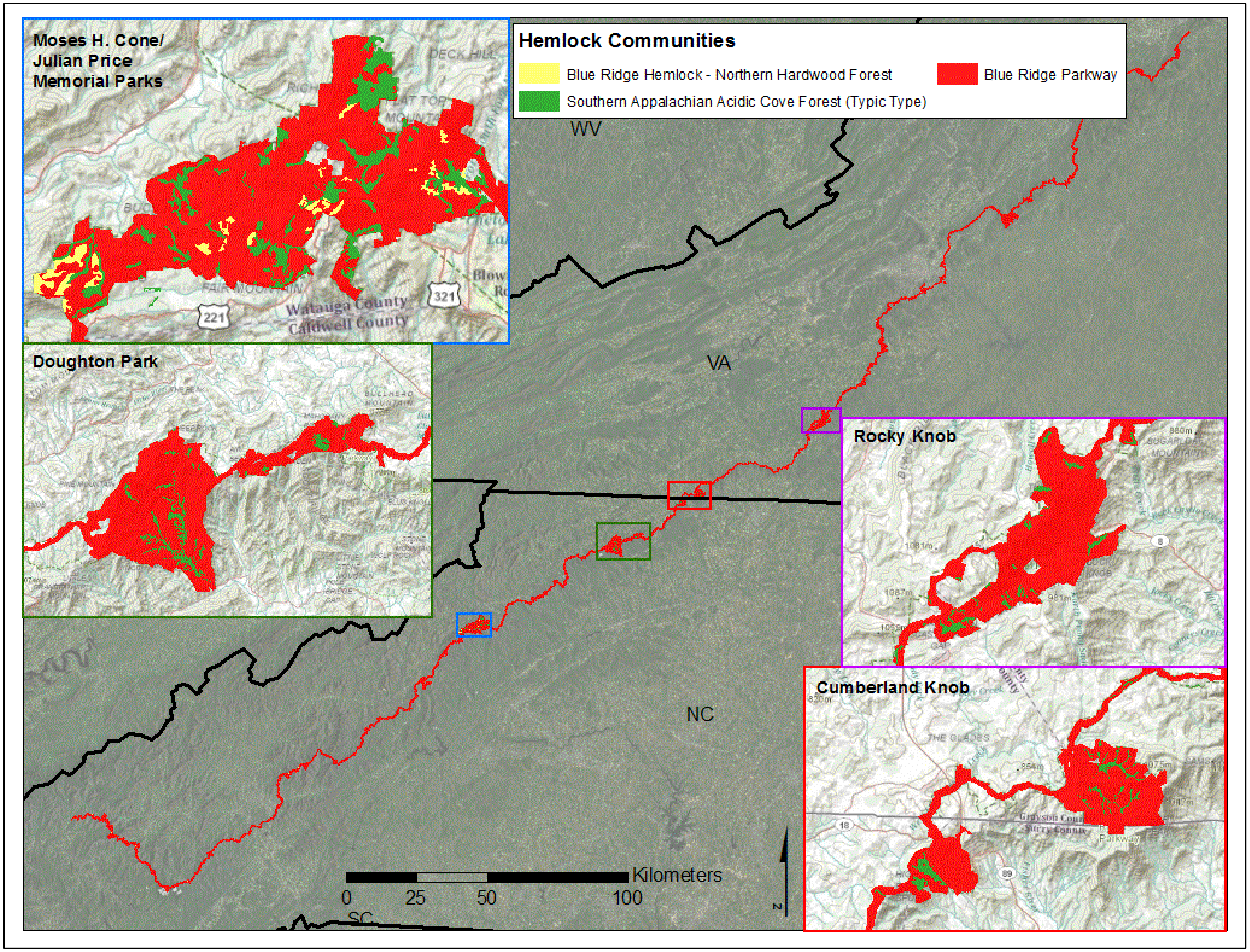

Figure 50. Examples of hemlock communities along BLRI which are susceptible to hemlock woolly adelgid.

In its 2007 environmental assessment on HWA control strategies, BLRI outlined its preferred management approach to be a combination of chemical and bio-control methods, a procedure the park has used since 2001 (C. Ulrey personal communication). Imidacloprid is commonly used as a soil drench or injection for HWA, as treatments can last 2-3 years with very high control rates. Imidacloprid treatments, combined with horticultural oil and insecticidal soap applications, would comprise the chemical treatment options, though spray application would be avoided in riparian areas to prevent toxic effects on aquatic invertebrates. Biological controls include the release of exotic beetle species that predate HWA—this option is particularly expensive and its long-term efficacy still uncertain, though early stage control results are encouraging (NPS 2007). This method of control will be important in remote locations where chemical treatment is impractical.

4.8.4 Gypsy Moth

The European gypsy moth (*Lymantria dispar*) is an exotic forest pest that infests multiple vegetation types. Originally introduced in the 1860's, this species defoliates several tree species, though it shows preference to certain oaks (*Quercus* spp.), Sweetgum (*Liquidambar styraciflua*), and aspen (*Populus* spp.). The larva of these moths can quickly defoliate trees and portions of forests, eventually resulting in tree mortality.

Gypsy moth egg masses were first observed in the James River District at BLRI in 1988, while aerial treatments began in 1990 using a combination of the nucleopolyhedrosis virus (NPV), the chemical diflubenzuron, and the bacterium *Bacillus thuringiensis* (Ohlsen and Rakes 1992). Defoliation damage was observed in 1990 on 16 ha along the northernmost 50 km (30 miles) of the Parkway; the following year, 327 ha were defoliated. In 1992, 664 ha were defoliated, and hundreds of dead trees were removed from the James River District (Ohlsen 1993). After the introduction of the epizootic fungus *Entomophaga maimaiga* in 1995, populations of gypsy moth crashed to levels, but again resurging in 2000 (Figure 53). In 2002, funding was requested for the treatment of 324 ha at BLRI (Sellers 2001). Although annual surveys were not available after that year, the 1992 Integrated Pest Management (IPM) Plan for gypsy moth at BLRI predicted full infestation of counties that contain the Parkway by 2010. Recent data from the Cooperative Agricultural Pest Survey (CAPS) shows this appears to be the case (Figure 52), as only a handful of counties in western North Carolina remained uninfested in 2011. The CRMS vegetation map developed for BLRI included a total of 27 ha in ten separate parcels mapped as successional gypsy moth damaged forest, meaning damage was significant enough in these areas such that the original community type became unrecognizable.

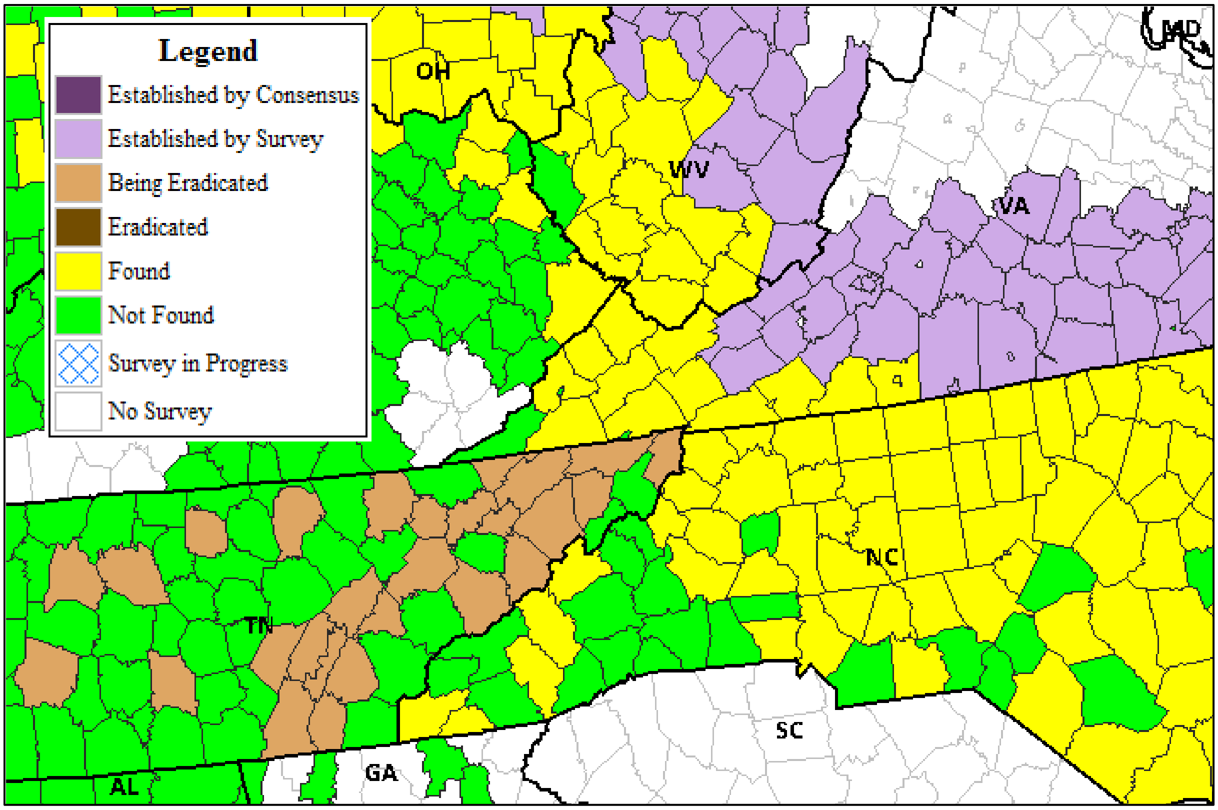

Figure 51. Shown since 2009, the invasion front of gypsy moth continues to spread southwest into western North Carolina and Virginia [Source: NAPIS 2012].

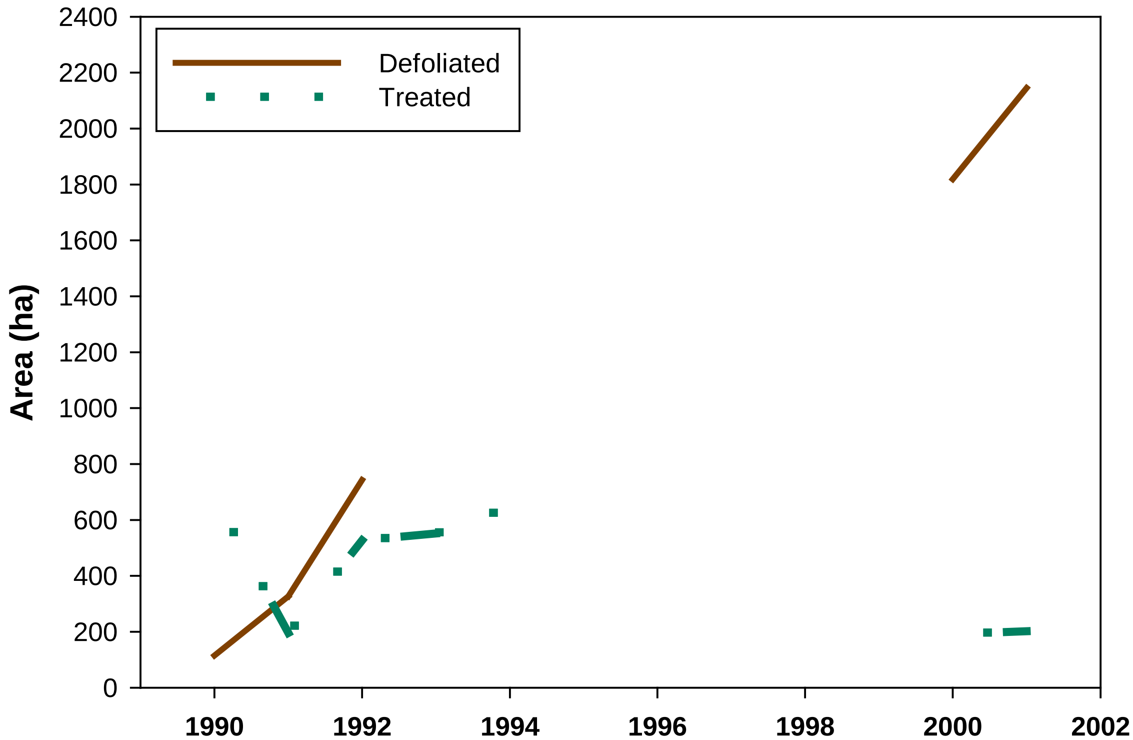

Figure 52. Gypsy moth defoliation and treatment area at BLRI. Populations crashed in 1995 following the spread of *Entomophaga maimaiga*, a fungus that kills the moth. Drought from 1995-1999 suppressed the fungus activity, and moth populations resurged in 2000 (Sellers 2001).

4.8.5 Southern Pine Beetle

Southern pine beetle (*Dendroctonus frontalis*) is a forest insect native to the southern US, where outbreaks occur every few years and are usually short in duration (Teague et al. 1994). The beetle infests all species of pine, though the main ones affected at BLRI include pitch pine (*Pinus rigida*), shortleaf pine (*P. echinata*), eastern white pine (*P. strobus*), and Virginia pine (*P. virginiana*).

Roadside surveys of pine beetle damage were conducted at BLRI each year during the period 1989-1993, during which a total of 25 sites comprising a total of 4 ha were documented between MM5 and MM70 (Teague et al. 1994). No additional on-the-ground data is available for southern pine beetle after that time.

A spatial model produced by the Forest Health Technology and Enterprise Team (FHTET) used a combination of pine species composition, slope, shadow effect, and basal area to predict the susceptibility and vulnerability of forested regions in the southeastern U.S. to southern pine beetle using a categorical ranking from no risk to very high risk. The southeast region was divided into eight different zones covering 15 ecoregions. Southern pine beetle infestation risk is generally highest for lower elevation areas in the Piedmont and Coastal Plain, and generally quite low in the mountainous Appalachian corridor, though the Parkway does cross small swaths of areas with elevated risk.

4.8.6 Pine Sawfly

The pine sawfly (*Diprion similis*) is a relatively uncommon pest at BLRI, first found in the park in 1977 at the Linville Falls area and again in 1990 in the Jeffress Park area (Teague and Ohlsen 1991). This species feeds primarily on Eastern white pine, though secondary preferences include shortleaf and Virginia pine. Feeding by the larvae of this species can result in tree dieback or overall mortality. Due to the presence of two native predatory wasp species—*Monodontomerus dentipes* and *Exenterus amictorius*—pine sawfly occurrences need little management intervention. Following the 1990 outbreak, several dead pines were removed. No data on outbreaks of pine sawfly is available for BLRI after 1990.

4.8.7 Emerald Ash Borer

Emerald ash-borer (EAB) is native to NE Asia, and was first discovered in the U.S. in Michigan in 2002. It attacks only ash trees (*Fraxinus* spp.), which are usually killed 3-4 years after infestation (McCullough and Usborne 2012). Although the natural spread of EAB is slow—about 5 miles per year—its range extends much more rapidly due to the transport of infested firewood. Ash borer larvae feed on the tree cambium, resulting in large galleries that eventually kill the trees. Although their introduction was relatively recent, EAB is estimated to cause up to $20 billion dollars in economic impact to the U.S. (USDA 2012a). Since 2009, no counties along the Parkway have documented its presence, though several nearby counties in West Virginia, Virginia, and Tennessee have reported the pest (Figure 54).

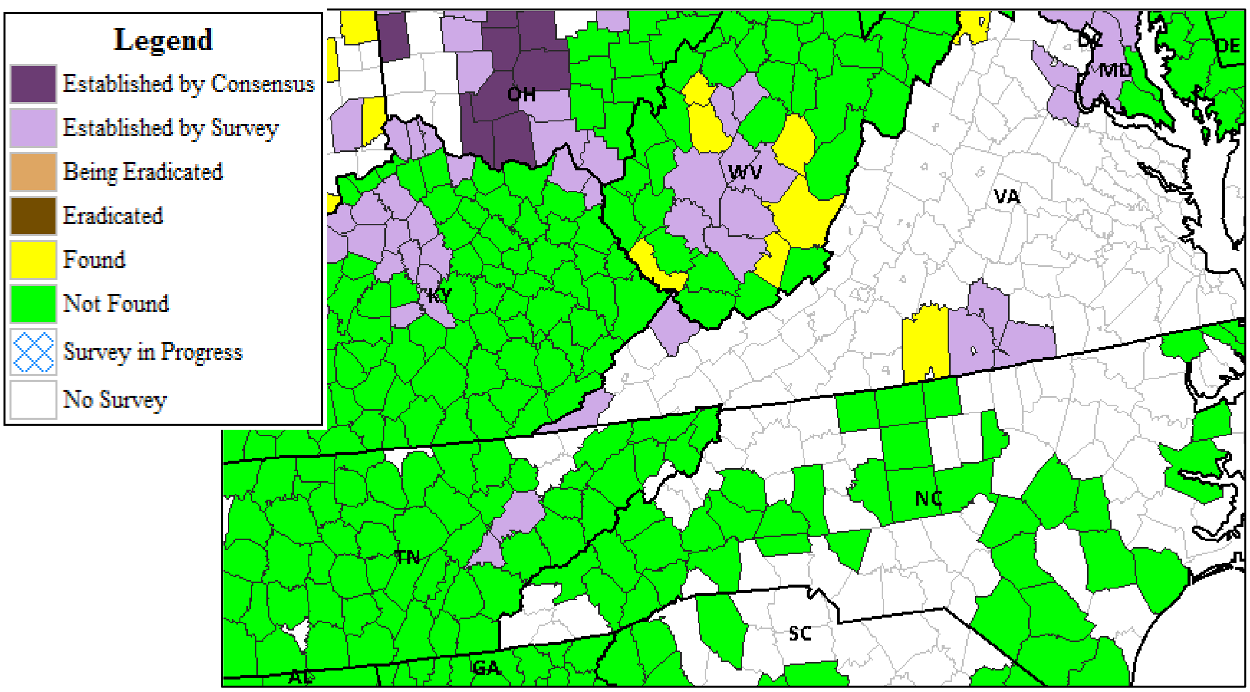

Figure 53. Since 2009, emerald ash borer (*Agrilus planipennis*) has been documented in counties near BLRI (e.g. Pittsylvania Co., VA, Loudon and Knox Co., TN), but not on the Parkway itself. [Source: NAPIS 2012]

4.8.8 Beech Bark Disease

Beech bark disease is the result of both an insect, beech scale (*Cryptococcus fagisuga*), and a fungus—either *Nectria coccinea* var. *faginata* or *N. galligena*. Beech scale infects the tree first, infesting the bole and feeding on the bark. The *Nectria* invasion is facilitated by the feeding activity of the scale and is what ultimately what results in tree mortality. Trees larger than 20 cm are somewhat more susceptible to the disease, though some trees do have a natural resistance to the insect (Houston and O'Brien 1998).

Beech scale was first observed killing trees in conjunction with the *Nectria* fungus in New England in the 1930s. As of 2005, the disease had reached as far south as West Virginia, with an isolated patch identified in several counties around the NC-TN border and along the southern portion of BLRI (Figure 55). Treatment options are very limited, and no large-scale treatment options exist. Breeding programs are conducted on resistant trees for the potential goal of helping affected areas.

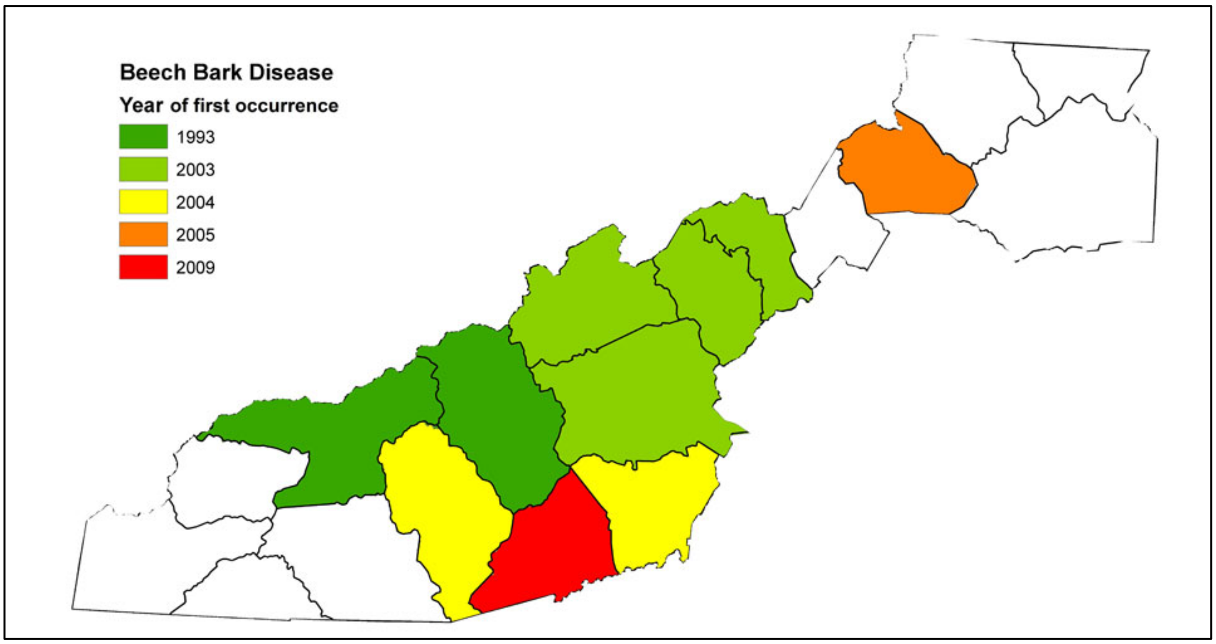

Figure 54. As beech bark disease continues to spread in western NC, new areas along BLRI will likely become infected. [Source: WNC Forest Report Card 2012]

4.8.9 Dogwood Anthracnose

Dogwood anthracnose (*Discula destructiva*) is a fungal disease that infects flowering dogwood (*Cornus florida*). Originally detected in the northeast, the disease has spread to the south (Figure 56) and has been reported in some western states, where it infects Pacific dogwood (*Cornus nuttallii*). Contributing factors include cold and wet spring and fall weather, and over time the disease may kill the tree. Symptoms include necrotic leaf blotches and retained dead leaves in the fall. Eventually symptoms may spread to the twigs and main trunk, where cankers and split bark may result. Prevention includes watering during drought in the case of individuals and avoiding mechanical injuries. Fungicides may also be effective (Mielke and Daughtrey 2012).

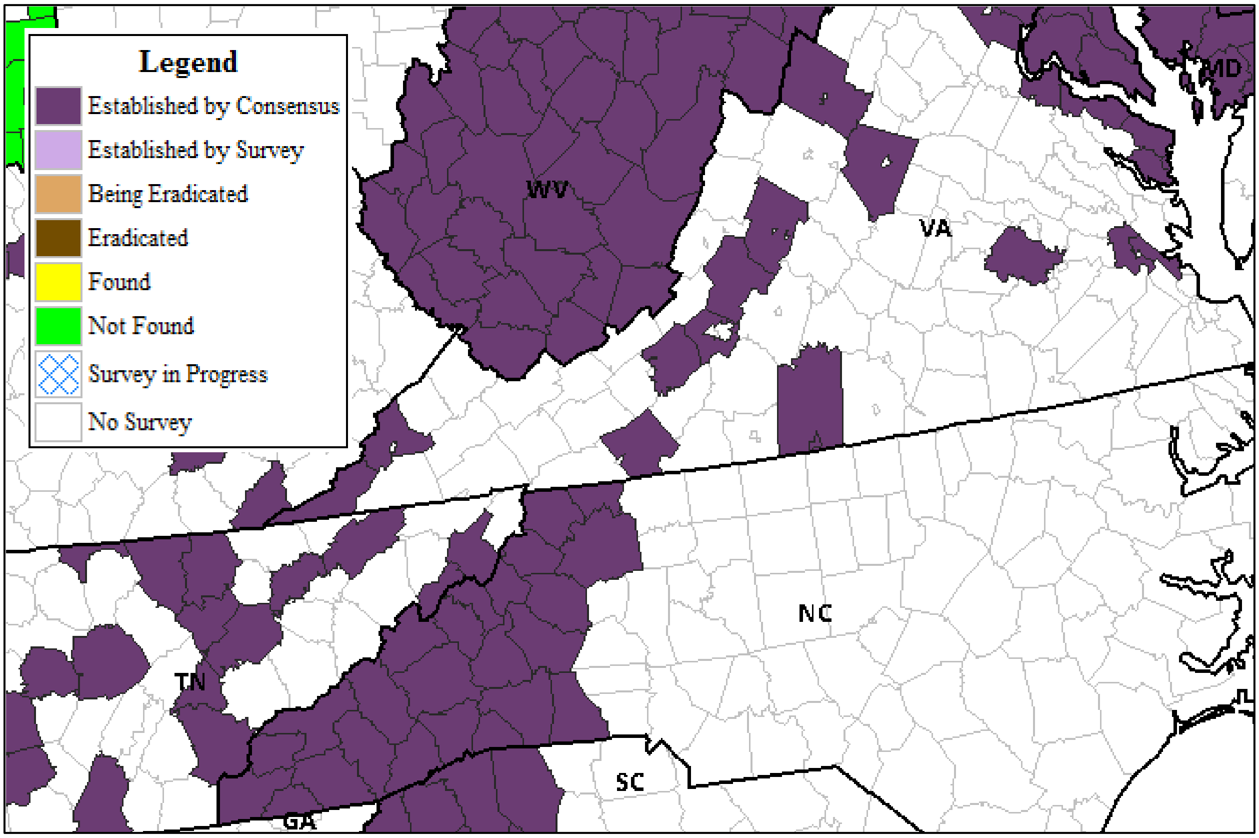

Figure 55. Dogwood anthracnose is established throughout the Southern Appalachians. [Source: NAPIS 2012]

4.8.10 Asian Longhorn Beetle

Another invasive, the Asian longhorn beetle (*Anoplophora glabripennis*; ALB) is native to China and Korea and was originally found in New York in 1996, Illinois in 1998, and most recently in Ohio in 2011. This pest bores into trees to reproduce, after which larvae form galleries in the main bole, which can weaken and eventually kill the tree. Preferred hosts are hardwood species such as maple (*Acer* spp.), buckeye (*Aesculus* spp.), elm (*Ulmus* spp.), birch (*Betula* spp.), and willow (*Salix* spp.) (USDA 2012b). So far, ALB has not been documented in areas near BLRI where surveys have been conducted (Figure 57) and mainly remain a problem in certain areas in New England. The variety of hosts present at BLRI, necessitates alertness for the arrival of this invasive.

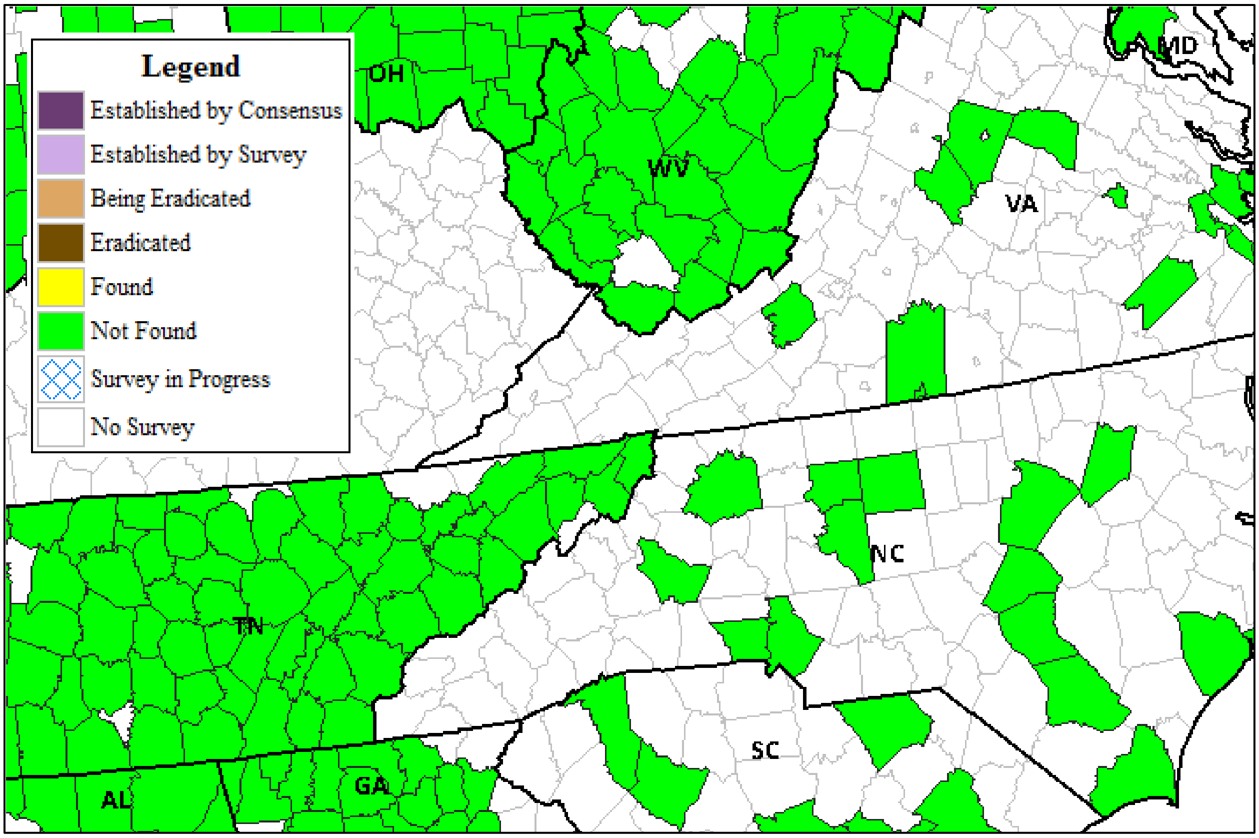

Figure 56. Asian longhorn beetle has not been identified close to BLRI as of 2012. [Source: NAPIS 2012]

4.8.11 Summary

Arguably the most important issue currently facing ecosystems at BLRI is the presence of hemlock woolly adelgid. The adelgid was originally found on the Parkway in 1984 in Virginia, and though it continues to cause mortality as it spreads, opportunities remain to prevent and slow further damage. Several forest community types throughout BLRI could be altered greatly due to hemlock decline, including cove and hemlock forests where hemlock loss could result in altered habitat for terrestrial and aquatic species. The Parkway also contains remaining habitat for the extremely rare Carolina hemlock forest type, which represents a crucial conservation opportunity.

BLRI faces an ongoing threat from several other insect species, but at the same time has already undergone complete ecosystem changes in certain areas due to effects from chestnut blight and balsam woolly adelgid. Both of these pests remain present, and as a result, American chestnut and Fraser fir trees will undergo continued mortality as they mature. Overall, 47 plots (13%) surveyed by NatureServe at BLRI showed signs of either HWA, gypsy moth, or southern pine beetle.

The European gypsy moth poses a great threat to forest health throughout BLRI. Originally observed at the park in 1988, the invasion front of gypsy moth continues to spread southward and was predicted to be present throughout the park by 2010. Since 2009, gypsy moth has been documented in all but seven counties in the southern section of the Parkway (NAPIS 2012). Effective treatment options are available for gypsy moth, and its ability to quickly defoliate stands and induce tree mortality make it a high treatment priority. Other pests present on the Parkway, including southern pine beetle and pine sawfly. In addition to the species outlined in this section the recent NPS Rapid Response (2010) report outlines several other pest species that could present a threat to eastern forests.

Because of the major threat posed to several vegetation types at BLRI from HWA-induced hemlock loss, as well as the ongoing threat of mortality to hardwoods by European gypsy moth and Emerald ash borer, forest pests and disease receives a condition ranking of fair with a degrading trend (Table 46).

Table 46. The condition status for forest pests and disease at BLRI was ranked fair with a degrading trend. The data quality for forest pests was ranked good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Forest Pests and Disease		✓	✓	✓
		3 of 3: Good		

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4.9 Fish Assemblages

4.9.1 Relevance and Context

The southeastern United States supports the richest fish diversity in North America, north of Mexico (Warren et al. 2000). The river basins of the region harbor fish assemblages characterized by high species richness and endemism (Sheldon 1988). The Blue Ridge Parkway traverses a long swath of this region and includes portions of multiple drainages. The park might be expected to support an unusually diverse fish fauna with many species of concern. However, the BLRI is typically located along high mountain ridges and many of the streams within its boundaries are short reaches of small headwater flows. These habitats are expected to have lower fish diversity than larger, downstream river reaches (Matthews 1998). Many of the streams within the BLRI are trout streams for which the natural expected assemblage consists of a few or a single species. Therefore, expectations of fish diversity in the park must be tempered by these competing factors.

Brook trout (*Salvelinus fontinalis*) are the only native salmonid in the Appalachian Mountains and occur in the BLRI. They are a popular game species and are sensitive to habitat degradation. In North Carolina and Virginia, naturally occurring brook trout are restricted to the Appalachian Mountains. Local populations in these states have suffered anthropogenic impacts resulting in many declines and extirpations (Hudy et al. 2005). The species has been widely introduced and many pure endemic strains have been replaced or diluted by non-local and genetically distinct varieties (Habera and Moore 2005). Because of the recreational importance of the species, its limited range within the southeast, and its susceptibility to anthropogenic impacts, the brook trout is a species of potential management concern in the BLRI.

The park includes portions of seven USGS HUC 4 watersheds and 15 HUC 8 watersheds. From north to south, these include headwater tributaries of the Potomac, James, Roanoke, Ohio, Pee Dee, Santee, and Tennessee River systems (Figure 58). Potomac drainage streams are located at the extreme north end of Parkway. The James and Roanoke Rivers cross the BLRI in the northern one-third of its length and drain generally eastward, emptying into the lower Chesapeake Bay and Atlantic, respectively. The James and Roanoke are the largest rivers crossing the park, and the valleys created by these flows contain the lowest elevations found in the park. The northern region of the BLRI is characterized by these large water gaps and by generally lower elevations relative to the rest of the park. The central section of the park follows the edge of the Blue Ridge escarpment and the divide between Atlantic and Mississippi drainages. In this region, north and westward draining streams flow into the interior of the ridge and valley region and eventually into the Ohio or Tennessee Rivers. Southward draining streams descend the escarpment to the North Carolina piedmont, eventually entering the Pee Dee or Santee Rivers and draining to the Atlantic. The southern portion of the park is in the interior of the mountainous southern Appalachian region and is surrounded by watersheds of the Tennessee River drainage. The French Broad River flows northwest across the park, forming the largest water gap through the BLRI in the southern region.

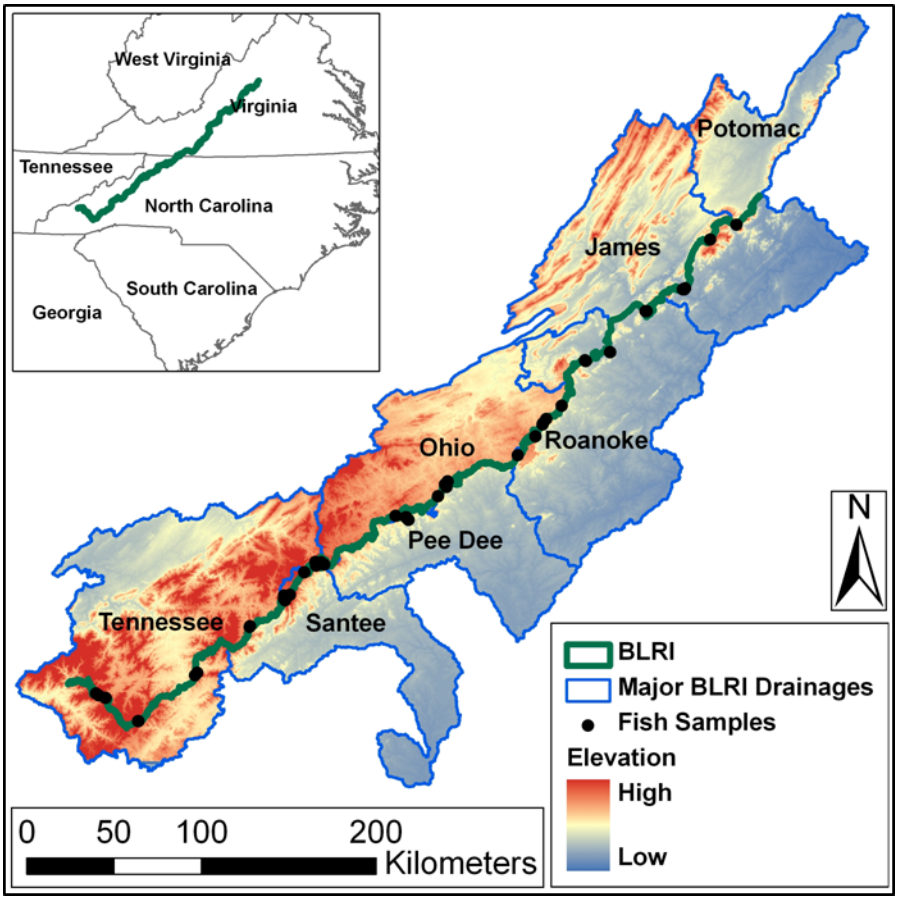

Figure 57. Elevation and major drainages of the BLRI region. Outer boundaries of the elevation area are the outer boundaries of all USGS HUC 8 watersheds that touch the park. Major drainages are named for the rivers the regions ultimately drain into.

4.9.2 Resource Knowledge

Scott (2007) conducted a comprehensive inventory of BLRI fishes from 2004-2007. Sampling occurred in all the major drainages discussed above, except the Potomac (Scott 2007). Scott (2007) used backpack electroshocking, boat electroshocking, and snorkeling to collect 50 fish assemblage samples along the parkway (Figure 58). Samples included 44 stream samples and six samples from artificial impoundments (Scott 2007). These efforts reported 82 species of fish from 11 families, and included an unidentified cyprinid, a hybrid sunfish, and an undescribed species of stoneroller (Table 47). No state or federally threatened or endangered species occurred in the samples, although five species were considered of special concern at the state or federal level (Table 47). The most common family was Cyprinidae, accounting for 35 of the species reported. The most abundantly occurring species was the golden shiner (*Notemigonus crysoleucas*), which accounted for over 20% of the overall individuals sampled. However, this resulted because an unusually high number of this species were collected from Price Lake, an artificial impoundment where they were introduced for forage (Scott 2007). The next most abundant species collected were the rosyside dace (*Clinostomus funduloides*), mountain redbelly dace (*Phoxinus oreas*), and the bluehead chub (*Nocomis leptocephalus*), occurring at about 6%, 5%, and 5% respectively. The most widely occurring species among samples was the white sucker (*Catostomus commersonii*) which occurred in 18 (36%) of the samples (Scott 2007). The rosyside dace, bluehead chub, fantail darter (*Etheostoma flabellare*), and creek chub (*Semotilus atromaculatus*) each occurred in 17 (34%) of the samples (Scott 2007). A further 29 species were only found in a single sample, and 17 only occurred in two samples (Scott 2007).

Of the six major drainages where sampling was conducted, the Tennessee received the most effort with 13 samples (Table 48). The Roanoke drainage had the greatest reported species richness with 47 species (Table 48). Many of the unique species were large river species collected from the Roanoke River itself which are not expected to be found in the small streams typically found in the park.

Brook trout occur in BLRI and southern strain brook trout appear to be relatively common in the park and in the general area. Of the 50 samples collected by Scott (2007), 11 (22%) contained brook trout. Shull and Walker (1995) examined the proportion of northern and southern strain brook trout in BLRI. They identified and sampled 20 potential brook trout streams in the park. Of these, 14 (40%) contained brook trout. Six streams contained either no fish or contained other species of trout (Shull and Walker 1995). Four streams contained low density populations or populations lacking adult fish, and were not analyzed (Shull and Walker 1995). Of the 10 populations analyzed six (60%) had genetic material indicating the presence of southern strain fish, and two (20%) of the populations appeared to be pure southern strain. Davis (2008) analyzed the prevalence of northern and southern strain genetic markers in brook trout from 56 streams in southwestern Virginia. Although most samples were not collected within the BLRI, around 10 were collected near the Parkway in streams that cross park boundaries or occur within two km of park boundaries. Of these samples, eight occurred in the New River (Ohio) drainage and two occurred in the Yadkin (Pee Dee) drainage. Seven of these stream samples contained 100% southern strain, two contained 95% southern strain, and one contained 93% southern strain brook trout (Davis 2008). Davis (2008) searched the literature and found that, at the major drainage level, no pure southern strain brook trout populations were reported from Virginia or North Carolina. Pure endemic strain populations found in individual streams may be especially important for conservation.

Table 47. Fish families and species reported during a 2004-2007 fish inventory of the Blue Ridge Parkway (Scott 2007). Also shown are species of special concern federally (FED), in North Carolina (NC), or in Virginia (VA).

Scientific Name	Common Name	Conc. Spp.
Family Anguillidae		
Anguilla rostrata	American eel	
Family Catostomidae		
Carpiodes cyprinus	Quillback	
Catostomus commersonii	White sucker	
Hypentelium nigricans	Northern hog sucker	
Hypentelium roanokense	Roanoke hog sucker	FED
Moxostoma cervinum	Black jumprock	
Moxostoma collapsum	Notchlip redhorse	
Moxostoma erythrurum	Golden redhorse	
Moxostoma macrolepidotum	Shorthead redhorse	
Moxostoma pappillosum	V-lip redhorse	
Moxostoma rupiscartes	Striped jumprock	
Thoburnia rhothoeca	Torrent sucker	
Family Centrarchidae		
Ambloplites rupestris	Rock bass	
Lepomis auritus	Redbreast sunfish	
Lepomis cyanellus	Green sunfish	
Lepomis gibbosus	Pumpkinseed	
Lepomis hybrid	Hybrid sunfish	
Lepomis macrochirus	Bluegill	
Micropterus dolomieu	Smallmouth bass	
Micropterus salmoides	Largemouth bass	
Family Clupeidae		
Dorosoma cepedianum	Gizzard shad	
Family Cottidae		
Cottus bairdii	Mottled sculpin	
Family Cyprinidae		
Campostoma anomalum	Central stoneroller	
Campostoma sp. Cf. anomalum	undescribed stoneroller	
Clinostomus funduloides	Rosyside dace	
Cyprinella analostana	Satinfin shiner	
Family Cyprinidae		
Cyprinella galactura	Whitetail shiner	
Cyprinella spiloptera	Spotfin shiner	
Cyprinus carpio	Common carp	
Hybopsis hypsinotus	Highback chub	
Luxilus albeolus	White shiner	
Luxilus cerasinus	Crescent shiner	
Luxilus coccogenis	Warpaint shiner	
Luxilus cornutus	Common shiner	
Lythrurus ardens	Rosefin shiner	
Nocomis leptocephalus	Bluehead chub	
Nocomis micropogon	River chub	
Nocomis raneyi	Bull chub	
Notemigonus crysoleucas	Golden shiner	
Notropis amoenus	Comely shiner	
Notropis chiliticus	Redlip shiner	
Notropis hudsonius	Spottail shiner	
Notropis procne	Swallowtail shiner	
Notropis rubellus	Rosyface shiner	
Notropis rubricroceus	Saffron shiner	
Notropis spectrunculus	Mirror shiner	
Notropis telescopus	Telescope shiner	
Notropis volucellus	Mimic shiner	
Phenacobius teretulus	Kanawha minnow	NC
Phoxinus oreas	Mountain redbelly dace	
Pimephales notatus	Bluntnose minnow	
Pimephales promelas	Fathead minnow	
Rhinichthys atratulus	Eastern blacknose dace	
Rhinichthys cataractae	Longnose dace	
Rhinichthys obtusus	Western blacknose dace	
Semotilus atromaculatus	Creek chub	
Semotilus corporalis	Fallfish	

Table 37. continued

Scientific Name	Common Name	Conc. Spp.	Scientific Name	Common Name	Conc. Spp.
Family Esocidae			**Family Percidae**		
Esox masquinongy	Muskellunge		*Etheostoma flabellare*	Fantail darter	
Family Ictaluridae			*Etheostoma kanawhae*	Kanawha darter	FED
Ameiurus melas	Black bullhead		*Etheostoma nigrum*	Johnny darter	
Ameiurus natalis	Yellow bullhead		*Etheostoma olmstedi*	Tessellated darter	
Ameiurus nebulosus	Brown bullhead		*Etheostoma podostemone*	Riverweed darter	FED, NC
Ameiurus platycephalus	Flat bullhead		*Etheostoma rufilineatum*	Redline darter	
Ictalurus punctatus	Channel catfish		*Etheostoma swannanoa*	Swannanoa darter	
Noturus insignis	Margined madtom		*Perca flavescens*	Yellow perch	
Pylodictis olivaris	Flathead catfish		*Percina gymnocephala*	Appalachia darter	FED
Family Moronidae			*Percina notogramma*	Stripeback darter	
Morone americana	White perch		*Percina roanoka*	Roanoke darter	
Morone saxatilis	Striped bass		**Family Salmonidae**		
			Oncorhynchus mykiss	Rainbow trout	
			Salmo trutta	Brown trout	
			Salvelinus fontinalis	Brook trout	

Table 48. Summary of fish sampling results by drainage for a 2004-2007 fish inventory conducted in BLRI. Drainages are identified by major downstream river, and immediate river drainages where samples were collected are included in parentheses.

	James	Ohio (New)	Pee Dee (Yadkin)	Roanoke (Dan, Roanoke)	Santee (Catawba)	Tennessee (French Broad, North Toe, Pigeon, Tuckasegee, Watauga)
Samples Collected	5	10	5	9	8	13
Species Collected	36	26	16	47	20	25
Total Individuals	678	1560*	263*	1359	941*	2102
Samples Without Fish	1	0	1	2	1	2
Lake Samples	1	1	0	1	1	2
Unique Species	11	3	3	18	0	3

* Excludes a single qualitative sample in which fish were not counted.

4.9.3 Threats and Stressors

General threats and stressors for fishes in the region primarily result from anthropogenic habitat changes (Warren et al. 2000, Angermeier 1995). Many of the streams in the BLRI are small headwater streams and are subject mainly to air pollution-related impacts. Because the Blue Ridge Parkway is a roadway, habitat alterations associated with road maintenance and development may potentially impact park streams. Exotic fish species may present threats to native species, although specific competitive interactions are not well-known for many species. Many of the exotic species reported from BLRI in the recent survey were placed and managed for recreational reasons, and some occurred in artificial impoundments. Threats to southern brook trout populations include competition from introduced rainbow trout (*Oncorhynchus mykiss*) and brown trout, and genetic dilution from introduced northern strain brook trout (Habera and Moore 2005).

4.9.4 Data

For our analyses we used the data reported by Scott (2007) from a recent inventory of BLRI fishes.

4.9.5 Reporting Areas

We divided the park into three broad reporting areas based on drainage boundaries and geography (Figure 59). The North reporting area consisted of the streams of the James and Roanoke River drainages. This area is characterized by two large river crossings and lower elevation relative to the rest of the park. The Atlantic reporting area consisted of the streams of Yadkin and Catawba drainages, which drain into the Pee Dee and Santee Rivers. This area is typified by small headwater streams that flow down the steep east face of the Blue Ridge escarpment and eventually drain into the Atlantic Ocean. The South reporting area consisted of the streams of the Ohio and Tennessee River drainages. Streams in this region flow north and west through mountainous terrain and empty eventually into the Gulf of Mexico. This region contains the highest elevations in the BLRI.

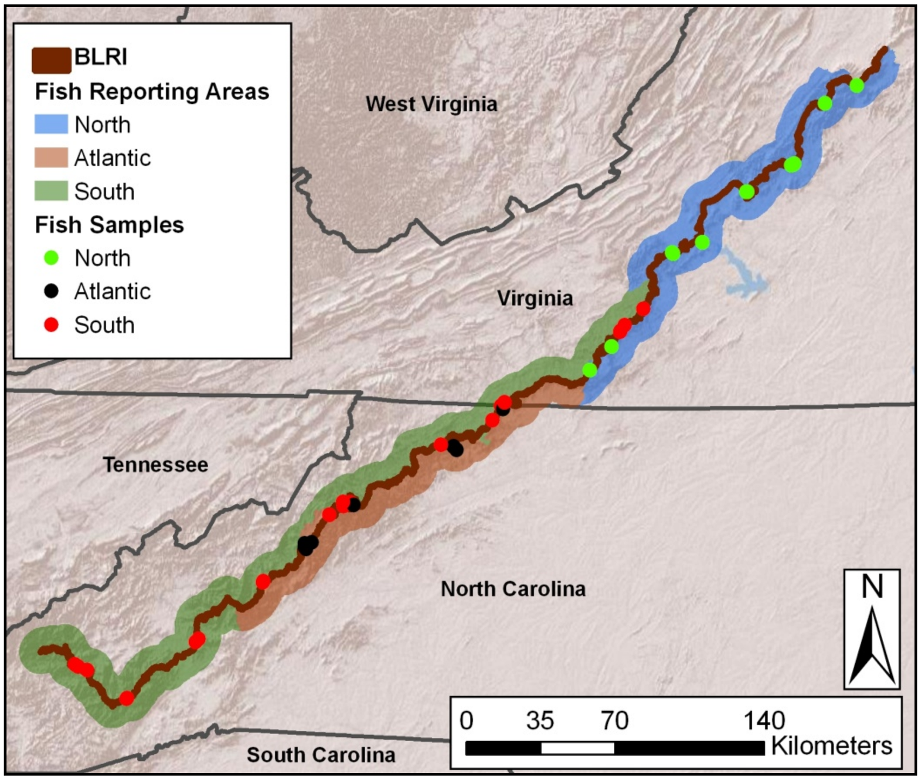

Figure 58. Fish assemblage condition reporting areas and corresponding fish sample locations used for the BLRI NRCA. A buffer region was used in the graphic to facilitate visualization.

4.9.6 Methods

We used a modified index of biotic integrity (IBI) to assess suitable fish assemblages sampled in the Atlantic and South reporting areas. Fish-based IBIs evaluate freshwater aquatic resources based upon relative density, diversity, and ecological attributes of sampled species (Karr 1981). Quality rankings are developed by analyzing assemblages from sites with known and independently-assessed levels of anthropogenic disturbance (Karr 1981). Generally, good conditions are indicated when communities contain a wide diversity of trophic specialists, and relatively high proportions of specialists and sensitive species. We used the North Carolina Index of Biotic Integrity (NCIB I) developed to assess stream fish communities in wadeable streams in the northern and piedmont regions of North Carolina (NCDENR 2006). The NCIBI was developed using samples taken over 600-foot reaches. The reach length of the BLRI fish sample data were unknown and this criterion may not have been met for all samples. The calculations of the NCIBI vary by watershed and are dependent on sample catchment area for some regions (NCDENR 2006). The NCBI index score is based on a combination of 10 or 12 individual metric scores. Because data on age class and number of diseased fish were unavailable, we scaled our scores to nine and 10 metric indices using the method described in the NCIBI manual for 10-metric indices (NCDENR 2006). We applied the NCIBI to samples collected within the appropriate region of application and samples that also met the published criteria for catchment area (NCDENR 2006).

We also considered the percentage of “natural” brook trout samples among the subset of samples containing brook trout.

Reference Condition

We used the ranges of values presented in the NCIBI to define the quality of fish assemblages at individual sample locations (Table 49). These values were empirically derived based on findings at sites with known levels of biological integrity (NCDENR 2006).

For brook trout sample data, we defined “natural” brook trout assemblages as those lacking other trout (ie. brown or rainbow trout), environmentally tolerant, or nonnative species.

Table 49. Possible index scores and integrity class interpretations from the North Carolina Index of Biotic Integrity (NCDENR 2006), and the basins where the scores were applied for the BLRI NRCA.

Drainage	Score	Interpretation
New, Tennessee	58, 60	Excellent
	48, 50, 52, 54, 56	Good
	40, 42, 44, 46	Good-Fair
	34, 36, 38	Fair
	≤ 32	Poor
Pee Dee, Santee	54, 56, 58, 60	Excellent
	48, 50, 52	Good
	42, 44, 46	Good-Fair
	36, 38, 40	Fair
	≤ 34	Poor

4.9.7 Resource Condition and Trend

North

The North reporting area received 14 fish samples during the fish inventory, and included 60 species of which 39 were not found in the other reporting areas (Table 50). Much of the relatively high richness in this reporting area resulted from a sample collected in the Roanoke River that included 34 species. At least eight of the species unique to this reporting area were large river species sampled from the James and Roanoke Rivers. Five species of the genus *Moxostoma* were sampled in this reporting area, including four species reported only from the Roanoke River. Eight species were considered nonnative to the drainages where they were sampled in the North reporting area. At least four of these species were actively stocked or managed in support of recreational fisheries. These were: striped bass (*Morone saxatilis*), muskellunge (*Esox masquinongy*), rainbow trout, and brown trout. Striped bass and muskellunge were reported from boat shocking samples collected in the Roanoke and James Rivers respectively. Striped bass are an anadromous species native to Atlantic drainages, but the individuals sampled in the BLRI came from a managed land-locked population. North reporting area samples included 22% intolerant and 17% tolerant individuals. Tolerance ratings were based on NCIBI designations (NCDENR 2006). North area samples included two species of special concern at the state or federal level.

Because the samples in this area were collected outside the application area of the NCIBI, we did not use this tool to assess them. The area demonstrably has high fish richness relative to the other

BLRI fish reporting areas, resulting largely from the presence of large rivers. Two samples in the reporting area contained brook trout, and both of those samples were “natural” brook trout assemblages because they occurred in the absence of other fish species.

Table 50. Summary of fish sampling effort and summary statistics by reporting area for the 2004-2007 fish inventory at BLRI (Scott 2007). Tolerance ratings were taken from the NCIB I (NCDENR 2006).

	North	Atlantic	South
Samples	14	13	23
Species Richness	60	30	37
Individuals	2037	1204*	3662*
Unique Species	39	3	8
Special Concern Species	2	0	3
Lake Samples	2	1	3
Samples Without Fish	3	2	2
Nonnative Species	6	3	3
Intolerant Species (streams)	10	5	6
Percent Intolerant Individuals (streams)	22	6	10
Tolerant Species (streams)	10	6	5
Percent Tolerant Individuals (streams)	17	6	10
IBI Samples	N/A	6	5
Good IBI Scores	N/A	0	0
Good-Fair IBI Scores	N/A	1	2
Fair IBI Scores	N/A	2	0
Poor IBI Scores	N/A	3	3
Mean IBI Score (SD)	N/A	35 (9)	33 (11)
Brook Trout Samples	2	1	8
Natural Brook Trout Samples	2	0	4

* Excludes qualitative samples in which individuals were not counted.

We did not rank the quality of fish assemblages in the BLRI North reporting area (Table 51). The results of a recent fish inventory suggested that the drainages in this region of the park contained a regionally typical fish fauna. We did not apply an IBI to these samples because a finalized fish IBI for the region did not exist to our knowledge. We did not assign a trend to BLRI North fish assemblage quality. Our analyses were primarily based upon a single comprehensive inventory and were insufficient to determine trend. We ranked the quality of the data as fair because the spatial category did not receive a checkmark. Although the data were recently collected in park boundaries using appropriate methods, a relatively small proportion of potential fish-containing streams were sampled. The inventory was well-conducted and included a representative sample of streams in the area. However, we feel that given the unique size and location of the BLRI, additional effort may be needed to provide a comprehensive picture of park fishes.

Table 51. No rank or trend was assigned to the condition of BLRI fish assemblage in the North reporting area. The quality of the data was fair.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
BLRI North: Fish Assemblages		✓		✓
		2 of 3: Fair		

<u>Atlantic</u>

The Atlantic fish reporting area received 13 samples during the fish inventory, and included 30 species of which three were unique to the reporting area (Table 50). Four species were considered nonnative to the drainages in which they were sampled. At least two of these species (rainbow and brown trout) have been introduced in support of recreational fisheries. Atlantic reporting area samples included 6% intolerant and 6% tolerant individuals, based on NCIBI designations (NCDENR 2006). Atlantic reporting area samples did not contain any species of special concern.

Six samples within this reporting area met our criteria for application of the NCIBI. Of these, one was scored as good-fair, two as fair, and three as poor (Table 50). The mean IBI score of the samples was 35 (SD ± 9) which corresponds to an interpretation between poor and fair (Table 49). The NCIBI includes catchment area in its calculations, and we applied the metric only to catchments within the suggested range of application. However, because the NCIBI was not specifically developed for high-elevation streams, and because of the caveats mentioned above (see Methods), some caution is warranted when interpreting these results. A single sample in this reporting area contained brook trout and this assemblage also contained brown trout. Brook trout may not have occurred naturally in these drainages and Shull and Walker (1995) suggested the possibility that they were introduced here. However, Davis (2008) found that individual stream populations sampled in the Yadkin River drainage near BLRI consisted of 100% southern strain brook trout, suggesting that any introductions in those streams used fish from local sources.

We ranked the quality of BLRI Atlantic reporting area fish assemblages as fair (Table 52). We did not assign a trend to BLRI Atlantic fish assemblage quality. Our analyses were primarily based upon a single comprehensive inventory and were insufficient to determine trend. We ranked the quality of the data as fair because the spatial category did not receive a checkmark. Although the data were recently collected in park boundaries using appropriate methods, a relatively small proportion of potential fish-containing streams were sampled. The inventory was well-conducted and included a representative sample of streams in the area. However, we feel that given the unique size and location of the BLRI, additional effort may be needed to provide a comprehensive picture of park fishes.

Table 52. The BLRI Atlantic fish assemblage condition was ranked as fair. No trend was assigned to this condition. The quality of the data used to make the assessment was fair

Attribute	Condition & Trend	Data Quality: Thematic	Spatial	Temporal
BLRI Atlantic: Fish Assemblages	●	✓		✓
		2 of 3: Fair		

South

The South reporting area received 23 samples that included 37 species, of which eight were unique to the reporting area (Table 50). The south reporting area received the greatest sampling effort among the three reporting areas. Four species were considered nonnative to the drainages where they were sampled. Nonnative species included rainbow and brown trout which have been introduced to support recreational fisheries. South reporting area samples included 10% tolerant and 10% intolerant individuals based on NCIBI designations (NCDENR 2006). The area contained three species of special concern.

Five samples within this reporting area met our criteria for application of the NCIBI. Of these, two were scored as good-fair, and three scored as poor (Table D). The mean IBI score of the samples was 33 (SD ± 11) which corresponds to an interpretation between poor and fair (Table 49). Eight samples within this reporting area contained brook trout. Four samples were "natural" and four also contained other trout or tolerant species.

We ranked the quality of BLRI South reporting area fish assemblages as fair (Table 53). We did not assign a trend to BLRI Atlantic fish assemblage quality. Our analyses were primarily based upon a single comprehensive inventory and were insufficient to determine trend. We ranked the quality of the data as fair because the spatial category did not receive a checkmark. Although the data were recently collected in park boundaries using appropriate methods, a relatively small proportion of potential fish-containing streams were sampled. The inventory was well-conducted and included a representative sample of streams in the area. However, we feel that given the unique size and location of the BLRI, additional effort may be needed to provide a comprehensive picture of park fishes.

Table 53. The BLRI South fish assemblage condition was ranked as fair. No trend was assigned to this condition. The quality of the data used to make the assessment was fair.

Attribute	Condition & Trend	Data Quality: Thematic	Spatial	Temporal
BLRI South: Fish Assemblages	●	✓		✓
		2 of 3: Fair		

4.9.8 Literature Cited

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4.10 Bird Assemblages

4.10.1 Relevance and Context

Birds specialize in a variety of habitats and are relatively easy to monitor, making them valuable indicators of terrestrial ecosystem quality and function (Maurer 1993). Key species of eastern U.S. obligate forest birds have shown a steady decline in abundance for over 40 years (USGS 2009), causing concern for managers. The southern Appalachians have a rich bird fauna including many species of management concern.

4.10.2 Resource Knowledge

Pearson and Smith (2006) conducted a comprehensive inventory of BLRI birds from May 2003 – February 2005. Effort included breeding season point counts and winter bird surveys along the length of the Parkway. Point counts were conducted with standard methods: 10-minute counts during which individual birds heard or seen were identified to species and were categorized by distance from observer and time period (Pearson and Smith 2006). Birds noted before and after each count were also recorded separately. Counts were conducted in the morning, during suitable weather, between May 10 and June 30 for the 2003 and 2004 breeding seasons. Over 650 counts were conducted at 238 locations along the Parkway, resulting in over 7,000 individuals of 122 species. These results include all birds reported, including those noted before/after the standardized count period. Winter birds were surveyed using walking transect surveys and timed searches at 106 locations. These efforts resulted in over 3,500 individuals of 63 species. Combined, the breeding season and winter sampling efforts resulted in over 10,000 individual birds of 136 species. Twenty-one species of conservation concern were identified from the BLRI (Table 54). No federally threatened or endangered species were reported from the Pearson Smith (2006) survey, although 16 species were listed as threatened, endangered, or of special concern at the state level. Eleven species had the highest rank (4) based on the ranking methodology of Nuttel et al.(2003) which uses regional Partners in Flight (PIF) scores (Panjabi et al. 2005) to assess the conservation importance of bird species (Table 54). A high rank indicates that a bird is important for conservation because it experiences a high level of threats to persistence.

Table 54. Bird species of conservation concern reported from a 2003-2005 bird survey of BLRI (Pearson and Smith 2006). Table lists species which were endangered (E), threatened (T), or of special concern (S) in North Carolina or Virginia, as well as birds with the highest conservation concern rankings from PIF score-based ranking system (Nuttle et al. 2003).

Scientific Name	Common Name	NC	VA	PIF
Aegolius acadicus	Northern Saw-whet Owl	T	S	X
Ammodramus savannarum	Grasshopper Sparrow			X
Bonasa umbellus	Ruffed Grouse			X
Carpodacus purpureus	Purple Finch		S	
Catharus guttatus	Hermit Thrush		S	
Certhia americana	Brown Creeper	S	S	
Colinus virginianus	Northern Bobwhite			X
Dendroica cerulean	Cerulean Warbler	S	S	X
Empidonax alnorum	Alder Flycatcher		S	
Falco peregrinus	Peregrine Falcon	E	T	X
Haliaeetus leucocephalus	Bald Eagle	T	T	
Limnothlypis swainsonii	Swainson’s Warbler		S	X
Loxia curvirostra	Red Crossbill	S	S	X
Melanerpes erythrocephalus	Red-headed Woodpecker			X
Poecile atricapillus	Black-capped Chickadee	S		
Pooecetes gramineus	Vesper Sparrow	S		X
Regulus satrapa	Golden-crowned Kinglet		S	
Seiurus motacilla	Louisiana Waterthrush			X
Sitta canadensis	Red-breasted Nuthatch		S	
Sphyrapicus varius	Yellow-bellied Sapsucker	S		
Troglodytes troglodytes	Winter Wren		S	

Pearson and Smith (2006) summarized and analyzed the results of their survey by four ecological districts along the BLRI (Figure 60). From north to south these were Ridge (MP 0 - 104), Plateau (MP 104 - 217), Highlands (MP 217 - 305), and Pisgah (MP 305 - 469). In general, BLRI bird assemblages were dominated by forest species. Pearson and Smith (2006) reported only minor differences in breeding bird richness among the districts and suggested the observed differences were likely attributable to the different habitats available and predominant in each district. The greatest species richness of breeding birds was observed in the Ridge and Pisgah districts which have the greatest range of elevations and include large river valleys (Pearson and Smith 2006). The Plateau and Highlands districts had greater percentages of non-forest habitat and exhibited a greater number of early-successional breeding species (Pearson and Smith 2006). Winter bird diversity and relative abundance was also related to habitat, with the greatest density of birds found in edge and shrub habitats, and lower density and diversity at lower elevations relative to higher elevations (Pearson and Smith 2006). Although they acknowledged the subjectivity of determining the true “expected” species list of any region, Pearson and Smith (2006) suggested they had reported over 90% of the bird species expected for the BLRI.

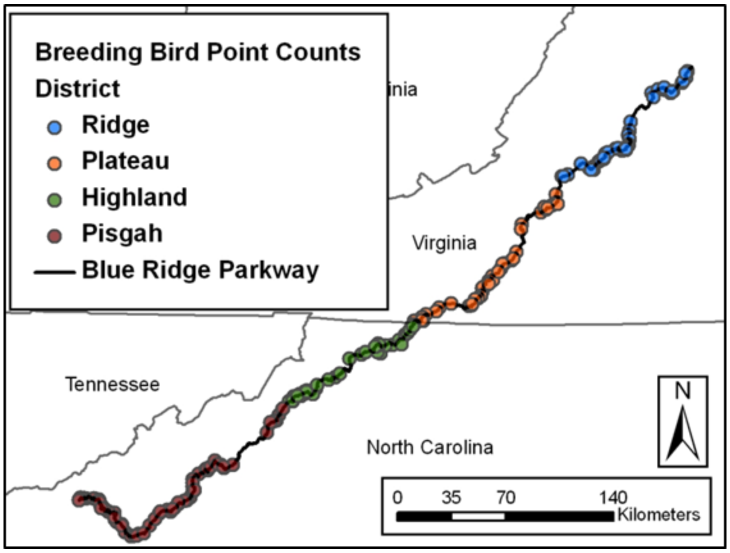

Figure 59. Location of breeding season bird point counts conducted during the 2003-2004 in four districts of the Blue Ridge Parkway by Pearson and Smith (2006).

4.10.3 Threats and Stressors

North American forest birds face a number of general threats including land conversion from natural types to agriculture or development, exotic species, forest pests, and poor land management (USGS 2009). Approximately one third of U.S. forest-breeding bird species have declined since 1966, although some indicators show stabilizing trends in the last decade (USGS 2009). Eastern forest birds have declined more than populations from western or boreal regions of the U.S. have (USGS 2009). Common species breeding in the BLRI that have persistently declined throughout their range include the Kentucky Warbler (*Oporornis formosus*), Wood Thrush (*Hylocichla mustelina*), Eastern Wood-Pewee (*Contopus virens*), and Cerulean Warbler (*Dendroica cerulea*) (Pearson and Smith 2006, USGS 2009). Causes of these declines may include loss or alterations of habitat in the U.S. and in tropical over-wintering locations (USGS 2009). Forest habitat can be lost or altered by development, logging, or forest pests (USGS 2009). In studies of bird assemblages in the southern Appalachian region of North Carolina and Tennessee, Haney et al. (2001) found that the late 1990s assemblage composition in a large, mature Appalachian forest was similar to the composition reported in the mid-1940s, and that no species has apparently been lost. Haney et al. (2001) hypothesized that at the meta-population level, large, protected Appalachian forests such as the one in their study may function as sources (as opposed to sinks) and be important in maintaining abundance or slowing the decline of some forest species. Threats specific to the BLRI include losses of unique and specialized forest types from exotic pests such as adelgids (*Adelgis* spp.) that threaten hemlocks (*Tsuga* spp.) and Frazer firs (*Abies fraseri*), and acid deposition that affects high-altitude forest communities (Rabenold et al. 1998; Pearson and Smith 2006). Exotic plants are a major concern on the BLRI, and can negatively impact native bird habitat. The Parkway itself may pose some level of threat to forest birds because it provides a corridor for disturbance-tolerant species to enter large forested patches and compete with interior species. Haney et al. (2001) suggested that a relative increase in some disturbance tolerance species may have resulted after a parkway was completed into the area. Development along hundreds of miles of BLRI boundaries has allowed free-roaming domestic animals and wild animals that associate with people to have easy access to BLRI lands where they can prey on eggs, hatchlings and adult birds.

4.10.4 Data

For our analyses of BLRI bird condition, we used the data collected by Pearson and Smith (2006) that was provided in electronic database format. This included data from 659 individual point counts, 106 winter samples, and associated data (e.g. numbers and species of birds seen before and after point counts). Summer data were collected at 238 points along the BLRI, and each winter transect was a different road, trail, or area. The data from this database were termed the analysis dataset. The analysis dataset contained 10,665 individuals of 136 species.

4.10.5 Methods

We summarized the BLRI bird data for the entire Parkway and by the districts as described by Pearson and Smith (2006). We summarized species richness and reported abundance by season and by park district. Species richness was the number of species occurring in a sample or collection of samples. Reported abundance was the number of individuals occurring in a sample or a collection of samples. Relative abundance referred to the proportion of individuals of a species or group of species within the total individuals of a sample or group of samples. We used an index of biotic integrity (IBI) and a conservation value index to compare observed bird assemblages to reference assemblages and to compare assemblages among districts.

BCI

We used an index of biotic integrity to evaluate BLRI bird assemblages. Such indices were originally developed for use with fish data to evaluate the level of anthropogenic disturbance to aquatic habitat (Karr 1981). Similar approaches have been developed using sampled bird assemblages to assess the ecological integrity of terrestrial habitat (Bradford et al. 1998, Canterberry et al. 2000, O'Connell et al. 2000). O'Connell et al. (1998) developed a breeding Bird Community Index (BCI) for the broad region of the eastern U.S. including the Appalachian Mountains. To apply the BCI, bird species are grouped into guilds based upon breeding season, life history traits, and the relative proportions of species in each guild are used to create overall scores ranging from 20 (low integrity) to 77 (highest integrity, O'Connell 1998). Table 55 provides the reference range for interpreting BCI scores. The index was developed by analyzing forest bird assemblages and referencing them to independently measured levels of anthropogenic habitat disturbance. Higher scores result when more disturbance-sensitive species and species with forest-specialist life history traits are present in a bird list relative to nest disrupting species, urban-tolerant species, and exotic species (O'Connell et al. 1998). The BCI assumes the least disturbed state for the scoring region to be mature forest (O'Connell et al. 1998). Therefore, natural open grasslands or naturally disturbed early successional habitats may not receive a high BCI score, although managers may consider these habitats valuable in maintaining bird biodiversity.

Table 55. Reference range for interpreting scores from a Bird Condition Index for the Appalachian and Mid-Atlantic Highlands (O'Connell 1998).

Score Range	Interpretation
60.1 - 77.0	Highest Integrity
52.1 - 60.0	High Integrity
40.1 - 52.0	Medium Integrity
20.0 - 40.0	Low Integrity

PIF Rank-based Conservation Scores

We also used a conservation value index to compare selected samples. Such indices are designed to give a greater relative score to samples whose composition is more heavily weighted toward species that face greater threats to persistence (Nuttle et al. 2003). We used a ranking system designed by Nuttle et al. (2003) and based upon regional Partners in Flight scores (Panjabi et al. 2005). Using these scores, Nuttle et al. (2003) developed a method of assigning a single species score ranging from 0-4 with "0" representing exotic species and "4" representing "species of high concern", where high-concern species have populations that "are declining rapidly, have a small range, or high threats". We used these ranks to create two types of conservation value indices. We created a relative abundance score (RA conservation score) by multiplying each species by its sample relative abundance and summing these weighted scores for the entire sample. This score is independent of density and gives an indication of whether a sample contains a relatively high proportion of birds of concern. For the breeding season point count data we also calculated an abundance score (AB conservation score) by multiplying the rank of each species by the actual observed numbers of the species, summing these values and dividing by the number of point counts to standardize for effort. We did not apply the AB conservation scores to winter samples due to the variable types of efforts applied among the districts.

4.10.6 Reporting Areas

We analyzed and summarized BLRI bird data at the entire park level and by district, after Pearson and Smith (2006). Because the existing data were collected and summarized by district, and because these districts were deemed geographically meaningful by knowledgeable ornithologists, we analyzed and reported some values by district (Figure 60). We also provided a park-wide summary of important bird data. Minor differences were observed among districts, although all districts were similar by most measures. Because observed differences would not have resulted in different rankings among the districts, we chose to report bird assemblage condition at the park-wide level. Differences among districts are presented and discussed to provide better understanding of BLRI birds.

4.10.7 Condition and Trend

Of the 659 breeding season point count samples, 636 were suitable for analysis with the BCI (Table 56). The remaining counts were unsuitable for BCI analysis because they contained too few species or did not employ the standardized methods of the suitable counts. The mean BCI score of all points counts was 53.9 (SD ± 8.8), corresponding to an interpretation of high integrity (Table 55). For the entire BLRI 61% of the individual BCI scores were of "high integrity" or "highest integrity", indicating that species lists were dominated by interior forest species relative to early successional or urban tolerant species (O'Connell et al. 1998). High scores indicated that the sites sampled had bird species lists similar to high integrity forest sites in the broad region upon which the BCI was developed and tested (O'Connell et la. 1998). We further summarized BCI scores by plot location. For the breeding season point count surveys, 238 points were sampled from one to six times, and 231 of the points had at least one sample suitable for BCI analysis. We took the mean BCI value for each point. The mean of these mean point values, for the entire park, was 54.4 (SD ± 7.8) corresponding to an interpretation of high integrity. Park-wide, 63 points were of highest integrity, 88 were of high integrity, 68 were of medium integrity, and 12 had low integrity mean BCI scores. Of the 12 low integrity scoring plots, 11 were centered on grass, shrub, or bog habitat. Because the BCI is poorly-suited to assess the quality of naturally-occurring non-forest habitat, these scores probably do not accurately reflect the quality of bird assemblages in bogs and other natural open areas. Therefore, the occurrence of low integrity bird habitat is probably rarer than is indicated by the BCI scores presented here. Among the districts, the Ridge and Pisgah had the highest mean BCI scores, and the greatest percentage of high BCI scores (Table 56). This is consistent with the findings of Pearson and Smith (2006) that these districts were surrounded by more forested land relative to agricultural and developed lands.

The conservation index scores within each season were similar for the park as a whole and for the individual districts (Table 56). These scores are primarily of comparative value, and are not presented relative to sites of independently assessed quality. Relative abundance (RA) conservation scores were greater during summer than in winter for all cases, but varied only slightly among districts. Abundance (AB) conservation scores were more variable (Table 56). The Ridge District had the highest AB conservation score among the districts, and Pisgah had the lowest (Table 56). Interestingly, although Pisgah had the greatest number of reported high conservation concern species during the breeding season, it had the lowest conservation score among the districts. This results in part because species of special concern on state lists do not necessarily receive a high rank by PIF-based standards. Another reason is the low reported relative abundance of the concern species in this district. Conversely, in winter, the Pisgah District had the highest RA conservation score and Ridge district had the lowest.

Table 56. Summary of effort, diversity, number of conservation concern species, conservation value index scores, and bird community index scores for the entire BLRI and by district. Data were from a 2003-2005 bird inventory (Pearson and Smith 2006). Concern species are listed in Table 54.

Assemblage	Entire BLRI	Ridge	Plateau	Highland	Pisgah
All Birds					
Richness	136	103	105	100	102
Abundance	10,665	2,409	2,671	2,571	3,014
Concern Species	21	11	16	13	14
Conservation Score	2.0	2.0	2.0	1.9	2.0
Unique Species	NA	10	7	3	3
Breeding Birds					
Effort (point counts)	659	146	148	139	226
Richness	122	90	88	89	97
Abundance	7,087	1,734	1,595	1,474	2,284
Concern Species	18	3	8	12	14
RA Conservation Score	2.2	2.2	2.2	2.2	2.1
AB Conservation Score	23.5	26.6	24.1	25.1	21.3
Mean BCI score (SD)	53.9 (± 8.8)	56.2(± 8.2)	52.7(± 10.1)	53.2(± 9.1)	53.7(± 7.8)
# Highest BCI scores	188	55	38	35	60
# High BCI Scores	199	48	45	42	64
# Medium BCI Scores	195	31	33	47	84
# Low BCI Scores	55	6	26	12	11
Winter Birds					
Effort (samples)	106	20	17	47	22
Richness	63	39	47	44	37
Abundance	3,578	675	1,076	1,098	730
Concern Species	10	8	8	7	6
Conservation Score	1.6	1.5	1.6	1.6	1.7

We ranked the condition of the bird assemblages of the Blue Ridge Parkway as good (Table 57). Most of the birds expected to occur in the park were reported in a recent survey (Pearson and Smith 2006). A bird community integrity index applied to breeding bird point counts found that the majority of counts indicated high integrity (Table 56). As discussed, some of the low integrity ratings were probably inaccurate because they occurred in habitats for which the BCI tool was not designed. A conservation score indicated that birds of conservation concern occur throughout the park and during both summer and winter. We did not assign a trend to the BLRI bird assemblage condition. A single comprehensive survey is insufficient to determine trend. The quality of the data used to make the assessment was good. The 2003-2005 survey covered park habitats comprehensively and was conducted relatively recently using highly standardized methods.

Table 57. The condition of the bird assemblages in the Blue Ridge Parkway was good. No trend was assigned to bird condition. The data used to make the assessment was good.

Attribute	Condition & Trend	Data Quality: Thematic	Data Quality: Spatial	Data Quality: Temporal
Bird Assemblages	Good (green circle)	✓	✓	✓
		3 of 3: Good		

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4.11 Herpetofauna Assemblages

4.11.1 Context and Relevance

Amphibians and reptiles are important components of southeastern U.S. ecosystems. The southeastern U.S. contains the highest diversity of herpetofauna in North America (Gibbons and Buhlmann 2001), and the southern and central Appalachian region is characterized by high amphibian diversity (Dodd 2003). The Parkway contains more amphibian taxa than any other NPS unit, and represents a unique transect through this region of high amphibian richness. Global declines in amphibians (Stuart et al. 2004) and reptiles (Gibbons et al. 2000) have been noted for decades, and herpetofauna have become the focus of increasing management concern and effort. Wetland habitats are of particular importance to amphibians (Semlitsch 2000) and are important to many species of reptiles as well (Gibbons et al. 2000). The bog turtle (*Clemmys muhlenbergii*) is a species of particular management interest in the park. In its southern range, including within BLRI, the bog turtle is federally threatened because of similarity of appearance with the northern, federally threatened, population of the species. This turtle occurs in specialized wetland habitats within the park and surrounding areas.

4.11.2 Resource Knowledge

Hays and Hays (2006) conducted an inventory of Blue Ridge Parkway herpetofauna sampling 16 major park habitat types with a variety of methods. Hays and Hays (2006) used area constrained searches, cover boards, general unconstrained searching including seining and dip net collecting, nighttime spotlight surveys, binocular searches for basking animals, minnow and turtle traps, breeding frog call surveys, road cruising, and drift fence arrays with pit falls and funnel traps. Their efforts reported over 4,400 individuals of 54 species from the BLRI, including 24 salamanders, 11 frogs and toads, 11 snakes, five turtles, and three lizards (Table 58) (Hays and Hays 2006). They summarized their results by Parkway district and reported the greatest richness (42 species) in the Ridge district (Hays and Hays 2006). Of the 16 habitat types sampled, they reported the greatest richness (31 species) from northern hardwood habitat, followed by stream habitat (28 species) and mixed mesic hardwoods (27 species) (Hays and Hays 2006). Hays and Hays (2006) did not report any federal or state endangered or threatened species from their survey. Their samples included four species of special concern at the state or federal level, although only one of those (Peaks of Otter salamander, *Plethodon hubrichti*) was found in the state where it was listed as a species of concern (Hays and Hays 2006). The pygmy salamander (*Desmognathus wrighti*) and shovel-nosed salamander (*Desmognathus marmoratus*) listed as concern species in Virginia were reported from North Carolina, and the timber rattlesnake (*Crotalus horridus*), a North Carolina species of concern, was reported from Virginia (Hays and Hays 2006). Hays and Hays (2006) summarized their results by Parkway district and found that the Ridge district had the greatest richness with 42 species and that the Pisgah, Plateau, and Highland districts had 35, 28, and 26 species, respectively.

Table 58. Species of reptiles and amphibians reported from the Blue Ridge Parkway during an inventory by Hays and Hays (2006).

Scientific Name	Common Name	Scientific Name	Common Name
Salamanders		**Frogs and Toads**	
Ambystoma maculatum	Spotted Salamander	*Acris crepitans*	Northern Cricket Frog
Desmognathus carolinensis	Carolina Mountain Dusky Salamander	*Bufo americanus*	American Toad
Desmognathus fuscus	Dusky Salamander	*Bufo woodhousii fowleri*	Fowler's Toad
Desmognathus marmoratus	Shovel-nosed Salamander	*Hyla chrysoscelis*	Cope's Gray Treefrog
Desmognathus monticola	Seal Salamander	*Hyla versicolor*	Northern Gray Tree Frog
Desmognathus ochrophaeus	Allegheny Mountain Dusky Salamander	*Psedacris feriarum*	Upland Chorus Frog
Desmognathus ocoee	Ocoee Salamander	*Pseudacris crucifer*	Spring Peeper
Desmognathus orestes	Blue Ridge Dusky Salamander	*Rana catesbeiana*	Bullfrog
Desmognathus quadramaculatus	Black-bellied Salamander	*Rana clamitans*	Green Frog
Desmognathus wrighti	Pygmy Salamander	*Rana palustris*	Pickerel Frog
Eurycea bislineata	Northern Two-lined Salamander	*Rana sylvatica*	Wood Frog
Eurycea cirrigera	Southern Two-lined Salamander	**Lizards**	
Eurycea wilderae	Blue Ridge Two-lined Salamander	*Eumeces fasciatus*	Five-lined Skink
Gyrinophilus porphyriticus	Spring Salamander	*Plestiodon anthracinus*	Coal Skink
Notophthalmus viridescens	Red-spotted Newt	*Sceloporus undulatus*	Eastern Fence Lizard
Plethodon cinereus	Red-backed Salamander	**Snakes**	
Plethodon cylindraceus	White-spotted Slimy Salamander	*Agkistrodon contortrix mokasen*	Northern Copperhead
Plethodon hubrichti	Peaks Of Otter Salamander	*Carphophis amoenus*	Eastern Worm Snake
Plethodon metcalfi	Southern Gray-cheeked Salamander	*Coluber constrictor constrictor*	Northern Black Racer
Plethodon oconaluftee	Southern Appalachian Salamander	*Crotalus horridus*	Timber Rattlesnake
Plethodon serratus	Southern Red-backed Salamander	*Diadophis punctatus*	Ring-necked Snake
Plethodon yonahlossee	Yonahlossee Salamander	*Elaphe guttata*	Corn Snake
Pseudotriton montanus	Mud Salamander	*Elaphe obsoleta obsoleta*	Black Rat Snake
Pseudotriton ruber ruber	Northern Red Salamander	*Nerodia sipedon*	Northern Watersnake
Turtles		*Opheodrys aestivus*	Rough Green Snake
Chelydra serpentina	Common Snapping Turtle	*Storeria dekayi dekayi*	Northern Brown Snake
Chrysemys picta picta	Eastern Painted Turtle	*Thamnophis sirtalis*	Eastern Garter Snake
Pseudemys rubriventris	Redbelly Turtle		
Sternotherus odoratus	Stinkpot		
Terrapene carolina carolina	Eastern Box Turtle		

4.11.3 Threats and Stressors

General threats to herpetofauna include habitat loss and fragmentation, habitat degradation, pollution, disease, climate change, direct consumptive use, and exotic species (Gibbons et al. 2000, Semlitsch 2000). Habitat loss and fragmentation are inevitable threats to BLRI herpetofauna, given the long, thin shape of the park and the fact that it traverses a variety of landscapes. Human density and fragmentation have increased in some areas of the park, particularly those passing through urban areas (Asheville and Roanoke) (See Landscape Dynamics). Other areas of the park, particularly those adjacent to National Forest or other National Park units, are relatively protected from the effects of fragmentation. Other potential threats to the persistence of amphibians in BLRI include infestations of the pathogens *Ranavirus* and the chytrid fungus (*Batrachochytrium dendrobatidis*). Both pathogens are implicated in the decline or failure of amphibian populations in the U.S. The chytrid fungus is an emerging disease that is the cause of local declines and extinctions of anuran populations in the western U.S. (Briggs et al. 2005). The fungus has been found to be widely occurring in anuran populations in the northeastern (Longcore et al. 2007) and southeastern (Rothermel et al. 2008) U.S. where it has not been specifically implicated in large-scale amphibian die-offs and is believed to result in sub-clinical infestations in many cases. *Ranavirus* is known to kill larval amphibians, including wood frogs and spotted salamanders, and caused high mortality from 1997-2006 in populations of these amphibians in the Tulula Wetland Mitigation Site in western North Carolina (Petranka et la. 2007).

4.11.4 Data

For our data analyses we used the inventory data of Hays and Hays (2006).

4.11.5 Methods

One approach to assessing the quality of an animal assemblage is to compare the observed assemblage to an ideal or potential assemblage. Due to shape and geographic extent of BLRI, it is very difficult to compile a reasonably robust expected list for the park. Hays and Hays (2006) suggested 90 species might be expected to occur in the park, although some of these species would be at the edge of their known range if they occurred in BLRI. Parkway lands form a long transect through a region of particularly notable salamander diversity. The lands within BLRI, occurring largely on high ridgelines, are often unique even within the context of local scales such as counties. Salamanders are highly endemic and cryptic and are therefore difficult to sample for assemblage richness estimates. Therefore, although we compared overall expected vs. observed species richness to provide context for understanding the observed BLRI assemblage, we note that this comparison should be interpreted with caution.

We compared species lists from the analysis dataset to other species lists compiled from three efforts in the southern Appalachians and Cumberland Plateau region. For comparison studies, we used inventories conducted at Cumberland Gap National Historical Park (CUGA) (Meade 2003) and at Big South Fork National River and Recreation Area (BISO) (Stephens et al. 2008). We chose these locations because we had access to these data and because these were single intensive efforts with similar intent and using similar methods to those used at BLRI. The area sampled differed considerably among the compared studies; BISO is larger and CUGA is smaller than BLRI. Because of its shape, BLRI contains a greater variety of habitat, but is generally characterized by higher elevation Appalachian habitats. BISO and CUGA contain lower elevation habitat more associated with the Cumberland Plateau region of the southern Appalachians. To partially account for differences in size, we plotted the natural log transformed species counts against the area for the three studies.

4.11.6 Condition and Trend

The recent inventory reported 54 (60%) of the approximately 90 expected herpetofaunal species, although due to the caveats discussed above, it is probable that the park contains a significant number of species not reported. It is also probable that some of the species included on the expected list do not actually occur in BLRI or occur there at extremely low densities.

The Blue Ridge Parkway had lower species richness than BISO and greater species richness than CUGA (Table 59). BLRI had high salamander richness relative to the comparison parks, emphasizing the importance of the BLRI as an important hotspot of salamander diversity and conservation. When the natural log transformed species counts for BLRI and the comparison sites were plotted against area sampled, the relationship was highly linear (R^2=0.95) (Figure 61). These comparisons are suggestive that BLRI supports herpetofaunal richness that is comparable, for its size, to well-protected natural sites in the southern Appalachians. However, due to its unique geographical extent, we believe some caution is warranted when comparing this park to any more “typically” shaped geographic area.

Table 59. Numbers of herpetofaunal species reported at BLRI and at two comparison locations, including information about location, area, effort, and sampled habitat for each study. Unique species refers to species unique among the three studies.

	Hays and Hays 2006	Stephens et al. 2008	Meade 2003
Location	Blue Ridge Parkway, Western Virginia/Northwestern North Carolina	Big South Fork National River and Recreation Area, Northeast TN/Southeast KY	Cumberland Gap National Historical Park, Northeast TN/Southeast KY
Area (ha)	36,615	50,586	9,712
Effort	March 2003-Sept. 2004; coverboards, road cruising, call surveys, constrained & unconstrained area searches, minnow traps, turtle traps, drift fences w/ pitfalls, spotting scopes	Feb. 2004 - June 2007; coverboards, road cruising, call surveys, constrained & unconstrained area searches, spotting scopes	Jan. - Dec. 2003; coverboards, road cruising, constrained and unconstrained area searches, minnow traps, hoop nets
Habitat	Blue Ridge southern Appalachian, all habitats including fields, forests, streams, ponds, vernal pools, wetlands, rock faces	Southwestern Appalachians, Cumberland Plateau, all habitats including fields, forests, streams, wetlands	Southwestern Appalachian, Cumberland Plateau, all habitats including fields, forests, streams, caves, wetlands
All Species	54	57	36
Salamanders	24	17	14
Anurans	11	11	11
Snakes	11	16	8
Lizards	3	6	2
Turtles	5	7	1
Unique Species	22	17	2

We did not assign a condition to BLRI herpetofauna assemblages (Table 60). Species richness was similar to other protected natural sites in the southern Appalachians when area was accounted for. Salamander richness was greater for BLRI than for the comparison sites, which is consistent with the understanding that the park is uniquely rich in salamander fauna. We did not assign a trend to herpetofaunal assemblage condition. A single baseline inventory is insufficient to determine changes in condition over time. The data used to make the assessment were fair (Table 60). The rating of fair was assigned primarily because the unique size and extent of the BLRI likely dictates that more than one inventory is required to gain a working knowledge of the park's reptile and amphibian assemblages. The data used were from efforts primarily directed at discovering the largest possible number of species. Data were collected recently with significant effort using multiple appropriate methods over an approximately two-year period. Typical habitats in multiple areas along the length of the BLRI were sampled with multiple methods. Furthermore, understanding the ideal or potential assemblage is especially difficult for these taxa in this park.

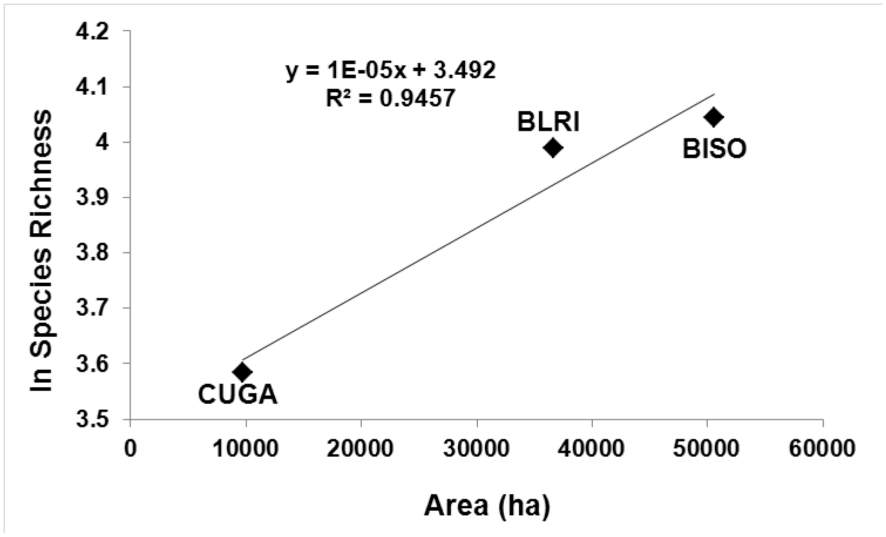

Figure 60. Natural log transformed species richness of herpetofaunal species plotted against area sampled for BLRI and two other National Park units in the southern Appalachians. BISO = Big South Fork National River and Recreation Area; CUGA = Cumberland Gap National Historical Park.

Table 60. No condition was assigned to BLRI herpetofauna assemblages. The data used to make the assessment was fair. No trend was assigned to reptile and amphibian assemblage condition.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Herpetofauna Assemblages			✓	✓
		2 of 3: Fair		

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4.12 Mammal Assemblages

4.12.1 Relevance and Context

Mammals are important components of all ecosystems where they affect plant communities, engineer landscapes, and play roles at multiple trophic levels (Ryszkowski 1975, Marti et al. 1993, Rooney and Waller 2003). The Appalachian Highlands region supports the most diverse mammal fauna in eastern North America, and at least 90 species historically occurred in the southern Appalachians (Handley 1971). The Blue Ridge Parkway protects unique mammal habitat and mammal species (Knowles et al. 1989, Handley 1971). Some species occurring here are remnants of populations pushed into the region during the last glacial maxima (Handley 1971). Therefore, some mammal species found in the southern Appalachian Mountains, especially at the highest elevations, are at the southernmost extent of their distribution, are locally rare, and require specialized high-elevation habitat. Because of great variation in size, behavior, and life history, mammals require diverse techniques to effectively sample and samples should be temporally repeated.

4.12.2 Resource Knowledge

Knowles et al. (1989) attempted to document rare vertebrate species present or potentially present in the BLRI within North Carolina. The study consisted of surveys of experts, literature review, and field surveys (Knowles et al. 1989). Small mammal sampling occurred from 1987 to 1989 and included 2,977 trap nights with live box traps and pitfalls. Knowles et al. (1989) suggested that 15 rare mammal species could potentially occur in the North Carolina section of the park, although not all of these species had actually been reported from within park boundaries. Of these, the mountain lion (*Felis concolor*) is considered locally extirpated and not likely to be present in BLRI. Another species, the New England cottontail (*Sylvilagus transitionalis*), has since been subdivided into two species (Litvaitis et al. 2006), of which the southern species, the Appalachian rabbit (*Sylvilagus obscurus*), occurs in the BLRI and is not state or federally listed. Therefore, 13 rare mammals were reported to be potentially present in the North Carolina portion of the park (Table 61). Rarity of these species was based, in part, upon the judgment of the authors at the time of publication. Relatively low sampling effort was used in the field surveys of the report. Therefore, this list is provided as a useful starting point for determining rare mammal potential in the North Carolina BLRI. Knowles et al. (1989) also created an overall list of 64 mammals expected to occur in the BLRI.

Table 61. Rare mammal species expected to occur in or near the BLRI as reported by Knowles et al. 1989.

Scientific Name	Common Name
Sorex dispar	Long-tailed shrew
Sorex hoyi	Pygmy shrew
Sorex palustris	Water shrew
Myotis sodalis	Indiana bat
Corynorhinus rafinesquii	Eastern big-eared bat
Corynorhinus townsendii virginianus	Virginia big-eared bat
Sciurus niger	Fox squirrel
Glaucomys sabrinus coloratus	Carolina northern flying squirrel
Neotoma magister	Allegheny woodrat
Neotoma floridana haematoreia	Southern Appalachian eastern woodrat
Microtus chrotorrhinus	Rock vole
Synaptomys cooperi	Southern bog lemming
Ursus americanus	Black bear

The most current understanding of BLRI mammal assemblages comes from an inventory conducted by Britzke (2007) during 2003-2004. Britzke (2007) used personal knowledge, published range maps, and consultation with local experts to compile an expected species list of 64 mammals for BLRI. Britzke (2007) used Sherman and Tomahawk live box traps, snap traps, unfenced pitfall buckets, road cruising, and incidental observations to sample non-chiropteran mammals. He also relied on first-hand reports from NPS staff made during the course of the survey, and reported on efforts in conjunction with North Carolina Wildlife Resource Commission (NCWRC) biologists working in the park during the time of the survey (Britzke 2007). State biologists used small pitfall bucket traps to sample for shrews, and checks of specifically-designed nest boxes for Carolina northern flying squirrels (*Glaucomys sobrinus coloratus*) (Britzke 2007). Britzke (2007) sampled bats using mist netting and Anabat II electronic bat detectors. Britzke (2007) sampled 96 sites for non-bat mammals, employing 4,375 trap nights of which 3,390 were Sherman live traps and 685 were pitfall traps. Britzke (2007) mist-netted for bats at 11 sites, and used Anabat II detectors at a number of fixed points and transects throughout the park.

Britzke's (2007) results (including results reported from NC WRC biologists) included 42 species of non-bat mammals and eight species of bats (Table 62). These species were reported from 1,650 captures or observations of non-bats, 82 captures or observations of bats, and 10,653 bat echolocation calls. Seven orders were represented, and order Rodentia had the greatest number of species with 19. Of the 50 total mammals reported by the inventory, two, domestic dog (*Canis familiaris*) and domestic cat (*Felis catus*), were non-native species. Two species, Carolina northern flying squirrel, and Virginia big-eared bat (*Corynorhinus townsendii*), were federally endangered. A further seven species were state listed as endangered or as species of concern (Table 62). Nine of the 13 species reported as rare by Knowles et al. (1989) were observed in the inventory (Table 62). The most commonly detected terrestrial species included the smoky shrew (*Sorex fumeus*), the masked shrew (*Sorex cinereus*), and the deer mouse (*Peromyscus maniculatus*). The predominance of shrews resulted, in part, because particular effort was directed at these species by the NCWRC. Because these results were not standardized by sampling effort, we do not suggest that these are necessarily the most abundant mammal species present in the park. The most commonly detected bats (excluding electronic detections) were little brown bats (*Myotis lucifugus*), red bats (*Lasiurus borealis*), and tricolored bats (*Perimyotis subflavus*).

Table 62. Species of mammals, with federal and state listing status, reported by Britzke (2007) from a 2003 – 2004 mammal inventory of BLRI. Listing status codes are: E = endangered, T = threatened, and S = species of concern. In parentheses: F = federal, N = North Carolina, and V = Virginia. An "*" indicates species reported as rare by Knowles et al. (1989). Two species in bold font are non-native.

Species	Common Name	Listing	Species	Common Name	Listing
Order Rodentia			**Order Insectivora**		
Castor canadensis	Beaver		*Blarina brevicauda*	Northern short-tailed shrew	
Clethrionomys gapperi	Southern red-backed vole		*Condylura cristata*	Star-nosed mole	S(N,V)
*Glaucomys sabrinus coloratus**	Carolina n. flying squirrel	E(F,N,V)	*Parascalops breweri*	Hairy-tailed mole	
Glaucomys volans	Southern flying squirrel		*Scalopus aquaticus*	Eastern mole	
Marmota monax	Woodchuck		*Sorex cinereus*	Masked shrew	
*Microtus chrotorrhinus**	Rock vole	S(N),E(V)	*Sorex dispar**	Long-tailed shrew	S(N)
Microtus pennsylvanicus	Meadow vole		*Sorex fumeus*	Smoky shrew	
Microtus pinetorum	Woodland vole		*Sorex hoyi**	Pygmy shrew	
Napaeozapus insignis	Woodland jumping mouse		*Sorex palustris**	Water shrew	S(N),E(V)
*Neotoma magister**	Allegheny woodrat	S(N,V)	**Order Chiroptera**		
Ochrotomys nuttalli	Golden mouse		*Corynorhinus townsendii virginianus**	Virginia big-eared bat	E(F,N,V)
Ondatra zibethicus	Muskrat		*Eptesicus fuscus*	Big brown bat	
Peromyscus leucopus	White-footed mouse		*Lasiurus borealis*	Red bat	
Peromyscus maniculatus	Deer mouse		*Lasiurus cinereus*	Hoary bat	
Sciurus carolinensis	Eastern gray squirrel		*Myotis leibii*	Eastern small-footed bat	S(N,V)
*Synaptomys cooperi**	Southern bog lemming		*Myotis lucifugus*	Little brown bat	
Tamias striatus	Eastern chipmunk		*Myotis septentrionalis*	Northern long-eared bat	
Tamiasciurus hudsonicus	Red squirrel		*Perimyotis subflavus*	Tricolored bat	
Zapus hudsonius	Meadow jumping mouse		**Order Lagomorpha**		
Order Carnivora			*Sylvilagus floridanus*	Eastern cottontail	
Canis familiaris	**Domestic dog**		*Sylvilagus obscurus*	Appalachian rabbit	
Felis catus	**Domestic cat**		**Order Artiodactyla**		
Lontra canadensis	River otter	S(V)	*Odocoileus virginianus*	White-tailed deer	
Lynx rufus	Bobcat		**Order Didelphimorphia**		
Mephitis mephitis	Striped skunk		*Didelphis virginiana*	Opossum	
Mustela frenata	Long-tailed weasel				
Procyon lotor	Raccoon				
Urocyon cinereoargenteus	Gray fox				
*Ursus americanus**	Black bear				
Vulpes vulpes	Red fox				

Britzke (2007) collected mammals in a variety of habitats, including boulder fields and talus slopes, mesic hardwood forest, spruce-fir forest, grasslands, roadsides, wetlands, riparian zones, and human structures. Sampling in boulder fields and talus slopes and mesic hardwoods produced the greatest number of species, although sampling effort differed among habitats and differences in detectability were not accounted for. Bats were captured most often over streams, but were observed roosting in four man-made structures as well. Britzke (2007) also reported that rare species were concentrated in the southern, higher-elevation sections of the park in North Carolina.

Britzke (2007) commented on several difficulties and considerations of the BLRI mammal inventory. Human presence and easy access to much of the park decreased the number of locations suitable for trapping activities. The linear nature of the park made the detection of some larger species difficult. These species are most likely to occur in larger habitat patches found in areas where the Parkway abuts on National Forest land. Because the park is a narrow corridor through this habitat, larger mammals may not spend much time within BLRI boundaries.

4.12.3 Threats and Stressors

Habitat fragmentation can cause loss of species and lowered abundance of some species (Andren 1994), and is an important potential stressor on BLRI mammals. Where adjacent land is not state or federally protected or in conservation easement, suitable park mammal habitat may occur in relatively small fragments. However, adjacent land use conversion from natural to developed or agricultural land has been relatively stable in recent years (Landscape sections, this report). Furthermore, many mammals reported from BLRI are edge or early successional habitat specialists that are less susceptible to negative population effects from fragmentation.

The presence of the Parkway (a major and heavily traveled roadway), and the density of roads in and around the park, present a potential threat to BLRI mammals. Roads may impact mammal populations through direct mortality, by altering habitat, by causing avoidance, and by presenting barriers to movement (Foreman and Alexander 1998). Although these threats are presented as potential issues for BLRI mammals, population level effects of roadways on park mammals are not known.

White-nose syndrome (WNS) is a severe and emerging threat to hibernating bats throughout the eastern U.S. (Cyran 2011). This disease, caused by infection with the *Geomyces destructans* fungus (Lorch et al. 2011), was discovered in New York in 2006, and has spread rapidly south and westward where it has been reported from the Blue Ridge region of Virginia and North Carolina (Cryan 2011). The disease affects hibernating bats and may result in catastrophic declines of >75% in local hibernating populations (Blehert et al. 2009). Of the eight bat species reported from BLRI, six are hibernating species and WNS is known to occur in five of them. Because major hibernacula are not known to occur on BLRI, the WNS threat to these species is largely beyond the scope of park management. The threat from WNS is discussed here because it is expected to result in population-level declines that may become apparent in species that forage and roost on park lands.

Non-native mammal species can pose threats to native wildlife, through predation, competition, or habitat alteration. Domestic cats and dogs were the only non-native mammal species noted in the recent mammal inventory. These species, particularly cats, prey on native wildlife (Baker et al. 2005). However, neither dogs nor cats were common in the inventory. Coyotes (*Canis latrans*) were not reported in the recent inventory, though they likely occur on BLRI lands. Introduction of cattle and horses has resulted in large patches of land being converted to grasslands with some mammals benefiting and some being harmed due to habitat changes.

4.12.4 Data

To assess the mammal assemblages of BLRI, we used the data presented in a single mammal inventory report by Britzke (2007). These data were termed the analysis dataset. We used data from other parks and other studies in the southeast for comparison purposes.

4.12.5 Reporting Areas

We reported mammal condition at the park level. Although the BLRI passes through multiple habitats, the available mammal data were not sufficiently explicit to assess specific areas.

4.12.6 Methods

To assess the condition of mammal assemblages we compared reported BLRI mammal lists to expected lists, and also considered the presence of species of concern and non-native species. For the expected mammal list we used the list compiled by Britzke (2007). Britzke (2007) created the list from literature, through consultation with locally-knowledgeable mammologists, and from personal knowledge and experience. We compared the entire observed mammal list to the entire expected list, and we compared the lists by categories of mammals. We also compared observed BLRI small mammal results to results from comparable studies. For comparison studies we used mammal inventory data from Cumberland Gap National Historical Park (Gumbert et al. 2006), from the George Washington National Forest in northern Virginia (Mitchell et al. 1997), and from Nantahala National Forest in western North Carolina (Menzel et al. 1999).

4.12.7 Condition and Trend

The recent inventory of BLRI mammals reported 48 (80%) of 60 expected native species (Table 63). Native rodents and insectivores were well-represented in the inventory with over 80% of expected species found. Bats and carnivores were less well-represented with 73% of expected species reported. Of the missing species of bats and terrestrial carnivores, some are difficult to document and others are probably uncommon, if present. The mink (*Mustela vison*) and the least weasel (*Mustela nivalis*) are cryptic carnivores that are difficult to document. It is uncertain whethert the least weasel ever actually occurred on park lands but it is reasonable to assume that it could survive in the current habitat types. The silver-haired bat (*Lasionycteris noctivagans*) is migratory and is expected to be only periodically present in BLRI and therefore easy to miss (Britzke 2007). The eastern big-eared bat (*Corynorhinus rafinesquii*) and the endangered Indiana bat (*Myotis sodalis*) are also probably uncommon in BLRI because the park lacks prime roosting and hibernating habitat for these species (Britzke 2007). The comparison of reported mammal lists with expected mammal lists suggests that a relatively high percentage of the mammal species that could potentially use park habitat actually occur in the park. A caveat for this finding is that compiling an expected list is somewhat subjective. Comparisons between BLRI mammal sample results and the results of similar regional efforts, suggest that the park supports a mammal assemblage that includes many of the native rats, mice, voles and shrews that are commonly sampled in the southern Appalachians (Table 64).

Table 63. Number of native species of mammals in different categories expected to occur, and the number and percent of expected species actually reported by Britzke (2007) from the Blue Ridge Parkway.

Native Species Group	Reported	Expected	% Reported
Bats	8	11	73
Rats/mice/voles	12	15	80
Non-rat/mice/vole rodents	7	8	88
Shrews/moles	9	11	82
Carnivores	8	11	73
Cervids	1	1	100
Lagomorphs	2	2	100
Marsupials	1	1	100
All Native Species	48	60	80

Table 64. Comparison of the number of shrews and native rats, mice, and voles reported by Britzke (2007) from the Blue Ridge Parkway, and from other mammal surveys in the southern Appalachian region. Non-native species are not included. Trapping efforts at BLRI included an unspecified number of pitfall trap nights conducted in conjunction with state biologists.

	Britzke 2007	Gumbert et al. 2006	Mitchell et al. 1997	Menzel et al. 1999
Location	Blue Ridge Parkway, western North Carolina and Virginia	Cumberland Gap National Historical Park, eastern Kentucky	George Washington National Forest, northern Virginia	Nantahala National Forest, western North Carolina
Habitat	Southern Appalachian forests, fields, talus slopes, wetlands, roadsides	All types including fields, wetlands, forests	Gradient from recent clearcut to climax hardwood forest	Gradient from wildlife openings to deep forest
Effort	>4,375 trap nights with live box traps and pitfalls	11,348 trap nights with snap traps, live box taps, and pitfalls	12,600 trap nights with drift fence pitfall arrays	12,000 trap nights with live box traps and pitfalls
Total Species	17	14	11	7
Shrew Species	6	5	5	2
Rats/mice/voles	11	9	6	5
Unique Species	3	0	0	0

The BLRI mammal inventory reported nine species that were threatened, endangered, or of special concern at the state or federal level (Table 62). Of these, the federally endangered Carolina northern flying squirrel and Virginia big-eared bat were each detected only a single time during the survey. The most commonly detected species of concern were the long-tailed shrew (*Sorex dispar*) and the water shrew (*Sorex palustris*), with 32 and 15 detections respectively. The remaining five species were detected from one to five times each. The Carolina northern flying squirrel, water shrew, and rock vole (*Microtus chrotorrhinus*) are boreal species with highly disjunct distributions in their southern range where they are remnants of populations established during the last glacial maxima (Handley 1971). Therefore, these species are rare in the BLRI region and limited to relatively small patches of suitable habitat. The fact that BLRI harbors species of conservation concern, including species requiring specialized high-elevation habitat, suggests that the park has significant conservation value in terms of protecting rare or locally rare mammals.

Only two non-native species, domestic dog and domestic cat, were reported from the Britzke (2007) inventory. Neither species was commonly detected; dogs were detected seven times and cats were detected three times. Observations of these species usually occurred in roadside habitats. Other potential non-native mammals for the park included the feral hog (*Sus scrofa*) and the coyote.

We ranked the condition of the BRLI mammal assemblage as good (Table 65). A high percentage of the expected species were reported from the park, and the observed species included most of the rats, mice, voles, and shrews commonly sampled in the southern Appalachians. Reported species included regionally rare species specializing in boreal habitats found only at the highest elevations of the Appalachian Mountains. Non-native species were uncommon in inventory. Several caveats apply to the interpretation of this condition ranking. The amount of effort was apparently relatively low, relative to other studies sampling mammal assemblages. However, because the amount of effort by state biologists was not included in the total traps for this inventory, the precise total effort is not known. Comparison mammal assemblage sampling efforts in the southern Appalachians included >10,000 trap nights (Gumbert et al. 2006, Menzel et al. 1999, Mitchell et al. 1997). The known effort for this study was <5,000 trap nights. Even with the addition of pitfall shrew sampling by state biologists, the effort may be relatively low for a park of this size and spatial extent. Camera sampling was not conducted as part of this inventory. This technique has proved successful in documenting larger mammals, and at providing information about the relative abundance of larger mammals, including non-native species (Linehan et al. 2008, Gumbert et al. 2006). Because of the relatively low effort used, and the lack of camera sampling, the thematic data quality category did not receive a check and the data quality was ranked as fair (Table 65). No trend was assigned to mammal assemblage condition (Table 65). A single inventory is insufficient to establish trend.

Table 65. The condition of mammal assemblages at BLRI was good. No trend was assigned to mammal assemblage condition. The condition of data used to make the assessment was fair.

		Data Quality		
Attribute	**Condition & Trend**	**Thematic**	**Spatial**	**Temporal**
Mammal Assemblages			✓	✓
		2 of 3: Fair		

A single well-conducted mammal inventory has provided insight into the mammal assemblage found in BLRI. The issues with trapping effort and type result largely because of limitations imposed by the nature of the park. The BLRI provides unique access by visitors to most park areas. Therefore, finding suitable sampling locations is challenging, and sampling with expensive remote field equipment (e.g. cameras) may be precluded. These challenges were stated by Britzke (2007) in the narrative of the inventory report. Furthermore, the large size and extreme geographical extent of the park probably mandate that multiple efforts are required to gain a sound understanding of mammal assemblages. Despite relatively low sampling effort, the observed richness was greater than observed for comparable studies, and a high percentage of expected species were reported.

4.12.8 Literature Cited

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4.13 Landscape Change

A landscape, broadly defined, is an area that is heterogeneous in one or more factors of interest (Turner et al. 2001). Landscape change, one of the vital signs assigned to the APHN, is a broad category that can potentially utilize a variety of metrics or measures to describe how these factors can change over time. Multiple processes can affect resources in a park, which in turn may depend on temporal and spatial scale of consideration (Kotliar and Wiens 1990). One of the most relevant considerations associated with landscape dynamics at BLRI is habitat loss and fragmentation, which, though independent of each other, often happen in association. Complete loss of habitat through anthropogenic conversion is one of the greatest threats to biodiversity (Bender et al. 1998, Turner et al. 2001, Fahrig 2003,). Both of these effects, even if they take place on the periphery of the park unit, may contribute to a loss of biodiversity or other environmental degradation within the park itself. This is particularly relevant at BLRI because of its linear orientation that facilitates maximum edge effect on the park area as well as compounding the effect of latitudinal and altitudinal gradients. The range of a particular species, for example, may be larger than the protected area of a park unit, in which case the periphery area can play a large role in determining species composition within the park. In addition, changes in the landscape can alter communities over vastly different temporal scales such that effects of a disturbance may not be apparent for many years (Kuussaari et al., 2009). For these reasons, it is important to consider the dynamics of these surrounding areas in order to preserve the integrity of the biological habitat in the park (Gross et al. 2009).

It is often difficult to relate large scale landscape monitoring into succinct and specific land management goals at the level of a park unit. Several studies have attempted to do this by identifying land use change thresholds that generally affect certain changes in ecosystems. Stranko et al. (2008), for instance, found that brook trout (*Salvelinus fontinalis*) populations in Maryland generally did not occur in watersheds with greater than 4% impervious surface. In a review of habitat fragmentation and its effects on species populations, Andrén (1994) notes that patch size and isolation become important only when the overall proportion of suitable habitat is low, and offers that this critical threshold occurs when less than 30% suitable habitat is available.

Although it is certainly difficult to assign a single critical proportion for multiple species and ecosystems, such a threshold may serve as a guideline for general changes in the landscape (Gross et al., 2009). A proportion of 60% has been offered as a theoretical threshold of critical habitat, reflecting the point where a landscape is mostly connected, (Gardner and Dean 2005). Field studies suggest that this threshold may, in reality, be much lower, and several offer critical thresholds closer to Andrén's (1994) stated proportion of 30% habitat (With and Crist, 1995).

The Blue Ridge Parkway traverses a long section of the Southern Appalachians, often passing through protected areas that are relatively free from edge impacts, including the Pisgah and Nantahala National Forests along the southern portion, as well as the George Washington and Jefferson National Forests towards the northern portion. Other sections pass through highly urban areas such as Roanoke, VA and Asheville, NC, whose continued expansion may threaten adjacent portions of the park. Gross et al. (2009) point out that even though natural disturbances may alter landscapes in various ways, they are generally temporary and return to habitat area. Conversely, anthropogenic disturbances such as agriculture, forest clearing, and urbanization often result in a permanent loss of natural habitat. In particular, infringements on the boundary of the park can serve as vectors for exotic species, contribute to increased air and depositional pollution, or facilitate water quality degradation.

4.13.1 NPScape and Landcover Analyses

In order to document land use change and provide landscape-scale information, the NPS created a series of analyses outlines and data products called NPScape. One of the main goals of NPScape is to facilitate natural resource management at a landscape scale for individual park units, and allow users to manipulate the data and products in such a way to meet their own needs (Gross et al. 2009). NPScape data focuses on six main landscape measures: landcover, housing, roads, population, pattern, and conservation status. Landscapes were analyzed at two main spatial scales defined by a 30km buffer and 3km buffer around the park.

NLCD
Several sources of landcover information are available to analyze anthropogenic land use alteration. The National Landcover Dataset (NLCD) produced by the Multi-Resolution Land Characteristics Consortium (MRLC) generated a retrofit change product that allows analysis of

landcover change between the period of its two datasets produced in 2001 and 2006. Although classification schemes were not identical for the two periods, the change product reconciles the different classes to common landcover names. As part of the NPScape product, Gross et al. (2009) reclassified the change product to include two main classes: natural and converted areas. The categories used to generate these main classes are outlined in Table 66. The ratio of these categories (converted area/natural area) is referred to as the U-index (O'Neill et al. 1988), and is intended as a direct representation of landscape anthropogenic disturbance.

Table 67 depicts landcover proportions for 2001 and 2006 at each buffer width, as well as the change product between those two time periods, adjusted for their different classifications schemes. For the 2001 NLCD classification, the proportion of forested land increases slightly beyond the park boundary to the first 3 km buffer width (73.6 to 79.6% forested), but is lowest within the largest extent 30 km buffer (70.9%). In turn, relative proportions of pasture/hay and agriculture classes increase across scales. In 2006, forested proportions show a similar pattern across scales, though each is higher. This pattern is due to the high amount of developed open space represented by the road corridor, which is over three times as high as the same class at the 3 km and 30 km buffer widths.

The change product shows negligible change within the park unit between 2001 and 2006, while the 3 km and 30 km buffer widths show the greatest transition from converted land to natural area, both of which accounted for 0.2% of the land area. Other change transitions were negligible. U-indices calculated for the park boundary and 30 km buffer were both 0.35, though much lower—0.23—for the 3 km buffer. This certainly reflects the influence of the Parkway road within the boundary, as indicated by the elevated U-index, while at the same time demonstrating its association with surrounding natural areas, which in turn is reflected by the lower U-index for the 3 km buffer compared to the 30 km buffer. Figure 62 depicts the proportion of natural area within the 30 km BLRI landscape compared to other NPS units. In it, natural landcover proportion at BLRI appears to fall in the middle-of-the-road compared to other NPS units.

Table 66. Aggregation of NLCD landcover classes into general categories of converted and natural land. [Source: Gross et al. 2009]

General Category	NLCD classes
Converted	Low intensity developed; Medium intensity developed; High intensity developed; Open space developed; Pasture/Hay; Cultivated crops
Natural	Grassland/herbaceous; Shrub/scrub; Mixed forest; Evergreen forest; Deciduous forest; Barren land; Perennial ice/snow; Woody wetlands; Emergent herbaceous wetlands; Open water

Table 67. Landcover area and proportions of BLRI for each buffer class based on two separate NLCD classifications and change product, as aggregated by Gross et al. (2009).

	-30 km buffer-		-3 km buffer-		-no buffer-	
NLCD 2001	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Open Water	236.4	0.6	6.3	0.1	0.6	0.2
Developed Open Space	2353.3	6.3	304.5	6.9	75.1	22.7
Developed Low Intensity	647.9	1.7	62.7	1.4	1.7	0.5
Developed Medium Intensity	16.3	0.4	16.1	0.4	0.1	<0.1
Developed High Intensity	58.7	0.2	4.5	0.1	0	0
Barren Land	31.5	0.1	2.4	0.1	<0.1	<0.1
Deciduous Forest	22721.2	61.2	3158.6	71.5	218.0	65.9
Evergreen Forest	2319.9	6.2	215.2	4.9	16.4	5.0
Mixed Forest	1267.7	3.4	134.8	3.1	8.6	2.6
Scrub/Shrub	320.9	0.9	32.6	0.7	1.4	0.4
Grassland/Herbaceous	307.7	0.8	15.5	0.4	0.1	<0.1
Pasture/Hay	6445.6	17.3	450.6	10.2	8.4	2.5
Cultivated Agriculture	244.6	0.7	9.9	0.2	0.1	<0.1
Woody Wetlands	30.0	0.1	3.4	0.1	0.2	0.1
Emergent Herbaceous Wetlands	0.8	<0.1	0.2	<0.1	0	0
NLCD 2006						
Open Water	236.8	0.6	6.2	0.1	0.6	0.2
Developed Open Space	2370.7	6.4	305.3	6.9	74.3	22.5
Developed Low Intensity	646.4	1.7	62.9	1.4	1.7	0.5
Developed Medium Intensity	166.9	0.4	16.2	0.4	0.1	<0.1
Developed High Intensity	58.7	0.2	4.6	0.1	<0.1	<0.1
Barren Land	29.0	0.1	2.2	0.1	<0.1	<0.1
Deciduous Forest	23156.4	62.1	3197.4	72.4	219.9	66.5
Evergreen Forest	2248.8	6.0	204.5	4.6	15.9	4.8
Mixed Forest	1192.8	3.2	125.3	2.8	8.0	2.4
Scrub/Shrub	304.9	0.8	31.1	0.7	1.3	0.4
Grassland/Herbaceous	312.1	0.8	15.2	0.3	0.1	<0.1
Pasture/Hay	6346.5	17.0	435.2	9.9	8.2	2.5
Cultivated Agriculture	165.2	0.4	5.4	0.1	0.1	<0.1
Woody Wetlands	29.1	0.1	3.2	0.1	0.2	0.1
Emergent Herbaceous Wetlands	0.8	<0.1	0.2	<0.1	0	0
NLCD Change (2001-2006)						
--Unchanged--						
Converted	8820.1	25.9	815.3	18.5	84.1	25.6
Natural	24960.4	73.3	3559.6	80.8	243.2	74.2
--Changed--						
Natural to Agriculture	15.1	<0.1	1.4	<0.1	<0.1	<0.1
Natural to Urban	10.2	<0.1	1.5	<0.1	0	0
Agriculture to Urban	11.5	<0.1	2.2	<0.1	<0.1	<0.1
Converted to Natural	72.2	0.2	9.4	0.2	<0.1	<0.1
U-Index	**0.35**		**0.23**		**0.35**	

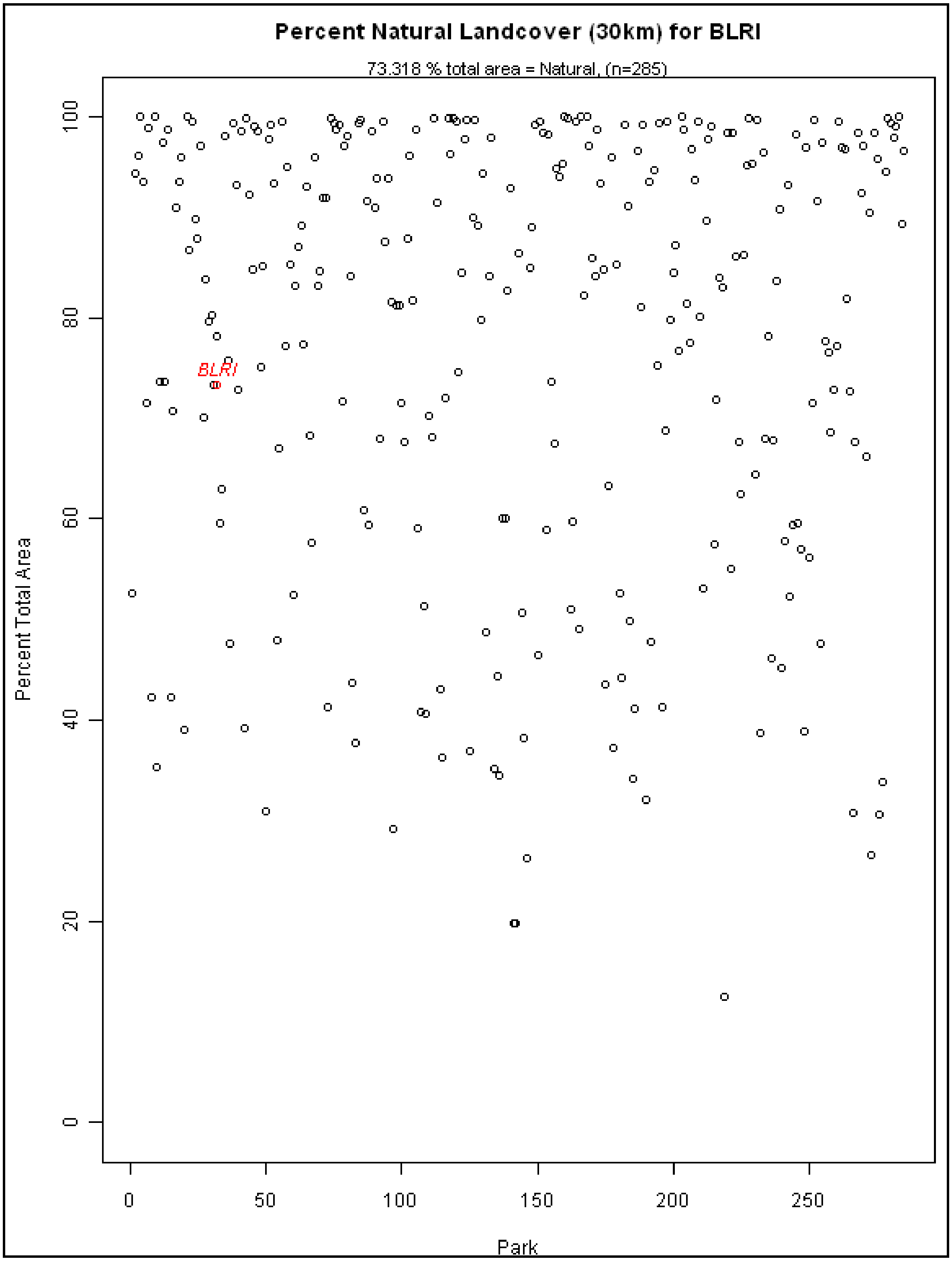

Figure 61. NPScape landcover product showing percent natural landcover of BLRI relative to other NPS units. The x-axis represents an indexed placeholder for each park unit.

LANDFIRE

Another source of landcover information is the Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) Existing Vegetation Type (EVT) dataset, which includes several national data products. The landcover map is based on mid-scale ecological system classifications outlined by Comer et al. (2003). LANDFIRE, despite being classified at a 30m resolution, is mainly intended at a large landscape-scale such as at a state or sub-regional level. Figure 63 depicts the LANDFIRE classification for the 30 km buffer at BLRI. Table 68 shows the amount and proportions of 32 landcover classes at BLRI with 3km and 30km buffer widths, for which, at each of the buffer widths, the most abundant classes are the Beech-Maple-Basswood Forest. The Chestnut Oak Forest and Woodland is the second most abundant class in the buffer polygons, though it is developed open space within only the park boundary. Calculation of U-indices show a similar pattern as the NLCD data, where the park boundary index (0.31) falls between the two buffer widths (0.41 for 30 km and 0.25 for 3 km). Disregarding the roads class within the boundary, the U-index falls to 0.19—lower than both buffer widths. Story et al. (unpublished) caution, however, that landcover analysis revealed that LANDFIRE data tends to focus on the predominant fuel type in an area, possibly resulting in an overestimation of that type of landcover. This effect is likely minimal, however, because of the consistent U-index with NLCD classification.

Table 68. Landcover area and proportions of BLRI based on Landfire classification. Data is presented for two buffer widths and no buffer. '*' denotes 'converted' landcover used to calculate U-index.

	-30 km buffer-		-3 km buffer-		-no buffer-	
LANDFIRE	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Open Water	240.1	0.6	6.3	0.1	0.6	0.2
Developed-Open Space*	1507.6	4.0	193.5	4.4	45.8	13.9
Developed-Medium Intensity*	108.8	0.3	10.0	0.2	0.1	<0.1
Developed-High Intensity*	43.7	0.1	179.7	0.1	0	0
Developed-Roads*	1581.2	4.2	179.7	4.1	31.1	9.4
Barren	31.3	0.1	2.3	0.1	0.1	<0.1
Quarries-Strip Mines-Gravel Pits*	24.9	0.1	5.5	0.1	0.1	<0.1
Herbaceous wetlands-Semi-wet/dry	48.2	0.1	19.7	0.4	7.6	2.3
Agriculture-Pasture and Hay*	3157.0	8.5	206.3	4.7	0.4	0.1
Agriculture-Cultivated Crops and Irrigated Agriculture*	4052.1	10.9	268.0	6.1	0.6	0.2
Introduced Grassland*	2.4	0.6	0.4	<0.1	<0.1	<0.1
Introduced Upland Vegetation—Tree/Shrub*	47.5	0.1	1.7	<0.1	<0.1	<0.1
Transitional Herbaceous	31.6	0.1	1.9	<0.1	0.2	<0.1
White Oak-Red Oak-Hickory Forest and Woodland	1908.2	5.1	249.5	5.6	12.7	3.8
Yellow Birch-Sugar Maple Forest	735.6	2.0	196.0	4.4	18.6	5.6
Chestnut Oak Forest and Woodland	5807.4	15.6	719.5	16.3	40.2	12.1
White Oak-Beech Forest and Woodland	1798.6	4.8	45.5	1.0	0.6	0.2
Beech-Maple-Basswood Forest	7251.9	19.5	1264.6	28.6	107.2	32.4
Montane Oak Forest	1125.5	3.0	229.0	5.2	17.6	5.3
Chestnut Oak-Virginia Pine Forest and Woodland	3433.6	9.2	300.1	6.8	10.2	3.1
Post Oak Woodland and Savanna	0.1	<0.1	0	0	0	0
Spruce-Fir-Hardwood Forest	228.7	0.6	49.1	1.1	8.8	2.7
Pitch Pine Woodlands	498.7	1.3	76.2	1.7	7.2	2.2
Virginia Pine Forest	151.3	0.4	2.2	0.1	<0.1	<0.1
Pine-Hemlock-Hardwood Forest	940.8	2.5	221.8	5.0	16.4	5.0
Glades and Barrens	207.2	0.6	18.5	0.4	0.6	0.2
Eastern Floodplain Forest	27.2	0.1	3.8	0.1	0.1	<0.1
Eastern Small Stream Riparian Forests	89.1	0.2	9.4	0.2	0.7	0.2
Atlantic Swamp Forests	24.4	0.1	0.8	<0.1	<0.1	<0.1
Hardwood Flatwoods	1.8	<0.1	0.1	<0.1	<0.1	<0.1
Ruderal Forest	1800.9	4.8	124.5	2.8	3.2	1.0
Managed Tree Plantation*	349.4	0.9	8.8	0.2	0.1	<0.1
U-Index	**0.41**		**0.25**		**0.31**	

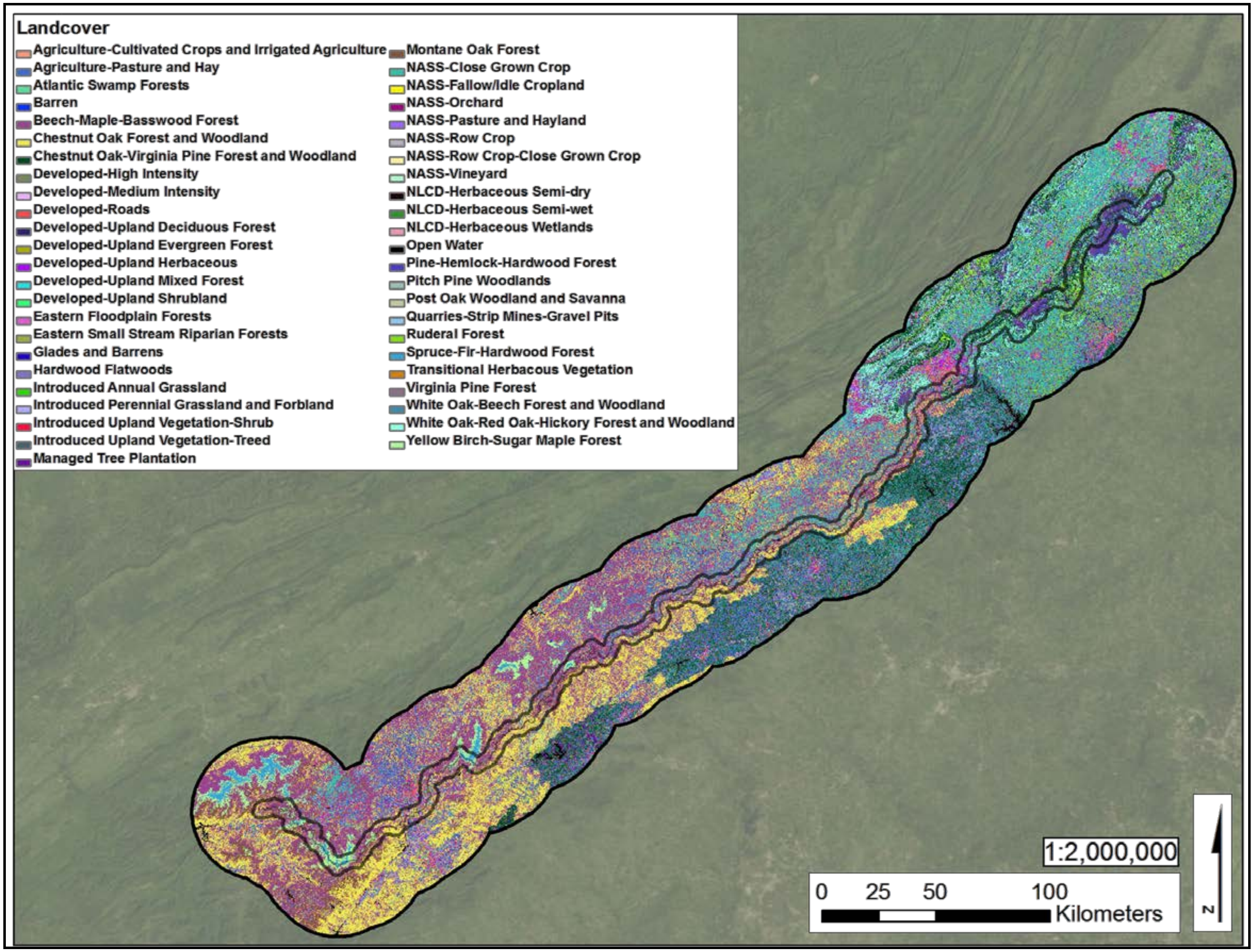

Figure 62. LANDFIRE landcover classification for BLRI shown with 30km and 3 km buffers.

Gap Analysis Program (GAP)
The third source of landcover information is the Gap Analysis Program (GAP) dataset, for which initial efforts were launched in the 1980s in the upper midwest region. Like the NLCD program, GAP is part of the MRLC and is intended for use at a relatively large ecoregional scale. The original and main purpose of the GAP project is to monitor the amount of protected area for plant communities and animal habitat in order to "keep common species common" (GAP 2010). A main use of the data products is to compare biodiversity patterns with networks of protected lands in order to identify potential areas for additional conservation efforts (i.e. the "gaps") (Story et al., unpublished).

Table 69 and Figure 64 shows the comparison of GAP landcover types for BLRI by buffer class. Like LANDFIRE, classifications are provided at a mid-scale ecological system level with detailed classes, though the overall classification is slightly more finely classified. For each of the buffer categories, the predominant class is the Southern and Central Appalachian Oak Forest. Overall, about 71.0% of BLRI is forested land, according to GAP data, and with subsequent buffer classes increases to 76.4% (3 km) and decreases to 67.6% (30 km). In turn, total amount of developed area decreases from 23.1% (no buffer) to 8.4% (3 km) and 8.2% (30 km), while pasture/hay areas increase from 2.6%, to 10.3% and 17.6% for the same respective classes. Again, the high proportion of developed class in the park boundary is due to the Parkway road itself. Calculated U-Indices also showed converted landcover proportions comparable to both LANDFIRE and NLCD classes.

As stated earlier, landscape ecology widely supports a critical habitat threshold of 60% to meet connectivity requirements (Wade et al. 2003, Gardner and Dean 2005, Gross et al. 2009). Empirical data supports even lower thresholds (With and Crist 1995, Andrén 1994). The U-Index is one method of assessing the impact of anthropogenic change on an area via converted landcover, as opposed to natural landcover that provide essential habitat (O'Neill et al. 1988). Viewed in this context, the U-Indices representing the ratio of converted to natural habitat for the GAP, LANDFIRE, and NLCD classifications are encouraging. Although the U-indices represent a ratio and not the proportion of habitat, the latter would be even lower than the U-index, and thus the already low U-indices are encouraging. Respectively, the 30 km buffer, 3 km buffer, and no buffer classes average U-Indices plus or minus standard error of 0.40 ± 0.03, 0.25 ± 0.01, and 0.34 ± 0.02. However, the natural landcover category includes multiple vegetation classes, and therefore individual areas of essential habitat likely demonstrate less connectivity than would a U-Index using fewer types of natural landcover. Habitat specialists would not perceive all natural areas as suitable habitat, and therefore experience a lower connectivity. Nevertheless, the indices are encouraging, and are well below even the conservative theoretical threshold for connectivity.

Table 69. Landcover area and proportions of BLRI based on GAP classification. Data is shown for two buffer widths and no buffer. '*' depicts 'converted' landcover used to calculate U-index.

	-30 km buffer-		-3 km buffer-		-no buffer-	
Gap Analysis Program (GAP) Landcover	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Developed Open Space*	2264.4	6.1	295.5	6.7	74.1	22.4
Low Intensity Developed*	606.5	1.6	59.9	1.4	2.2	0.7
Medium Intensity Developed*	127.9	0.3	12.5	0.3	0.1	<0.1
High Intensity Developed*	50.1	0.1	3.8	0.1	<0.1	<0.1
Quarries, Mines, Gravel Pits, and Oil Wells*	8.3	<0.1	1.0	<0.1	<0.1	<0.1
Cultivated Cropland*	332.0	0.9	16.3	0.4	0.2	0.1
Pasture/Hay*	6225.4	16.7	437.0	9.9	8.3	2.5
Open Water (Fresh)	236.9	0.6	6.3	0.1	0.6	0.2
Undifferentiated Barren Land	18.6	<0.1	0.3	<0.1	<0.1	<0.1
Central Interior Calcareous Cliff and Talus	31.7	0.1	0.1	<0.1	<0.1	<0.1
North-Central Appalachian Cliff and Talus	38.9	0.1	13.1	0.3	0.7	0.2
Southern Piedmont Cliff	1.0	<0.1	0.2	<0.1	<0.1	<0.1
Southern Appalachian Montane Cliff	6.8	<0.1	1.4	<0.1	0.2	0.1
Southern Appalachian Rocky Summit	4.8	<0.1	1.3	<0.1	0.2	0.1
Southern Appalachian Granitic Dome	0.1	<0.1	0	0	0	0
Central / Southern Appalachian Northern Hardwood Forest	550.5	1.5	192.0	4.3	21.1	6.4
Southern Piedmont Mesic Forest	358.5	1.0	13.7	0.3	0.4	0.1
Southern Piedmont Dry Oak (Pine) Forest	3735.1	10.0	94.9	2.1	3.3	1.0
Northeastern Interior Dry Oak Forest	232.6	0.6	8.4	0.2	0.2	0.1
Southern and Central Appalachian Oak Forest	11311.0	30.3	1874.4	42.4	128.4	38.8
Southern Ridge and Valley Dry Calcareous Forest	164.0	0.4	1.2	<0.1	<0.1	<0.1
Southern Piedmont Dry Oak-Heath Forest	0.2	<0.1	0.1	<0.1	0	0
Central Appalachian Oak and Pine Forest	0.1	<0.1	<0.1	<0.1	0	0
Appalachian Hemlock-Hardwood Forest	728.6	2.0	112.5	2.5	10.0	3.0
Southern and Central Appalachian Cove Forest	3282.7	8.8	730.7	16.5	40.0	12.1
South-Central Interior Mesophytic Forest	<0.1	<0.1	0	0	0	0
Southern Appalachian Montane Pine Forest and Woodland	167.3	0.4	33.9	0.8	3.3	1.0
Southern Appalachian Low Mountain Pine Forest	437.7	1.2	20.4	0.5	1.0	0.3
Central and Southern Appalachian Spruce-Fir Forest	148.0	0.4	28.4	0.6	4.6	1.4
Southern Appalachian Grass and Shrub Bald	21.7	0.1	6.9	0.2	0.5	0.2
Disturbed/Successional*	915.9	2.5	66.0	1.5	1.7	0.5
Harvested Forest*	328.5	0.9	24.2	0.5	0.5	0.2
Evergreen Plantation or Managed Pine*	584.6	1.6	43.2	1.0	2.8	0.8
Southern and Central Appalachian Bog and Fen	0.3	<0.1	0.1	<0.1	<0.1	<0.1
Central Appalachian Riparian	0.4	<0.1	0.2	<0.1	0	0
South-Central Interior Large Floodplain	7.4	<0.1	0.4	<0.1	<0.1	<0.1
Southern Piedmont Large Floodplain Forest	<0.1	<0.1	0	0	0	0
Southern Piedmont Small Floodplain and Riparian Forest	56.2	0.2	0.7	<0.1	0	0
South-Central Interior Small Stream Riparian	289.9	0.8	53.2	1.2	3.6	1.1
U-Index	**0.44**		**0.28**		**0.37**	

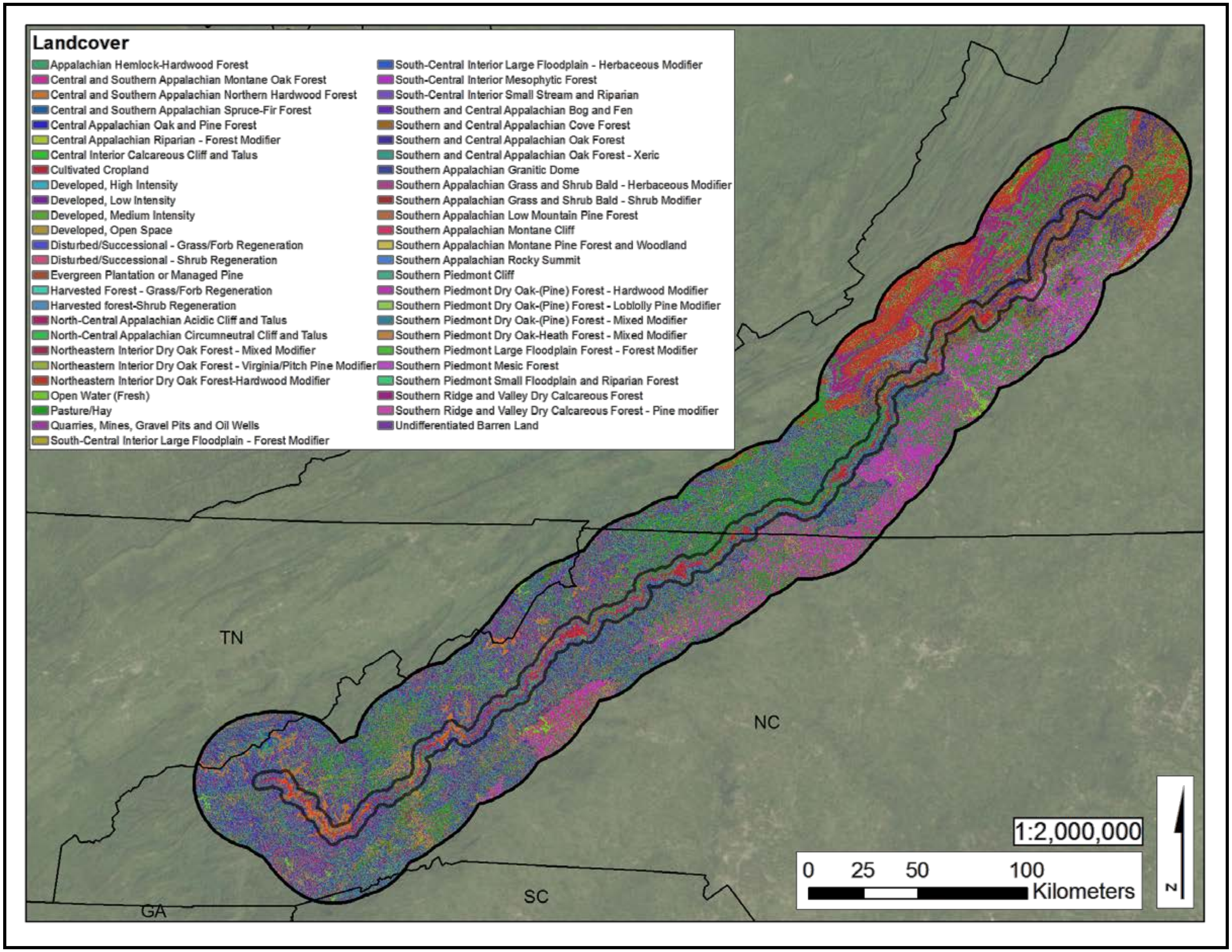

Figure 63. Gap Analysis Program (GAP) landcover shown for BLRI with 3km and 30 km buffers.

Impervious Surface

One of the most direct influences of anthropogenic conversion on natural areas comes from the amount of impervious surface within a watershed. Highly urbanized areas with large amounts of impervious surface can disrupt hydrologic regimes in several ways, such as increased amounts of flow and decreased infiltration rates. This, in turn, can result in lower water tables, stream flashiness, and intermittent flow (Arnold and Gibbons 1996, Harbor 1994). Decreased water tables in areas with high areas of impervious surface can negatively affect wetland areas maintained by ground water flow. In smaller catchments, storm events can also greatly increase peak flow over a short period of time.

Many studies have outlined threshold levels of impervious surface at different scales for biotic integrity, and like the thresholds of connectivity for essential habitat, these values vary widely. Stranko et al. (2008), for instance, analyzed several stream catchments in Maryland for the presence of brook trout and found that they were mostly absent from sites with greater than 4% impervious cover. Another study in Maryland by Klein (1979) reported a threshold of 12% - 15% imperviousness before encountering a drop in stream quality, while severe inhibition was generally associated with levels of imperviousness 30% and above. Klein (1979) further recommended a limit of 10% imperviousness for areas with trout populations. These higher levels of imperviousness resulted in poorer quality benthic communities, lower species diversity indices, and overall reduction of fish populations. In several Wisconsin watersheds, Wang et al. (2001) measured the effects of urbanization on fish habitat using several biotic and abiotic factors and found 8% imperviousness as a threshold for negative effects. Above 12% imperviousness, minor increases in urbanization resulted in sharply declining quality of fish communities. In a review of the effects of impervious cover and urbanization, Paul and Meyer (2001) outlined an even lower threshold for change in geomorphological characteristics, starting at proportions of 2 - 6%.

Due to its positioning predominantly along the ridgeline, BLRI is largely protected from deleterious biotic and geomorphological effects stemming from impervious surface cover. The main exception to this is the northern portion of the Parkway that descends in elevation to pass through Roanoke, VA. The NPScape version of impervious surface includes landcover classification of bare rock, paved roads, and most developed areas (Gross et al. 2009). Using this classification, proportion impervious area with each successive buffer class is 12.2% within the park boundary, 6.3% at the 3 km buffer, and 7.1% at the 30 km buffer width. The effect from the Parkway road is particularly evident using this metric, and the calculated 12.2% imperviousness within BLRI falls around the minimum threshold for affecting stream quality.

4.13.2 Roads

The unique role of roads at BLRI centers on the fact that the park itself is a road corridor, originally envisioned as a way to connect SHEN in Virginia to GRSM in NC. Although essential to the access of the park, roads that dissect the landscape can have a tremendous effect on many ecological factors important to the park. Roads are one of the main drivers of landscape fragmentation (Gross et al. 2009), and can also disrupt hydrological processes (Jones et al. 1999). Trombulak and Frissell (1999) outline the seven main effects of roads on biotic integrity as follows: (1) construction-related mortality, (2) vehicle mortality, (3) animal behavior modification, (4) alteration of the physical environment, (5) alteration of the chemical environment, (6) spread of exotics, and (7) increased use by humans. Even in relatively undeveloped areas, effects are pervasive and can impact areas several hundred meters beyond the roadside (Forman et al., 2002; Forman, 2000). Gross et al. (2009) outlines several sources of information documenting the effects of roads on natural resources and terrestrial biodiversity. The NPScape analysis of roads selected three main metrics to describe their effects: road density, distance to road, and effective mesh size.

Road density, or total road length (km) per area (km^2), can directly affect wildlife populations. Steen and Gibbs (2004) reported altered sex ratios and populations of painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*) in high road density sites (>1.5 km km^{-2}) in central New York. Gibbs and Shriver (2002) found that areas with >1 km km^{-2} and >100 vehicles $lane^{-1}$ day^{-1} were likely to contribute to the mortality of land turtles, especially in the eastern U.S. where road densities are higher. Analysis of roads in the BLRI vicinity reveals that road density within the park boundary is 4.5 km km^{-2}, which decreases to 1.9 km km^{-2} at both the 3 km and 30 km buffer widths. Figure 65 shows the NPScape product for weighted road density within the 30 km buffer.

The distance to nearest road metric can help determine how much roads can influence certain ecological factors. Roads, for example, are a main contributor to human-caused vertebrate mortality in addition to altered population densities around zones of road avoidance. Exotic plant species can also be introduced and spread via road corridors up to 1 km from the roadside. Traffic exhaust, another byproduct of road presence, can influence roadside vegetation up to 200 m away (Forman and Alexander 1998). Using the NPScape product, average distance to roads is 191 m within the park unit, and 325 m and 341 m at the 3 km and 30 km buffer widths, respectively.

In an attempt to address the influence of roads on landscape fragmentation, the final measurement, effective mesh size, refers to road-created contiguous patches, or the area enclosed by the road network. Girvetz et al. (2007) define this metric as “the average size of the area that an animal placed randomly in the landscape would be able to access without crossing barriers.” At 30 km buffer, the average roadless patch area is 1.2 km^2, while at 3 km, average patch size is 1.4 km^2. Within the park unit, average patch size is 0.6 km^2. Figure 66 shows the NPScape version of effective mesh size within the 30 km buffer, from which it is easy to see the greatest concentrations of roadless patch areas occur in the southern portion of the Parkway, including the area within GRSM and the surrounding Nantahala, Pisgah, and Cherokee National Forests. The area around Roanoke is virtually devoid of roadless patches, with additional small roadless patches to the north as the Parkway nears SHEN by way of the George Washington and Jefferson National Forests.

Another important consideration is the effect of road crossings and their role as barriers to aquatic species. Depending on the type of road crossing, fish can be restricted from accessing spawning or feeding habitat upstream. Much of this influence of these barriers is due to the alteration of natural flow of the streams (Warren and Pardew 1998). Culvert crossings can also affect reproduction of aquatic macroinvertebrates (Blakely et al. 2006). At BLRI, there are over 1200 streams that intersect Parkway lands, including around 150 whose headwaters are located in the park. On a positive note, however, many of these streams do not cross the road, and in addition, streams that are impeded by crossings on the Parkway may continue for only short distances before reaching headwaters. Nevertheless, road crossings with inaccessible areas upstream have the potential to contribute to aquatic habitat fragmentation.

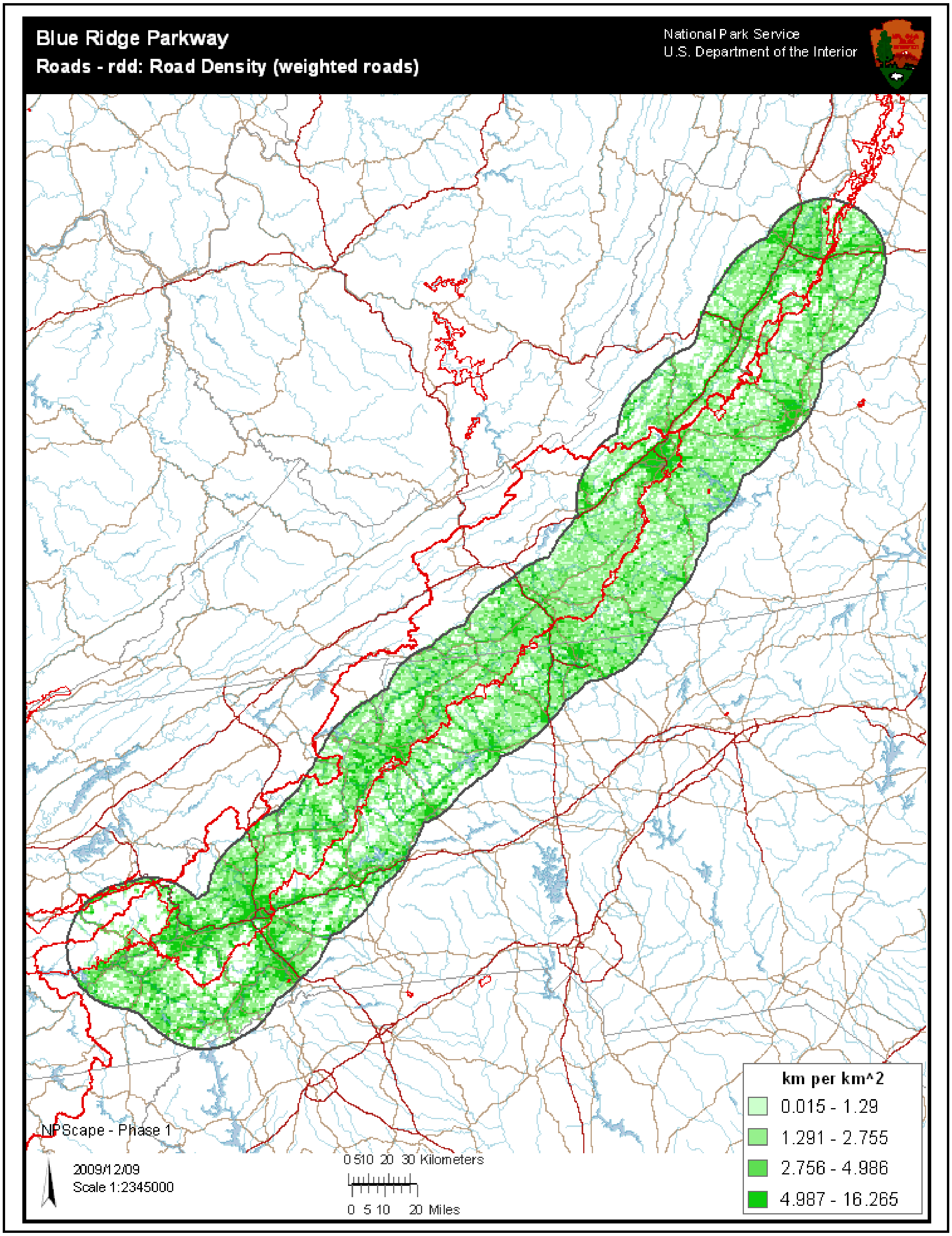

Figure 64. NPScape product (Gross et al. 2009) showing BLRI with weighted road density.

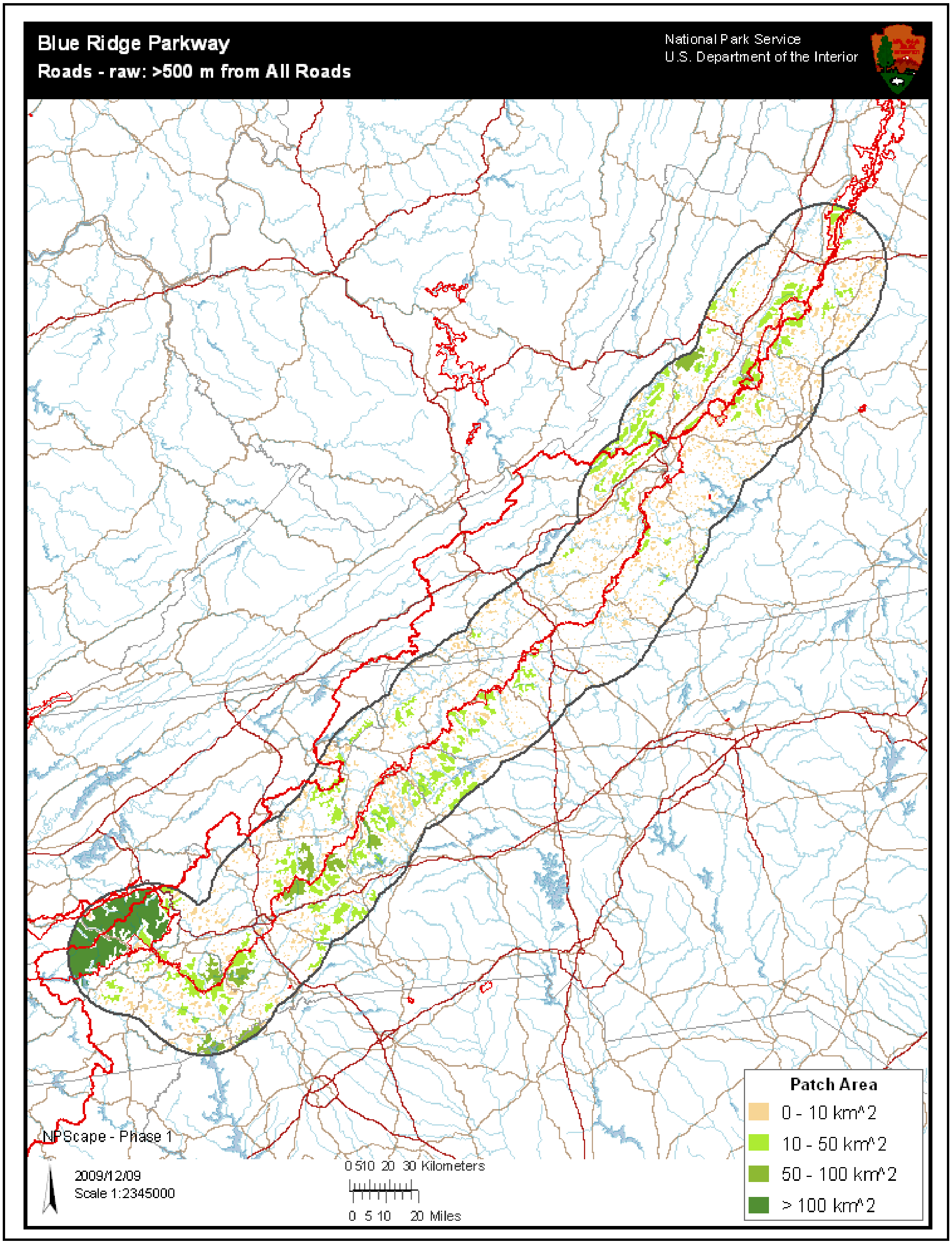

Figure 65. NPScape product (Gross et al. 2009) showing effective mesh size created by roads.

4.13.3 Population and Housing

Population pressure can provide an approximation of how much impact humans have on the landscape in a given area. Areas of high population have been shown to contribute to the decline of terrestrial biodiversity (Kerr and Curie 1995), which is usually the result of habitat loss stemming from land use conversion (Wilcove 1998). Gross et al. (2009) provide a comprehensive reference list for the effects of population pressure on different taxa, and outline the following six main effects resulting from human settlements: (1) loss of habitat to structures and non-habitat cover types, (2) habitat fragmentation, (3) resource consumption, (4) disturbance by people and their animals (pets, livestock, etc.), (5) vegetation modification, and (6) light and noise pollution. In general, they offer that the impact of human settlements is far-reaching, and certain species are more sensitive to humans and their effects than others.

NPScape products developed to analyze trends include population and housing density maps created at the county level from U.S. Census Bureau data. Gross et al. (2009) report that housing density is closely correlated with population density, but as Liu et al. (2003) point out, housing density also accounts for changing household demographics, such as average household size and per capita consumption. The NPScape product for housing density divides developed areas into 11 classes plotted for five decades between 1950 and 2000. Figure 67 depicts the change of each housing density class within the 30 km buffer. Although data is only available at five points, there is a visible decreasing trend of the three housing classes of least density, while the remaining higher density classes show continuous increases for the most part. This is consistent with the findings of Hansen et al. (2005), who noted that beginning in 1950, exurban development (6-25 units km^{-2}) became the fastest-growing form of land use. Population data for counties adjacent to BLRI show mostly steady increases during the period 1790 to 1990 (Figure 68), with large jumps in population reflecting the growth of the two largest cities along the Parkway—Asheville, NC and Roanoke, VA.

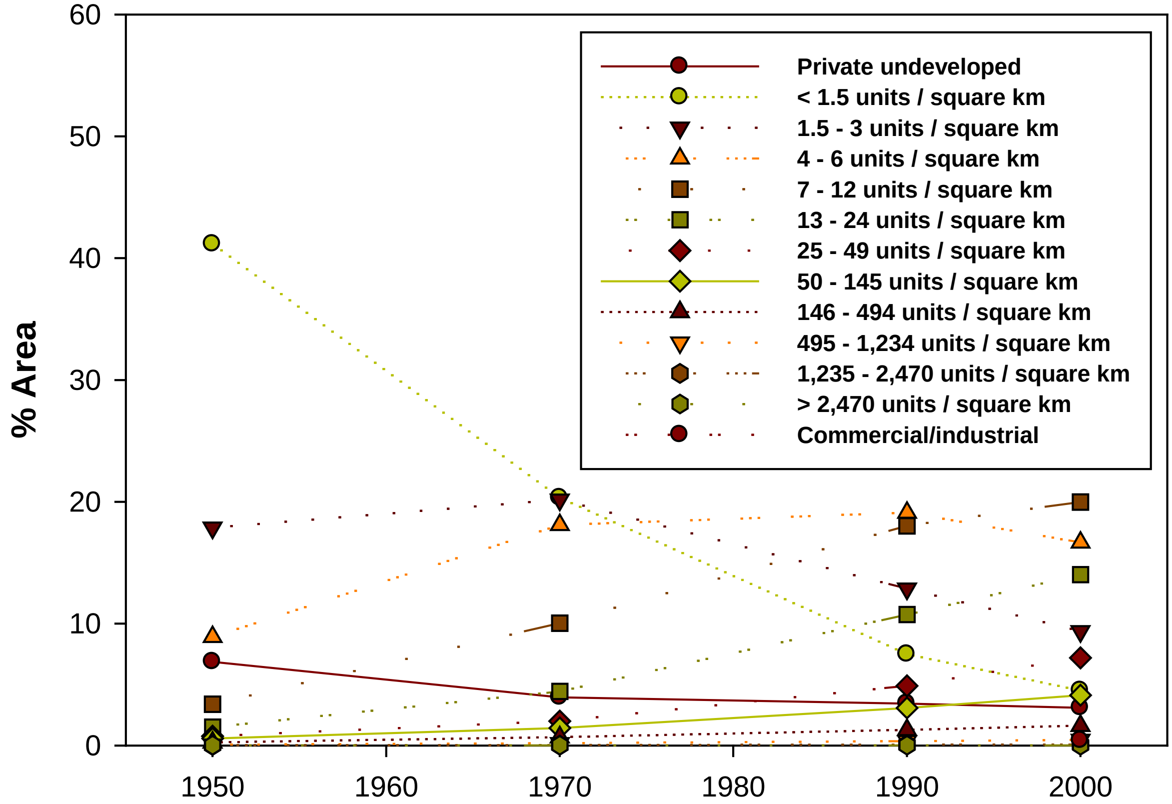

Figure 66. Historical NPScape data for housing density classes within the 30 km buffer.

Table 70 shows the breakdown of housing density classes in the 2010 prediction for each buffer size. As expected, all development classes are lower for the 3 km buffer than 30 km buffer, due to the higher proportion of protected land proximate to the Parkway. Proportions of developed classes, however, rank virtually the same for both buffer widths, suggesting there is no difference in housing patterns due to proximity of Parkway lands.

Table 70. Proportion of housing density classes for the 2010 NPScape prediction at each buffer size. Development classes are according to Theobald (2005).

Density Class	**-30 km buffer-**	**-3 km buffer-**	**Development Class**
	-%-		
Private undeveloped	1.9	2.0	Rural
< 1.5 units / square km	4.8	4.3	|
1.5 - 3 units / square km	8.8	6.2	|
4 - 6 units / square km	16.1	13.4	↓
7 - 12 units / square km	20.0	14.7	Exurban
13 - 24 units / square km	14.9	11.2	|
25 - 49 units / square km	8.0	6.3	|
50 - 145 units / square km	4.4	3.8	↓
146 - 494 units / square km	1.7	1.7	Suburban
495 - 1,234 units / square km	0.5	0.5	Suburban/Urban
1,235 - 2,470 units / square km	0.1	0.1	Urban
> 2,470 units / square km	<0.1	<0.1	|
Commercial/industrial	0.4	0.3	↓
Protected Area	18.6	35.3	--

Gross et al. (2009) acknowledge that housing density might be most useful when used as a constituent of other, more complex and ecologically-relevant landscape metrics. Although population and housing also correlate highly with other more ecologically-relevant factors like impervious surface and road density, their ease of use makes them valid for comparisons across scales and regions. To that end, NPScape also produced a plot of population densities for all areas of NPScape analyses in 1990 and 2000 (Figure 69), which shows that BLRI falls within an extremely low population density class (44.7 individuals km^{-2}) at the 30 km buffer scale relative to other NPS units.

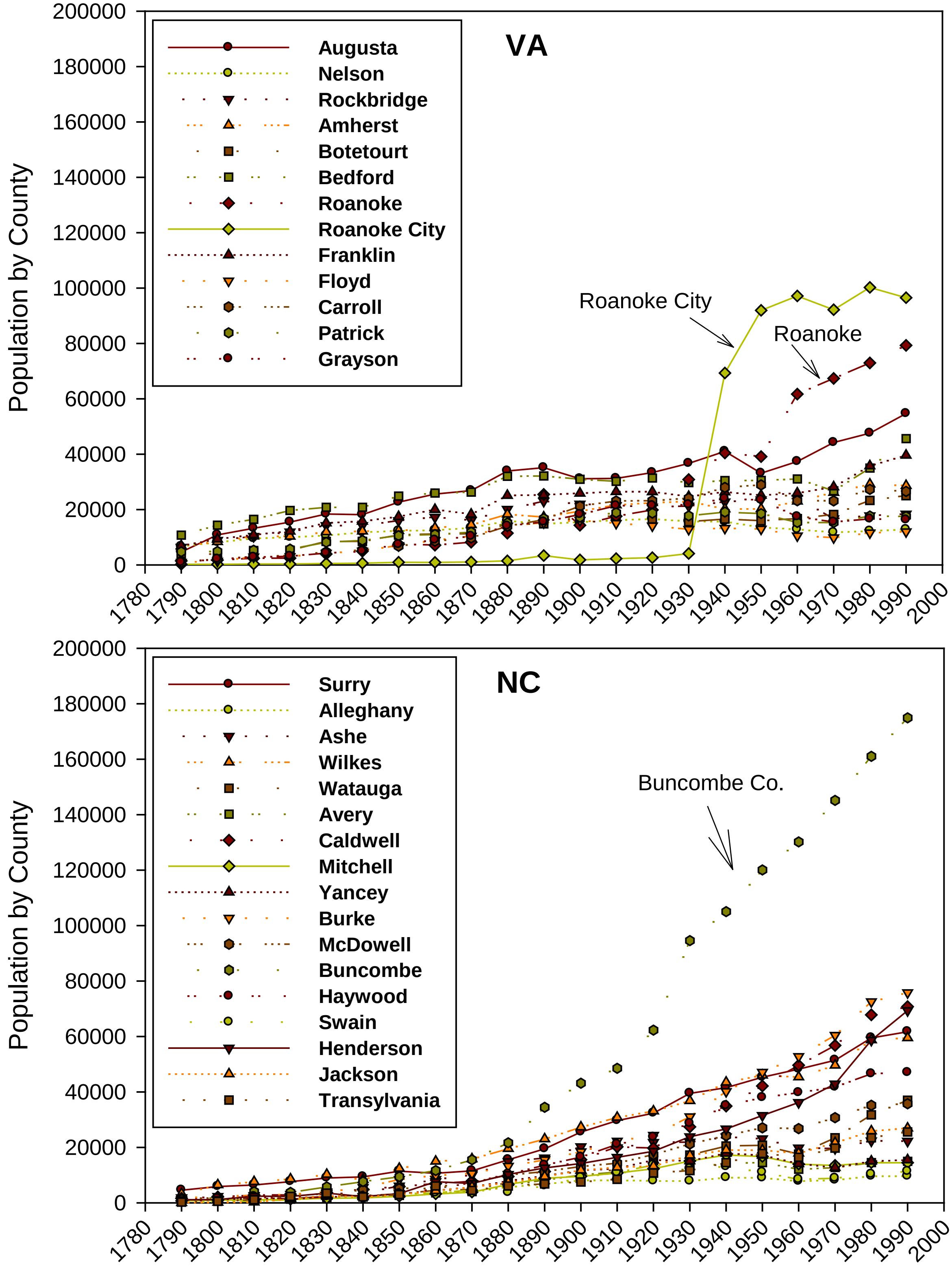

Figure 67. Population by county for VA (top) and NC (bottom) for the period 1790 to 1990. Counties listed are those adjacent to BLRI.

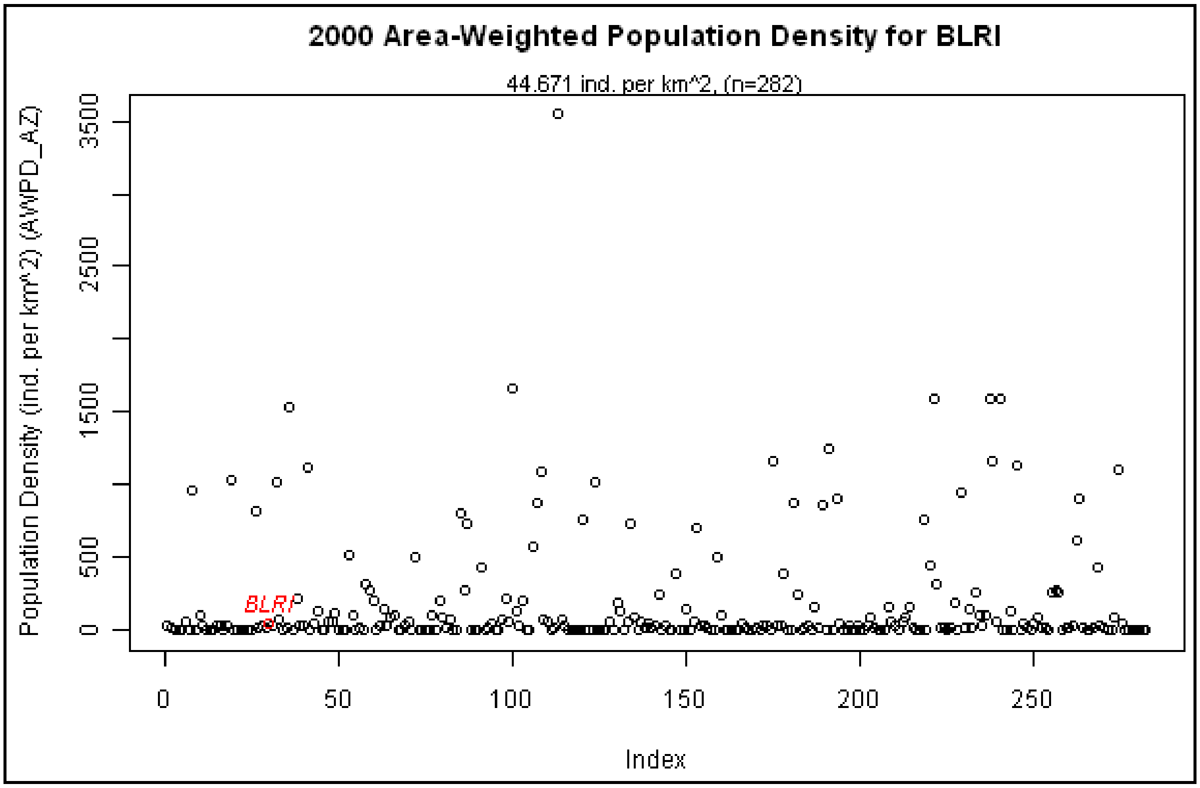

Figure 68. NPScape product showing population density of BLRI relative to landscapes of other NPS units.

4.13.4 Pattern

The configuration and composition of landcover types and specific landscape features play a large role in the dynamics of ecological processes, and more specifically can play a role in determining the species assemblages found in a certain area (Turner 1989). Natural landcover and the amount of suitable habitat it provides is one component of species composition, though it is also affected by the arrangement of that habitat. These two components of landcover are often confounded, and thus individual effects are difficult to identify (Trzcinski et al. 1999). However, landscape metrics intended to describe general patterns of landcover can be helpful in determining which features strongly influence patterns of species distribution. Gross et al. (2009) point out that some of the most commonly used landscape metrics include patch size and shape, connectivity, core habitat, and edge habitat.

<u>Edge</u>
Edges are the boundary between two different patch types, and as certain landcover types are divided and become more patchy, edge density increases, which can affect numerous ecological processes. Conditions at patch edges may be intermediate of those at adjacent patches, such that a forested edge next to an open patch may be hotter, drier, windier, and lighter than interior forest conditions, which may in turn also result in different species composition (Ries et al. 2004). Edges may also alter species composition by facilitating the transport of pollen or other organisms into interior habitat area. Species interactions may also be affected by the presence of

edges. Numerous studies report that birds undergo increased rates of parasitism and predation within edge habitats and demonstrate greater rates of nest success in larger patches (Andrén and Angelstem 1988, Paton 1994, Donovan et al. 1997)).

Patch Size.

The patch size of individual landcover types is closely related to the effects of edges on organism interactions and resource movement. A larger patch will usually contain more core habitat than a smaller patch size, meaning that the habitat is not subject to the higher predation rates and other outcomes associated with edge effects. The amount of edge, however, can increase or decrease depending on the shape of the patch, which lends usefulness to the perimeter (edge) to area ratio—another commonly used landscape metric. However, as Andrén (1994) notes, patch size is also confounded by fragmentation, and thus each of these three metrics (patch size, edge, and fragmentation) must be considered in tandem.

The NPScape project constructed maps of core habitat using edge widths of 30 m and 150 m. In an assessment of microclimate variation along forest edges, Matlack (1993) found that edge effects for several factors were detectable at sites of eastern deciduous forest up to 50 m from the edge. Another estimate by Ranney (1977) suggested that edge habitats extend from 5 m up to 20 m and may affect a variety of factors including tree species composition, primary productivity, structure and development, animal activity, and propagule dispersal. Both of these estimates most closely match the 30 m edge width used in the NPScape product describing forest habitat types shown in Figure 71. In this product, landscape elements are classified according to morphological spatial pattern analysis (MSPA) types, which include core, islet, perforation, edge, bridge, branch, and background. Table 71 shows definitions for these features and their respective contribution for each of the classes using a 30 m edge definition. Figure 70 shows just the change in proportion of core, background, and edge types for each buffer class. Although edge proportion is virtually unchanged between the no buffer and 3 km buffer classes, it increases slightly at the 30 km buffer width. Core and background area decrease and increase, respectively, at the 3 km but match the no buffer proportions at 30 km width. This demonstrates an association between the Parkway and the intactness of forest habitat at proximate locations—an effect that seems to be diminished at 30 km. The Parkway road undermines the protective nature of the park unit itself to forest habitat, contributing to additional edge effect and higher proportion of background within the park boundary. Figure 72 depicts the proportion of core and edge area within the vicinity of BLRI compared to other NPS units. Both plots show BLRI at a relatively high percentile of both core and edge proportion, suggesting that there are large sections of contiguous forest and large sections of fragmented forest, with relatively small proportions of non-forested background area.

Table 71. Morphological spatial pattern analysis (MSPA) class types used by NPScape for BLRI forest patches at 30 km, 3 km, and no buffer widths. Edge width was defined as 30 m.

Pattern type	Definition	-30 km buffer- Area (km²)	% Area	-3 km buffer- Area (km²)	% Area	-No buffer- Area (km²)	% Area
Core	Interior forest area not influenced by edge	21192.4	56.9	2982.0	67.5	184.0	55.7
Islet	Patch too small to contain core area	170.0	0.5	12.1	0.3	0.6	0.2
Perforated	Edge (linear) internal to core forest type (30 km)	507.5	1.4	66.2	1.5	7.9	2.4
Edge	Perimeter (linear) of forest patch (30 km)	3363.9	9.0	345.7	7.8	41.1	12.4
Bridge	Non-core (linear) forest connecting disjunct core patches	487.4	1.3	45.4	1.0	4.1	1.2
Branch	Non-core (linear) forest connected to perforation, bridge, or edge	622.3	1.7	52.6	1.2	4.6	1.4
Background	Non-forested area	10891.6	29.3	913.3	20.7	88.3	26.7

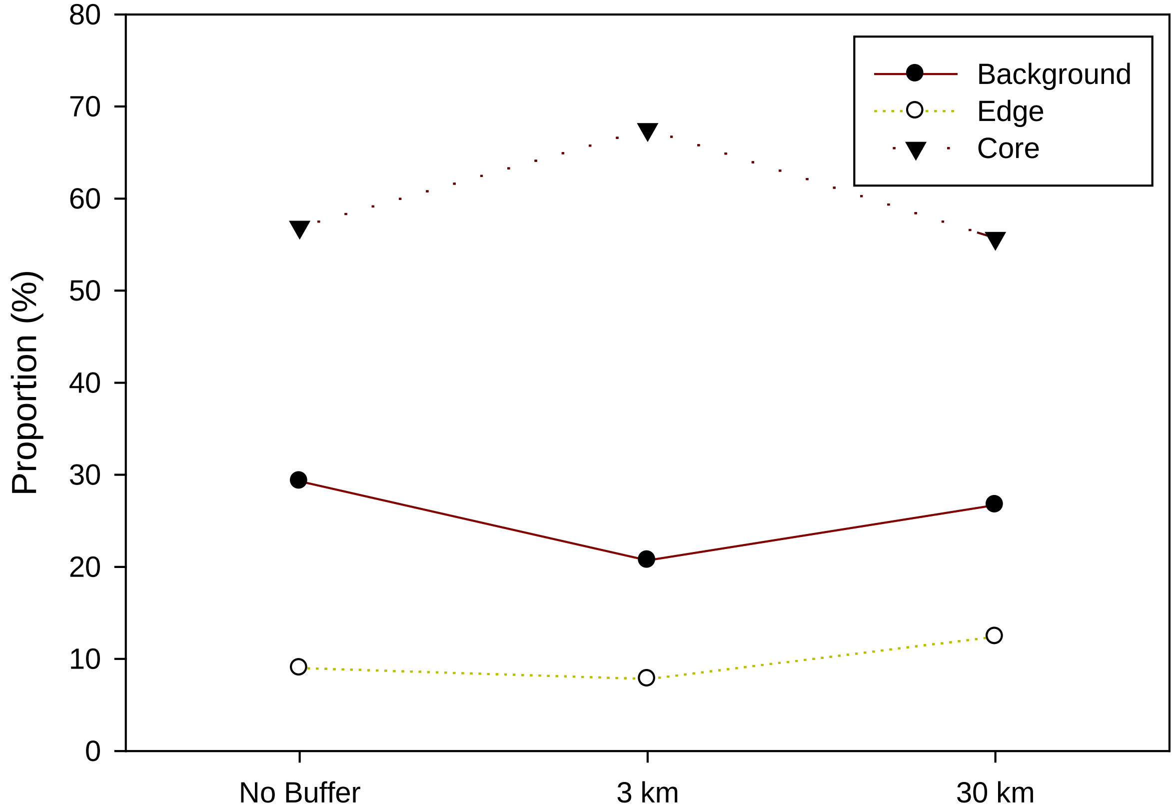

Figure 69. Forest edge and core areas increase and decrease, respectively, as buffer width around BLRI increases. Background, representative of non-forested area, also predictably increases with buffer width.

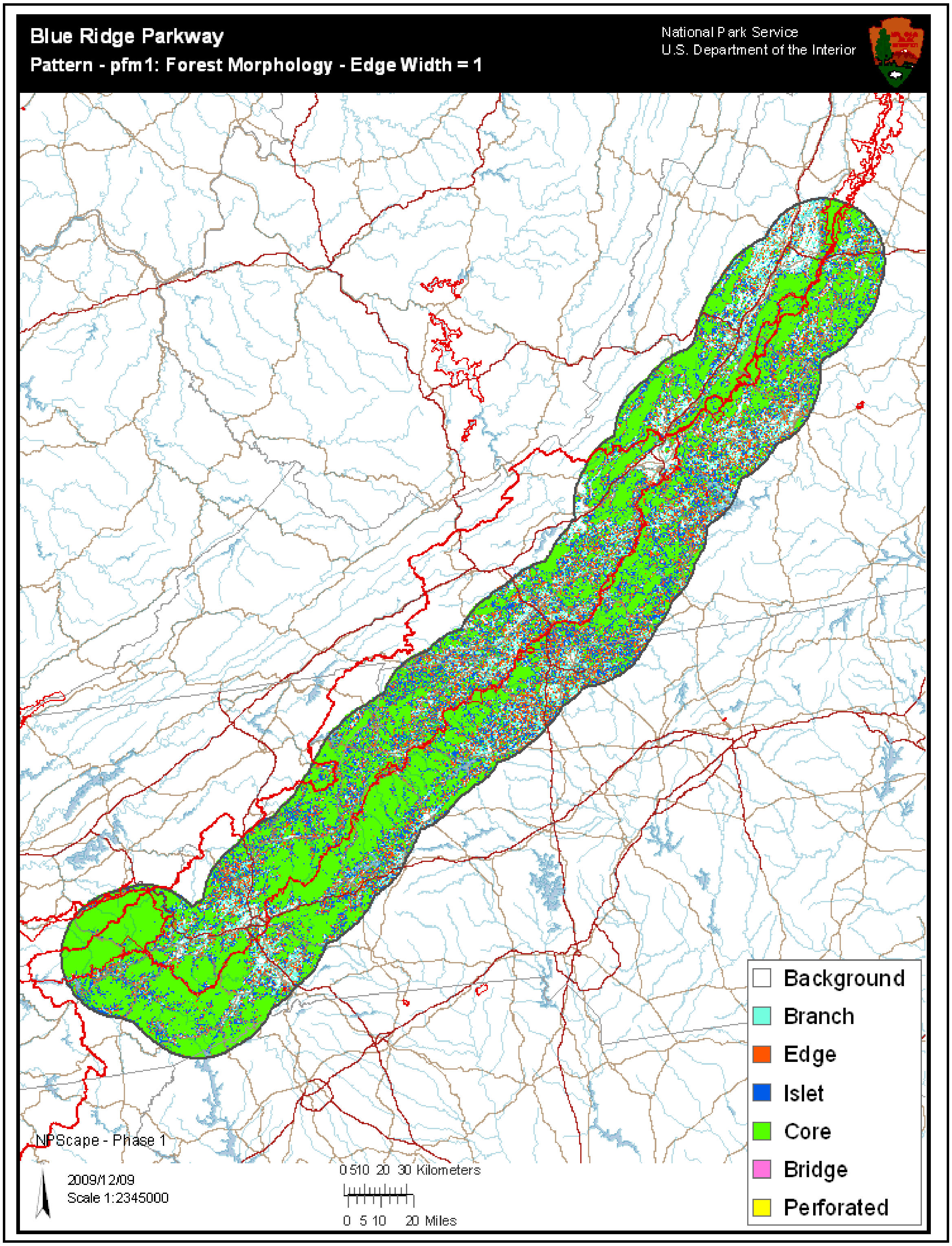

Figure 70. NPScape product showing forest morphology metrics for BLRI with a 30 km buffer. Edge width is defined as 30 m.

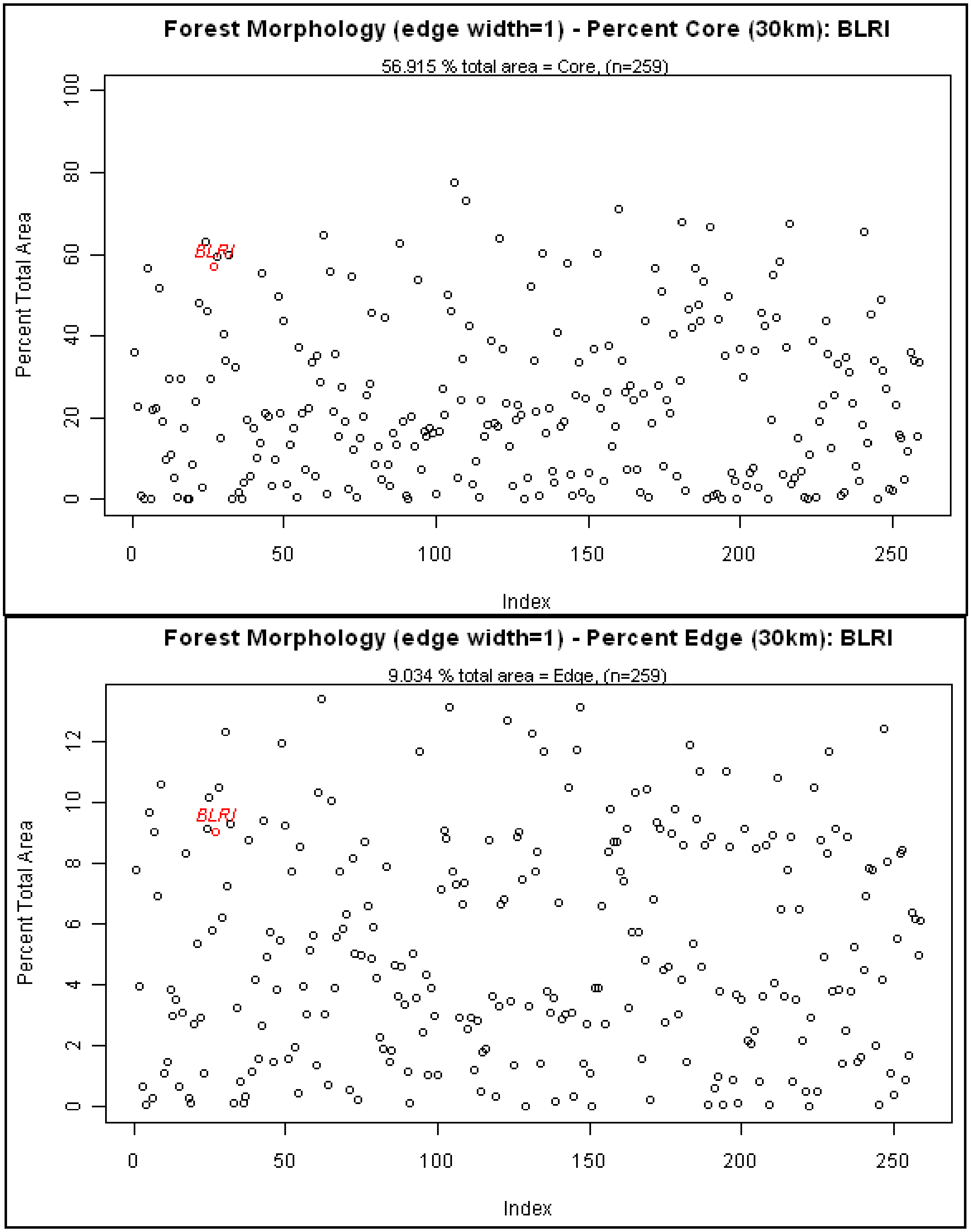

Figure 71. NPScape pattern product showing percent core (top) and percent edge (bottom) for BLRI compared to other NPS units.

4.13.5 Conservation Status

The creation of protected areas is generally considered a safeguard against habitat loss and degradation. These protected areas, in combination with other landscape factors posing a risk to natural resources, can help prioritize areas for further conservation at fairly large scales. To this end, the Gap Analysis Program (GAP) has developed the Protected Areas Database (PAD) of the US, based primarily on the prescribed management of individual land units. This database ranks protected areas on a scale of 1 (highest protection) to 4 (lowest protection) depending on the relative degree of biodiversity protection offered by each unit (Gross et al. 2009). The NPScape product for protected areas calculates the amount of land within a 30 km buffer classified as either 1 or 2, but not 3 or 4 (Figure 73). Ironically, this excludes BLRI from the proportion of protected land within its buffer because of its assignment to a level-3 protection class. Gross et al. (2009) note that 5% intensive human use is the maximum threshold used when assigning a protection rank, and thus the level-3 ranking for BLRI likely stems from the fact that 9% of land area is converted to road alone. Gross et al. (2009) also point out that the level-3 protection class is considered typical of “multiple-use” areas, such as those managed by the Bureau of Land Management (BLM) or the USFS.

Overall, there are 2,394 km^2 of protected area within the 30 km buffer, or approximately 6.4% of the land area, not including water. Of this area, 1,482 km^2, or 62% of the protected area, is listed as level-1 protection, which include SHEN, GRSM, Roan Mountain State Park, and Pond Mountain Wilderness. Other level-2 protected areas include Shining Rock Wilderness Area, Linville Gorge Wilderness Area, James River Face Wilderness, and George Washington National Forest. Figure 74 plots the amount of protected area around BLRI with that of other NPS units, wherein BLRI appears to fall within an average range.

Similar to the variety of thresholds discussed for critical habitat, impervious surface, and road density, Gross et al. (2009) point out that conservation goals describing ideal amounts of protected area also vary widely. As Soulé and Sanjayan (1998) note, preservation goals such as 10% to 12% protected area are posed frequently for their political appeal (Rodrigues and Gaston 2001, Svancara et al. 2005), but such low proportions, when considered in the context of species-area relationships, are grossly inadequate and could translate into a loss of up to 50% of species richness. This sensitivity to species loss is especially true in a long, narrow corridor like BLRI. A review of evidence-based studies outlining conservation targets by Svancara et al. (2005) yielded an average threshold of 41.6% ± 7.7% (n = 33), wherein the studies considered were ones whose “research results…identified thresholds at which habitat fragmentation or loss has deleterious effects on the feature of interest.” This threshold was much higher than the average threshold value of 13.3% ± 2.7% for policy-based targets that were based in little or no scientific grounding. Although it is difficult to identify a one-size-fits-all threshold, evidence-based examples express the need for much higher thresholds of protected area, as well as ones that are individually targeted toward the biological needs of communities, species, and ecosystems of the area in question (Svancara et al. 2005).

Besides thresholds of protection, Gross et al. (2009) outline out a metric described by Hoekstra et al. (2005) called the Conservation Risk Index (CRI). Similar to the U-Index calculated as the ratio of natural to converted land, the CRI is calculated as the ratio of area converted to the area protected. Hoekstra et al. (2005) outlines thresholds for the index based on the IUCN Red List species, such that areas where habitat conversion is > 20% and CRI > 2 is classified as vulnerable; those with conversion > 40% and CRI > 10 as endangered; and those with conversion > 50% and CRI > 25 as critically endangered. When applied to BLRI using GAP level-1 and -2 protected areas (i.e. excluding BLRI) and NLCD 2001 converted area over the 30 km buffer, the CRI yields a value of 4.03, while 25.9% of the area is classified as converted landcover according to 2001 NLCD. This calculation is conservative, but still above threshold for the lowest “vulnerable” CRI calculation. If level-3 GAP status land was included in the CRI, which would incorporate BLRI and more of the Daniel Boone NF, the CRI ratio is reduced to 1.50, which is below the threshold for the “vulnerable” rating, though proportion converted area still remains past the threshold.

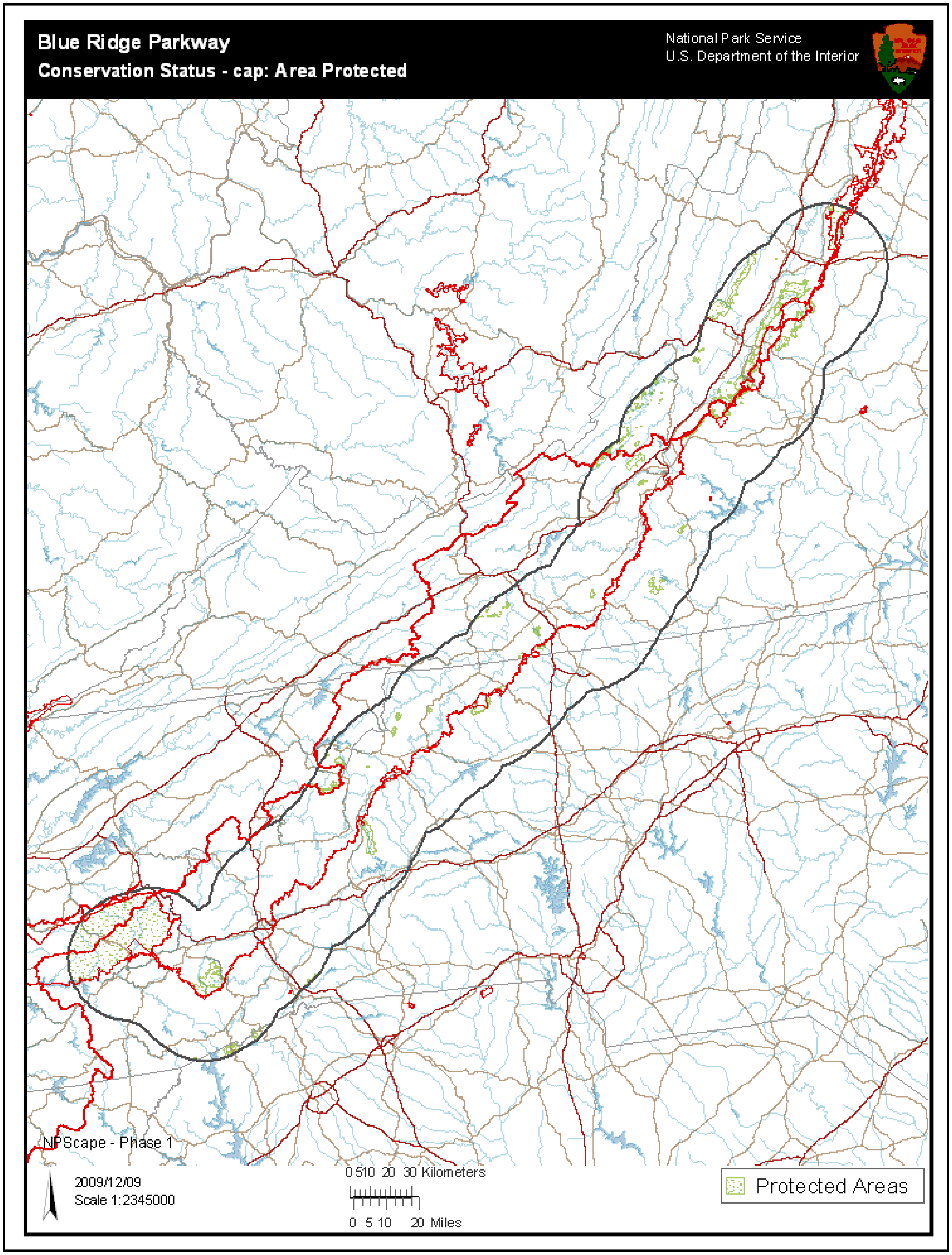

Figure 72. NPScape product depicting protected areas, as defined by the Gap Analysis Program (GAP), within a 30 km buffer of BLRI (Gross et al. 2009). GAP-defined protected areas only include class 1 and 2 land units, and thus the classification of BLRI as class 3 excludes it from the list of protected areas.

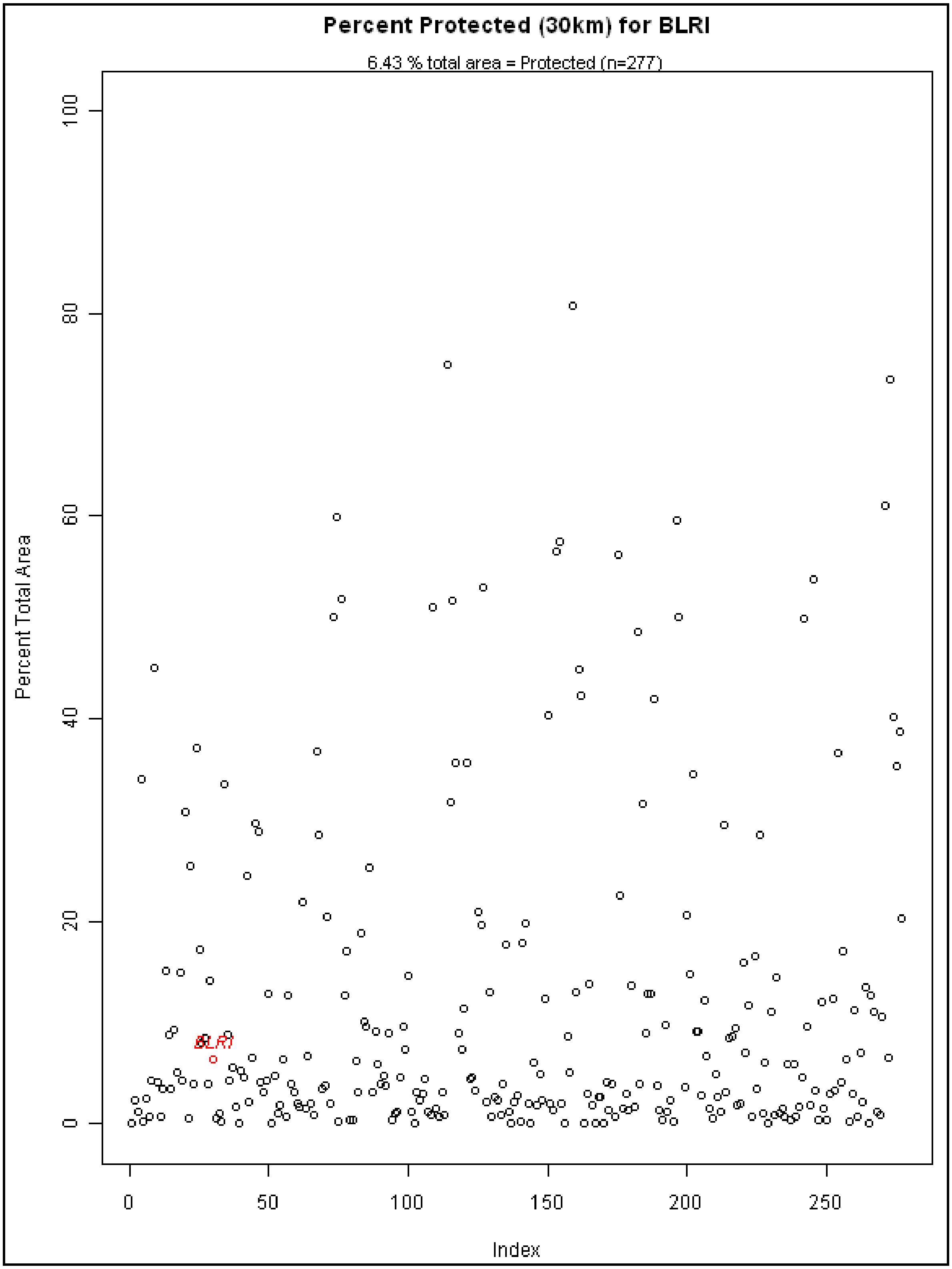

Figure 73. NPScape conservation status product showing percent protected area of BLRI within the 30 km buffer relative to landscapes of other NPS units.

4.13.6 Landscape Synthesis and Considerations

The NPScape effort that directs much of the landscape dynamics section was designed to outline specific measureable features that would reflect resource condition within individual park units. Because most of the park units lie within larger ecosystems and exchange resources far beyond their own boundaries, three spatial scales were considered for analysis. Gross et al. (2009) also indicates that additional scales will be analyzed in future NPScape products. In an effort to strike a balance between reproducibility among park units and relevancy across scales and regions, analysis was divided among five main landscape aspects: landcover, roads, population and housing, pattern, and conservation status. Below, each of these five sections is summarized with a general description, key references, and challenges describing the landscape aspect, followed by the main points pertaining to BLRI for each section.

Landcover

Analyses of landcover was based mainly on data from the NLCD, which includes 2001 and 2006 classifications, in addition to a change product between the two periods that outlines them as natural or converted areas. The other two classifications included LANDFIRE, EVT, and GAP landcover layer. For each of the three data sources, a U-index representing the ratio of converted to natural area was derived, with the results as shown in Table 72.

Table 72. U-indices for three landcover sources at each buffer width.

	-U-Index-		
-Data Source-	**-30 km-**	**-3 km-**	**-No buffer-**
NLCD	0.35	0.23	0.35
LANDFIRE	0.41	0.25	0.31
GAP	0.44	0.28	0.37
Average	**0.40**	**0.25**	**0.34**

O'Neill et al. (1988) showed a correlation between the U-Index and the domination of different landcover types. Forested landscapes tended to show a high fractal dimension and correlated positively with the U-Index, while the opposite was true for agricultural landscapes. Either way, the index corresponded well to the level of human manipulation within the landscape. Although no specific thresholds were offered, O'Neill et al. (1988) calculated the index for 94 landscapes in the eastern U.S., for which the average value was 3.22 ± 0.71 SE.

Amount of impervious surface area is another metric used often in landcover analyses. Perhaps more than several other aspects of landscape change and analysis, the effects of imperviousness has a large literature base that tries to relate specific thresholds to changes in water and habitat quality. Some of the lowest thresholds, identified by Paul and Meyer (2001), indicate potential for changes in geomorphological characteristics—mainly stream channel enlargement and destabilization—at levels of 2 to 6% imperviousness. Several studies also focus on how impervious surface affects stream habitat quality. Klein (1979) defined a limit of 10% imperviousness for areas with trout populations, while Stranko et al. (2008) found a much lower threshold of 4% imperviousness for brook trout populations in Maryland stream catchments. Klein (1979) suggests that larger thresholds such as 12 - 15% imperviousness are where stream water quality begins to degrade.

- Average values of imperviousness for BLRI are around 12% and represent the minimum threshold where stream water quality and aquatic communities are affected according to literature above. However, the threat is likely much less than this because the overall imperviousness in the surrounding watershed is lower than just BLRI itself. As a result, there may be some effects to aquatic habitat directly downstream of the Parkway, but overall, the low levels of imperviousness in the watershed suggest minimal effects on stream water quality as a whole.

- Imperviousness for successive buffer widths of 3 km and 30 km are respectively 6.3 and 7.1%. While low, these proportions are still potentially in the range that could result in geomorphological alterations (Paul and Meyer 2001).

Roads

NPScape used three main metrics to describe the effects of roads in the landscape: road density, distance to road, and effective mesh size. Mean rates of traffic were not used in the NPScape assessment but were used to estimate land turtle mortality by Gibbs and Shriver (2002), who suggested a road density threshold at 1.0 km km^{-2}. Steen and Gibbs (2004) offered another threshold of 1.5 km km^{-2} for a central NY study, while Forman and Alexander (2002) suggest that 0.6 km km^{-2} represents the upper threshold of a landscape that can support large predators such as wolves and mountain lions. In addition, Frair et al. (2008) found a low threshold between 0.25 km km^{-2} and 0.50 km km^{-2} where elk populations in Alberta, Canada began to be affected, while effect on the landscape reached a saturation level at 1.6 km km^{-2}.

- At BLRI, road density decreases from 4.5 km km^{-2} with no buffer, to 1.9 km km^{-2} at both the 3 km 30 km buffer widths. Lin (2006) offers that the average road density throughout the U.S. is 0.67 km km^{-2}. Road densities at both buffer widths and for the park boundary are greater than all the thresholds presented from literature above, though the park itself demonstrates a much higher density and suggests a potential effect on wildlife populations.

- Consistent with the results of road density, the average distance to road measure is much lower within the park boundary—191 m—than for the 3 km (325 m) and 30 km (341 m) buffer widths.

- The average roadless patch area for BLRI is 0.6 km^2, but because of its nature as a road corridor, this metric holds limited meaning. The 3 km and 30 km buffer widths have respective roadless patch areas of 1.4 km^2 and 1.2 km^2.

- Unlike other metrics, these road metrics do not show an obvious influence of the park unit on nearby areas. Only the roadless patch area shows a higher average metric at the 3 km buffer, while the road density and average distance to road metrics reflect equal or greater levels of road disturbance within the 3 km buffer closer to the park.

Population and Housing
These two measures are highly related and correlate well with other landscape metrics like impervious surface and road density. Unlike other metrics, perhaps, it becomes more difficult to identify thresholds of housing or population densities that affect specific changes in the landscape. However, Gross et al. (2009) points out several studies that make general observations regarding the influences of human settlements on plants and vertebrates. In a study involving exurban areas in Colorado, Maestas et al. (2002), for example, found (1) increased richness and cover of exotic plant species, (2) increased densities of human-commensal bird species such as blue jays (*Cyanocitta cristata*) and black-billed magpies (*Pica hudsonia*), and (3) high densities of domestic dogs and cats. In a study in California, Merenlender et al. (2009) found lower proportions of temperate migrant bird species in exurban and suburban areas, and in dense housing areas found higher relative abundances of urban adapter species like American crow (*Corvus brachyrhynchos*) and turkey vulture (*Cathartes aura*).

- Relative to other NPS units, BLRI falls within one of the lowest population density classes for its surrounding vicinity (Figure 69). Within the 30 km^2 buffer, the average population density is 44.7 individuals per km^2, which falls midway between the exurban and suburban development classes outlined by Theobald (2005).

- Although the highest proportion of developed area in the park vicinity falls within the exurban class for both buffer widths, the proportion of developed area is lower at the 3 km buffer for all except the densest development classes. This is due in part to the greater proportion of protected area within the 3 km buffer.

- Since 1950, private undeveloped land and the two lowest density housing classes (<3 units km^{-2}) show a decreasing trend within the 30 km buffer. Most of the other higher density classes show a steady increase.

Pattern.
The NPScape product used the GUIDOS package to derive a set of eight metric classes for the landcover around BLRI. Metrics were derived using both a 30 and 150 m definition for forest edge width. Several papers have identified thresholds for edge effects. Matlack (1993) selected 50 m as the width of influence for several microenvironmental factors, while Ranney (1977) stipulated 5 m to 20 m as the range of influence.

Besides edge effect, patch size is a fundamental landscape metric that addresses habitat availability. Although the effect of patch size is dependent on scale, both spatially and temporally, small patches often offer insufficient levels of habitat to maintain high levels of biodiversity.

- The pattern landscape metrics offer another good example of the masking effect of the park unit, wherein the park unit is associated with lower levels of disturbance and fragmentation at the proximate 3 km buffer class, though within the park itself these metrics are elevated.

- This is particularly evident for the background (i.e. non-forested) and core metrics, which appear at virtually the same proportions within the park unit and at the 30 km buffer, though they are respectively lower and higher at the 3 km buffer, representing more and less fragmented forest area. This is consistent with the forest patterns shown in the landcover analyses.

Conservation Status.
The NPScape assessment used the PAD created by the Gap Analysis GAP to analyze the amounted of protected area within the vicinity of BLRI. Protected areas are assigned a rating of 1 to 4 corresponding to a descending scale of the amount of biodiversity protection offered by each land unit. As a guideline, 10 to 12% protected area is often posed as a minimum objective (Rodrigues and Gaston 2001), though a review of evidence-based studies by Svancara et al. (2005) yielded a considerably higher minimum threshold of 41.6% ± 7.7 %.

- An additional guideline for amount of protected area outlined by Gross et al. (2009) is the CRI. This index is the ratio of converted area to protected area. Hoekstra et al. (2005) describes thresholds based on the amount of habitat conversion and the CRI, beginning with minimal threat when habitat conversion reaches 20% and CRI > 2.

- Notably, the PAD has assigned a rating of level-3 protection to BLRI, which connotes a minimal level of resource protection. This is most likely due to the large amounted of converted land (i.e. road) that exceeds the 5% threshold of intensive human use. The protected areas product created by NPScape only includes land units classified as either level-1 or level-2 protection, and thus they do not include BLRI or several portions of adjacent national forest in the protected areas of the landscape. The exclusion of national forest land is presumably due to allowance of resource extraction.

- Using Hoekstra et al.'s (2005) CRI rating, the ratio of converted area to protected area within the vicinity of BLRI is 4.03. Combined with the 25.9% classification of converted area taken from the 2006 NLCD, this yields a conservation risk rating within the criteria for a vulnerable classification (Hoekstra et al. 2005).

- Using level-3 protected areas from the PAD yields a lower CRI ratio of 1.50, which is below the "vulnerable" classification level, though converted area remains the same.

4.13.7 Landscape Conclusions

Each of the five components assessed by NPScape presents a slightly different outlook on the state of the landscape within the vicinity of BLRI. Considered individually, there are several aspects of the analysis that are encouraging, such as

1. Relatively low landcover U-indices at the 3 km buffer width, representing the area immediately adjacent to the park unit (Table 72). U-indices are higher at the park boundary scale due to the effect of the roadway within the park.

2. Compared to other NPS units nationwide, the landscape of BLRI at a 30 km buffer has a respectable proportion of natural landcover (73.3%). Over the period 2001-2006 represented by the latest NLCD change product, negligible portions of landcover transitioned from natural to converted at all buffer classes.

3. The 3 km buffer width shows the highest mean roadless patch areas (1.4 km^2), suggesting an association with the adjacent Parkway land.

4. Relatively undeveloped surrounding area, given the predominance of low-density development classes for all 3 buffer classes.

5. Pattern metrics also reveal beneficial patterns at the 3 km buffer, including highest core forest area and lowest background value, again suggesting an association with adjacent Parkway land.

Other aspects of the analysis are less encouraging, especially when viewed across all buffer classes:

1. For the metrics that suggest a beneficial association of proximity to BLRI at 3 km, this effect is unfortunately not observable within the park itself because of the high proportion of converted land represented by the Parkway road. This is why the U-index for NLCD data is 0.35 for both the park unit and the 30 km buffer. This effect is also strongly observed in the similar core and background pattern metrics observed for the park unit and 30 km buffer. Only at the 3 km buffer width does the core forest proportion exceed the 60% percolation threshold.

2. Predictably, proportion of imperviousness with BLRI is high (12%) relative to levels needed to minimize geomorphological alterations and impacts on aquatic habitat. Though lower at the 3 km and 30 km buffers, imperviousness proportions are still above the threshold identified by Paul and Meyer (2001) that would affect geomorphological characteristics such as stream channelization and substrate texture.

3. Because they are highly correlated with amount of converted land and imperviousness, road metrics are naturally much higher within the park unit than both buffer widths. Road densities were higher than all thresholds for wildlife effects found in literature examples.

4. Again reinforcing the influence of the roadway on other metrics, BLRI is assigned a relatively low level-3 protection class within the GAP PAD. Because of the high proportion of converted land area, as well as its ratio to protected area, the BLRI landscape received a vulnerable CRI classification.

It is important to note that although the Parkway road confers many unfavorable landscape metric statistics on the park unit, this is to be expected because the basic unit of analysis—the Blue Ridge Parkway—is in fact a roadway. Although there are undoubtedly adverse effects facilitated by the Parkway road including degraded water quality, propagation of exotic species, wildlife disturbance, and habitat loss, these would most certainly be the observed results of any analysis that centered on roads in the region. The difference is that these Parkway lands, despite their level-3 GAP protection ranking, make a difference in the surrounding forest habitat through protection from conversion. This effect may be associated with the more favorable metric rankings in the proximate 3 km buffer class compared to the 30 km class, where it may no longer be present.

The complexity of the landscape change vital sign makes it difficult to summarize into a single condition status ranking. By summarizing each of the NPScape aspects into key points as above, it becomes easier to pick out the most significant landscape qualities. By using this approach, landscape change is assigned an overall ranking of fair with a stable trend (Table 73). Although the landscape surrounding BLRI contains many large tracts of public lands and protected areas, the proportion of protected area is relatively average compared to other NPS units (Figure 74). This has to do with the large scale of the analysis buffer necessitated by the linear nature of the park. Nevertheless, this large amount of protected area, in addition to the minimal rates of conversion observed in the NLCD change product suggest that, in a general sense, landscape change will be minimized, and as a result this condition receives a stable trend (Table 73).

Table 73. The condition status for landscape change at BLRI is ranked fair with a stable trend. The data quality for this attribute is good.

Attribute	Condition & Trend	Data Quality		
		Thematic	Spatial	Temporal
Landscape Change		✓	✓	✓
		3 of 3: Good		

4.13.8 Literature Cited

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Chapter 5 Conclusions

5.1 Summary

The Blue Ridge Parkway stretches across a long linear expanse of the Southern Appalachians, and contains a vast array of natural resources. Natural resources for this report were chosen based on data availability, park-level importance, and vital sign status. The level of data completeness varied greatly among natural resource categories, though this aspect was considered independently when assigning condition rankings.

Based on a review of available ecological information for BLRI, we addressed the current condition of 15 natural resource attributes in the park. Thirteen of these were assessed at the park-wide scale. Two attributes—water quality and fish assemblages—were divided into smaller reporting areas for assessment. These attributes were assessed for reporting areas defined by groups of USGS hydrologic units. To include these attributes in the following park-wide summary, we used the proportions of individual reporting area condition ranks to create a mixed rank for the attributes. Overall, natural resource conditions in BLRI were ranked 31% good, 47% fair, and 7% poor. The remaining 15% were not ranked.

Summarized into broad categories, the percentages of condition rankings were:

Air and Climate (five attributes)—60% Fair, 20% Poor, 20% Not ranked
Water (one attribute)—73% Good, 27% Fair
Biological Integrity (eight attributes)—50% Good, 33% Fair, 17% Not ranked
Landscapes (one attribute)—100% Fair

We assigned trends to natural resource attribute conditions where appropriate. Because long-term data were not available in all cases, trends were not assigned to all attributes. Attributes assessed for multiple reporting areas were summarized as described above. Overall, natural resource condition trends in BLRI were 20% improving, 13% stable, and 20% declining. The remaining 47% were not assigned a trend.

Summarized into broad categories, the condition trend assignments were:

Air and Climate (five attributes)—60% Improving, 20% Stable, 20% Not ranked
Water (one attribute)—100% Not ranked
Biological Integrity (eight attributes)—37.5% Declining, 62.5% Not ranked
Landscapes (one attribute)—100% Stable

We also characterized the quality of data used to make each assessment. We considered the temporal, thematic, and spatial quality of available data for each attribute. Attributes assessed for multiple reporting areas were summarized as described above. Data quality was assessed for all instances where data existed. Therefore, all attributes were assigned a data quality ranking, regardless of whether the attribute was assigned a condition rank. Overall, natural resource attribute data quality, for the existing data used in this report, was ranked 73% good, 24% fair, and 3% poor.

Summarized into broad categories, the data quality rankings were:

Air and Climate (five attributes)—80% Good, 20% Fair
Water (one attribute)—64% Fair, 36% Poor
Biological Integrity (eight attributes)—62.5% Good, 37.5% Fair
Landscapes (one attribute)—100% Good

5.2 Discussion by Category

This project represents the first iteration in the development of a comprehensive natural resource monitoring program at BLRI. Beyond this report, continued monitoring of resources and attention to data gaps, as well as the development of additional condition assessment protocols will aid in the undertaking of future natural resource assessments.

5.2.1 Air and Climate

Air quality is a major consideration at the park, but controlling factors are largely out of control of park management. The geography and topography of the Southern Appalachians trap and concentrate pollutants emitted from numerous distant sources, resulting in impacted visibility, ecosystem health, and potentially human health. Numerous air quality monitors operate throughout the region, though additional monitors would be particularly useful in the central portion of the Parkway around the state boundary. This area represents a gap in coverage from stations measuring atmospheric deposition, ozone concentration, and visibility conditions. Measuring N and S in the park itself would also provide better estimates of deposition due to widely varying elevation which affects its levels

5.2.2 Water Quality

Water quality varies at a fine scale throughout the park. Impacts to water quality such as microorganism contamination are more likely in developed areas, where urban runoff and other anthropogenic inputs can introduce contaminants. However, negative effects atmospheric deposition such as acidic loading likely pose the greatest threat to water quality and aquatic species at BLRI, especially due to the naturally low buffering capacities in streams throughout the region. Although water quality at monitoring stations near the Parkway in a majority of cataloging units were determined to be in good condition, several entire cataloging units were not ranked due to a lack of data. A systematic sampling approach would ensure consistent measurements and help expose issues as they emerge. A rotating sample schedule could be used to best adapt to the large size of the Parkway and multi-parameter sondes would also help by automating collection.

5.2.3 Biological Integrity

The Parkway is demonstrated to contain a variety of significantly intact natural assemblages of flora and fauna. Many of the significant threats and stressors to native species and assemblages result from non-native species.

Flora

Exotic plants are an ongoing management issue along the Parkway, and serve as a prime example of how adjacent land can influence native communities. Oriental bittersweet, for instance, is widespread in the region around Asheville. Some exotics may be introduced from pasture feed in grazing lands as well.

Forest health is another major issue along the Parkway. Much like exotic plants, new infestations of insect pests can be difficult to predict, though management is usually able to anticipate the general flow of invasion fronts and affected areas. Hemlock woolly adelgid and gypsy moth are the main problems currently facing BLRI, affecting large areas and requiring repeated treatments to combat. Although eradication from the park is likely not an option, treatments may serve to slow their spread and protect particularly vulnerable areas. Forest health is also being threatened by plant poaching throughout the Parkway, though population monitoring is already underway to determine the extent of its impact.

Fauna

The BLRI appears to support a number of rare and unique species of aquatic macroinvertebrates. Most of these species reside in high-elevation seeps, springs, and headwater streams. Macroinvertebrates are important in nutrient cycling, and provide the trophic base upon which many native fishes and amphibians depend. Therefore, high elevation seeps and springs deserve dedicated protection within the park. As macroinvertebrate monitoring continues, it may be useful to expand sampling to include more larger, wadeable park streams. The available data from these habitats were relatively sparse, and more data would be beneficial in assessing park-wide aquatic habitat quality.

The Parkway supports a great variety of vertebrate animal species. Assemblages of fishes, birds, herpetofauna, and mammals all include species that are rare, require specialized Appalachian habitats, or are near the farthest extent of their known natural range. The park and immediately surrounding region appear to support a number of populations of genetically pure southern strain brook trout. Assemblages of shrews are exceptionally rich in BLRI, and the park is notable as a global hotspot of salamander diversity.

Vertebrate disease threats are recognized in the region and have the potential to impact BLRI animals, although these threats have not been reported to occur in the park. These include *Ranavirus* and chytrid fungal organisms that infect amphibians. These diseases have caused declines and extirpations of local amphibian populations in the eastern and western U.S. Periodic sampling for these diseases in the park could be a valuable management tool. White-nose syndrome is a disease affecting hibernating bats. This disease is most likely to infect and kill bats outside of park boundaries, but is therefore likely to result in declines in summertime bat populations in the park.

Non-native species, and species strains outside their native range represent threats to native vertebrates in BLRI. A notable example is the southern strain brook trout. This strain is precluded by non-native species and by northern strain brook trout from habitat it might otherwise occupy. Because the southern strain brook trout is a unique and iconic animal in the BLRI, data on the distribution of this strain within the park would be of interest.

5.2.4 Landscape Change

Due to its narrow width, the park remains vulnerable to impacts from the surrounding region, especially in places undergoing continued expansion around developed areas, such as the Asheville Basin and Roanoke. Population and housing growth in these areas, combined with road construction can result in the deterioration of habitat, affecting both aquatic and terrestrial environments. Whenever the opportunity arises, the Parkway will certainly benefit from expanding park boundaries to include surrounding areas. This will act as a buffer from adjacent development.

Appendix A. List of Initial Scoping Meeting Attendees

Blue Ridge Parkway:

Bambi Teague, Chief of Resource Management and Science
Bob Cherry, Resource Management Specialist
Chris Ulrey, Plant Ecologist

Appalachian/Highlands Inventory and Monitoring Network:

Robert Emmott, Coordinator
Patrick Flaherty, Data Manager

University of Georgia:

Nate Nibbelink, Principal Investigator
Gary Grossman, Co-Principal Investigator
Gary Sundin, Researcher
Luke Worsham, Researcher

Southeast Regional Office:

Dale McPherson, Regional NRCA Program Coordinator

Appendix B. List of rare plant species at BLRI (Source: NPS 2006).

Scientific Names	Common Names	G-Rank	S-Rank
Alnus incana ssp. rugosa	Speckled Alder	G3G5	S2
Anemone canadensis	Canada Anemone	G5	S1
Anomylia cuneifolia	A Liverwort	G4G5	S2
Arabis hirsuta var adpressipilis	Hairy Rockcress	G5T4Q	S1
Arisaema triphyllum ssp. stewardsonii	Bog Jack-in-the-pulpit	G5T4	S1
Botrychium simplex var simplex	Least Moonwort	G5T5	S1
Calamagrostis cainii	Cain’s Reed Grass	G1	S1
Calopogon tuberosus var. tuberosus	Tuberosus Grass-pink	G3	S2
Campylopus atrovirens var. cucullatifolius	Cliff Campylopus	G4?T3?	S1
Cardamine clematitis	Mountain Bittercress	G2G3	S2
Carex biltmoreana	Biltmore Sedge	G3	S3
Carex buxbaumii	Brown Bog Sedge	G5	S2
Carex misera	Wretched Sedge	G3	S3
Carex vesicaria	Inflated Sedge	G5	S1S2
Cephaloziella spinicaulis	A Liverwort	G3G4	S1
Cetraria arenaria	A Foliose Lichen	G4	S2
Cetrelia cetrarioides	A Foliose Lichen	G3	S2
Chelone cuthbertii	Cuthbert Turtlehead	G3	S2
Cirriphyllum piliferum	A Moss	G5	S1
Clematis glaucophylla	White-leaved Leatherflower	G5	SH
Clematis occidentalis	Mountain Clematis	G5	S1
Coeloglossum viride var virescens	Long-bracted Frog Orchid	G5T5	S1
Coreopsis latifolia	Broadleaf Coreopsis	G3	S3
Cornus sericea ssp. sericea	Red-osier Dogwood	G5	S1
Coscinodon cribrosus	Copper Grimmia	G3?	S1
Crataegus mollis	A Hawthorn	G5	S1
Crataegus pruinosa	A Hawthorn	G5	S2
Dalibarda repens	Robin Runaway	G5	S1
Delphinium exaltatum	Tall Larkspur	G3	S1
Dodecatheon meadia var meadia	Eastern Shooting Star	G5T5	S2
Epilobium angustifolium	Purple Wouldow-herb	G5	S1
Epilobium ciliatum	Purpleleaf Wouldow-herb	G5	S2
Epilobium leptophyllum	Linear-leaved Wouldow-herb	G5	S2
Euphorbia purpurea	Glade Spurge	G3	S2
Geum geniculatum	Bent Avens	G2	S2
Geum radiatum	Mountain Avens	G1	S1
Gymnoderma lineare	Rock Gnome Lichen	G2	S2
Helianthemum propinquum	Creeping Sunrose	G4	S1
Helonias bullata	Swamp-pink	G3	S2S3
Hexastylis shuttleworthii var. shuttleworthii	Large-flowered Heartleaf	G4T4	S2?
Homalia trichomanoides	Lime Homalia	G5	S1
Houstonia canadensis	Canada Bluets	G4	S2
Huperzia appalachiana	Appalachian Fir-clubmoss	G4G5	S2
Hydrothyria venosa	An Aquatic Lichen	G3	S2
Hypericum ellipticum	Pale St. John's-wort	G5	SH
Iliamna remota	Kankakee Globe-mallow	G1Q	S1
Isotria medeoloides	Small Whorled Pogonia	G2	S1
Juncus trifidus	Highland Rush	G5	S1
Leptodontium excelsum	Grandfather Mountain Leptodontium	G2	S1
Leptodontium flexifolium	Pale-margined Leptodontium	G5	S1
Leucothoe fontanesiana	Highland Dog-hobble	G5	S1S2
Liatris helleri	Heller's Blazing Star	G2	S2
Lilium grayi	Gray's Lily	G3	S2
Liparis loeselii	Fen Orchid	G5	S1
Lonicera canadensis	American Fly-honeysuckle	G5	S2

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