National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Bluestone National Scenic River

Natural Resource Report NPS/BLUE/NRR—2018/1810

ON THE COVER
The Bluestone River as it passes through Bluestone National Scenic River (SMUMN GSS photo by Andy Nadeau)

Natural Resource Condition Assessment

Bluestone National Scenic River

Natural Resource Report NPS/BLUE/NRR—2018/1810

Andy J. Nadeau
Kathy Allen
Hannah Hutchins
Andrew Robertson

GeoSpatial Services
Saint Mary's University of Minnesota
890 Prairie Island Road
Winona, Minnesota 55987

November 2018

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

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

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review, which was provided by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. The level and extent of peer review was based on the importance of report content or its potentially controversial or precedent-setting nature.

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

This report is available in digital format from the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Nadeau, A. J., K. Allen, H. Hutchins, and A. Robertson. 2018. Natural resource condition assessment: Bluestone National Scenic River. Natural Resource Report NPS/BLUE/NRR—2018/1810. National Park Service, Fort Collins, Colorado.

NPS 619/149441, November 2018

Contents

Page

Figures ... vii

Tables ... xiii

Appendices ... xix

Executive Summary ... xxi

Acknowledgments ... xxiii

Acronyms and Abbreviations ... xxv

1. NRCA Background Information ... 1

2. Introduction and Resource Setting ... 5

 2.1. Introduction ... 5

  2.1.1. Enabling Legislation ... 5

  2.1.2. Geographic Setting ... 5

  2.1.3. Visitation Statistics ... 7

 2.2. Natural Resources ... 8

  2.2.1. Ecological Units and Watersheds ... 8

  2.2.2. Resource Descriptions ... 9

  2.2.3. Resource Issues Overview ... 11

 2.3. Resource Stewardship ... 13

  2.3.1. Status of Supporting Science ... 13

3. Study Scoping and Design ... 17

 3.1. Preliminary Scoping ... 17

 3.2. Study Design ... 18

  3.2.1. Indicator Framework, Focal Study Resources and Indicators ... 18

  3.2.2. General Approach and Methods ... 22

4. Natural Resource Conditions ... 29

 4.1. Upland Forest Communities ... 30

  4.1.1. Description ... 30

  4.1.2. Measures ... 31

  4.1.3. Reference Condition/Values ... 32

Contents (continued)

Page

4.1.4. Data and Methods 32

4.1.5. Current Condition and Trend 34

4.1.6. Sources of Expertise 49

4.2. Riparian Vegetation Communities 50

4.2.1. Description 50

4.2.2. Measures 51

4.2.3. Reference Condition/Values 51

4.2.4. Data and Methods 51

4.2.5. Current Condition and Trend 52

4.2.6. Sources of Expertise 61

4.3. Birds 62

4.3.1. Description 62

4.3.2. Measures 64

4.3.3. Reference Condition/Values 64

4.3.4. Data and Methods 65

4.3.5. Current Condition and Trend 72

4.3.6. Sources of Expertise 89

4.4 Mammals 90

4.4.1. Description 90

4.4.2. Reference Condition/Values 90

4.4.3. Data and Methods 91

4.4.4. Current Condition and Trend 91

4.4.5. Sources of Expertise 98

4.5. Herpetofauna 99

4.5.1. Description 99

4.5.2. Measures 100

4.5.3. Reference Condition/Values 100

4.5.4. Data and Methods 100

Contents (continued)

Page

4.5.5. Current Condition and Trend.......... 100

4.5.6. Sources of Expertise.......... 106

4.6. Aquatic Wildlife Community.......... 107

4.6.1. Description.......... 107

4.6.2. Measures.......... 107

4.6.3. Reference Condition/Values.......... 108

4.6.4. Data and Methods.......... 108

4.6.5. Current Condition and Trend.......... 113

4.6.6. Sources of Expertise.......... 126

4.7. Water Quality.......... 127

4.7.1. Description.......... 127

4.7.2. Measures.......... 127

4.7.3. Reference Condition/Values.......... 129

4.7.4. Data and Methods.......... 129

4.7.5. Current Condition and Trend.......... 133

4.7.6. Sources of Expertise.......... 156

4.8. Air Quality.......... 157

4.8.1. Description.......... 157

4.8.2. Measures.......... 157

4.8.3. Reference Condition/Values.......... 159

4.8.4. Data and Methods.......... 161

4.8.5. Current Condition and Trend.......... 164

4.8.6. Sources of Expertise.......... 177

4.9. Dark Night Skies.......... 178

4.9.1. Description.......... 178

4.9.2. Measures.......... 180

4.9.3. Reference Condition/Values.......... 180

4.9.4. Data and Methods.......... 181

Contents (continued)

Page

4.9.5. Current Condition and Trend....181

4.9.6. Sources of Expertise....189

4.10. Surface Water Hydrology....190

4.10.1. Description....190

4.10.2. Measures....191

4.10.3. Reference Condition/Values....191

4.10.4. Data and Methods....191

4.10.5. Current Condition and Trend....193

4.10.6. Sources of Expertise....200

5. Discussion....201

5.1. Component Data Gaps....201

5.2. Component Condition Designations....203

5.3. Park-wide Condition Observations....205

5.3.1. Vegetation Communities....205

5.3.2. Wildlife....206

5.3.3. Environmental Quality....208

5.3.4. Physical Characteristics....209

5.3.5. Park-wide Threats and Stressors....209

5.3.6. Overall Conclusions....214

Literature Cited....215

Figures

Page

Figure 1. The location of Bluestone National Scenic River within West Virginia's Summers and Mercer Counties. 6

Figure 2. Kayaking on the Bluestone River. 8

Figure 3. Environmental Protection Agency Level IV ecoregions within Bluestone National Scenic River boundaries (EPA 2010). 9

Figure 4. Watersheds of Bluestone National Scenic River. 9

Figure 5. The great blue heron (*Ardea herodias*, left) and osprey (*Pandion haliaetus*, right) are two bird species of conservation concern that occur at Bluestone National Scenic River 11

Figure 6. The extent of upland forest vegetation community types within Bluestone National Scenic River (Vanderhorst et al. 2008). 35

Figure 7. Average (± standard error) proportion of the total cover held by invasive exotic plant species as measured in monitoring quadrats in Eastern Rivers and Mountains Network parks (based on 2013-2016 data) (ERMN 2017). 39

Figure 8. Mortality and recruitment rates (percent/year) for trees in Eastern Rivers and Mountains Network parks, 2007-2014. 40

Figure 9. Mortality and recruitment rates (percent/year) through 2014 for common tree species in xeric habitats at Bluestone National Scenic River (Perles et al. 2016) 41

Figure 10. Mortality and recruitment rates (percent/year) through 2014 for common tree species in mesic habitats at Bluestone National Scenic River (Perles et al. 2016). 41

Figure 11. Mean annual diameter increments (± standard error) by Eastern Rivers and Mountains Network park, based on growth between the 2007-2010 and 2011-2014 sampling periods (ERMN 2017). 43

Figure 12. The extent of riparian vegetation community types within the northern portion of Bluestone National Scenic River (Vanderhorst et al. 2008). 53

Figure 13. The extent of riparian vegetation community types within the southern portion of Bluestone National Scenic River (Vanderhorst et al. 2008). 54

Figure 14. The aerial tramway at Pipestem Resort State Park (WV DNR photo). 59

Figure 15. Eastern Rivers and Mountains Network streamside bird monitoring sample sites in Bluestone National Scenic River (Marshall et al. 2013). 68

Figure 16. Christmas bird count survey area for the Pipestem Christmas Bird Count (CBC). 69

Figure 17. Annual species richness at Bluestone National Scenic River during yearly point count survey (PCS) along the Bluestone River (NPS unpublished data). 73

Figures (continued)

Page

Figure 18. Number of bird species and observers during the Pipestem Christmas Bird Count between 1972 and 2015. 76

Figure 19. Number of individuals observed during the 1998 point count survey (PCS) efforts along the Little Bluestone River transect (Pauley et al. 2003). 78

Figure 20. Number of individuals observed during the 1998 point count survey (PCS) efforts along the Indian Creek transect (Pauley et al. 2003). 79

Figure 21. Bird community index of biotic integrity (O'Connell et al. 2000) for several Eastern Rivers and Mountains Network parks. 84

Figure 22. West Virginia black bear harvest, 1971-2015 (reproduced from WVDNR 2016a). 93

Figure 23. White-tailed deer harvest in West Virginia from 1945-2015 (reproduced from WVDNR 2016a). 94

Figure 24. Counties and districts across the continental U.S. and Canada where white-nose syndrome has been confirmed, as of April 2018 (Reproduced from USFWS 2018b).. 96

Figure 25. Rough greensnake, a West Virginia species of conservation concern. 101

Figure 26. USGS researchers sampling benthic macroinvertebrate with a slack sampler. 109

Figure 27. Streams/locations within Bluestone National Scenic River where aquatic wildlife community sampling has been conducted over time. 111

Figure 28. Modified Hilsenhoff Biotic Index (HBI) scores for fixed sampling locations throughout the Kanawha River Basin (Chambers and Messinger 2001). 120

Figure 29. Modified Hilsenhoff Biotic Index (HBI) scores for synoptic sampling locations throughout the Kanawha River Basin (Chambers and Messinger 2001). 121

Figure 30. Multimetric Index of Biotic Integrity (MIBI) scores for Bluestone National Scenic River sampling reaches, 2008-2013 and averages for the period (Tzilkowski et al. 2015). 123

Figure 31. Locations of water quality monitoring stations from the park’s baseline report (NPS 1995) (left) and stations used in more recent park monitoring (NPS 2017c) (right). 131

Figure 32. Stream reaches within Bluestone National Scenic River monitored by Eastern Rivers and Mountains Network (reproduced from Tzilkowski et al. 2015). 132

Figure 33. Water temperature ranges documented during Eastern Rivers and Mountains Network water quality sampling at Bluestone National Scenic River, ... 134

Figure 34. Continuous (hourly) water temperature observations at the upstream Bluestone River location, 2013-2014 (NPS 2017a). 135

Figures (continued)

Page

Figure 35. Continuous (hourly) water temperature observations at the downstream Bluestone River location, 2013-2014 (NPS 2017a). 135

Figure 36. pH ranges documented during Eastern Rivers and Mountains Network water quality sampling at Bluestone National Scenic River, 2008-2013 (reproduced from Tzilkowski et al. 2015). 138

Figure 37. DO ranges documented during ERMN water quality sampling at Bluestone National Scenic River, 2008-2013 (reproduced from Tzilkowski et al. 2015). 141

Figure 38. SpC ranges documented during Eastern Rivers and Mountains Network water quality sampling at Bluestone National Scenic River, 2008-2013 (reproduced from Tzilkowski et al. 2015). 143

Figure 39. Continuous (hourly) SpC observations at the upstream Bluestone River location, 2013-2014 (NPS 2017a). 144

Figure 40. Continuous (hourly) SpC observations at the downstream Bluestone River location, 2013-2014 (NPS 2017a). 144

Figure 41. Land use in and around Bluestone National Scenic River, 2011 (USGS 2011b). 151

Figure 42. Active gas production and wastewater/brine injection wells in the vicinity of Bluestone National Scenic River (WVDEP 2016b). 153

Figure 43. Annual mean pH of wet atmospheric deposition at National Trends Network Site WV04, Babcock State Park (NADP 2016b). 154

Figure 44. Locations of air quality monitoring stations in relation to Bluestone National Scenic River. 163

Figure 45. Estimated 5-year averages of nitrogen wet deposition (kg/ha/yr) at Bluestone National Scenic River (NPS 2015a). 165

Figure 46. Annual weighted mean concentration of nitrate in wet deposition from Babcock State Park (National Trend Network Site WV04) (NADP 2016b). 166

Figure 47. Annual weighted mean concentration of ammonium in wet deposition from Babcock State Park (National Trend Network Site WV04) (NADP 2016b). 166

Figure 48. Estimated 5-year averages of sulfur wet deposition (kg/ha/yr) at Bluestone National Scenic River (NPS 2015a). 167

Figure 49. Annual weighted mean concentration of sulfate in wet deposition from Babcock State Park (National Trend Network Site WV04) (National Trend Network Site WV04) (NADP 2016b).. 168

Figure 50. Total annual mercury wet deposition in 2015 (NADP 2017). 169

Figure 51. Total mercury concentrations in 2015 (NADP 2017). 170

Figures (continued)

Page

Figure 52. Estimated 5-year averages of the 4th-highest daily maximum of 8-hour average ozone concentrations for Bluestone National Scenic River (NPS 2015a)........................... 171

Figure 53. Annual 4th-highest 8-hour maximum ozone concentrations (ppb) at the Sam Black Church, West Virginia monitoring site (Site ID: 54-025-0003), 1999-2015 (EPA 2016a). 171

Figure 54. Estimated 5-year averages of the W126 ozone metric for Bluestone National Scenic River (NPS 2015a). 172

Figure 55. Estimated 5-year averages of visibility (dv above natural conditions) on mid-range days at Bluestone National Scenic River (NPS 2015a). 173

Figure 56. Annual 24-hour particulate matter ($PM_{2.5}$) concentrations (98th percentile) for the Bluestone National Scenic River region, 1999-2015 (EPA 2016a). 173

Figure 57. Surface coal mines (active as of 2016) in the Bluestone National Scenic River region (WVDEP 2017). 175

Figure 58. Location of Bluestone National Scenic River and nearby communities and roads that may contribute anthropogenic light to the night sky. 179

Figure 59. Grayscale representation of sky luminance from a location in Joshua Tree National Park (Figure provided by Dan Duriscoe, NPS NSNSD). 183

Figure 60. False color representation of Figure 59 after a logarithmic stretch of pixel values (Figure provided by Dan Duriscoe, NPS NSNSD). 183

Figure 61. Contour map of anthropogenic sky glow at a location in Joshua Tree National Park, analogous to Figure 60 with natural sources of light subtracted (Figure provided by Dan Duriscoe, National Park Service Night Sky Division). 184

Figure 62. Modeled all-sky average sky brightness (ALR) in and around Bluestone National Scenic River. 185

Figure 63. Modeled all-sky average sky brightness (ALR) for Bluestone National Scenic River. 186

Figure 64. The location of the USGS stream gage near Pipestem and the two weather stations closest to Bluestone National Scenic River. 192

Figure 65. Annual peak discharge (cms) for the Bluestone River near Pipestem (USGS 03179000) (USGS 2016a). 193

Figure 66. Annual mean discharge (cms) for the Bluestone River near Pipestem (USGS 03179000) (USGS 2016a). 194

Figure 67. Total annual precipitation at the Princeton, West Virginia weather station, 2007-2016, compared to the 30-year normal (1981-2010) (NCEI 2015a, 2017b). 195

Figures (continued)

Page

Figure 68. A comparison of monthly precipitation normals (1981-2010) for the Princeton, West Virginia weather station to monthly averages for the period 2007-2016 (NCEI 2015a, 2017b). 195

Figure 69. Total annual precipitation at the Bluestone Lake, West Virginia weather station, 2007-2016, compared to the 30-year normal (1981-2010) (NCEI 2017a). 196

Figure 70. A comparison of monthly precipitation normals (1981-2010) for the Bluestone Lake, West Virginia weather station to monthly averages for the period 2007-2016 (NCEI 2015b, 2017a). 196

Figure 71. The lowest mean daily discharge (cms) by water year (October-September) for the Bluestone River near Pipestem (USGS 03179000) (USGS 2016a). 199

Figure K-1. Sampling locations where eight different snake species were observed within Bluestone National Scenic River (Pauley et al. 2003). 307

Figure K-2. Sampling locations where lizard (upper left), turtle (upper right), toad (lower left), and treefrog (lower right) species were observed within Bluestone National Scenic River (Pauley et al. 2003). 308

Figure K-3. Sampling locations where several frog and two salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003). 309

Figure K-4. Sampling locations where several salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003). 310

Figure K-5. Sampling locations where several salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003). 311

Figure K-6. Sampling locations where two salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003). 312

Tables

Page

Table 1. 30-year climate normals (1981-2010) for the Bluestone Lake, West Virginia weather station just northeast of Bluestone National Scenic River (NCDC 2015b). 7

Table 2. Eastern Rivers and Mountains Network Vital Signs selected for monitoring in Bluestone National Scenic River (Marshall and Piekielek 2007a). 14

Table 3. Bluestone National Scenic River natural resource condition assessment framework. 20

Table 4. Scale for a measure's Significance Level in determining a components overall condition. 23

Table 5. Scale for Condition Level of individual measures. 23

Table 6. Description of symbology used for individual component assessments. 24

Table 7. Examples of how the symbols should be interpreted for individual component assessments. 25

Table 8. Upland forest vegetation associations documented within Bluestone National Scenic River and the most prominent tree and shrub species in each (Vanderhorst et al. 2008). 31

Table 9. Upland forest extent at Bluestone National Scenic River by vegetation community type (reproduced from Vanderhorst et al. 2008). 34

Table 10. Plant species richness by upland forest community type at Bluestone National Scenic River, as documented by Vanderhorst et al. (2008). 36

Table 11. Documented rare plant occurrences at Bluestone National Scenic River upland forest communities.. 37

Table 12. Mean exotic and invasive plant species cover by upland forest community type within Bluestone National Scenic River (Vanderhorst et al. 2008). 38

Table 13. Potential change in habitat suitability by 2100 for select Bluestone National Scenic River upland tree species based on two future climate scenarios. Reproduced from Fisichelli (2015). 46

Table 14. Current condition of Bluestone National Scenic River's Upland Forest Communities. 48

Table 15. Riparian vegetation associations documented within Bluestone National Scenic River and the most prominent plant species in each (Vanderhorst et al. 2008). 51

Table 16. Riparian vegetation extent at Bluestone National Scenic River by vegetation community type (reproduced from Vanderhorst et al. 2008). 52

Table 17. Plant species richness by riparian vegetation community type at Bluestone National Scenic River, as documented by Vanderhorst et al. (2008). 55

Tables (continued)

Page

Table 18. Documented rare plant occurrences at Bluestone National Scenic River riparian areas. ... 56

Table 19. Mean exotic and invasive plant species cover by riparian vegetation community type within at Bluestone National Scenic River (Vanderhorst et al. 2008). ... 57

Table 20. Potential change in habitat suitability by 2100 for select Bluestone National Scenic River riparian tree species based on two future climate scenarios. Reproduced from Fisichelli (2015). ... 60

Table 21. Current condition of Bluestone National Scenic River's Riparian Vegetation Communities. ... 61

Table 22. Avian species identified as Species of Conservation Concern by the West Virginia Wildlife Diversity Program (WVDNR 2017a). ... 64

Table 23. Migratory game bird hunting seasons in West Virginia for the 2016-2017 hunting season (WV DNR 2016b). ... 71

Table 24. Raptor species and total species abundance observed during raptor-specific play back surveys Bluestone National Scenic River in 1999 (Pauley et al. 2003). ... 73

Table 25. Waterfowl and shorebird species observed along the Bluestone River between Meador Camp and the Little Bluestone River in 1999 (Pauley et al. 2003). ... 74

Table 26. The most abundant (i.e., most commonly observed) bird species during National Park Service monitoring from 1998-2016. ... 77

Table 27. The five most commonly observed species at the Little Bluestone River and Indian Creek sites during Pauley et al. (2003). ... 80

Table 28. The five most commonly observed bird species during Marshall et al. (2013) monitoring at Mountain Creek, Little Bluestone River, and the Jarrell Branch from 2009-2012 ... 80

Table 29. Average annual abundance for the 10 most frequently observed species during the Pipestem Christmas Bird Count from 1972-2015.. ... 81

Table 30. Biotic integrity elements, guild categories, response guilds, and guild interpretations used in the O'Connell et al. (1998a, b, 2000) Bird Community Index of ecological integrity. ... 82

Table 31. Annual turkey harvest in Mercer and Summers Counties from 2011-2015 (WV DNR 2016a). "C" represents a closed hunting season. ... 85

Table 32. Current condition of Bluestone National Scenic River's Bird Community. ... 89

Table 33. Mammal species of concern occurring within Bluestone National Scenic River, along with their West Virginia state ranks (WVDNR 2015). ... 90

Tables (continued)

Page

Table 34. Bat species documented by surveys at Bluestone National Scenic River, 1997-2004...92

Table 35. Black bear harvest within the counties that include Bluestone National Scenic River, 2011-2017 (WVDNR 2016a, 2017b, 2018)...93

Table 36. White-tailed deer harvest within the counties that include Bluestone National Scenic River, 2007-2016 (WVDNR 2011, 2016a, 2017c). 94

Table 37. Current condition of Bluestone National Scenic River's Mammal Community.................98

Table 38. The abundance of herpetofauna categories documented at Bluestone National Scenic River by Pauley et al. (2003), along with the most abundant species in each category..101

Table 39. Number of herpetofauna species and total individuals observed by habitat type within Bluestone National Scenic River's (Pauley et al. 2003)...102

Table 40. Current condition of Bluestone National Scenic River's Herpetofauna Community. 106

Table 41. Sampling locations synthesized or surveyed by Welsh et al. (2006) within Bluestone National Scenic River boundaries...110

Table 42. Metrics included in the Multimetric Index of Biotic Integrity utilized by Eastern Rivers and Mountains Network benthic macroinvertebrate sampling (Tzilkowski et al. 2015, based on Klemm et al. 2003)..112

Table 43. Fish species present, probably present, or historically present within Bluestone National Scenic River, according to NPSpecies (NPS 2016b). 113

Table 44. Fish species relative abundance during 2004 sampling at Bluestone National Scenic River (Welsh et al. 2006). 116

Table 45. Fish species relative abundance during 2014 sampling at Bluestone National Scenic River (Faulk and Weber 2017)..117

Table 46. BMI taxa richness at sampling stream reaches within Bluestone National Scenic River (2008 data from Tzilkowski et al. 2010; 2009-2014 from NPS unpublished data, received from the Eastern Rivers and Mountains Network). 119

Table 47. Multimetric Index of Biotic Integrity (MIBI) scores and constituent metric results for samples from Bluestone National Scenic River, 2008-2013 (Tzilkowski et al. 2015). 122

Table 48. Current condition of Bluestone National Scenic River's Aquatic Wildlife Community 126

Table 49. West Virginia state water quality standards for the fish and aquatic life designated use (WVDEP 2014). 129

Tables (continued)

Page

Table 50. Historic (pre-1996) water temperature observations (°C) for Bluestone National Scenic River sampling locations (NPS 1995). ... 133

Table 51. Water temperature observations (°C) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012). ... 133

Table 52. Water temperature results (°C) from park monitoring efforts, 1996-2016 (NPS 2017c). ... 136

Table 53. Historic (pre-1996) pH observations for Bluestone National Scenic River sampling locations (NPS 1995). ... 137

Table 54. pH observations from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012). ... 137

Table 55. pH results from park monitoring efforts, 1996-2016 (NPS 2017c). ... 138

Table 56. Historic (pre-1996) DO (mg/L) observations for Bluestone National Scenic River sampling locations (NPS 1995). ... 139

Table 57. DO observations (mg/L) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012). ... 140

Table 58. DO concentrations (mg/l) from park monitoring efforts, 1996-2016 (NPS 2017c). ... 141

Table 59. Historic (pre-1996) SpC (µS/cm) observations for Bluestone National Scenic River sampling locations (NPS 1995). ... 142

Table 60. SpC observations (µS/cm) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012). ... 143

Table 61. Field conductivity results (µS/cm) from park monitoring efforts, 1996-2016 (NPS 2017c). ... 145

Table 62. Historic (pre-1996) turbidity observations for Bluestone National Scenic River sampling locations (NPS 1995). ... 146

Table 63. Turbidity observations (FTU) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012). ... 147

Table 64. Turbidity results (NTU) from park monitoring efforts, 1996-2016 (NPS 2017c). ... 147

Table 65. Historic (pre-1996) fecal coliform observations (FC/100ml) for Bluestone National Scenic River sampling locations (NPS 1995). FC = fecal coliforms. ... 148

Table 66. Fecal coliform bacteria results (FC/100 ml) from park monitoring efforts, 1996-2016 (NPS 2017c). ... 149

Table 67. Current condution of Bluestone National Scenic River's Water Quality. ... 156

Tables (continued)

Page

Table 68. National Park Service Air Resources Division air quality index values for wet deposition of nitrogen or sulfur, ozone, particulate matter, and visibility (NPS 2015b). 159

Table 69. National Park Service Air Resources Division air quality assessment matrix for mercury status (NPS 2015b). 159

Table 70. Current condition of Bluestone National Scenic River’s Air Quality. 177

Table 71. National Park Service Natural Sounds and Night Sky Division recommendations for condition levels for modeled Anthropogenic Light Ratio (ALR) values (Moore et al. 2013). 188

Table 72. Current condition of Bluestone National Scenic River s Dark Night Skies.....................189

Table 73. Current condition of Bluestone National Scenic River’s Surface Water Hydrology. 200

Table 74. Identified data gaps or needs for the featured components in Bluestone National Scenic River. 201

Table 75. Summary of current condition and condition trend for featured Natural Resource Condition Assessment components..203

Table 76. Description of symbology used for individual component assessments. 204

Table 77. Example indicator symbols and descriptions of how to interpret them. 205

Table A-1. Plant species observations in upland forests at Bluestone National Scenic River..235

Table B-1. Plant species observations in riparian communities at Bluestone National Scenic River. 263

Table C-1. Bird species observed in Bluestone National Scenic River during the various avian inventory and monitoring efforts. X indicates a confirmed species, P indicates a probable species, and U indicates an unconfirmed species. 283

Table D-1. Species abundance estimates during general surveys in Bluestone National Scenic River (Pauley et al. 2003)...289

Table E-1. Species abundance observed in Bluestone National Scenic River during point count survey efforts along the Little Bluestone River, Mountain Creek, Jarrell Branch from 2009-2012 (Marshall et al. 2013)..293

Table F-1. Mammal species occurring at Bluestone National Scenic River according to NPSpecies (2016b) and species observed by Pauley et al. (2003), 1997-1999. 295

Table G-1. Herpetofauna species of Bluestone National Scenic River (NPS Pauley et al. 2003, 2016b). 297

Tables (continued)

Page

Table H-1. Abundance of herpetofauna species at Bluestone National Scenic River by terrestrial habitat type, as observed from 1996-2000 by Pauley et al. (2003). 299

Table I-1. Abundance of herpetofauna species at Bluestone National Scenic River by aquatic habitat type, as observed from 1996-2000 by Pauley et al. (2003).. 301

Table J-1. Number of habitat types where each herpetofauna species was observed within Bluestone National Scenic River by Pauley et al. (2003)... 305

Appendices

Page

Appendix A. Plant species observations in upland forests at Bluestone National Scenic River....235

Appendix B. Plant species observations in Riparian Communities at Bluestone National Scenic River....263

Appendix C. Bird species observed in Bluestone National Scenic River during the various avian inventory and monitoring efforts....283

Appendix D. Bird species abundance estimates during general surveys in Bluestone National Scenic River....289

Appendix E. Species abundance observed in Bluestone National Scenic River during PCS efforts along the Little Bluestone River, Mountain Creek, Jarrell Branch from 2009-2012....293

Appendix F. Mammal species occurring at Bluestone National Scenic River....295

Appendix G. Herpetofauna species occurring at Bluestone National Scenic River....297

Appendix H. Abundance of herpetofauna species occurring at Bluestone National Scenic River by terrestrial habitat type....299

Appendix I. Abundance of herpetofauna species occurring at Bluestone National Scenic River by aquatic habitat type....301

Appendix J. Number of habitat types where each herpetofauna species was observed within Bluestone National Scenic River....305

Appendix K. Observation locations for herpetofauna species at Bluestone National Scenic River....307

Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA will help Bluestone National Scenic River (BLUE) managers to develop near-term management priorities, engage in watershed or landscape scale partnership and education efforts, conduct park planning, and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at BLUE. The final project framework contains 10 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in selected resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of each component. Weighted Condition Scores, ranging from zero to one, were divided into three categories of condition: good condition, moderate concern, and significant concern. These scores help to determine the current overall condition of each resource. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, including unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was reviewed by BLUE resource managers, NPS Eastern Rivers and Mountains Network (ERMN) staff, NPS Northeast Regional Office Staff, or outside experts.

Existing literature, short- and long-term datasets, and input from NPS and other outside agency scientists support condition designations for components in this assessment. However, in some cases, data were unavailable or insufficient for several of the measures of the featured components. In other instances, data establishing reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. In these cases, it was not possible to assign condition for the components. Current condition was not able to be determined for two of the 10 components due to these data gaps.

For featured components with available data and fewer data gaps, assigned conditions varied. Three components were considered to be in good condition: birds, mammals, and surface water hydrology. Of those three components, however, only the surface water hydrology component had enough data

to assess a current stable trend with high confidence. Three components (upland forest communities, water quality, dark night skies) were of moderate concern; upland forest communities and dark night skies lacked sufficient data to assign a current trend, while water quality had enough recent data to confidently assign a stable trend. Only the riparian vegetation communities and air quality components were determined to be of significant concern. The current trend of air quality in BLUE was determined to be improving (a designation assigned with moderate confidence), but trend was not able to be determined for riparian vegetation communities due to a lack of contemporary data. Condition could not be determined for two components: herpetofauna and aquatic wildlife communities.

Several park-wide threats and stressors influence the condition of priority resources in BLUE. Those of primary concern include climate change, exotic species, habitat fragmentation, and water quality degradation. Understanding these threats, and how they relate to the condition of park resources, can help the NPS prioritize management objectives and better focus their efforts to maintain the health and integrity of the park ecosystem.

Acknowledgments

We acknowledge Bluestone National Scenic River and Eastern Rivers and Mountains Network staff for the technical expertise provided during scoping, through multiple stages of review, and via phone and email; specifically, John Perez, Claire Rozdilski, Lenza Paul, Layne Stricker, Lisa Wilson, Kathy Oney, Caleb Tzilkowski, Andy Weber, Stephanie Perles, and Matt Marshall. Their logistical insight and critical review of interim documents was essential to this project's completion. Additional insight and reviews were provided by Sheila Colwell, Holly Salazar, Pete Sharpe, and Marian Norris. Christine Arnott, NPS Northeast Region Biologist and NRCA Coordinator, and Jeff Albright, National NRCA Coordinator, provided program guidance. Thank you to all others who assisted the development of this document.

Acronyms and Abbreviations

ALR – Anthropogenic Light Ratio

AQI – Air Quality Index

ARD – NPS Air Resources Division

BCI – Bird Community Index

Bd – Batrachochytrium dendrobatidis

BLUE – Bluestone National Scenic River

BMI – Benthic Macroinvertebrate

Bsal – Batrachochytrium salamandrivorans

CAA – Clean Air Act

CBC – Christmas Bird Count

CCD – Charged Coupled Device

CL – Condition Level

DAMS – Water Impoundments Database

DBH – Diameter at Breast Height

DEWA – Delaware Water Gap National Recreation Area

DO – Dissolved Oxygen

DRINKS – Drinking Water Supplies Database

dv – Deciview

EAB – Emerald Ash Borer

EO – Element Occurrence

EPA – Environmental Protection Agency

EPT – Ephemeroptera, Plecoptera, and Trichoptera

ERMN – Eastern Rivers and Mountains Network

FTU – Formazin Turbidity Unit

GAGES – Water Gages Database

GARI – Gauley River National Recreation Area

GI – Globally Imperiled

GIS – Geographic Information System

GPRA – Government Performance and Results Act

HBI – Hilsenhoff Biotic Index

HUC – Hydrologic Unit Code

HWA – Hemlock Wooly Adelgid

I&M – Inventory and Monitoring

IFD – Industrial Facilities Discharge Database

IMPROVE – Interagency Monitoring of Protected Visual Environments Program

IPCC – Intergovernmental Panel on Climate Change

IRMA – Integrated Resource Management Application

IV – Importance Values

MADI – Mean Annual Diameter Increment

MDN – Mercury Deposition Monitoring Network

MIBI – Multimetric Index of Biotic Integrity

MTI – Macroinvertebrate Tolerance Index

MTR – Mountain Top Removal

NAAQS – National Ambient Air Quality Standards

NADP-NTN – National Atmospheric Deposition Program-National Trends Network

NAWQA – National Water Quality Assesment

NCEI – National Centers for Environmental Information

NCHA – National Coal Heritage Area

NERI – New River Gorge National River

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

NSNSD – NPS Natural Sounds and Night Sky Division

NTU – Nephelometric Turbidity Unit

NVC – National Vegetation Classification

NWIS – National Water Information System

ORV – Off-road Vehicle

PAH – Polycyclic Aromatic Hydrocarbon

PCB – Polychlorinated biphenyl

PCS – Point Count Survey

PM – Particulate Matter

ppb – Parts per Billion

ppm-hrs – Parts per Million Hours

RF3 – River Reach File

RSS – Resource Stewardship Strategy

RTH – Richest Targeted Habitat

SE – Standard Error

SD – Standard Deviation

SGCN – Species of Greatest Conservation Need

SHEN – Shenandoah National Park

SL – Significance Level

SMC – Singing Male Census

SMUMN GSS – Saint Mary's University of Minnesota

SpC – Specific Conductance

SQM – Unihedron Sky Quality Meter

STORET – Storage and Retrieval Water Quality Database Management System

TDS – Total Dissolved Solid

USACE – United States Army Corps of Engineers

USFWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

VOC – Volatile Organic Compounds

WCS – Weighted Condition Score

WNS – White Nose Syndrome

WVDEP – West Virginia Department of Environmental Protection

WVDNR – West Virginia Division of Natural Resources

WVNHP – West Virginia National Heritage Program

WVWDP – West Virginia Wildlife Diversity Program

ZLM – Zenith Limiting Magnitude

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 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*

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.

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

---

[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-up 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.

understanding 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 decision making, 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 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.

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)***

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information visit the NRCA Program website.

[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.

[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.

2. Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

Bluestone National Scenic River was established in October 1988 as part of the West Virginia National Interest River Conservation Act in order to

> *… provide for the protection and enhancement of the natural, scenic cultural, and recreational values on certain free-flowing segments of the New, Gauley, Meadow, and Bluestone Rivers in the State of West Virginia for the benefit and enjoyment of present and future generations* (Public Law 100-534).

The legislation also acknowledged that the remarkable and outstanding values contained within the lower section of the Bluestone were due to its "…predominantly undeveloped condition" (P.L. 100-534). BLUE is protected under the National Wild and Scenic Rivers Act, which preserves rivers in free-flowing conditions (Public Law 90-542).

2.1.2. Geographic Setting

The BLUE boundary includes 1,744 ha (4,309 ac) in the Allegheny Mountains of south-central West Virginia, the majority of which is owned by the NPS (NPS 2015c). The park contains a 17-km (10.5-mi) stretch of the Bluestone River and a small portion of its tributary, the Little Bluestone River (Marshall and Piekielek 2007b). BLUE lies within a scenic valley noted for its natural diversity, and includes portions of Summers and Mercer Counties (Figure 1). Much of the southern portion of BLUE overlaps with or is bordered by Pipestem Resort State Park, and the northeast boundary adjoins Bluestone Wildlife Management Area.

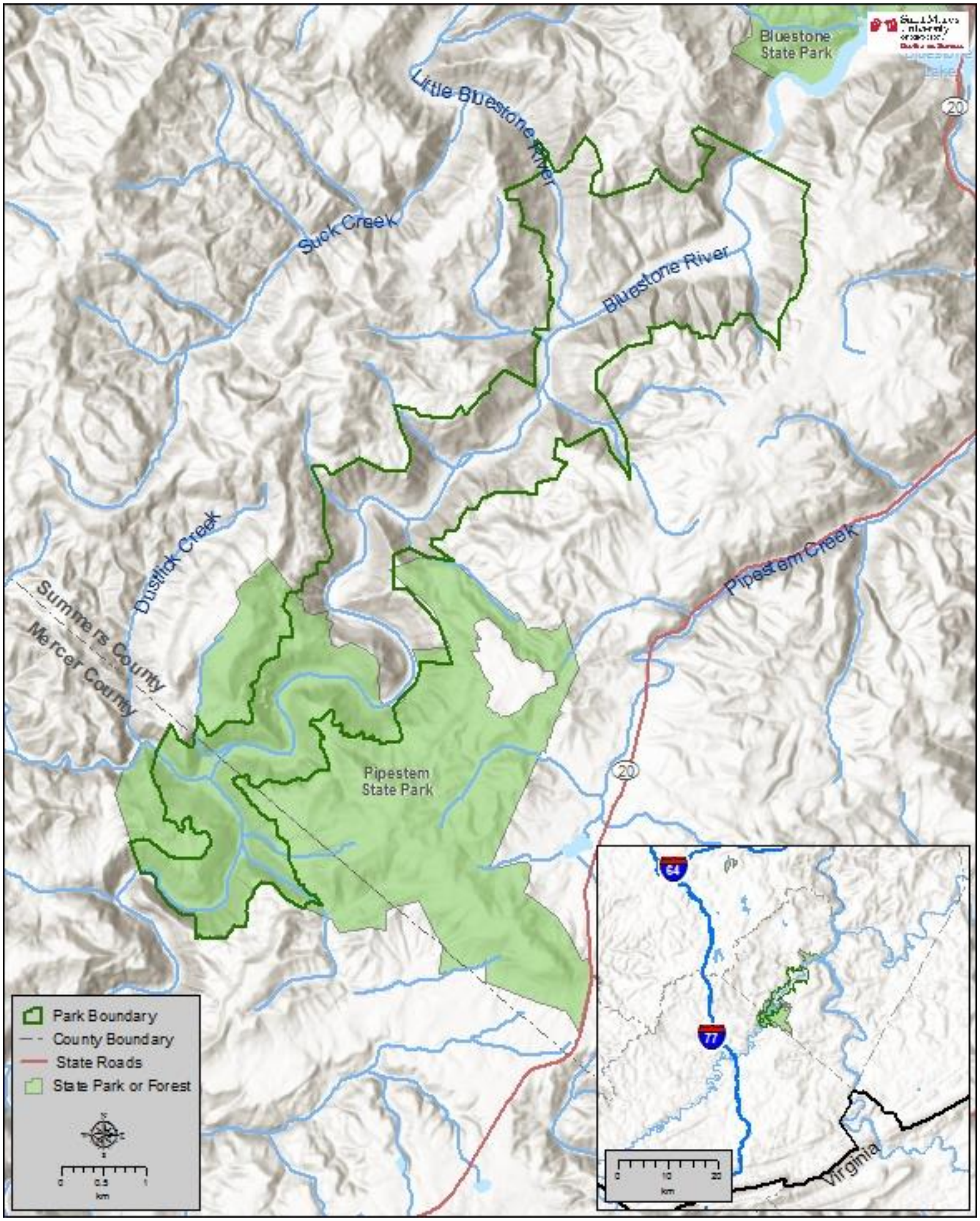


Figure 1. The location of Bluestone National Scenic River within West Virginia's Summers and Mercer Counties.

The region around BLUE has a humid, continental climate that can be influenced by local physiographic features (e.g., mountains, valleys) (Knight et al. 2015). The summers are warm, with average maximum temperatures in the 28-29°C range (82-84°F) (Table 1). Winter low temperatures average around -4°C (25°F), but can drop much lower during cold snaps (Davey et al. 2006). BLUE lies in a “rain shadow” on the eastern edge of the mountains and receives slightly less precipitation than areas just to the north and west (Davey et al. 2006). Precipitation is distributed throughout the year, with slightly higher amounts falling in the late spring and mid-summer (Table 1).

Table 1. 30-year climate normals (1981-2010) for the Bluestone Lake, West Virginia weather station just northeast of Bluestone National Scenic River (NCDC 2015b).

	Average Temperature (°C)		Average Precipitation (cm)
Month	**Max**	**Min**	**Total**
January	5.1	-4.4	7.3
February	7.7	-3.0	6.7
March	12.9	0.3	8.6
April	19.1	5.1	8.6
May	23.5	10.1	10.6
June	27.3	15.6	8.6
July	29.1	17.7	11.2
August	28.6	17.3	8.4
September	25.2	13.6	7.4
October	19.5	6.9	6.6
November	13.1	1.6	6.6
December	6.3	-2.6	7.4
Annual	18.1	6.5	98.1

2.1.3. Visitation Statistics

On average, BLUE received nearly 43,000 visitors per year between 2002 and 2016 (NPS 2017b). The highest visitation occurred in 2002 (just over 55,000 visitors), and the lowest level during this period was in 2016 (approximately 34,000 visitors). Popular recreational activities in the park include hiking, paddling, fishing, hunting, and wildlife watching (NPS 2016d). Canoeing and kayaking are typically limited to the spring, when water levels are high enough for the river to be passable (Figure 2). Camping is not allowed within BLUE boundaries, but state park campgrounds are available at the northern and southern ends of the park (NPS 2016d).

Figure 2. Kayaking on the Bluestone River (NPS photo).

2.2. Natural Resources

2.2.1. Ecological Units and Watersheds

The entirety of BLUE falls within the Central Appalachians Level III Ecoregion, which is characterized as:

> *…primarily a high, dissected, rugged plateau composed of sandstone, shale, conglomerate, and coal. The rugged terrain, cool climate, and infertile soils limit agriculture, resulting in a mostly forested land cover. The high hills and low mountains are covered by a mixed mesophytic forest with areas of Appalachian oak and northern hardwood forest. Bituminous coal mines are common, and have caused siltation and acidification of streams* (EPA 2013).

The Environmental Protection Agency (EPA) divides Level III Ecoregions into smaller Level IV Ecoregions. The boundary of BLUE spans three Level IV Ecoregions: Forested Hills and Mountains, Greenbriar Karst, and Dissected Appalachian Plateau (Figure 3).

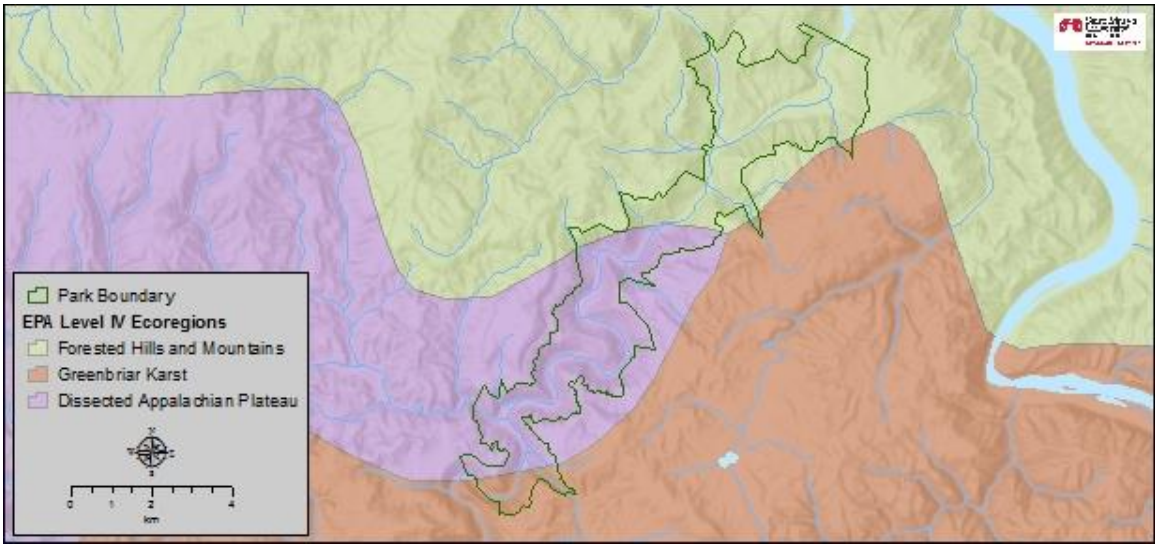


Figure 3. Environmental Protection Agency Level IV ecoregions within Bluestone National Scenic River boundaries (EPA 2010).

BLUE is located within the Middle New Hydrologic Unit Code (HUC) 8 subbasin, and both the Little Bluestone River-Bluestone River and Mountain Creek-Bluestone River HUC 12 subwatersheds (Figure 4). These two subwatersheds combined cover 28,801 ha (71,168 ac).

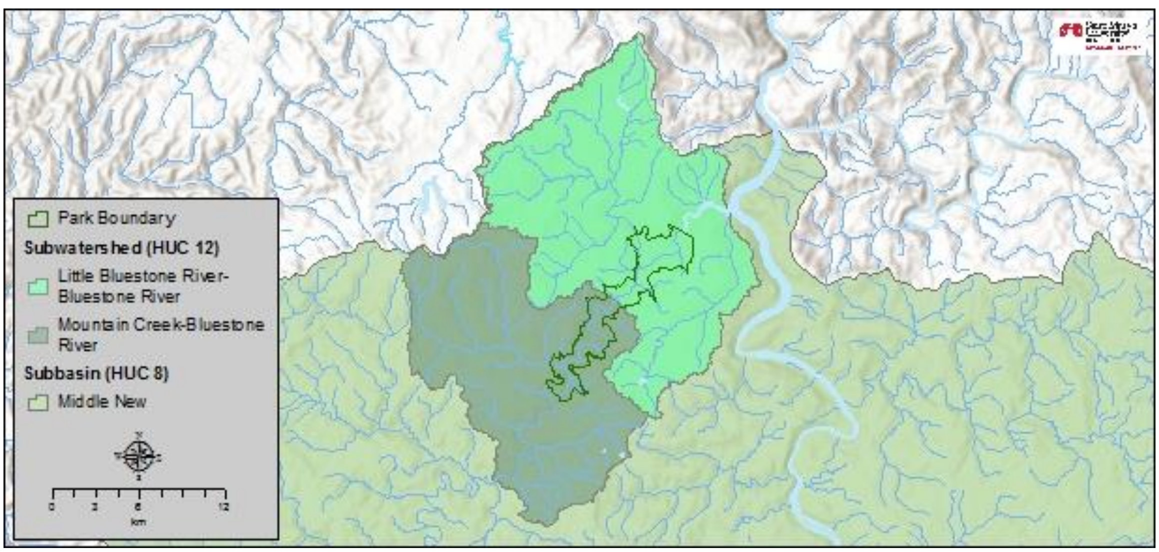


Figure 4. Watersheds of Bluestone National Scenic River.

2.2.2. Resource Descriptions

The central features of BLUE are the Bluestone River system and its surrounding gorge. The varying topography of the gorge supports a diversity of vegetation and wildlife. Much of the park is forested, but tree and plant species vary between drier forest areas towards the top of the gorge and forest areas that receive more moisture on the mid-slopes and along the streams (Marshall and Piekielek 2007b). Smaller non-wooded areas also occur along the river, where occasional flooding prevents the establishment of most trees. Over 800 vascular plant species have been documented in the park, including the federally-threatened Virginia spiraea (*Spiraea virginiana*) (NPS 2016b).

Soil conditions, particularly nutrient availability, often have a strong influence on vegetation composition, structure, and dynamics (Perles et al. 2012). The soils at BLUE are generally well-drained and lack a significant organic horizon (NRCS 2013, Perles et al. 2016). The organic horizon is important for water retention, nutrient provision, and insulating deeper soils from extreme temperatures (Binkley and Fisher 2012). As a result, BLUE soils are considered “droughty”, which puts the forests growing there under higher stress. However, some BLUE soils are richer and more calcareous than typical eastern forests, which buffers them from the negative impacts of atmospheric deposition (e.g., acidic precipitation) (Perles et al. 2014a). Within BLUE and other West Virginia parks, tree mortality and growth are known to be impacted by soil mineral and nutrient ratios (calcium:aluminum, carbon:nitrogen) (Perles et al. 2016).

Most mammals found at BLUE are typical of eastern forests, including white-tailed deer (*Odocoileus virginianus*), red foxes (*Vulpes vulpes*), raccoons (*Procyon lotor*), and squirrels (*Sciurus* spp.) (NPS 2016b). Nine species of bats (Order Chiroptera) also occur in the park, some of which are management priorities due to increasing conservation concern in recent years. The Allegheny woodrat, identified as a species of greatest conservation need (SGCN) by the state of West Virginia (WVDNR 2015), has been found in the park as well but is uncommon (NPS 2016b).

Just over 100 bird species have been observed at BLUE, including songbirds, waterfowl, and raptors (NPS 2016b). The park supports 11 species considered “Priority 1” SGCN in West Virginia (WVDNR 2015), including waterfowl, wading birds, and raptors (Figure 5). Like much of West Virginia, the forests of BLUE are largely unbroken, and provide critical habitat for forest interior dependent species (Weakland and Wood 2002). These types of forests are becoming increasingly rare, as forest fragmentation and loss accelerates due to human development.

Herpetofauna found at BLUE include 28 amphibian species (frogs, toads, and salamanders) and 12 reptile species (snakes, lizards, and turtles) (NPS 2016b). Two of the amphibians (black-bellied salamander [*Desmognathus quadramaculatus*] and cave salamander [*Eurycea lucifuga*]) and one of the reptiles (eastern box turtle [*Terrapene carolina carolina*]) are West Virginia Priority 1 SGCN (WVDNR 2015). The park’s waters support a diversity of warmwater fish (32 species confirmed present), but nearly half of them are non-native (NPS 2016b). Some were introduced intentionally to West Virginia for sport purposes, but other smaller fish were likely released from angler’s bait-buckets (Cincotta and Chambers 1999, Welsh et al. 2006). One fish species endemic to the New River drainage, the bigmouth chub (*Nocomis platyrhynchus*), is abundant in park waters (Welsh et al. 2006).


Figure 5. The great blue heron (*Ardea herodias*, left) and osprey (*Pandion haliaetus*, right) are two bird species of conservation concern that occur at Bluestone National Scenic River (NPS photos by Jim Ruff [left] and Cal Singletary [right]).

2.2.3. Resource Issues Overview

<u>Exotic Plants and Pests</u>

Exotic invasive species pose one of the greatest threats to biodiversity and ecosystem integrity worldwide, with the potential to impact ecological community composition, structure, and function (Mooney et al. 2005, Perles et al. 2014b). These species can compete with native plants and animals and disrupt ecosystem processes, such as nutrient cycling and disturbance regimes (e.g., fire, flooding). Invasive exotic species have been identified as a serious threat to BLUE's resources, particularly its vegetation communities (Perles et al. 2010). Just over 100 exotic plant species have been documented at BLUE, the majority of which are considered invasive in West Virginia (Appendix A) (WVNHP 2009, NPS 2016b). The most common invasive plants include multiflora rose (*Rosa multiflora*), wine raspberry (*Rubus phoenicolasius*), and Morrow's honeysuckle (*Lonicera morrowii*) (Perles et al. 2010). Trails, transportation corridors, and developed areas that attract visitors often serve as pathways for the spread of exotic plants (Perles et al. 2014b).

Several exotic pests (insects or diseases) are also impacting BLUE's vegetation. Perhaps the most serious is hemlock wooly adelgid (HWA; *Adelges tsugae*), an aphid-like insect native to Japan (Strickler 2014). The HWA, which feeds at the base of hemlock (*Tsuga* spp.) needles, was first observed at BLUE in 2000. Although a successful chemical treatment for HWA has been identified and subsequently applied at BLUE, the decline in hemlock triggered by this pest could still be significant. Additional exotic insects threatening the park include emerald ash borer (EAB; *Agrilus planipennis*) and gypsy moth (*Lymantria dispar*) (Perles et al. 2016). The disease butternut canker (*Sirococcus clavigignenti-juglandacearum*) may be impacting butternut trees (*Juglans cinerea*) in BLUE's riparian forests (Schlarbaum et al. 1998).

Mineral Extraction

West Virginia has long been known as a coal-bearing region, and the mining industry played a key role in the state's history (Purvis 2002, NPS 2011). A 13-county area in southern West Virginia is now designated as the National Coal Heritage Area (NCHA 2016). BLUE lies in the southeastern portion of this heritage area. Coal mining has occurred in the watersheds draining into BLUE and has impacted many park resources, particularly water quality (Purvis 2002). Streams draining mined areas typically have higher concentrations of dissolved minerals (e.g., calcium, magnesium, sulfate, bicarbonate) and higher specific conductance (Purvis 2002). Wastes from coal mining may also carry polycyclic aromatic hydrocarbons (PAHs), organic compounds that can be toxic to wildlife and humans, and trace metals (e.g., manganese, aluminum, iron) (Purvis 2002, Sheeder et al. 2004). Due to the low sulfur content of West Virginia's coal deposits, acidification (i.e., lowering of pH) of surface waters has not been as significant of an issue compared to other mining regions (Purvis 2002, NPS 2011).

The region around BLUE has also experienced natural gas exploration and extraction. According to the West Virginia Department of Environmental Protection (WVDEP), there are active gas wells within 15 km (9.3 mi) of the park (WVDEP 2016b) and a major natural gas pipeline currently crosses the park and the Bluestone River in the vicinity of Lilly (Purvis 2002). The Marcellus Shale is a gas-bearing rock formation that underlies New York, Pennsylvania, West Virginia, and eastern Ohio (NPS 2009). BLUE lies within the south central portion of this formation. Developments in drilling technology over the past two decades (e.g., hydraulic fracturing or "fracking" and horizontal drilling) have made development of the Marcellus Shale more viable than previously thought, triggering increased exploration and development during the past 10-15 years. The developments required to extract the shale gas found in the Marcellus pose risks for air and water quality, vegetation and wildlife, and park visitor experience (NPS 2009); water use and contamination issues are among the highest concerns. The hydraulic fracturing process requires significantly more water than traditional (vertical) drilling. While a traditional well typically requires less than 1 million gallons, a "fracking" well can use 3 to 5 million gallons (NPS 2009). This water is often taken from nearby ground or surface waters, which reduces the amount of water available for other purposes (e.g., streamflow, supplying plants and wildlife, recreation). Chemicals are added to the water during the drilling process and could contaminate local ground and surface waters if spills or leaks occur during the drilling and disposal of used fluids (NPS 2009).

The machinery required for drilling and vehicles needed for construction and transportation would generate emissions that may degrade the area's air quality (NPS 2009). Pollutants from these operations include nitrogen oxides and volatile organic compounds (VOCs), which can combine to form ozone, as well as particulate matter (PM) (NPS 2009). The construction of drilling and transportation infrastructure would also disturb soils and vegetation, while the noise from construction and drilling operations would disturb wildlife and human visitors alike (NPS 2009).

Development/Land Use Change

Development or other changes in surrounding land use can have a significant impact on the environmental quality, wildlife community, and visitor experience in protected areas. While much of the land within the BLUE watershed is forested, a small percentage is in agricultural use and logging occasionally occurs near the park (Purvis 2002, USGS 2011b). Agriculture and logging can contribute pollutants (e.g., chemicals, nutrients) and excess sediment to streams. Clearing and construction for residential and recreational developments can also impact water quality, cause habitat fragmentation, and increase threats to wildlife populations (Rentch 2006). Many communities and households in the region around the park lack adequate septic or sewage systems for the proper treatment of human and other domestic wastes, which has contributed to high fecal coliform bacteria levels in park waters (Purvis 2002, 2009). Developments often involve an increase in impervious surface area (e.g., roads, parking lots) and a reduction in precipitation infiltration. This can contribute to increased storm runoff (amount and velocity) and a higher potential for flash flooding (Purvis 2002). High stormflows can also cause streambank erosion and increased sedimentation, which can alter stream hydrology (Marshall et al. 2006).

Climate Change

Climate is a key driving factor in the ecological and physical processes influencing park ecosystems throughout the ERMN (Davey et al. 2006). As a result of global climate change, temperatures are projected to increase across the eastern United States over the next century (Horton et al. 2014). Warmer air temperatures will increase evaporation rates and plant transpiration (i.e., plant water use), meaning that even if annual precipitation remains constant or slightly increases, overall conditions could still become drier in the future (Dale et al. 2001, Carter et al. 2014). Drier conditions pose obvious threats to riparian vegetation communities, aquatic wildlife, herpetofauna, and surface hydrology, but will likely impact upland vegetation and other wildlife as well (NABCI 2010, Fisichelli et al. 2014). The potential impacts of climate change on various park resources will be discussed specifically in Chapter 4 of this report.

2.3. Resource Stewardship

2.3.1. Status of Supporting Science

The ERMN identifies key resources network-wide and for each of its parks that can be used to determine the overall health of the parks. These key resources are called Vital Signs. In 2005, the ERMN completed and released a Vital Signs Monitoring Plan (Marshall and Piekielek 2007a); Table 2 shows the ERMN Vital Signs selected for monitoring in BLUE.

Table 2. Eastern Rivers and Mountains Network Vital Signs selected for monitoring in Bluestone National Scenic River (Marshall and Piekielek 2007a).

Category	ERMN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]
Air and Climate	Ozone	–	X	–
	Wet and Dry Deposition	–	X	–
	Weather and Climate	X	X	–
Geology and Soils	Stream/River Channel Characteristics	–	–	X
	Soil Erosion and Compaction	–	–	X
	Soil Function and Dynamics	X	–	–
Water	Surface Water Dynamics	X	X	–
	Wetland Water Dynamics	–	–	X
	Groundwater Dynamics	–	–	X
	Water Chemistry	X	X	–
	Aquatic Macroinvertebrates	X	X	–
	Aquatic Periphyton	–	–	X
Biological Integrity	Invasive/Exotic Plants, Animals and Diseases – Status and Trends	X	–	–
	Invasive/Exotic Plants, Animals and Diseases – Early Detection	X	–	–
	Shrubland Forest and Woodland Communities	X	–	–
	Riparian Communities	X	–	–
	Birds – Riparian Communities	–	–	X
	Mammals – Riparian Communities	–	–	X
	Birds – Breeding Communities	X	–	–
	Terrestrial Invertebrates	–	–	X
	Freshwater Communities – Mussels	–	–	X
	Freshwater Communities – Crayfish	–	–	X
	Freshwater Communities – Macrophytes	–	–	X

[a] Category 1 represents Vital Signs for which the network will develop protocols and implement monitoring.

[b] Category 2 represents Vital Signs that are monitored by the park, another NPS program, or by another federal or state agency using other funding.

[c] Category 3 represents high priority Vital Signs for which monitoring will likely be done in the future.

Table 2 (continued). Eastern Rivers and Mountains Network Vital Signs selected for monitoring in Bluestone National Scenic River (Marshall and Piekielek 2007a).

Category	ERMN Vital Sign	Category 1[a]	Category 2[b]	Category 3[c]
Biological Integrity (continued)	Fish Communities – Streams	–	–	X
	Fish Communities – Rivers	–	–	X
	Amphibians and Reptiles – Vernal Pond Community	–	–	X
	Amphibians and Reptiles – Streamside Salamander Community	–	–	X
	T&E Species and Communities – State and Federal	X	–	–
Human Use	Bioaccumulation	–	–	X
	Visitor Use	–	–	X
Landscapes (Ecosystem Patterns and Processes)	Land Cover and Use	X	–	–
	Landscape Pattern	X	–	–
	Primary Production	–	–	X
	Nutrient Dynamics	–	–	X

[a] Category 1 represents Vital Signs for which the network will develop protocols and implement monitoring.

[b] Category 2 represents Vital Signs that are monitored by the park, another NPS program, or by another federal or state agency using other funding.

[c] Category 3 represents high priority Vital Signs for which monitoring will likely be done in the future.

3. Study Scoping and Design

This chapter documents the study scoping process. It also describes study design outcomes. Input from parks and other NPS subject matter experts is essential to selecting a good subset of park resources and indicators to focus on, to help identify appropriate data sets and analytical approaches, to determine the indicator framework(s) that will be used in the study, and to decide on the park areas to use for a more holistic "roll up" and summary of overall conditions.

3.1. Preliminary Scoping

A preliminary scoping meeting was held from 24-27 October 2016. At this meeting, SMUMN GSS and NPS, ERMN, and park staff confirmed that the purpose of the BLUE NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to BLUE managers. Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information;
- Identification of data needs and gaps is driven by the project framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by BLUE resource management;

This condition assessment provides a "snapshot-in-time" evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid BLUE resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding
- resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan "land health" goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including BLUE resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project;
- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point;

- Clearly identify “management critical” data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process;
- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually;
- Utilize “gray literature” and reports from third party research to the extent practicable.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a “framework” is developed for a park or preserve. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

“Components” in this process are defined as natural resources (e.g., birds), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) that are considered important to current park management. Each key resource component has one or more “measures” that best define the current condition of a component being assessed in the NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain “stressors,” which are also considered during assessment. A “stressor” is defined as any physical, biological, or chemical agent that induces adverse changes within a component (EPA 2016c). These typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation.

During the BLUE NRCA scoping process, key resource components were identified by NPS staff and are represented as “components” in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, or are of greatest concern or highest management priority in BLUE. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A “reference condition” is a benchmark to which current values of a given component’s measures can be compared to determine the condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd of at least 200 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference before human activity and disturbance was a major driver of ecological populations and processes, such as "pre-fire suppression." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's "State of Our Nation's Ecosystems 2008" (Heinz Center 2008). Key resources for the park were adapted from the ERMN Vital Signs monitoring plan (Marshall and Piekielek 2007a). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized the end of January 2017 following a scoping workshop 24-27 October 2016, and acceptance from NPS resource staff. The framework contains a total of 10 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Table 3. Bluestone National Scenic River natural resource condition assessment framework.

Component	Measures (Significance Level)	Stressors	Reference Condition
Upland Forest Communities	Community extent (3), plant species richness (3), rare plant element occurrences (number and ranks) (3), proportion of total cover of exotic and invasive plants (3), tree mortality (3), recruitment (3), tree mean annual diameter increment (3)	Pests and pathogens, exotic species, extreme weather events, climate change, deer browse, feral swine, fire suppression, forest fragmentation	Unknown; Best professional judgement and comparisons to similar forests in other ERMN parks will be used to assess condition
Riparian Vegetation Communities	Total acreage (3), acreage by wetland type (3), plant species diversity by type (3), water quality (3), soil quality (2)	Invasive exotic species, pests and pathogens, climate change, mowing regimes (for wildlife management), Bluestone dam flow/flood management, potential recreational development/use	Same as above
Birds	Species richness (3), species abundance (2), species distribution (2), Bird Community Index (BCI) (3), annual waterfowl harvest (3), annual turkey harvest (3)	Hunting pressure, climate change, water quality, mowing regimes, adjacent land use (e.g., logging, agriculture), Bluestone Dam maintenance/safety work	Undefined
Mammals	Species richness (3), bat species richness (3), annual harvest numbers (3)	Habitat fragmentation, hunting pressure, dam maintenance/safety work, feral swine, invasive vegetation, adjacent land use, white nose syndrome	Undefined
Herpetofauna (Reptiles and Amphibians)	Species richness (3), species abundance (3), species distribution (3)	Water quality, recreational use, bait collection, diseases, climate change, invasive vegetation, fragmentation, pesticides, non-native bait releases	Undefined
Aquatic Wildlife Community	Fish species richness (3), percent native species (3), fish species relative abundance (3), macroinvertebrate species richness (3), benthic macroinvertebrate IBI (3)	Non-native species (e.g., bait bucket releases), inundation due to Bluestone Dam operations, invasive aquatic plants, boat traffic, gas pipelines, extreme hydrologic/weather events, pesticides, adjacent and upstream land use/development	Welsh et al. (2006) for fish measures, ranges used by ERMN for macroinvertebrate IBI

Table 3 (continued). Bluestone National Scenic River natural resource condition assessment framework.

Component	Measures (Significance Level)	Stressors	Reference Condition
Water Quality	Temperature (2), pH (3), conductivity (3), dissolved oxygen (3), turbidity (3), fecal coliform bacteria (3)	Upstream land use (agriculture, logging), residential & other development, inadequately treated sewage, pesticides, industrial chemicals/waste, road de-icers, bilge waste from boats on Bluestone Lake	West Virginia state standards
Air Quality	Ozone (3), atmospheric deposition of sulfur/nitrogen (3), atmospheric deposition of mercury (3), visibility (3)	Power plant emissions, vehicle emissions, dust from mountaintop mining, prescribed burning	NPS ARD standards and ranges
Dark Night Skies	NPS NST Suite of 6 measures	Light trespass from state parks, nearby city light pollution, nighttime lake traffic and construction at Bluestone Dam	Absence of anthropogenic light
Surface Water Hydrology	Annual peak discharge (3), annual mean discharge (2), annual minimum discharge (1), timing and amount of precipitation (2)	Climate change, extreme weather events, dam operations (maintenance/construction, malfunction, etc.), changes in upstream land use/development	Gage period of record (1950-present) for discharge measures, 30-year normals for precipitation

3.2.2. General Approach and Methods

This study involved gathering and reviewing existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study; however, where appropriate, existing data were further analyzed to provide summaries of resource condition or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time BLUE staff provided data and literature in multiple forms, including: NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, databases, tabular data, and charts. GIS data were provided by NPS staff. Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis

Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available for the component and recommendations from NPS reviewers and sources of expertise including NPS staff from BLUE and the ERMN. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

Significance Level

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A “Significance Level” represents a numeric categorization (integer scale from 1-3) of the importance of each measure in assessing the component’s condition; each Significance Level is defined in Table 4. This categorization allows measures that are more important for determining condition of a component (higher significance level) to be more heavily weighted in calculating an overall condition. If a measure is given a Significance Level of 1, it is thought to be of low importance when determining the overall condition of the component. For this reason, measures with a Significance Level of 1 are not discussed in detail in the Current Condition and Trends section of a component’s chapter. Significance Levels were determined for each component measure in this assessment through discussions with park staff and/or outside resource experts.

Table 4. Scale for a measure's Significance Level in determining a components overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

Condition Level

After each component assessment is completed (including any possible data analysis), SMUMN GSS analysts assign a Condition Level for each measure on a 0-3 integer scale (Table 5). This is based on all the available literature and data reviewed for the component, as well as communications with park and outside experts.

Table 5. Scale for Condition Level of individual measures.

Condition Level (CL)	Description
0	Of NO concern. No net loss, degradation, negative change, or alteration.
1	Of LOW concern. Signs of limited and isolated degradation of the component.
2	Of MODERATE concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of SIGNIFICANT concern. Nearing catastrophic, complete, and irreparable degradation of the component.

Weighted Condition Score

After the Significance Levels (SL) and Condition Levels (CL) are assigned, a Weighted Condition Score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: resource is in good condition (WCS = 0.0 – 0.33); condition warrants moderate concern (WCS = 0.34 - 0.66); and condition warrants significant concern (WCS = 0.67 to 1.00). Tables 6 and 7 display and describe the symbology used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern, and green circles are in good condition. White circles are used to represent situations in which SMUMN GSS analysts and park staff felt there was currently insufficient data to make a statement about the condition of a component. The border of the circles represents the confidence in the assessment of current condition; bold borders indicate high confidence, normal borders indicate medium confidence, and a dashed-border indicates low confidence. The arrows inside the circles indicate the trend of the condition of a resource component, based on data and literature from the past 5-10 years, as well as expert opinion. An upward pointing arrow indicates the condition of the component has been improving in recent times. An arrow that points to the left and right indicates a stable condition or trend and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. An empty circle with no arrow is reserved for situations in which the trend of the component's condition is currently unknown.

Table 6. Description of symbology used for individual component assessments.

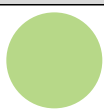
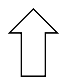
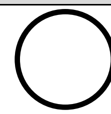
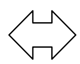
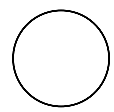
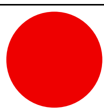
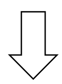
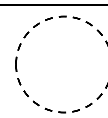
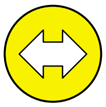
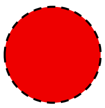
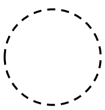
Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 7. Examples of how the symbols should be interpreted for individual component assessments.

Symbol	Interpretation
	Resource is in good condition, its condition is improving, high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment (explanation is required if a trend symbol or a medium/high confidence band is shown).

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts, and BLUE and ERMN staff. Though SMUMN GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or multiple individuals considered local experts on the resource components under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by BLUE resource staff and other experts, the final component assessments represent the most relevant and current data available for each component and the sentiments of park resource staff and resource experts.

Format of Component Assessment Documents

All resource component assessments are presented in a standard format. The format and structure of these assessments is described below.

Description

This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. For example, a component may represent a unique feature of the park, it may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Also emphasized are interrelationships that occur among the featured component and other resource components included in the NRCA.

Measures

Resource component measures were defined in the scoping process and refined through dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items.

Reference Conditions/Values

This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the NPS experts or SMUMN GSS analysts, an explanation of how they were developed is provided.

Data and Methods

This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix for the reader or a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend

This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors

This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with resource experts and NPS natural resources staff.

Data Needs/Gaps

This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in determining the current condition or trend of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff seeking to prioritize monitoring or data gathering efforts.

Overall Condition

This section provides a qualitative summary statement of the current condition that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component. Sources are listed alphabetically by last name.

4. Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 10 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Table 3):

4.1 Upland Forest Community

4.2 Riparian Vegetation Communities

4.3 Birds

4.4 Mammals

4.5 Herpetofauna (Reptiles and Amphibians)

4.6 Aquatic Wildlife Community

4.7 Water Quality

4.8 Air Quality

4.9 Dark Night Skies

4.10 Surface Water Hydrology

4.1. Upland Forest Communities

4.1.1. Description

BLUE lies in the mixed mesophytic region of the eastern deciduous forest (Braun 1950, Vanderhorst et al. 2008). The vast majority of the park (85%) is covered in upland deciduous forest and woodland dominated by oaks (*Quercus* spp.), maples (*Acer* spp.), hickories (*Carya* spp.), and other hardwood species (Vanderhorst et al. 2008). These forests provide food and habitat for a variety of wildlife and perform many valuable ecosystem services (e.g., carbon storage, air purification, erosion control) (Miller et al. 2016). The ERMN identified vegetation and soils as high priorities for long-term monitoring as part of the Vital Signs program (Marshall and Piekielek 2007a, Perles et al. 2010). The condition of vegetation communities often provides insight into overall terrestrial ecosystem health (Perles et al. 2010).

Oak-hickory-sugar maple forest at Bluestone National Scenic River (Vanderhorst et al. 2008).

Vegetation classification and mapping efforts at BLUE identified 12 unique upland forest community types occurring within park boundaries (Vanderhorst et al. 2008). These types (or “associations”) and the prominent or characteristic tree species in BLUE stands are presented in Table 8.

Table 8. Upland forest vegetation associations documented within Bluestone National Scenic River and the most prominent tree and shrub species in each (Vanderhorst et al. 2008).

Vegetation Community	Prominent Tree/Shrub Species
Calcareous Oak Forest	sugar maple (Acer saccharum var. saccharum), white ash (Fraxinus americana), white oak (Quercus alba), chinkapin oak (Q. muehlenbergii), northern red oak (Q. rubra), eastern redbud (Cercis canadensis var. canadensis)
Eastern Hemlock – American Basswood Forest	eastern hemlock (Tsuga canadensis), sugar maple, chestnut oak (Q. montana), northern red oak, American basswood (Tilia americana), striped maple (A. pensylvanicum)
Eastern Hemlock – Chestnut Oak Forest	eastern white pine (Pinus strobus), eastern hemlock, red maple (A. rubrum var. rubrum), sweet birch (Betula lenta), white oak, scarlet oak (Q. coccinea var. coccinea), chestnut oak, northern red oak, sourwood (Oxydendrum arboreum)
Eastern Hemlock – Sweet Birch – Tuliptree/Great Laurel Forest	eastern hemlock, sweet birch, great laurel (Rhododendron maximum)
Oak – Eastern White Pine/Ericad Forest	eastern white pine, white oak, scarlet oak, chestnut oak, northern red oak, black oak (Q. velutina), red maple, sourwood
Oak – Hickory – Sugar Maple Forest	sugar maple, white ash, pignut hickory (Carya glabra), white oak, northern red oak, chestnut oak, black oak
Successional Black Locust Woodland	black walnut (Juglans nigra), black locust (Robinia pseudoacacia), slippery elm (Ulmus rubra)
Successional Eastern White Pine – Tuliptree Forest	eastern white pine, tuliptree (Liriodendron tulipifera), sourwood, northern spicebush (Lindera benzoin)
Successional Tuliptree/Northern Spicebush Forest	white ash, tuliptree, northern spicebush
Successional Virginia Pine Forest	Virginia pine (Pinus virginiana)
Sugar Maple – Yellow Buckeye – American Basswood Forest	sugar maple, yellow buckeye (Aesculus flava), northern red oak, tuliptree, American basswood, northern spicebush
Virginia Pine – Oak Shale Woodland	post oak (Q. stellata), Virginia pine, pignut hickory, chestnut oak, northern red oak, eastern redcedar (Juniperus virginiana var. virginiana)

4.1.2. Measures

- Community extent
- Plant species richness
- Rare plant element occurrences
- Proportion of total cover of exotic plants and invasive plants
- Tree mortality
- Recruitment
- Tree mean annual diameter increment

4.1.3. Reference Condition/Values

Due to the relatively recent establishment of the park, there is little historical information available on vegetation communities within BLUE. This makes identifying reference conditions challenging. For the purposes of this assessment, current condition will be assessed based on comparisons to similar forests in other ERMN parks (particularly within West Virginia) and on best professional judgement. The information presented here could serve as a baseline for future assessments.

4.1.4. Data and Methods

The earliest known vegetation investigation in the area that is now BLUE was conducted from August 1973 to October 1974 in Indian Branch Gorge (Oxley 1975). The Indian Branch Gorge runs southeast from the Bluestone River for approximately 975 m (3,200 ft) and is located west of the current boundary of Pipestem State Park. The gorge was surveyed for plants each weekend for just over 1 year, weather permitting, to create a species list and characterize vegetation communities (Oxley 1975). A line transect was also established from the top of the south rim to the top of the north rim of the gorge. The transect was divided into 10-m (32.8-ft) segments and plant species were documented on each segment to compare vegetation composition at different slope positions and aspects (north vs. south-facing) within the gorge (Oxley 1975).

In 1992, BLUE was surveyed for rare plant and animal species and for significant natural communities (Norris 1992). Both banks of the Bluestone River were searched on foot, totaling nearly 43 km (27 mi), as were most roads and trails and some additional floodplain and upland areas of interest. When rare species were found, the location was noted, along with information on its habitat, biology, and management needs (Norris 1992).

Grafton (1993) sampled vegetation transects in “moist” and “dry” vegetation communities along the Gauley, Meadow, and Bluestone Rivers throughout the 1992 growing season. The objective was to identify the most common plant species and community types along these rivers and document variation between moist and dry habitats and different slope aspects. Data recorded along two transects at BLUE included forest cover type, overstory age, dominant shrub species, and dominant herbaceous species (Grafton 1993, Vanderhorst et al. 2008).

A reconnaissance study of vegetation in the Bluestone, Gauley, and New River gorges was completed by Fortney et al. (1995) during the summer and fall of 1994. For the Bluestone gorge, a sampling transect was established at Pipestem State Park near the aerial tramway. This transect included three 20x50 m (65.6x164.0 ft) quadrats, representing upper, middle, and lower slope positions (Fortney et al. 1995). Vegetation composition and structure were studied by measuring diameter at breast height (DBH) of all trees and number of saplings in the full quadrat. The number of seedlings and shrubs were recorded in smaller, nested 5x5 m (16.4x16.4 ft) plots within the quadrats. Percent cover of herbaceous species, woody debris, and exposed rock were estimated in nested 1x1 m [3.3x3.3 ft] plots. Herbaceous species observed in the larger quadrat but not within these smaller plots were also noted (Fortney et al. 1995).

Rentch et al. (2005) studied forest vegetation patterns in the lower Bluestone Gorge, conducting field work from 1994 to 1999. Fifty-one 0.1-ha (0.25-ac) quadrats were sampled, primarily along 11 transects extending from the bottom of the gorge to its rim. All quadrats were within the BLUE boundary. Data gathered included DBH of all trees, number of shrubs (in nested 5x5 m plots), and percent cover of herbaceous species (in nested 1x1 m plots). These data were used to calculate species "importance values" (IV) for trees and herbaceous plants. Tree ages were determined for several dominant trees in or near each quadrat by taking growth increment cores (Rentch et al. 2005).

The West Virginia Natural Heritage Program (WVNHP) completed a vegetation classification and mapping project for BLUE based on field sampling and aerial imagery interpretation (Vanderhorst et al. 2008). Researchers sampled 135 vegetation plots across the park from 2003-2005. These plots were typically 20×20 m^2 (65×65 ft^2), but shape and size were occasionally changed to accommodate linear communities or small patches. Data collected addressed species composition and community structure (e.g., percent cover by strata, DBH of woody species). Plant communities were classified into vegetation associations using the U.S. National Vegetation Classification (NVC). Vegetation mapping was based on 2003-2004 aerial imagery of the park (Vanderhorst et al. 2008). Concurrent to this effort, the WVNHP also completed a floristic inventory for the park; surveying for this inventory extended from spring 2003 through summer 2006 (Streets et al. 2008).

In 2007, the ERMN initiated vegetation and soil monitoring in eight of its nine parks, including BLUE (Perles et al. 2010). Approximately one-quarter of each park's plots are sampled per year, so that individual plots are visited on a 4-year rotation. Forty monitoring plots are located at BLUE, 22 in mesic (moderate moisture levels) vegetation communities and 18 in xeric (dry) communities (Perles et al. 2016). Thirty-two of these plots fall within upland forest communities. Each plot is circular, with a 15-m (49.2-ft) radius, but contains smaller embedded plots for sampling various parameters. Sampling methods are described in detail in the ERMN monitoring protocol document (Perles et al. 2014c). Data collected allows managers to evaluate forest stand structure, tree regeneration, tree health and growth, understory diversity, invasive species, and soils (Perles et al. 2010). Assessments based on monitoring data collected to date are presented in Perles et al. (Perles et al. 2010, 2014b, 2016). These reports provide information for the tree mortality, recruitment, and mean annual diameter increment measures of this NRCA.

The ERMN assesses tree mortality by calculating the annual mortality rate (% trees/year) between sampling periods. This is done by dividing the current number of dead trees by the total number of trees during the previous sampling period, and then dividing this by the number of years between sampling periods (Perles et al. 2016). Recruitment is based on the annual recruitment rate (% trees/year), which is based on the percentage of trees that crossed the minimum threshold for trees (DBH = 10 cm) between sampling periods. This is calculated by dividing the number of "new" trees by the total number of trees during the previous sampling period, and dividing this by the number of years between sampling periods (Perles et al. 2016).

Tree mean annual diameter increment (MADI) is one way to measure and assess tree growth (Perles et al. 2016). MADI is calculated by first summing the diameter increment (DBH increase in cm between sampling periods) for all trees within a plot or of a particular species. This sum is first divided by the number of years between sampling periods, and then divided by the total number of trees included in the calculation (Perles et al. 2016).

4.1.5. Current Condition and Trend

<u>Community Extent</u>

According to the vegetation map generated by Vanderhorst et al. (2008), upland forest communities cover 1,486 ha (3,672 ac) within BLUE (Table 9). The most extensive community was Oak-Hickory-Sugar Maple Forest, with 622.5 ha (1,538.3 ac) (Figure 6). The smallest community extent, at just 0.1 ha (0.2 ac), was Eastern Hemlock-Sweet Birch-Tuliptree/Great Laurel Forest (Vanderhorst et al. 2008).

Table 9. Upland forest extent at Bluestone National Scenic River by vegetation community type (reproduced from Vanderhorst et al. 2008).

Vegetation Community	Area in ha (ac)
Calcareous Oak Forest	19.3 (47.8)
Eastern Hemlock – American Basswood Forest	69.6 (172.0)
Eastern Hemlock – Chesnut Oak Forest	43.1 (106.5)
Eastern Hemlock – Sweet Birch – Tuliptree/Great Laurel Forest	0.1 (0.2)
Oak – Eastern White Pine/Ericad Forest	396.8 (980.6)
Oak – Hickory - Sugar Maple Forest	622.5 (1,538.3)
Successional Black Locust Woodland	2.9 (7.1)
Successional Eastern White Pine – Tuliptree Forest	72.0 (178.0)
Successional Tuliptree/Northern Spicebush Forest	20.2 (49.8)
Successional Virginia Pine Forest	1.3 (3.2)
Sugar Maple – Yellow Buckeye – American Basswood Forest	212.1 (524.1)
Virginia Pine – Oak Shale Woodland	26.1 (64.5)
Total upland forest and woodland	1,486.1 (3,672.2)

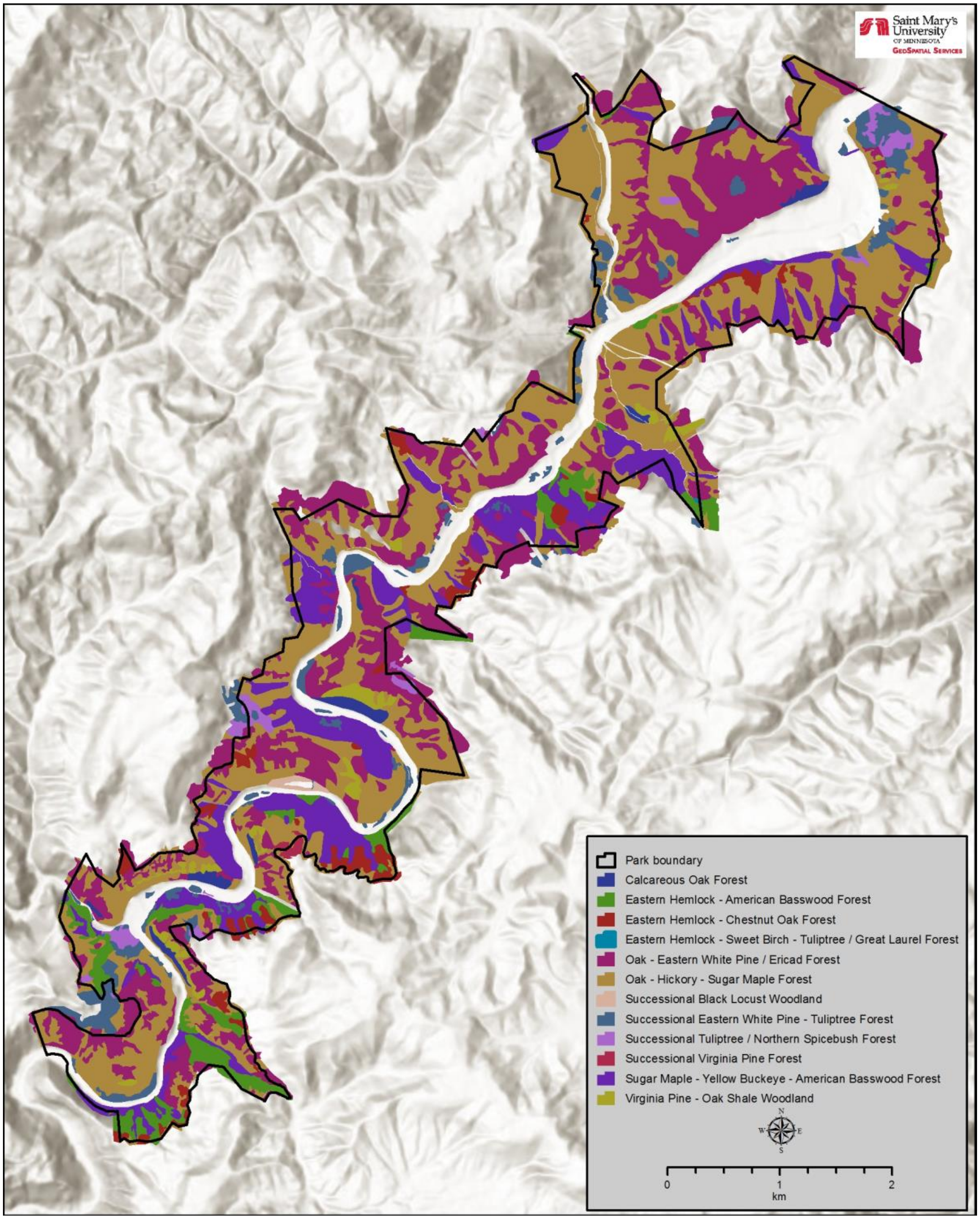


Figure 6. The extent of upland forest vegetation community types within Bluestone National Scenic River (Vanderhorst et al. 2008).

<u>Plant Species Richness</u>

Vanderhorst et al. (2008) documented 392 plant taxa (including subspecies and varieties) within BLUE's upland forest vegetation communities (Appendix A). Only 28 of these species (7.1%) are considered exotic. The greatest total number of plant species was documented in the Oak - Hickory -

Sugar Maple Forest, with 213 species (Table 10). However, this may be related to the relatively high number of plots sampled within this community. The highest mean number of species per plot (total species per community divided by total number of plots) was 38.7 in the Successional Tuliptree/Northern Spicebush Forest. The lowest mean number of species per plot was 9.2 for the Oak-Eastern White Pine/Ericad Forest.

During 2007-2016 ERMN forest monitoring, 405 plant species have been documented in upland forest plots (Appendix A) (ERMN 2017). Thirty-four of these species (8.4%) are exotic. A cumulative list of all plant species confirmed in BLUE's upland forests includes 541 different taxa (species and subspecies/varieties), 46 of which are exotic (8.5%) (Appendix A).

Table 10. Plant species richness by upland forest community type at Bluestone National Scenic River, as documented by Vanderhorst et al. (2008).

Vegetation Community	# of Plots	# of Species	Mean Species/Plot
Calcareous Oak Forest	5	115	23.0
Eastern Hemlock – American Basswood Forest	8	137	17.1
Eastern Hemlock – Chesnut Oak Forest	9	92	10.2
Eastern Hemlock – Sweet Birch – Tuliptree/Great Laurel Forest	1	27	27.0
Oak – Eastern White Pine/Ericad Forest	16	147	9.2
Oak – Hickory – Sugar Maple Forest	15	213	14.2
Successional Black Locust Woodland	2	44	22.0
Successional Eastern White Pine – Tuliptree Forest	11	186	16.9
Successional Tuliptree/Northern Spicebush Forest	3	116	38.7
Sugar Maple – Yellow Buckeye – American Basswood Forest	12	143	11.9
Virginia Pine – Oak Shale Woodland	9	118	13.1

Rare Plant Element Occurrences

Element occurrences (EOs) are one way of surveying, mapping, and assessing populations of high-priority species (NatureServe 2016). NatureServe (2016) developed the EO data standard, which provides standardized vocabulary, definitions, and guidelines for the collection and management of EO data. EO data provides information on where specific species exist on the ground, and their populations are ranked based on their overall viability or probability of persistence (NatureServe 2016). This information is stored in a georeferenced database called Biotics, which is maintained by NatureServe and various state Natural Heritage Programs (Streets et al. 2008).

According to Streets et al. (2008), 19 rare plant species have been confirmed in BLUE's upland forests (Table 11). Several of these species were first documented in the park during the Streets et al. (2008) 2003-2006 inventory. Norris (1992) only observed 13 of these species, and the number of occurrences for each species ranged from one to four (wild bergamot [*Monarda fistulosa* ssp. *brevis*]. The number of EOs per species reported by Streets et al. (2008) ranged from one (14 species) to three (three species) (Table 11). The number of EOs increased between these two reports for two species

(*Allium oxyphilum* and *Scutellaria saxatilis*) but decreased for four species (*Carex woodii, Monarda fistulosa* ssp. *brevis, Thuja occidentalis,* and *Viburnum rafinesquianum*). Given the limited data, small overall number of occurrences, and difficulty in locating many rare species, it is not practical to conclude whether these changes represent a trend of concern or are due to natural variation and/or differences in survey intensity. During regular forest monitoring by ERMN since 2007, three of these rare species have been observed in sampling plots (Table 11) (ERMN 2017). No rank information could be found for park EOs; it is likely that ranks have not been assessed/assigned.

Table 11. Documented rare plant occurrences at Bluestone National Scenic River upland forest communities. Norris (1992) reported the number of personal observations during a thorough park survey. Streets et al. (2008) reported the number of element occurencess in the Biotics database as of 31 May 2007. The Eastern Rivers and Mountains Network (2017) column represents species observed during routine forest monitoring (i.e., opportunistic observations, not a targeted search) since 2007.

Scientific Name	Common Name	State Rank[a]	Norris 1992	Streets et al. 2008	ERMN 2007-2016
Agrimonia microcarpa	smallfruit agrimony	S1	1	1	X
Allium oxyphilum	lillydale onion, shale onion	S2	1	3	–
Berberis canadensis	American barberry	S1	–	3	–
Carex cumberlandensis	Cumberland sedge	S2	–	3	–
Carex molesta	troublesome sedge	S3	1	1	–
Carex normalis	greater straw sedge	S3	1	1	–
Carex woodii	pretty sedge	S2	2	1	–
Goodyera repens	lesser rattlesnake plantain	S1S2	–	1	–
Helianthus laevigatus	smooth sunflower	S2	–	1	–
Lonicera canadensis	American fly honeysuckle	S2	1	1	–
Lysimachia tonsa	southern yellow loosestrife	SH	1	1	–
Monarda fistulosa ssp. brevis	wild bergamot	S1	4	2	–
Myosotis macrosperma	largeseed forget-me-not	S2	1	1	–
Prunus alleghaniensis var. alleghaniensis	Allegheny plum	S3	1	1	–
Scutellaria saxatilis	smooth rock skullcap	S2	1	2	X
Thuja occidentalis	arborvitae	S2	2	1	–
Trifolium reflexum	buffalo clover	S1	–	1	–
Viburnum rafinesquianum	downy arrowwood	S2	2	1	X
Viburnum rufidulum	rusty blackhaw	S1	–	1	–

[a] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation, SH = state historical, has not been relocated within the last 20 years.

Proportion of Total Cover of Exotic Plants and Invasive Plants

Not all exotic plant species are considered invasive. Exotic species considered invasive by the State of West Virginia, and therefore a greater threat to native plants, are noted in Appendix A. Both categories (exotic and invasive) will be addressed within this measure.

The Vanderhorst et al. (2008) report includes mean percent cover estimates by plant species for each vegetation community identified within the park. Within the 11 upland forest community types sampled, mean *exotic* plant species cover ranged from 0% in Eastern Hemlock - Sweet Birch - Tuliptree/Great Laurel Forest to 15.0% in Successional Tuliptree/Northern Spicebush Forest. Mean *invasive* species cover was nearly identical to exotic cover, with the exception of one forest community (Oak - Hickory - Sugar Maple Forest). Exotic and invasive species percent covers for all upland forest communities are shown in Table 12.

Table 12. Mean exotic and invasive plant species cover by upland forest community type within Bluestone National Scenic River (Vanderhorst et al. 2008).

Vegetation Community	# of Exotic Species	Mean % Exotic Cover	Mean % Invasive Cover
Successional Tuliptree/Northern Spicebush Forest	6	15.0	15.0
Successional Eastern White Pine – Tuliptree Forest	14	12.8	12.8
Oak – Hickory – Sugar Maple Forest	7	4.0	3.0
Successional Black Locust Woodland	6	4.0	4.0
Sugar Maple – Yellow Buckeye – American Basswood Forest	5	3.0	3.0
Eastern Hemlock - American Basswood Forest	4	2.0	2.0
Calcareous Oak Forest	3	1.5	1.5
Oak – Eastern White Pine / Ericad Forest	2	1.0	1.0
Virginia Pine – Oak Shale Woodland	4	0.5	0.5
Eastern Hemlock – Chestnut Oak Forest	1	0.5	0.5
Eastern Hemlock – Sweet Birch – Tuliptree /Great Laurel Forest	0	0	0

The ERMN forest monitoring program has documented exotic and invasive plant cover in 32 upland forest plots within BLUE. Based on 2013-2016 data, the average proportion of total cover in native species is 89.9% (standard deviation [SD] = 8.9%) (ERMN 2017). The average proportion of total cover in exotic species in upland forest plots is 1.9% (SD = 4.2%), and cover in invasive species is 1.6% (SD = 4.1%). This most recent proportion of native species cover is higher than 2007-2009 results from the park, when xeric plots averaged 86.7% native species cover and mesic plots (including some riparian areas) averaged 81.9% native cover (Perles et al. 2010). Compared to other parks within ERMN, BLUE shows a higher proportion of invasive species cover park-wide than the two other parks in West Virginia, but a much lower proportion of invasive cover than four of the five parks in Pennsylvania (Figure 7) (Perles et al. 2014b).

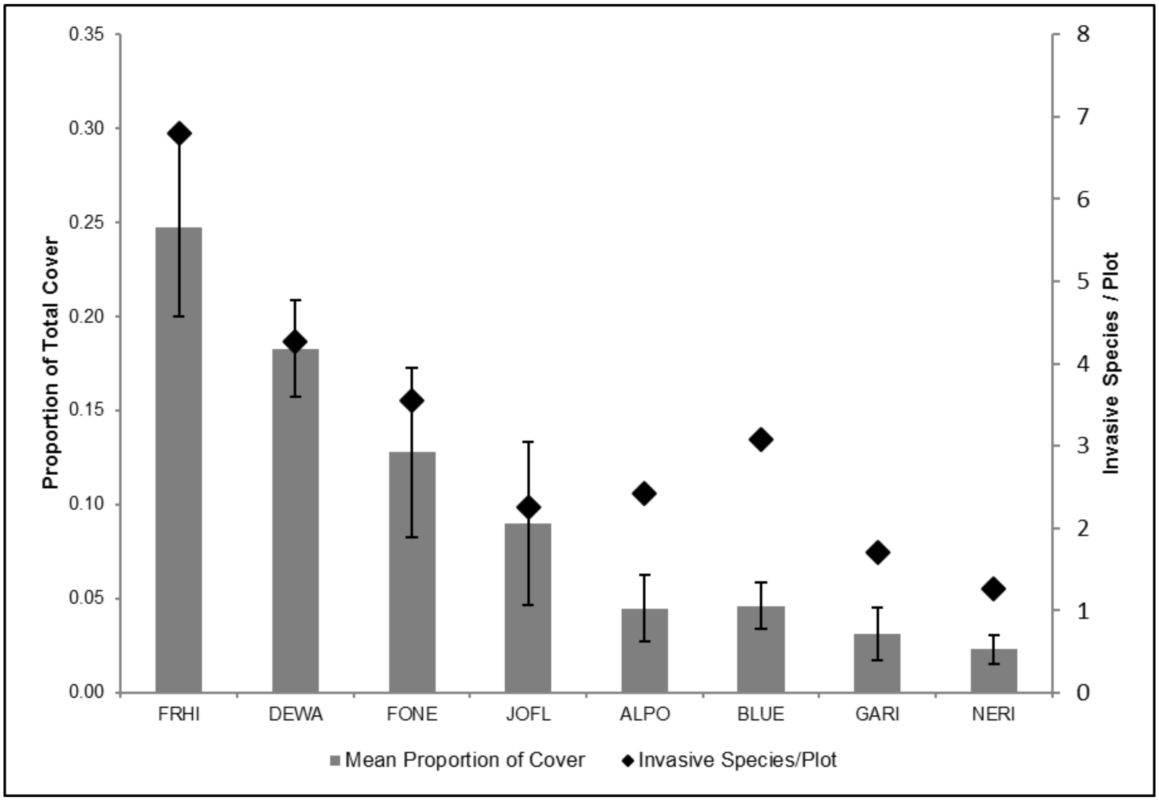


Figure 7. Average (± standard error) proportion of the total cover held by invasive exotic plant species as measured in monitoring quadrats in Eastern Rivers and Mountains Network parks (based on 2013-2016 data) (ERMN 2017). Note that these proportions are park-wide and not limited to upland forests alone. The black diamonds show the average number of invasive species/plot for each park (based on 2012-2015 data). The three West Virginia parks (Gauley River National Recreation Area, New River Gorge National River, and Bluestone National Scenic River) are on the far right of the graph.

Tree Mortality

BLUE generally experiences one of the highest annual tree mortality rates among ERMN parks (Perles et al. 2014b, 2016). From 2013-2016, annual tree mortality rates in BLUE upland forest monitoring plots alone ranged from 0-7%/year, with a mean of 1.7%/year (SD = 1.5%) (ERMN 2017). This is slightly above reported rates for other eastern forests, which ranged from 0.3-1.6%/year (Lorimer 1980, Runkle 1998, 2000, Busing 2005, Perles et al. 2016). In comparison, the nearby New River Gorge National River (NERI) showed a tree mortality rate of 1.5%/year (Figure 8) (Perles et al. 2016). During the previous monitoring cycle (2009-2012), BLUE tree mortality was slightly lower (~1.4%/year) (Perles et al. 2014b). At that time, species experiencing the highest mortality were eastern white pine (*Pinus strobus*) (2%/year), eastern hemlock (*Tsuga canadensis*) (1.5%/year), various oaks (0.6-1.0%/year), and sugar maple (*Acer saccharum* var. *saccharum*) (0.9%/year).

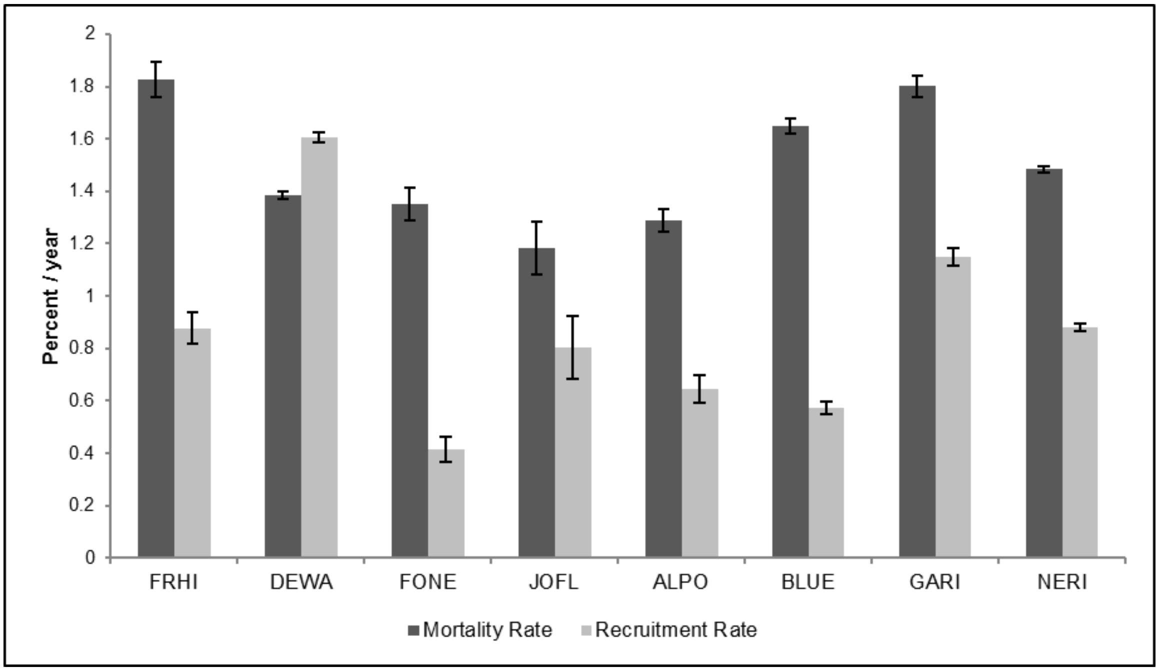


Figure 8. Mortality and recruitment rates (percent/year) for trees in Eastern Rivers and Mountains Network parks, 2007-2014 (note that these results are not limited to upland forest communities and also incorporate riparian community plots for some parks, including Bluestone National Scenic River). Error bars represent one standard error above and below the mean (Perles et al. 2016).

In xeric habitats within BLUE, tree mortality rates were highest for scarlet oak (*Quercus coccinea* var. *coccinea*), eastern hemlock, black oak (*Q. velutina*), eastern white pine, white oak (*Q. alba*), and red maple (*Acer rubrum* var. *rubrum*) (Figure 9) (Perles et al. 2016). In mesic habitats, mortality rates were highest in black locust (*Robinia pseudoacacia*), eastern white pine, eastern redbud (*Cercis canadensis* var. *canadensis*), and northern red oak (*Q. rubra*) (Figure 10). In mesic habitats, three tree species showed annual mortality rates >4%, while the highest mortality rate in xeric habitats was just above 3.5% (Perles et al. 2016).

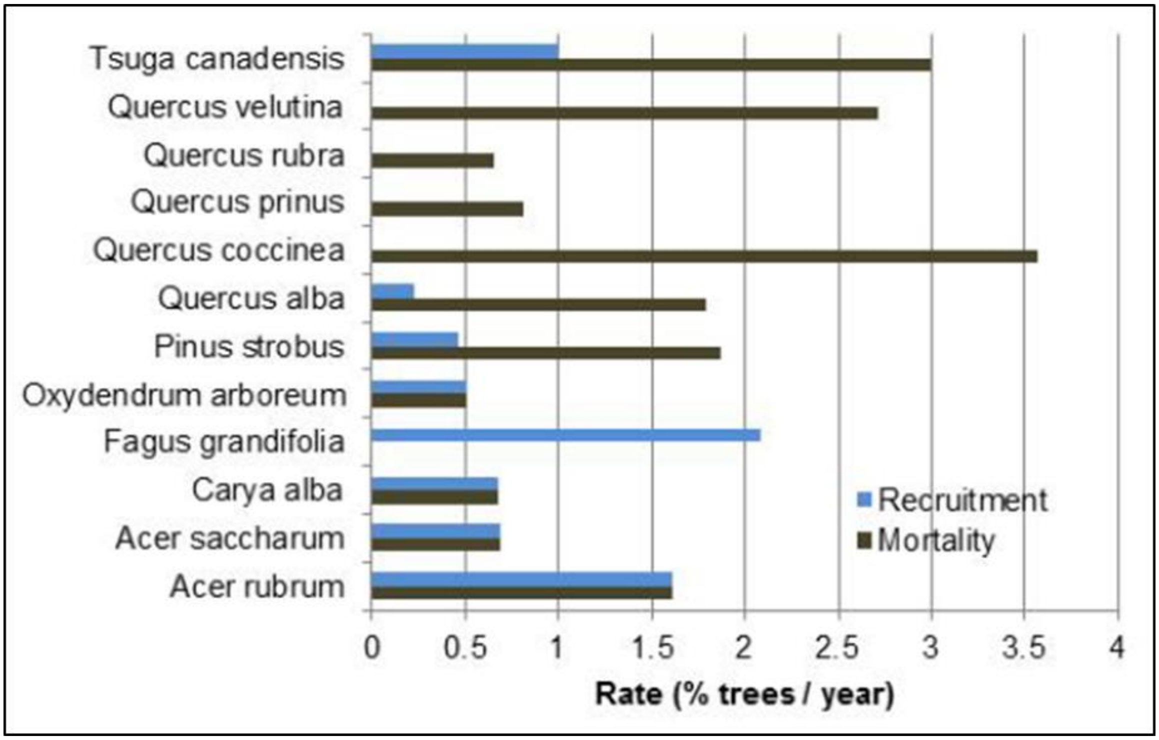


Figure 9. Mortality and recruitment rates (percent/year) through 2014 for common tree species in xeric habitats at Bluestone National Scenic River (Perles et al. 2016) (*Quercus prinus* = *Q. montana*).

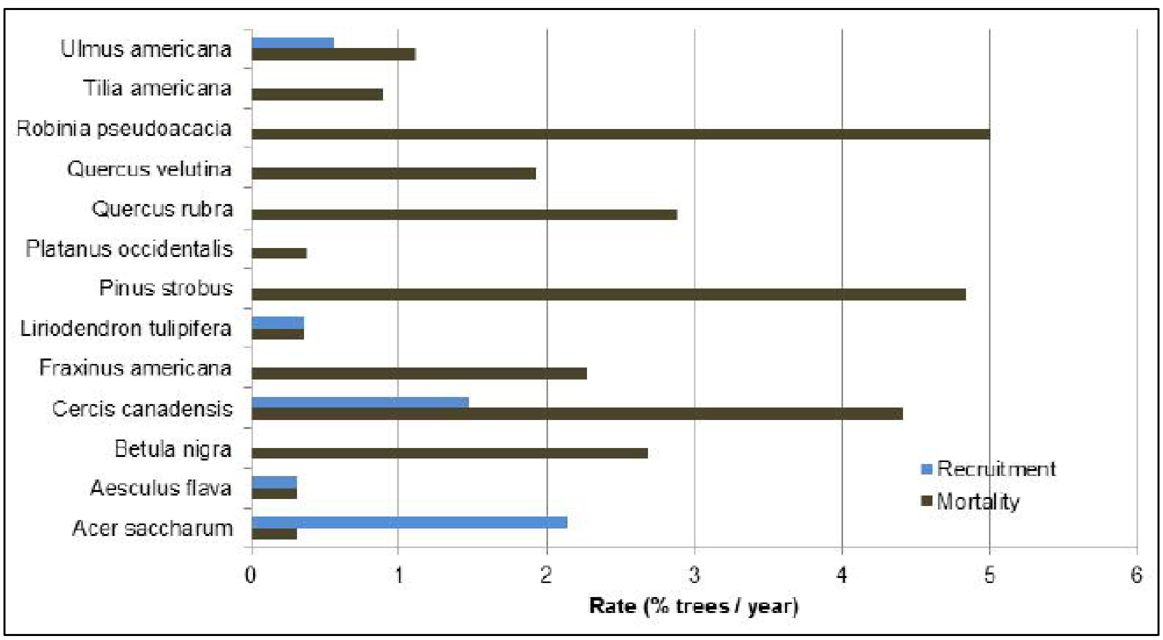


Figure 10. Mortality and recruitment rates (percent/year) through 2014 for common tree species in mesic habitats at Bluestone National Scenic River (Perles et al. 2016). Note that these results are not limited to upland forest communities and also include eight riparian community plots.

Recruitment

From 2013-2016, annual tree recruitment rates in BLUE upland forest monitoring plots ranged from 0-4.2%/year, with a mean of 0.7%/year (SD = 0.95%) (ERMN 2017). In comparison, nearby NERI showed a tree recruitment rate of approximately 0.9%/year (Perles et al. 2016). BLUE tree recruitment was similar during the previous monitoring cycle (2009-2012) at approximately 0.6%/year (Perles et al. 2014b).

The highest species annual recruitment rates in BLUE's xeric habitats were shown by American beech (*Fagus grandifolia*), red maple, and eastern hemlock (Figure 9) (Perles et al. 2016). However, annual recruitment rate only matched the mortality rate for red maple, and recruitment was three times lower than the mortality rate for eastern hemlock. Recruitment was notably absent among scarlet oak, black oak, chestnut oak (*Q. montana*), and northern red oak. In mesic habitats, annual recruitment rate was highest for sugar maple and eastern redbud, although the eastern redbud recruitment rate was less than half the annual mortality rate (Figure 10). No recruitment was noted for black locust, eastern white pine, river birch, green ash (*Fraxinus pennsylvanica*), northern red oak, and black oak (Perles et al. 2016).

Tree Mean Annual Diameter Increment

The ERMN (2017) has calculated MADI by comparing tree DBH measurements collected during the 2007-2010 sampling period to measurements from the 2011-2014 sampling period. Over this time, BLUE experienced the lowest MADI of the three West Virginia parks, at 0.21 cm/year (Figure 11). This falls slightly below the expected MADI range for Appalachian forests of 0.25-0.40 cm/year (Runkle 1998, 2000, Perles et al. 2016).

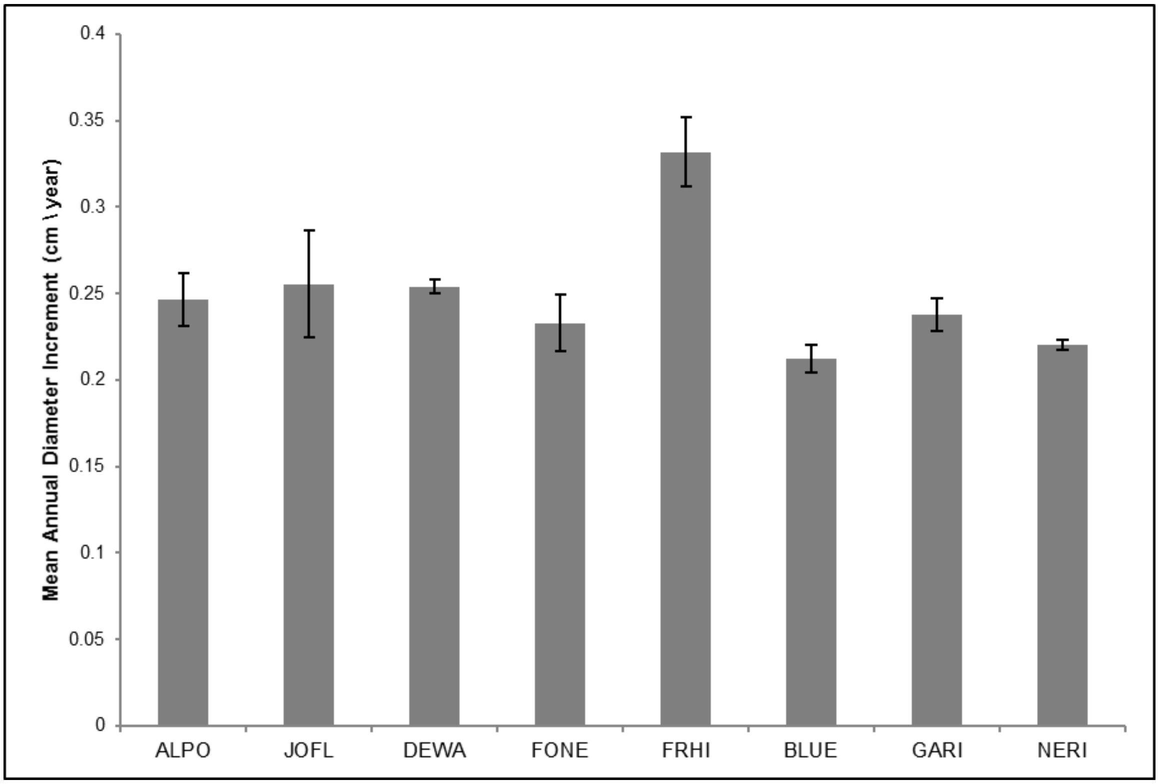


Figure 11. Mean annual diameter increments (± standard error) by Eastern Rivers and Mountains Network park, based on growth between the 2007-2010 and 2011-2014 sampling periods (ERMN 2017). Note that these are based on all forest monitoring plots, not strictly upland forests (at Bluestone National Scenic River, 32 of the 40 plots are in upland forests). The three West Virginia parks (Gauley River National Recreation Area, New River Gorge National River, and Bluestone National Scenic River) are on the far right of the graph.

Threats and Stressor Factors

Threats to BLUE's upland forests include exotic invasive species (plants and pests/pathogens), deer browsing, forest fragmentation, fire suppression, extreme weather events, and climate change. As mentioned in Chapter 2, exotic invasive species pose a serious threat to vegetation communities worldwide, due to their ability to compete with native plants and disrupt ecosystem processes, such as nutrient cycling and disturbance regimes (Mooney et al. 2005, Perles et al. 2014b). For example, the invasive Japanese stiltgrass (*Microstegium vimineum*) can form a dense, monospecific understory in temperate forests, severely inhibiting tree regeneration (Rentch 2006). Although invasive cover averages 1.6% across BLUE's upland forest (ERMN 2017), invasive cover has exceeded 10% in some of the park's successional forest types (Vanderhorst et al. 2008). One exotic wildlife species, the feral hog (*Sus scrofa*), is also a threat to vegetation in the region.

Native and exotic insect, fungal, and bacterial pests pose serious threats to forests across the eastern U.S., including the upland forests of BLUE. These pests are capable of altering plant community structure and composition, as well as reducing overall species diversity (Keefer 2009). Potential exotic insect threats to the park's upland forests include hemlock wooly adelgid (HWA), emerald ash borer (EAB), and gypsy moth (Perles et al. 2016).

The EAB infests only ash tree species and is always fatal, although it may take 1-3 years for trees to die (APHIS 2009). An early sign of EAB infestation is dead upper branches; in later stages, bark sloughs off to reveal S-shaped tunnels formed by feeding EAB larvae. EAB was first detected within BLUE boundaries on two trees in August 2014 (Manning 2016) and has spread since. Infestations are not typically treated because no cost-effective treatments for large numbers of trees are currently available (Manning 2016). However, during 2014-2015, NPS staff treated 303 ash trees in globally rare vegetation communities and riparian areas with the insecticide emamectin (Layne Strickler, NERI/GARI/BLUE Biological Science Technician, written communication, June 2017). In 2015, just over 37,200 ha (92,000 ac) of West Virginia forests were impacted by EAB mortality (USFS and WVDA 2016). EAB is considered pervasive at BLUE and has resulted in heavy mortality of green and white ash (*Fraxinus americana*) trees (Perez, email communication, 20 April 2017).

The HWA, an aphid-like insect, was first observed in the eastern U.S. in Virginia during the early 1950s (Wood et al. 2009). HWA feeds at the base of hemlock needles, depleting xylem cells of nutrients and desiccating the needles (McClure et al. 2001). The resulting needle loss prevents trees from generating new apical buds, where new growth occurs. Limb dieback can occur within 2 years, with tree mortality occurring in as little as 4 years from the initial infestation (McClure et al. 2001). HWA can be spread by wind, wildlife, or human activity.

Hemlock woody adelgid was first detected in BLUE during April of 2000 (Strickler 2014). Monitoring of hemlocks in GARI and NERI show declining crown vigor and increasing tree mortality since initial HWA infestations, with highest impacts in xeric forests (Strickler 2014). Although hemlock health has not been monitored at BLUE, park staff have observed significant decline of hemlocks within BLUE (Perez, written communication, June 2017). Since 2006, park management has been chemically treating certain hemlock areas within BLUE by applying insecticides to individual trees. Infestation rates have been calculated by inspecting 10 branches on five treated and five untreated (control) trees. Up to 10 wooly masses from HWA are recorded per branch and the total number of masses added up to provide an infestation rating from 0-100 (Strickler 2014). Infestation ratings and other measures of tree vigor show that insecticide treatment appears to be effective in stabilizing or even increasing the health of hemlock trees within infested areas. Infestation ratings at BLUE improved from nearly 50% in 2012-2013 to just above 10% in 2014-2015, and dropped below 10% in 2016 (Strickler 2016). However, chemical treatment is a resource-intensive process (i.e., staff time and chemical cost) and is considered a temporary solution (Strickler 2014). NPS staff are studying the potential of biocontrol with beetles that prey on HWA; insects have been released at GARI and NERI (Strickler 2014), and could be used at BLUE if found to be effective.

Gypsy moth infestation does not cause direct mortality but increases a tree’s vulnerability to other stressors (e.g., disease, other pests) (Hoover 2001). Oaks are the primary host for this moth, but it will also feed on basswood, poplars, willows, and other hardwoods (Weese 1992, Hoover 2001). In West Virginia in 2015, gypsy moths defoliated approximately 40,450 ha (100,000 ac) of forest, primarily in the eastern portion of the state (USFS and WVDA 2016). Gypsy moths have been present in low abundance at BLUE as far back as the 1990s (Weese 1992), but cause little defoliation and have not contributed to any known tree mortality (John Perez, NERI/GARI/BLUE Biologist, email communication, 20 April 2017).

Excessive browsing by white-tailed deer can inhibit forest regeneration and negatively affect some rare plant populations (Rentch 2006, Marshall and Piekielek 2007a, Perles et al. 2014b). For example, deer herbivory at BLUE is threatening two rare species: American fly honeysuckle (*Lonicera canadensis*) and American barberry (*Berberis canadensis*) (Streets et al. 2008). According to Rentch (2006), selective deer browsing can alter forests by contributing to tree regeneration failures, changes in species composition, and changes in forest structure (e.g., woody species density and height, herbaceous species abundance and height. These changes can result in "habitat simplification", where the forest understory is dominated by a small number of species unpalatable to deer (Rentch 2006). Deer browsing may be contributing to poor oak regeneration in eastern hardwood forests (Lorimer 1993).

Forest fragmentation has been occurring in the region around BLUE since commercial logging began in the late 1800s, aided by the 1872 construction of the Chesapeake and Ohio Railroad in Summers County (Rentch et al. 2005, Vanderhorst et al. 2008). Large commercial timber harvests continued through the 1940s and 1950s (Rentch et al. 2005). Fragmentation creates barriers to species dispersal, which can influence interspecific interactions, genetic and species diversity, and species density and abundance (Rentch 2006). Recreational trails, transportation corridors (roads and railways), and pipeline corridors also fragment the landscape, exposing the forest edges to additional threats such as exotic species invasion and exposure to harsh weather conditions (Rentch 2006, Perles et al. 2014b).

Prior to European settlement, fires were common in much of the eastern U.S., and helped to maintain the open character of oak-dominated hardwood forests (Van Lear and Waldrop 1989, Nowacki and Abrams 2008). However, fires were largely suppressed on public lands throughout the 20th century (Van Lear and Waldrop 1989). As a result, eastern forests (including BLUE's ridge top xeric forests) are denser now than they were historically, particularly in the understory (Nowacki and Abrams 2008). The increased density, particularly in the understory, likely inhibits oak regeneration and may be reducing native herbaceous plant species diversity (Lorimer 1993, Royo and Carson 2006).

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the ERMN (Davey et al. 2006). Climate affects the spread of invasive plant species and pathogens as well, which also threaten BLUE's upland forests (Fisichelli et al. 2014). As a result of global climate change, temperatures are projected to increase across the eastern United States over the next century (Horton et al. 2014). Warming temperatures will likely allow invasive plants and forest pests to expand their ranges and potentially their impact, as well as altering the habitat suitability of certain areas for some tree species (Fisichelli et al. 2014). As the impacts of climate change and related stressors compound over time, forests will experience more widespread changes in tree species composition, with cascading effects on other plants and wildlife (Fisichelli et al. 2014). In an effort to estimate the magnitude of potential change that forests on eastern NPS lands may experience, Fisichelli et al. (2014) assessed the percentage of tree species expected to show large decreases or large increases in habitat suitability under climate change scenarios. Across 121 NPS properties in the eastern U.S., estimated potential forest change (i.e., percent of tree species expected to experience large increases or decreases in habitat suitability) ranged from 22-77%. The estimated forest change for BLUE was 62% (Fisichelli et al. 2014). Habitat suitability projections for several of BLUE's key upland tree species are shown in Table 13.

Table 13. Potential change in habitat suitability by 2100 for select Bluestone National Scenic River upland tree species based on two future climate scenarios (the "least change" scenario represents strong cuts in greenhouse gas emissions and modest climatic changes, the "major change" scenario represents continued increasing emissions and rapid warming). Reproduced from Fisichelli (2015).

Scientific Name	Common Name	Least Change Scenario	Major Change Scenario
Acer pensylvanicum	striped maple	large decrease	large decrease
Acer rubrum	red maple	no change	large decrease
Acer saccharum	sugar maple	no change	large decrease
Betula lenta	sweet birch	small decrease	large decrease
Carya cordiformis	bitternut hickory	no change	large increase
Carya ovata	shagbark hickory	small increase	large increase
Celtis occidentalis	hackberry	small decrease	large increase
Cercis canadensis	eastern redbud	small increase	large increase
Juniperus virginiana	eastern redcedar	large increase	large increase
Liriodendron tulipifera	tuliptree	small increase	large decrease
Pinus strobus	eastern white pine	small decrease	large decrease
Quercus coccinea	scarlet oak	no change	large decrease
Quercus muehlenbergii	chinkapin oak	small increase	large increase
Quercus montana	chestnut oak	no change	large decrease
Robinia pseudoacacia	black locust	no change	large decrease
Tilia americana	American basswood	small decrease	large decrease
Ulmus rubra	slippery elm	small increase	large increase
Carya texana	black hickory	–	new habitat
Maclura pomifera	osage-orange	–	new habitat
Pinus elliotti	slash pine	–	new habitat
Pinus taeda	loblolly pine	new habitat	new habitat
Quercus marilandica	blackjack oak	–	new habitat
Ulmus alata	winged elm	new habitat	new habitat

Climate change may also alter the frequency and intensity of extreme weather events that already threaten BLUE's forests, such as tornadoes/wind storms, ice storms, and droughts (Dale et al. 2001, Rentch 2006). During the summer of 2012, a severe storm with high winds (called a derecho) passed north of BLUE, causing extensive damage to the forests at GARI (NWS 2012, Perles et al. 2016). So many trees fell that a slight decrease in live tree basal area was detected the following year. The canopy gaps opened by such storms provide opportunities for fast-growing invasive plant species, such as tree-of-heaven (*Ailanthus altissima*), which often out-compete native species that typically would regenerate in these openings (Perles et al. 2016). While the connections are not yet clear, evidence suggests that the storm conditions contributing to tornado formation have increased with warming temperatures and will continue to do so under projected future climate changes (Dale et al. 2001). The warmer temperatures associated with climate change are also likely to increase the survival, reproduction, and dispersal/distribution of some forest pests and pathogens (Dale et al. 2001). An increase in drought frequency and/or intensity as a result of climate change would likely make forests more vulnerable to these pests and pathogens (Dale et al. 2001).

Data Needs/Gaps

Prior to the 1990s, very little scientific information was gathered regarding the vegetation within current BLUE boundaries. Several surveys during the 1990s and the ERMN vegetation monitoring program have begun to address these data gaps and should continue. Additional research is needed into the current poor oak regeneration and factors that are contributing to it (Perles et al. 2010). This should include adaptive management experiments to monitor the impacts of fire, browsing (using exclosures), and canopy thinning on regeneration (Perles et al. 2014b). Lastly, little is known about the area's soil biota (e.g., invertebrates, fungi, bacteria) and the critical role they play in ecological processes that influence forest health (e.g., decomposition, nutrient cycling, mineralization) (Rentch 2006).

Overall Condition

Community Extent

The NRCA project team assigned this measure a *Significance Level* of 3. Upland forests and woodlands currently cover approximately 85% of the total park area (Vanderhorst et al. 2008). Given that there is little to no evidence that this extent is declining, this measure is assigned a *Condition Level* of 0, for no current concern.

Plant Species Richness

The species richness measure was also assigned a *Significance Level* of 3. BLUE's upland forests are particularly diverse, with 541 different plant taxa observed across various survey efforts. There is some concern that the number and proportion of exotic species may be increasing over time. Currently, 8.5% of all plant taxa documented are considered exotic (Appendix A). Therefore, this measure is assigned a *Condition Level* of 1.

Rare Plant Element Occurrences

A *Significance Level* of 3 was assigned for this measure. Nineteen rare plant species have been documented in BLUE's upland forest communities (Table 11), but information on the number of EOs within park boundaries is limited. No recent information on the condition (i.e., viability) of rare species EOs could be found. As a result, a *Condition Level* has not been assigned for this measure.

Proportion of Total Cover of Exotic Plants and Invasive Plants

The NRCA project team assigned this measure a *Significance Level* of 3. The average proportion of total cover in exotic species in upland forest plots is 1.9% (SD = 4.2%), and cover in invasive species is 1.6% (SD = 4.1%). Compared to other parks within ERMN, BLUE shows a higher proportion of invasive species cover park-wide than the two other parks in West Virginia, but a much lower proportion of invasive cover than four of the five parks in Pennsylvania (Perles et al. 2014b). At this time, this measure is considered of low concern for the park's upland forests (*Condition Level* = 1).

Tree Mortality

This measure was assigned a *Significance Level* of 3 as well. From 2013-2016, the mean annual tree mortality rate in BLUE upland forest monitoring plots was 1.7%/year (ERMN 2017). This is slightly higher than reported rates for other eastern forests, which ranged from 0.3-1.6%/year, and a small increase from the 2009-2012 rate of ~1.4% (Perles et al. 2014b, 2016). Several individual tree species experienced annual mortality rates >3.5% (Figure 9, Figure 10). Therefore, tree mortality is assigned a *Condition Level* of 2, indicating moderate concern.

Recruitment

The recruitment measure was assigned a *Significance Level* of 3. The 2013-2016 mean annual tree recruitment rate for BLUE upland forest monitoring plots (0.7%/year) was lower than nearby NERI's rate (~0.9%) and less than half of the park's annual tree mortality rate (ERMN 2017). Several key tree species showed no recruitment at all, including scarlet, black, chestnut, and northern red oak (Perles et al. 2016). As a result, this measure is of moderate concern (*Condition Level* = 2).

Tree Mean Annual Diameter Increment

This final measure was also assigned a *Significance Level* of 3. The MADI calculated for BLUE based on ERMN monitoring (0.21 cm/year) was the lowest of all three West Virginia parks and slightly below the range expected for Appalachian forests (0.25-0.40 cm/year) (Perles et al. 2016). Therefore, this measure is assigned a *Condition Level* of 2.

Weighted Condition Score

The *Weighted Condition Score* for BLUE's upland forest communities is 0.44, which indicates moderate concern (Table 14). Given that data and information for the selected measures is somewhat limited, a trend has not been assigned and a moderate confidence border is applied.

Table 14. Current condition of Bluestone National Scenic River's Upland Forest Communities.

Measures	Significance Level	Condition Level	WCS = 0.44
Community Extent	3	0	
Plant Species Richness	3	1	
Rare Plant EOs	3	n/a	
Exotic & Invasive Cover	3	1	
Tree Mortality	3	2	
Recruitment	3	2	
Mean Ann. Diameter Increment	3	2	

4.1.6. Sources of Expertise

- John Perez, NERI/GARI/BLUE Biologist
- Stephanie Perles, ERMN Plant Ecologist
- Layne Strickler, NERI/GARI/BLUE Biological Science Technician

4.2. Riparian Vegetation Communities

4.2.1. Description

Riparian and wetland vegetation communities cover just 8% of BLUE, but contribute significant biological diversity to the park (Vanderhorst et al. 2008). These riparian areas are primarily wooded, with species such as eastern hemlock, American sycamore (*Platanus occidentalis*), and river birch, but include some open areas with herbaceous vegetation, particularly where flooding disturbance is frequent. The park's riparian areas support high plant diversity and a number of rare species, including the federally-threatened Virginia spiraea (Norris 1992, Vanderhorst et al. 2008). The ERMN identified vegetation and soils as high priorities for long-term monitoring as part of the Vital Signs program (Marshall and Piekielek 2007a, Perles et al. 2010). The condition of vegetation communities often provides insight into overall terrestrial ecosystem health (Perles et al. 2010).

Vegetation classification and mapping efforts at BLUE identified 10 unique riparian vegetation community types occurring within park boundaries (Vanderhorst et al. 2008). These types (or "associations") and the prominent or characteristic plant species in BLUE stands are presented in Table 15. One of these vegetation associations, the Oak-Hickory Floodplain Forest, is ranked as critically imperiled globally (G1) by NatureServe (2011).

A Sycamore-River Birch Riverscour Woodland within the riparian area of Bluestone National Scenic River (Vanderhorst et al. 2008).

Table 15. Riparian vegetation associations documented within Bluestone National Scenic River and the most prominent plant species in each (Vanderhorst et al. 2008). * denotes exotic species.

Vegetation Community	Prominent Plant Species
Eastern Hemlock Floodplain Forest	eastern hemlock, red maple, northern red oak, great laurel
Oak – Hickory Floodplain Forest	tuliptree, northern red oak, black oak, American hornbeam (Carpinus caroliniana ssp. virginiana), American witchhazel (Hamamelis virginiana)
River Birch Backwater Floodplain Forest	red maple, green ash, American sycamore, river birch, northern spicebush, multiflora rose*
Successional Eastern Redcedar Woodland	eastern redcedar, tuliptree, European privet (Ligustrum vulgare)*, northern spicebush, multiflora rose*
Riverbank Tall Herbs	river birch, tuliptree, American sycamore, eastern poison ivy (Toxicodendron radicans), smallspike false nettle (Boehmeria cylindrica), giant goldenrod (Solidago gigantea), wingstem (Verbesina alternifolia), deertongue (Dichanthelium clandestinum)
Successional Black Walnut Floodplain Forest	black walnut, pawpaw (Asimina triloba), northern spicebush
Successional Boxelder Floodplain Forest	boxelder (Acer negundo var. negundo)
Sycamore – Ash Floodplain Forest	green ash, American sycamore, American elm (Ulmus americana), northern spicebush
Sycamore – River Birch Riverscour Woodland	river birch, American sycamore
Sycamore – Yellow Buckeye Floodplain Forest	American sycamore, yellow buckeye, northern spicebush

4.2.2. Measures

- Riparian vegetation community extent
- Plant species richness
- Rare plant element occurrences
- Proportion of total cover of exotic plants and invasive plants

4.2.3. Reference Condition/Values

As with upland forests, identifying reference conditions for riparian communities are challenging, as little historical information is available on vegetation within BLUE. For the purposes of this assessment, current condition will be assessed based on comparisons to similar forests in other ERMN parks and on best professional judgement. The information presented here could serve as a baseline for future assessments.

4.2.4. Data and Methods

The majority of sources utilized for the upland forest communities component will also be used for this component. These include Oxley (1975), Norris (1992), Grafton (1993), Fortney et al. (1995), Vanderhorst et al. (2008), Streets et al. (2008), and Perles et al. (2010, 2014b, 2016). A discussion of the methodology of those studies can be found in the upland forest communities component (Chapter 4.1).

4.2.5. Current Condition and Trend

Riparian Vegetation Community Extent

The Vanderhorst et al. (2008) vegetation map shows that riparian vegetation communities cover just 146 ha (361 ac) of BLUE (Figure 12, Figure 13). The most extensive community was Modified Successional Floodplain Forest and Woodland (81 ha [201 ac]), a complex map class which includes seven vegetation associations (River Birch Backwater Floodplain Forest, Riverbank Tall Herbs, Successional Black Walnut Floodplain Forest, Successional Box-elder Floodplain Forest, Successional Eastern White Pine - Tuliptree Forest, Successional Tuliptree/Northern Spicebush Forest, and Sycamore - Ash Floodplain Forest) (Table 16). The smallest community, at just 1.6 ha (4.0 ac), was Successional Eastern Redcedar Woodland (Vanderhorst et al. 2008).

Table 16. Riparian vegetation extent at Bluestone National Scenic River by vegetation community type (reproduced from Vanderhorst et al. 2008).

Vegetation Community	Area in ha (ac)
Eastern Hemlock Floodplain Forest	2.9 (7.2)
Floodplain Forest and Woodland	57.1 (141.1)
Modified Successional Floodplain Forest and Woodland	81.3 (201.0)
Successional Eastern Redcedar Woodland	1.6 (4.0)
Sycamore – River Birch Riverscour Woodland	3.2 (7.8)
Total riparian vegetation community	146.2 (361.2)

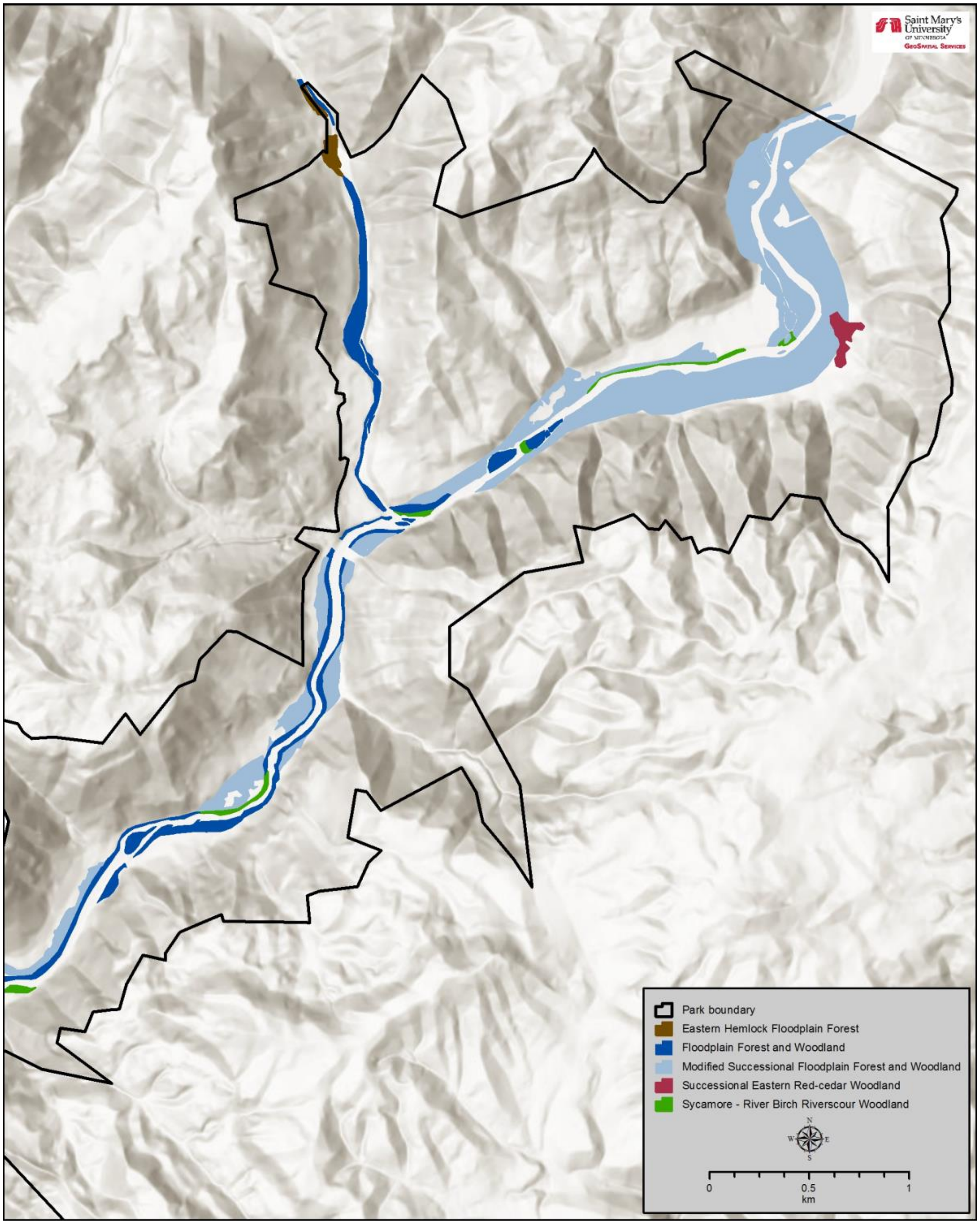


Figure 12. The extent of riparian vegetation community types within the northern portion of Bluestone National Scenic River (Vanderhorst et al. 2008).

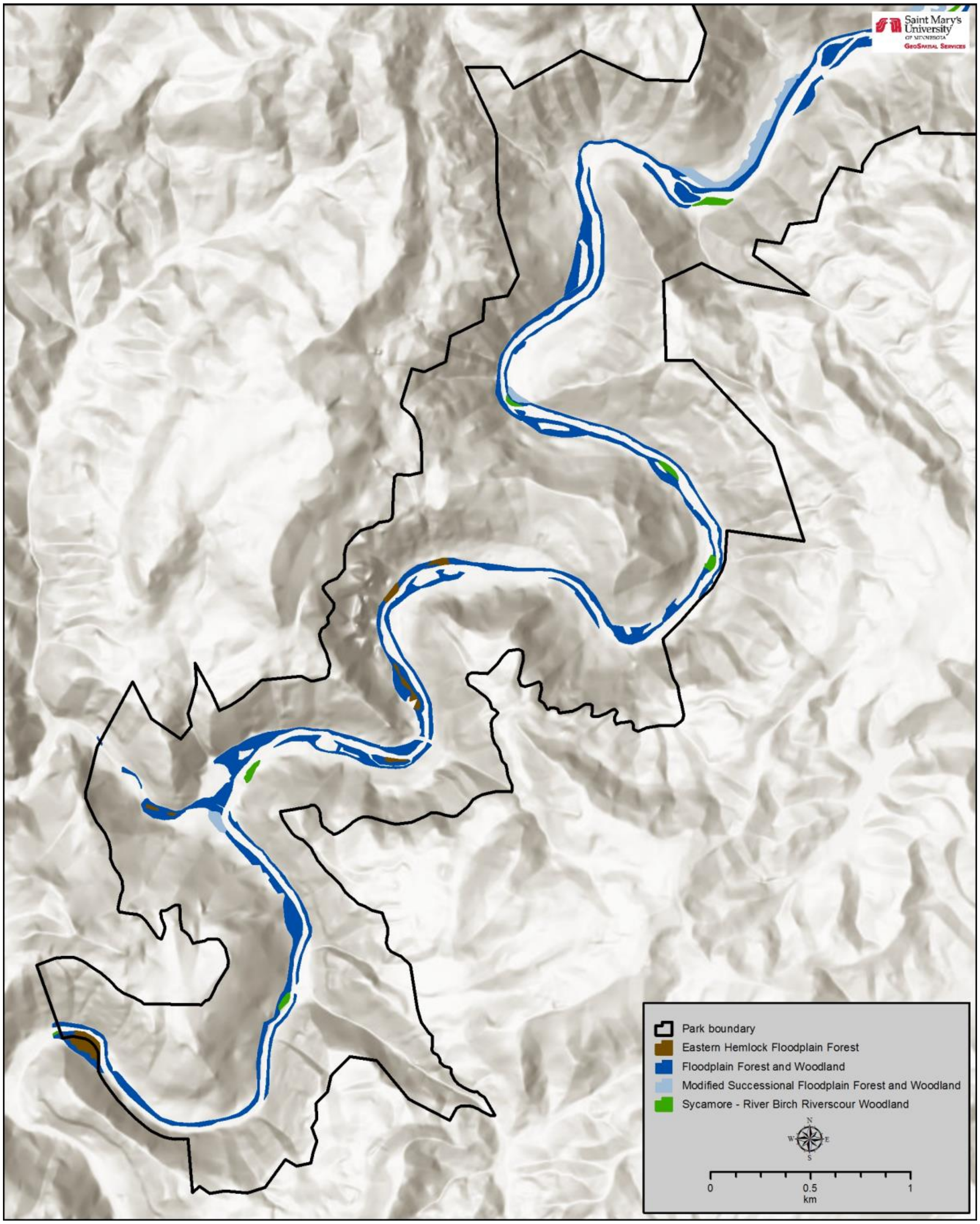


Figure 13. The extent of riparian vegetation community types within the southern portion of Bluestone National Scenic River (Vanderhorst et al. 2008).

Plant Species Richness

Vanderhorst et al. (2008) documented 377 plant taxa (including subspecies and varieties) within BLUE's riparian vegetation communities (Appendix B). Forty-nine of these species (13%) are considered exotic. The greatest total number of plant species was documented in the Sycamore - River Birch Riverscour Woodland, with 245 species (Table 17). However, this may be related to the relatively high number of plots sampled within this community, as the Sycamore - River Birch Riverscour Woodland had the lowest mean number of species per plot at 17.5. The highest mean number of species per plot (total species per community divided by total number of plots) was 45.3 in the Oak - Hickory Floodplain Forest.

Table 17. Plant species richness by riparian vegetation community type at Bluestone National Scenic River, as documented by Vanderhorst et al. (2008).

Vegetation Community	# of Plots	# of Species	Mean Species/Plot
Eastern Hemlock Floodplain Forest	1	31	31
Oak – Hickory Floodplain Forest	3	136	45.3
River Birch Backwater Floodplain Forest	6	113	18.8
Riverbank Tall Herbs	7	153	21.9
Successional Black Walnut Floodplain Forest	3	60	20
Successional Box-elder Floodplain Forest	1	36	36
Sycamore – Ash Floodplain Forest	1	30	30
Sycamore – River Birch Riverscour Woodland	14	245	17.5
Sycamore – Yellow Buckeye Floodplain	3	114	38

During 2007-2016 ERMN forest monitoring, 265 plant species have been documented across eight sampling plots (Appendix B) (ERMN 2017). Thirty-eight of these species (14.3%) are considered exotic. Cumulatively, a total of 459 different taxa have been found in BLUE's riparian vegetation communities over time (see Appendix B). This is only 82 fewer species than the number documented in BLUE's upland forests (541), which cover 10 times as much area as the riparian vegetation communities. Sixty-six species (14.4%) are exotic, a higher percentage than in upland forest communities (8.5%).

Rare Plant Element Occurrences

According to Streets et al. (2008), 20 rare plant species have been confirmed in BLUE's riparian vegetation communities (Table 18). As in the upland forests, several of these species were first documented in the park during the Streets et al. (2008) 2003-2006 inventory. Norris (1992) only observed five of these species, and the number of occurrences for each species ranged from one to eight (Virginia spiraea). Only one EO per species was reported by Streets et al. (2008), with the exception of smooth hedgenettle (*Stachys tenuifolia*), which had two EOs. The number of EOs decreased between these two reports for two species: butternut (from four EOs to one) and Virginia spirea (from eight EOs to one) (Table 18). Given the limited data, small overall number of occurrences, and difficulty in locating many rare species, it is not practical to conclude whether these changes represent a trend of concern or are due to natural variation and/or differences in survey intensity. During regular forest monitoring by ERMN since 2007, three of these rare species have been observed in sampling plots (Table 18) (ERMN 2017).

Table 18. Documented rare plant occurrences at Bluestone National Scenic River riparian areas. Norris (1992) reported the number of personal observations during a thorough park survey. Streets et al. (2008) reported the number of element occurences in the Biotics database as of 31 May 2007. The Eastern Rivers and Mountains Network (2017) column represents species observed during routine forest monitoring (i.e., opportunistic, not a targeted search) since 2007.

Scientific Name	Common Name	State Rank[a]	Norris (1992)	Streets et al. (2008)	ERMN 2007-2016
Anemone canadensis	Canada anemone	S1	1	1	–
Anemone quinquefolia var. minima	nightcaps	S2	–	1	–
Calycanthus floridus var. glaucus	eastern sweetshrub	SH	–	1	–
Cardamine flagellifera	Blue Ridge bittercress	S2	–	1	–
Carex aggregata	glomerate sedge	S2	–	1	–
Carex emoryi	Emory's sedge	S2	1	1	–
Carex hirtifolia	pubescent sedge	S2	–	1	–
Carex tenera	quill sedge	S1	–	1	–
Carex typhina	cattail sedge	S2	–	1	–
Eleocharis palustris	common spikerush	S3	1	1	–
Juglans cinerea	butternut	S3	4	1	–
Juncus dichotomus	forked rush	S1	–	1	–
Lemna valdiviana	Valdivia duckweed	S3	–	1	–
Ribes lacustre	prickly currant	S2	–	1	–
Senecio (Hasteola) suaveolens	false Indian plantain	S3	–	1	X
Spiraea virginiana	Virginia spiraea	S1	8	1	–
Stachys cordata (S. nuttallii)	heartleaf hedgenettle	S3	–	1	X
Stachys tenuifolia	smooth hedgenettle	S3	–	2	X
Taxus canadensis	Canada yew	S2S3	–	1	–
Vitis rupestris	sand grape	S2	–	1	–

[a] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation, SH = state historical, has not been relocated within the last 20 years.

Proportion of Total Cover of Exotic Plants and Invasive Plants

The Vanderhorst et al. (2008) report includes mean percent cover estimates by plant species for each vegetation community identified within the park. Within the nine riparian vegetation community types, mean *exotic* plant species cover ranged from 0% in Eastern Hemlock Floodplain Forest (only one plot sampled) to 47.4% in the Riverbank Tall Herbs community. Exotic plant cover in six of the nine community types exceeded 10% (Vanderhorst et al. 2008). The highest *invasive* plant cover was 36.5% in Successional Box-elder Floodplain Forest. Exotic and invasive species percent covers for all riparian vegetation communities are shown in Table 19.

Table 19. Mean exotic and invasive plant species cover by riparian vegetation community type within at Bluestone National Scenic River (Vanderhorst et al. 2008).

Vegetation Community	# of Exotic Species	Mean % Exotic Cover	Mean % Invasive Cover
Riverbank Tall Herbs	30	47.4	36.4
Successional Box-elder Floodplain Forest	4	36.5	36.5
River Birch Backwater Floodplain Forest	12	31	31
Sycamore - River Birch Riverscour Woodland	36	22.1	19.2
Successional Black Walnut Floodplain Forest	4	14.5	14.5
Sycamore - Yellow Buckeye Floodplain Forest	11	12.3	11.8
Oak - Hickory Floodplain Forest	5	5.5	5.5
Sycamore - Ash Floodplain Forest	3	1.5	1.5
Eastern Hemlock Floodplain Forest	0	0	0

The ERMN forest monitoring program has documented exotic and invasive plant cover in eight riparian community plots within BLUE. Based on 2013-2016 data, the average proportion of total cover in native species was 67.1% (SD = 11.8%) (ERMN 2017). The average proportion of total cover in exotic species is 16.5% (SD = 7.9%), and cover in invasive species is 14.1% (SD = 8.9%). These proportions are much higher than in BLUE's upland forest communities, where exotic and invasive species covers averaged 1.9% and 1.6%, respectively (ERMN 2017). This may be related to the fact that historic human use in the area (and therefore disturbance) tended to be near the Bluestone River, for ease of access to a reliable water source. Riparian areas also typically experience more frequent natural disturbance (e.g., flooding) and have more hospitable soils than xeric upland forests (Stephanie Perles, ERMN Plant Ecologist, written communication, May 2017).

<u>Threats and Stressor Factors</u>

The project team identified the following threats to the park's riparian vegetation communities: exotic invasive species (plants and pests/pathogens), mowing regimes for wildlife management, potential recreational development, climate change, and river flow/flood management via the Bluestone Dam. Human activity in the park floodplain prior to Bluestone Dam construction in 1949 caused disturbance to the vegetation communities (e.g., clearing for settlement and agriculture), including the introduction of exotic plant species (Vanderhorst et al. 2008). Shortly after park establishment, Norris (1992) noted that many exotic plants were present, and invasive species such as multiflora rose were the dominant plants in some areas. According to recent ERMN (2017) monitoring, the average cover of invasive plant species in BLUE's riparian communities (14.1%) is much higher than in the park's upland forests (1.6%). The river itself and recreational trails near the floodplain may serve as pathways for the invasion and spread of these exotic species (Richardson et al. 2007, Perles et al. 2014b).

Many of the forest pests that threaten BLUE's uplands also impact the riparian communities, particularly EAB and HWA. In addition, butternut trees in the floodplain are threatened by butternut canker. This fungal disease is currently decimating butternut populations throughout their range and may have already extirpated the species in some southern states (Schlarbaum et al. 1998). The decline has been so severe that the U.S. Fish and Wildlife Service (USFWS) has listed butternut as a species of federal concern (Schlarbaum et al. 1998).

Since the construction of the Bluestone Dam and subsequent creation of Bluestone Lake downstream of BLUE, reservoir waters occasionally back up into the park and flood the lower reaches of the Bluestone and Little Bluestone Rivers (Norris 1992, Vanderhorst et al. 2008). These events typically occur during the winter or early spring (outside the growing season) and may be short enough in duration that there is little impact on existing vegetation (Norris 1992, Vanderhorst et al. 2008). However, inundation during the growing season can kill or reduce the growth of plants, potentially opening up areas for the opportunistic establishment of exotic invasive plant species (Richardson et al. 2007).

The West Virginia Division of Natural Resources (WV DNR) owns and manages several parcels of land within BLUE's legislative boundary. As part of their objective to maintain wildlife habitat and create hunting opportunities for state residents, the WV DNR mows some areas within the floodplain towards the north end of the park (Vanderhorst et al. 2008). However, these open areas tend to be weedy and offer opportunities for invasive plant species to become established (Vanderhorst et al. 2008; Perez, personal communication, October 2016). The openings also fragment the floodplain forest, exposing the forests to the risks associated with fragmentation (e.g., exposure to harsh weather conditions, alterations to interspecific interactions, etc.) (Rentch 2006).

Recreational use within the park's riparian areas has been somewhat limited to date due to its relative remoteness. However, the Bluestone Turnpike Trail is accessible from Pipestem Resort State Park's Mountain Creek Lodge, which lies at the base of the aerial tramway that travels up to the main resort area (Figure 14) (NPS 2016e). This trail parallels the Bluestone River for 15.3 km (9.5 mi) on the path of a historic riverbank road, and also connects to Bluestone State Park's Campground Road on its north end. Additional recreational development and/or increased visitation at these state parks could contribute to increased use of the Turnpike Trail within BLUE.

Figure 14. The aerial tramway at Pipestem Resort State Park (WV DNR photo).

As noted in the previous chapter, climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the ERMN (Davey et al. 2006). As with the upland forests, warming temperatures will alter the habitat suitability of certain areas for some riparian tree species (Fisichelli et al. 2014). Habitat suitability projections for several key riparian tree species are shown in Table 20. Higher temperatures also increase evaporation and transpiration (by plants), causing less water to be available for plants and increasing moisture stress (Dale et al. 2001), particularly for species adapted to wet environments.

Table 20. Potential change in habitat suitability by 2100 for select Bluestone National Scenic River riparian tree species based on two future climate scenarios (the "least change" scenario represents strong cuts in greenhouse gas emissions and modest climatic changes, the "major change" scenario represents continued increasing emissions and rapid warming). Reproduced from Fisichelli (2015).

Scientific Name	Common Name	Least Change Scenario	Major Change Scenario
Acer negundo	boxelder	small decrease	large increase
Acer saccharinum	silver maple	small decrease	large increase
Asimina triloba	pawpaw	small decrease	large decrease
Diospyros virginiana	common persimmon	large increase	large increase
Gleditsia triacanthos	honeylocust	extirpated	large increase
Juglans cinerea	butternut	extirpated	extirpated
Platanus occidentalis	sycamore	large increase	large increase
Salix nigra	black willow	small decrease	large increase
Ulmus americana	American elm	no change	large increase
Gleditsia aquatica	water locust	–	new habitat
Populus deltoides	eastern cottonwood	–	new habitat
Quercus nigra	water oak	–	new habitat
Quercus phellos	willow oak	–	new habitat
Quercus texana	Nuttall oak	–	new habitat

Data Needs/Gaps

As with upland forests, the ERMN vegetation monitoring program has begun to address historical data gaps for BLUE's riparian vegetation communities. Additional surveys to document the locations, numbers, and status of rare plants in the park's riparian areas, particularly Virginia spiraea, would be helpful in better understanding the condition of these species.

Overall Condition

Riparian Vegetation Community Extent

The project team assigned this measure a *Significance Level* of 3. The riparian vegetation community covers a relatively small area within BLUE, making it somewhat vulnerable to both natural and anthropogenic changes. However, there is no current evidence that the community's extent is declining, and the park's status as a National Scenic River, as well as its remoteness, offers some protection for the riparian areas. As a result, this measure is assigned a *Condition Level* of 1, indicating low concern.

Plant Species Richness

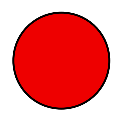
This measure was also assigned a *Significance Level* of 3. BLUE's riparian areas are highly diverse, with 459 different taxa recorded in a relatively small area (Appendix B). The proportion of these species that are exotic (14.4%) is higher than the proportion of exotics in the upland forest communities 8.5%. Because of the threat invasive exotic species pose to native plant diversity, this measure is of moderate concern (*Condition Level* = 2).

Rare Plant Element Occurrences
The rare plant measure was assigned a *Significance Level* of 3. Twenty rare plant species have been documented in BLUE's riparian vegetation communities (Table 18), but information on the number of occurrences (EOs) within park boundaries is limited. No recent information on the condition (i.e., viability) of rare species EOs could be found. As a result, a *Condition Level* has not been assigned for this measure.

Proportion of Total Cover of Exotic Plants and Invasive Plants
A *Significance Level* of 3 was also assigned to this measure. Based on 2013-2016 ERMN data, the average proportion of total cover in exotic species is 16.5%, and cover in invasive species is 14.1% (ERMN 2017). These proportions are more than 10 times higher than the exotic and invasive species proportions for BLUE's upland forest communities. Vanderhorst et al. (2008) found invasive species cover exceeding 30% in three different riparian vegetation community types. At this time, exotic and invasive plant cover is of significant concern (*Condition Level* = 3).

Weighted Condition Score
The *Weighted Condition Score* for BLUE's riparian vegetation communities is 0.67 (Table 21), which is at the lower end of the significant concern range. As with upland forest communities, data and information for the selected measures is somewhat limited, so a trend has not been assigned and a moderate confidence border is applied.

Table 21. Current condition of Bluestone National Scenic River's Riparian Vegetation Communities.

Measures	Significance Level	Condition Level	WCS = 0.67
Community Extent	3	1	
Plant Species Richness	3	2	
Rare Plant EOs	3	n/a	
Exotic and Invasive Cover	3	3	

4.2.6. Sources of Expertise

- John Perez, NERI/GARI/BLUE Biologist
- Stephanie Perles, ERMN Plant Ecologist
- Layne Strickler, NERI/GARI/BLUE Biological Science Technician

4.3. Birds

4.3.1. Description

Bird populations often serve as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically highly visible components of ecosystems, and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). BLUE is home to many unique ecosystems, all of which support specific bird communities. The Bluestone River provides migratory and wintering habitat for many species, and is an important feature in West Virginia for a variety of bird species. While not the most abundant habitat type in the park (present in only 8% of BLUE's total area), riparian and streamside habitats feature several species that are dependent upon these habtiat types (Vanderhorst et al. 2008). Like much of West Virginia, the forests of BLUE are largely unbroken, and provide critical habitat for forest interior dependent species (Weakland and Wood 2002). These types of forests are becoming increasingly rare, as forest fragmentation and loss accelerates due to human development. Mining in West Virginia is a major source of fragmentation, and the forest areas surrounding the active or reclaimed mines often result in edge habitats that attract nest predators (Weakland and Wood 2002). The unbroken forests of BLUE and the surrounding area are perhaps the most important avian habitat in the greater region.

In total, BLUE has more than 100 species of birds that are either confirmed as present or are listed as probable species (NPS 2016b). BLUE is located between two important migratory crossover locations for the Atlantic flyway, as species cross over to the Atlantic Coast from the Mississippi River Flyway. Several migratory species cross through the park in the spring and fall on their way to and from breeding grounds in northern North America. The summer breeding bird community in BLUE also includes a large influx of migratory songbirds. The winter community of the park includes some migratory waterfowl that utilize the riparian habitats of the park.

A great blue heron (*Ardea herodias*) flying across open water. Great blue herons are one of the more recognizable wading birds that frequent the Bluestone River Gorge (NPS Photo).

Additionally, BLUE has confirmed the presence of 11 species identified as species of concern by the West Virginia Wildlife Diversity Program (WVWDP) (Table 22). These species represent approximately 10.5% of all confirmed species in the park (NPS 2016b). Species are ranked on how imperiled/rare that species is in West Virginia, and are classified at six levels:

- **S1 - Critically Imperiled** - Critically imperiled in the state because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the state. Typically 5 or fewer occurrences and very few remaining individuals (<1,000);
- **S2 - Imperiled** - Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the state. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000);
- **S3 - Vulnerable** - Vulnerable in the state either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals;
- **S4 - Apparently Secure** - Uncommon but not rare, and usually widespread in the state. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals;
- **S5 - Secure** - Common, widespread, and abundant in the state. Essentially ineradicable under present conditions. Typically considerably more than 100 occurrences and more than 10,000 individuals;

- **SH - State Historical** - Species occurred historically in the state and there is some expectation that it may be rediscovered. Its presences may not have been verified in the past 20 years (WVDNR 2017a).

Table 22. Avian species identified as Species of Conservation Concern by the West Virginia Wildlife Diversity Program (WVDNR 2017a). N = Non-breeding population; B = Breeding population. Other acronyms defined in the bullet points above.

Scientific Name	Common Name	WVNHP Classification
Anas rubripes	American black duck	S2B, S2N
Fulica americana	American coot	SHB, S2N
Buteo platypterus	broad-winged hawk	S3B
Mergus merganser	common merganser	S3B, S3N
Chordeiles minor	common nighthawk	S2B
Ardea herodias	great blue heron	S3B, S4N
Anas crecca	green-winged teal	SHB, S2N
Lophodytes cucullatus	hooded merganser	S1B, S4N
Pandion haliaetus	osprey	S2B
Podilymbus podiceps	pied-billed grebe	S2B, S4N
Zonotrichia albicollis	white-throated sparrow	SHB, S5N

4.3.2. Measures

- Species richness
- Species abundance
- Species distribution
- Bird Community Index
- Annual waterfowl harvest
- Annual turkey harvest

4.3.3. Reference Condition/Values

Due to a lack of historic surveys or inventories in the park, an appropriate quantitative reference condition does not exist for this component at this time. The Bluestone River gorge area (including BLUE) was historically covered in continuous, mature forests. While logging removed many trees from the area in the 1800s, the area has returned to a landscape that is largely unfragmented and densely forested. For this assessment, a reference condition of a ‘rich and diverse breeding forest bird community’ will be used. Because there are no historic data from forest bird communities in the area, the best professional judgement of the identified subject matter experts and NPS staff was used to assess current condition. Future assessments of condition may be able to utilize this summary as a baseline for comparison.

4.3.4. Data and Methods

The NPS Certified Bird Species List (NPS 2016b) for BLUE was used for this assessment, as this list represents all of the confirmed bird species present in the park. The list is populated by the various bird inventories and surveys that occur in the park's area, and in the case of parks with limited bird work, will likely resemble the overall species list of the primary bird inventory effort for the park.

Beginning in 1998, NPS staff initiated annual avian fixed-radius point count surveys (PCS) in BLUE, Gauley River National Recreation Area (GARI), and NERI. The PCS route in BLUE is situated along the Bluestone Turnpike Trail, and consists of 20 points that are spaced approximately 250 m (820 ft) apart. At approximately the mid-point of the PCS route, the route crosses into Pipestem Resort State Park. Observers begin survey efforts within three hours after sunrise, and stop at each point for 10 minutes. Each individual that is heard or seen within a 20 m (66 ft) radius from the point is identified to species and recorded. Data from these PCS efforts are current in BLUE through 2016.

Some of the PCS observations were adjusted slightly by SMUMN GSS analysts when compiling this report. These adjustments dealt primarily with the naming convention of bird species and are outlined below:

- Records of the eastern tufted titmouse were merged with records of the tufted titmouse, as both referred to *Baeolophus bicolor*;
- Rufous-sided towhee observations were combined with observations of the eastern towhee (*Pipilo erythrophthalmus*) to reflect current taxonomic classification;
- Records of the solitary vireo were combined with observations of the blue-headed vireo (*Vireo solitarius*) to reflect current taxonomic classification (Cicero and Johnson 1998).

As part of a park-wide vertebrate inventory effort, Pauley et al. (2003) inventoried the bird community of BLUE in 1998 and 1999. The methodology for this inventory consisted primarily of PCSs, with three routes established in the park: Little Bluestone River, Indian Creek, and Mountain Creek. Along each PCS route, there were nine to 10 points spaced between 200 m (656 ft) and 300 m (984 ft) apart. At each point, observers identified all individuals seen and heard at intervals of 3, 5, and 10 minutes. It must be noted, though, that raw species abundance data are not available for the Mountain Creek route. Each PCS route was surveyed three to five times from mid-May to mid-July.

Point counts were not the only inventory method used during Pauley et al. (2003), as singing male censuses (SMC), raptor counts, and waterfowl/shorebird counts were also completed. The SMCs were completed in BLUE in 1998 and 1999, and consisted of observers recording all territorial singing males heard within the overall study area (primarily along the PCS routes). Additionally, because PCS efforts typically do not assess raptor populations accurately, specific diurnal and nocturnal raptor counts were conducted in 1999. Diurnal raptor counts were completed two times in 1999, with counts occurring between 1500-1700 hours. Nocturnal raptor counts, designed to target owl species, were completed between 2100-2400 hours and utilized song-playback to stimulate owl vocal responses. The last survey methodology utilized by Pauley et al. (2003) was a shorebird and waterfowl search. These efforts focused on the Bluestone River between the Little Bluestone River and the Meador Campground. Counts occurred five times between 5 October and 15 December 1999.

The ERMN identified "streamside birds" as a key natural resource network-wide, and initiated a long-term monitoring program in 2007. The term "streamside bird" was chosen as the monitoring protocol calls for avian sampling along a specific habitat corridor: forested, closed canopy streams. It is this sampled area – the closed canopy streams – that calls for distinction; ERMN monitoring samples the breeding bird community of this habitat type, and the data collected are analogous to data collected by other NPS monitoring programs in regard to "breeding birds", "landbirds", or other labels for bird communities (Marshall et al. 2012, 2013). Marshall et al. (2013, p. 3) identified the following objectives prior to initiating annual PCS efforts:

- Estimate occupancy, density, and/or indices of abundance annually for select bird species and guilds at the park (target stream network) and stream reach scale;
- Estimate trends among years in occupancy, density, and/or indices of abundance for select bird species and guilds at the park (target stream network) and stream reach scale;
- Calculate the Bird Community Index [BCI] of biotic integrity annually at the park (target stream network) and stream reach scale; and
- Compare trends in occupancy, density, and/or indices of abundance for select bird species and guilds within ERMN parks to regional and continental trends.

The ERMN streamside bird monitoring efforts in BLUE used the methodology outlined by Marshall et al. (2012). Sampling sites consist of closed canopy, wadeable stream reaches within a park's administrative boundary, and ranged between 250 m (820 ft) and 1 km (0.6 mi) in length. Selected stream reaches had between two and five PCS locations, with each station being spaced at least 250 m (820 ft) apart and up to 25 m (82 ft) upslope from the stream (Marshall et al. 2012). In BLUE, five potential stream reaches were selected for initial monitoring; however, one of the five locations was inaccessible due to failure to receive permission from the land owner, and another location was abandoned after monitoring in 2009 due to treacherous terrain (i.e., steep slopes and many waterfalls) (Marshall et al. 2013). The three sites in BLUE have a combined 12 PCS locations, with the Little Bluestone stream reach having five PCS stations, Mountain Creek having four, and the Jarrell Branch having three (Figure 15).

Each PCS location was visited twice per year, typically between May and July. Not all locations in BLUE were sampled in the same years: the Little Bluestone River reach was visited in 2009, 2010, and 2012; Mountain Creek was visited in 2010, 2011, and 2012; and the Jarrell Branch was established and visited only in 2012. During a visit, observers documented all bird species seen or heard during a 10 minute window and recorded species identity, type of detection, the distance of detection, the time frame of detection (e.g., minute 4 of observation window), life stage of the species (i.e., if species is a juvenile or not), and whether or not the species was flying over the canopy (Marshall et al. 2012). Observers conducted two "passes" of a stream reach during a visit, conducting an upstream pass and a downstream pass separated by at least 10 minutes to allow for each pass to be treated as an independent observation (i.e., each visit consisted of two passes).

An annual Christmas Bird Count (CBC) is centered east of BLUE boundaries near the town of Pipestem, WV and has been completed annually since 1972. The Pipestem area CBC is part of the International CBC, which started in 1900 and is coordinated by the Audubon Society. Multiple volunteers surveyed a 24-km (15-mi) diameter area on one day, typically between 14 December and 5 January, by foot, boat, or car. The center point of the 24-km (15 mi) diameter was 37.579952ºN, -80.919631ºW (Figure 16). The majority of surveys that have occurred in BLUE have occurred during the breeding/summer seasons (with the exception of the shorebird/waterfowl surveys of Pauley et al. (2003) which occurred in October and December). The CBC surveys overwintering and resident birds that are not territorial and singing and provides managers with a course idea of overwintering species in the BLUE area. The total number of species and individuals were recorded each year.

The organization and analysis of the Pipestem CBC data (obtained from: http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx) required SMUMN GSS to make some adjustments:

- Observations that were not specific to a species (e.g., buteo species, vireo sp.) were omitted from analysis;
- Observations of northern flicker and yellow-shafted flicker were combined and renamed to *Colaptes auratis*. Yellow-shafted flickers and red-shafted flickers were previously believed to be a separate species, but genetic analysis has classified them as one species (commonly referred to as northern flicker) (Sibley and Ahlquist 1983);
- Dark-eyed junco and dark-eyed junco (slate-colored) were treated as one species (*Junco hyemalis*) (Sibley and Ahlquist 1983);
- Observations of Pacific wrens were treated as observations of winter wrens. These two species were formerly grouped as a singular species, however molecular analysis has revealed that there are two distinct species: the Pacific wren (*Troglodytes pacificus,* found on the West Coast of the U.S.) and the winter wren (*Troglodytes hyemalis,* found on the East Coast and Midwest regions of the U.S.) (Toews and Irwin 2008);
- Observations of the spotted towhee (*Pipilo maculatus*) were treated as observations of the eastern towhee (*Pipilo erythrophthalmus*). These two species were formerly grouped as the rufous-sided towhee, but have since been separated into two species, with the spotted towhee ranging in the Western portion of the U.S., and the eastern towhee occurring in the east (AOU 1995).

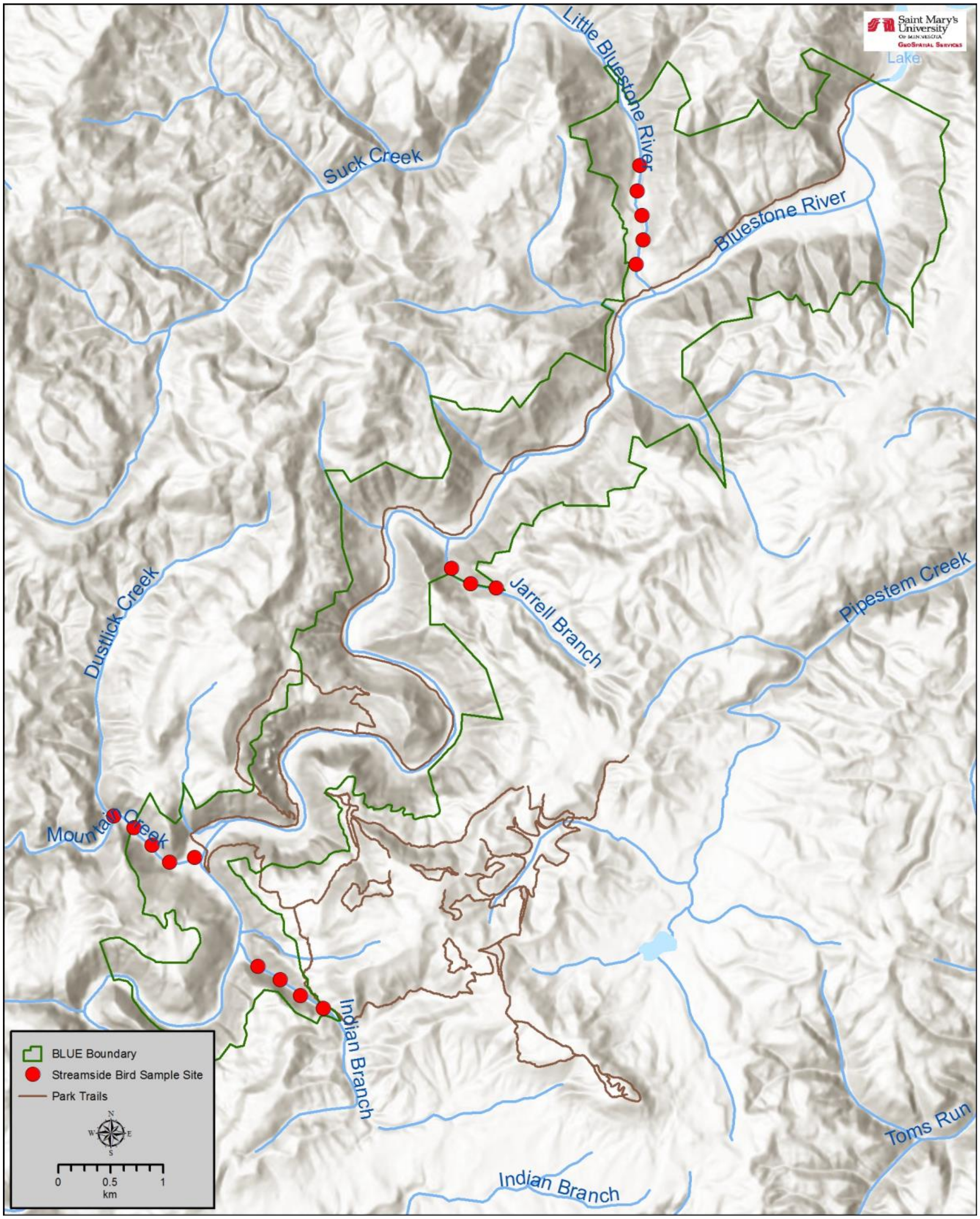


Figure 15. Eastern Rivers and Mountains Network streamside bird monitoring sample sites in Bluestone National Scenic River (Marshall et al. 2013). The Indian Branch sites have been abandoned and are no longer used for ERMN monitoring.

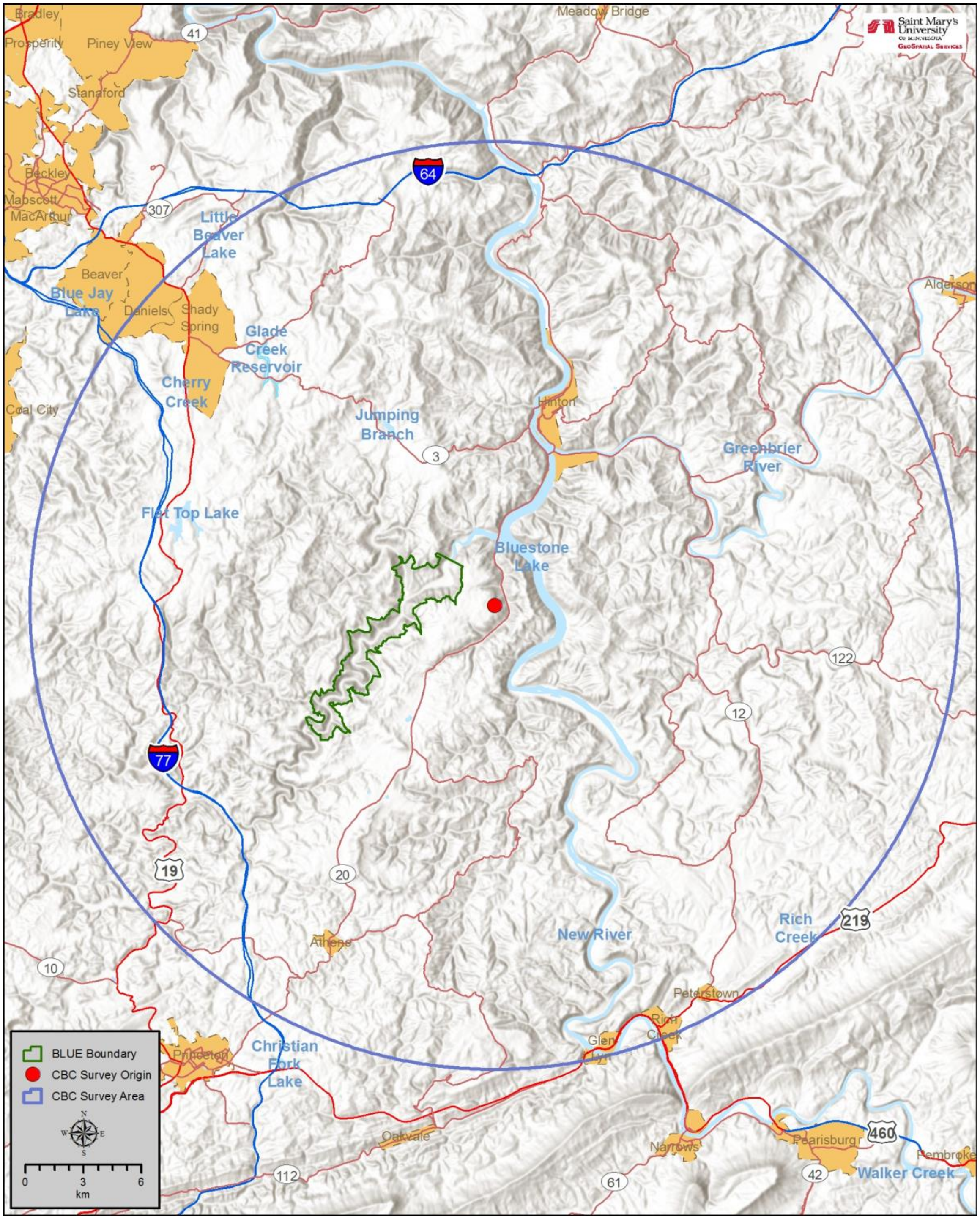


Figure 16. Christmas bird count survey area for the Pipestem Christmas Bird Count (CBC). The Pipestem CBC has been conducted annually since 1972.

View of a West Virginia Division of Natural Resources-maintained food plot along the Bluestone Turnpike Trail. These plots are maintained for the benefit of harvested wildlife species such as white-tailed deer and wild turkey (Photo by Kathy Allen, SMUMN GSS).

Situated adjacent to Pipestem Resort State Park, Bluestone State Park, and Bluestone Wildlife Management Area, approximately 70% of BLUE is jointly managed by the WV DNR. Unlike many NPS units, hunting and trapping is allowed on these jointly managed lands. Some areas of the park have WV DNR-maintained food plots, which are mowed and relatively open areas that are designed to benefit huntable wildlife populations (e.g., white-tailed deer [*Odocoileus virginianus*], wild turkey [*Meleagris gallopavo*]). Several of these plots can be observed along the Bluestone Turnpike Trail in the park, as seen in the photo below.

The WV DNR summarizes the annual spring and fall turkey harvests statewide, and reports the harvests by county. Although data are not available specific only to BLUE, Mercer and Summers County each have harvest data available from 2011-2015 (WV DNR 2016a). The 2016-2017 turkey hunting seasons in Summers and Mercer Counties were:

- Spring Turkey Hunting: Bearded turkeys only, open between 17 April and 13 May. Daily bag limit is one bearded turkey, with a season limit/possession limit of two bearded turkeys;
- Spring Youth Turkey Hunting: 15 April only – one bird which counts towards the spring season bag limit of two.
- Fall Turkey Hunting: 8-15 October – only one either sex turkey may be taken.

Turkeys may only be hunted with rifles, handguns, muzzleloaders, shotguns, or bows/crossbows (WV DNR 2016a). Hunting hours are one half hour before sunrise until one half hour after sunset. The use of electronic calls or bait are illegal (WV DNR 2016a).

Waterfowl are also harvested in West Virginia, with most hunting seasons occurring in late fall (Table 23). Unlike turkey, statewide and countywide harvest estimates are not available via a web portal or annual summary report. Hunting hours are from noon until sunset on the opening day, and then one half hour before sunrise until sunset; hunting is prohibited on Sundays except on private land. Hunters must use non-toxic shot sized T or smaller.

Table 23. Migratory game bird hunting seasons in West Virginia for the 2016-2017 hunting season (WV DNR 2016b).

Season	Dates	Daily Bag Limit[a]	Possession Limit
youth waterfowl	17 September 5 November	Same as the daily limit of the regular duck and goose seasons	Same as the daily limit of the regular duck and goose seasons
duck	1-8 October 7-12 November 14 December-28 January	6[b,d]	6[b,d]
coot	Same as duck	15	30
gallinules	1-8 October 28 November-28 January	15	30
merganser	Same as duck	5[c,d]	15[c,d]
early Canada goose	1 September-10 September	5	15
Canada goose and white-fronted goose	1 October-15 October 7 November - 12 November 1 December - 28 January	5[d]	15[d]
snow and blue goose	1 October-15 October 7 November - 12 November 1 December - 28 January	5[d]	15[d]
brant	30 November - 28 January	1	3

[a] The daily bag limit for falconry hunting is three migratory game birds in the aggregate, and the possession limit is nine migratory game birds in the aggregate

[b] The daily limit of six can include only two pintails, four long-tail ducks, two scaup, one black duck, three wood ducks, two redheads, four scoters, two canvasback and four mallards of which only two may be hens. The duck possession limit can include only three times the daily bag limit.

[c] The daily merganser bag limit can include only two hooded mergansers, with a possession limit of six.

[d] In aggregate

4.3.5. Current Condition and Trend

Species Richness

The species richness measure in this component refers to the total number of species present in a given study, survey, or other monitoring effort. This definition is in line with the traditional definition in published literature.

It is important to note that a higher species richness estimate does not always correlate to a “healthier community”. This is particularly true in the mature, largely unfragmented forests typical of the GARI/NERI/BLUE areas in West Virginia. These areas often have highly specialized avian guilds that depend upon the interior forest communities for breeding. Accordingly, these ecosystems may exhibit lower species richness estimates but still be considered in good condition as they provide and sustain critical habitat for these specialized groups of birds. The fragmentation of these forests may encourage generalist bird species or guilds to move in, which would increase the species richness estimate, but would lower the overall condition of the measure. In instances where trends or ecosystem function was unclear, the best professional judgement of NPS managers was used for this measure.

NPS Certified Species List (NPS 2016b)

The NPS Certified Bird Species List contains 104 species that are confirmed in the park (Appendix C). This list also identifies species that may be present in the area but have not been confirmed within the park’s boundaries. These species were identified as “Probably Present” by NPS (2016b) and included the winter wren (*Troglodytes hiemalis*) and the black-capped chickadee (*Poecile atricapullus*). One species, the northern waterthrush (*Parkesia noveboracensis*), was identified as unconfirmed. The designation of unconfirmed indicates that the species has been attributed to the park, but little or no evidence to support its presence exists.

Unlike annual bird surveys, NPS (2016b) is not well suited for an analysis of annual species richness, as no data are collected yearly. The NPS Certified Species List documents the presence (or historic presence) of the identified species and serves as a useful point of comparison to determine which species have been documented in the park.

NPS Point Count Surveys (1998-Present)

The NPS has conducted annual avian point counts in BLUE since 1998. The total number of species observed from 1998-2016 was 64 (Appendix C). Annual species richness estimates have varied over the 18 years of the surveys, with species richness estimates ranging from 23 species (2010, 2013) to 40 species (2006) (Figure 17). The average number of species observed along the BLUE PCS route from 1998-2016 was 30.1 species (Figure 17).

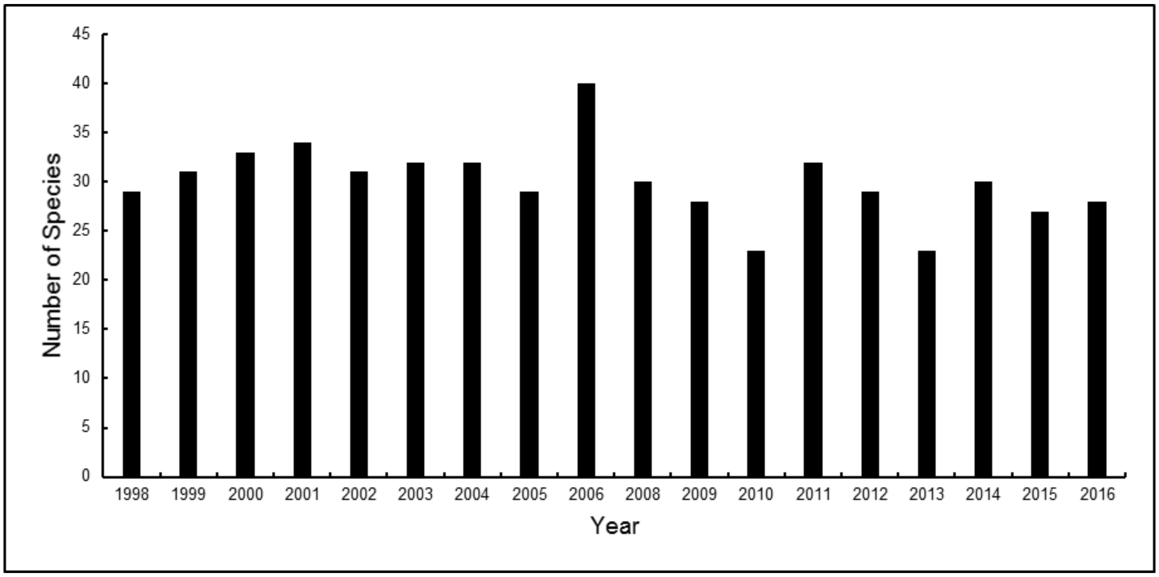


Figure 17. Annual species richness at Bluestone National Scenic River during yearly point count survey (PCS) along the Bluestone River (NPS unpublished data). The dashed red line indicates the 18-year species richness average for the PCS (30.1 species).

Within the last 5 years (2012-2016), the average species richness along the PCS route in BLUE has been 27.4 species, which is slightly below the 18-year average. Species richness estimates for 2013 (23 species) were the lowest recorded during all PCS efforts; however, most of the species richness estimates in the past 5 years have been relatively stable (Figure 17).

Pauley et al. (2003)

Pauley et al. (2003) cannot be used to examine species richness trends, as its duration (one to two field seasons) was insufficient to discover any significant trends or patterns. Instead, these data are used here to show what species may be present in BLUE and are useful as a baseline for comparison for future studies. Pauley et al. (2003) documented 93 bird species in BLUE during a 1998-1999 inventory of the park (Appendix C). Seventy-five species were documented during the PCS and SMC efforts (74 species on the Little Bluestone River, 55 on Indian Creek; Appendix D), while the raptor survey efforts documented nine species (Table 24) and the waterfowl surveys documented 16 species (Table 25).

Table 24. Raptor species and total species abundance observed during raptor-specific play back surveys Bluestone National Scenic River in 1999 (Pauley et al. 2003).

Scientific Name	Common Name	Indian Creek	Little Bluestone	Mountain Creek
Pandion haliaetus	osprey	0	1	0
Accipiter striatus	sharp-shinned hawk	2	5	2
Accipiter cooperii	Cooper's hawk	2	1	1
Buteo jamaicensis	red-tailed hawk	0	2	2
Buteo lineatus	red-shouldered hawk	1	1	3

Table 24 (continued). Raptor species and total species abundance observed during raptor-specific play back surveys Bluestone National Scenic River in 1999 (Pauley et al. 2003).

Scientific Name	Common Name	Indian Creek	Little Bluestone	Mountain Creek
Buteo platypterus	broad-winged hawk	3	2	1
Megascops asio	eastern screech owl	4	8	2
Bubo virginianus	great-horned owl	2	1	0
Strix varia	barred owl	3	2	3

Table 25. Waterfowl and shorebird species observed along the Bluestone River between Meador Camp and the Little Bluestone River in 1999 (Pauley et al. 2003). Note that the number of individuals reported below represent the highest number of individuals observed during any visit between October and December 1999.

Scientific Name	Common Name	Number of Individuals
Podilymbus podiceps	pied-billed grebe	9
Phalacrocorax auritus	double-crested cormorant	4
Branta canadensis	Canada goose	112
Anas rubripes	American black duck	9
Anas strepera	gadwall	6
Anas platyrhynchos	mallard	44
Anas acuta	pintail	1
Aix sponsa	wood duck	16
Anas crecca	green-winged teal	5
Aythya americana	redhead	2
Aythya affinis	lesser scaup	36
Bucephala albeola	bufflehead	11
Oxyura jamaicensis	ruddy duck	3
Mergus merganser	common merganser	6
Lophodytes cucullatus	hooded merganser	15
Fulica americana	American coot	8

Marshall et al. (2013)

The ERMN streamside bird monitoring efforts in BLUE sampled three sites along the Little Bluestone River, Mountain Creek, and the Jarrell Branch (Figure 15). Surveys were conducted from 2009-2012, although each site was not visited every year (see methodology described above). Marshall et al. (2013) documented 44 bird species during the four years of streamside bird monitoring (Appendix C); this species richness total should be interpreted with a degree of caution, as only areas along streams and rivers were sampled.

As mentioned previously, a higher species richness estimate may not be truly indicative of good condition in an ecosystem. Marshall et al. (2013) observed an unexpected relationship between species richness and BCI scores at two ERMN parks (Delaware Water Gap National Recreation Area [DEWA] and NERI) where BCI scores for a site were negatively correlated to species richness (i.e., higher BCI scores corresponded to lower species richness). An explanation for this trend is that areas have higher species richness estimates when more generalist species are present than specialist species. A higher percentage of generalist species generally reduce an area's BCI score. The BCI scoring process is much more nuanced than a simple species richness tally for a given year, as the BCI weights each species encountered differently, depending upon avian guilds. An explicit reference condition also exists for BCI (mature forests). A more detailed look at BCI results in BLUE is presented later on in this component.

Pipestem CBC (1972-Present)

The Pipestem CBC survey area encompasses BLUE (Figure 16). Counts such as the CBC (or other index counts, e.g., breeding bird surveys) are neither censuses nor density estimates (Link and Sauer 1998). The overall usefulness of index count data is often limited by possible biases of count locations and the number of observers, and it is often not advisable to estimate overall population sizes from these data alone (Link and Sauer 1998). These biases may influence how many individuals are observed in a given year, and may potentially explain the annual variation observed in species each year. Results of the Pipestem CBC should be interpreted with a degree of caution.

During the 44 years of CBC efforts for the entire Pipestem count circle (not just within BLUE boundaries), 127 bird species have been observed (Appendix C). The highest number of species observed in a given year was 79 (2010; 14 observers), while the lowest number of species observed was 51 (1977, 11 observers) (Figure 18). The average number of bird species observed during the Pipestem CBC was 62.5, and the average number of observers per year was 15.5.

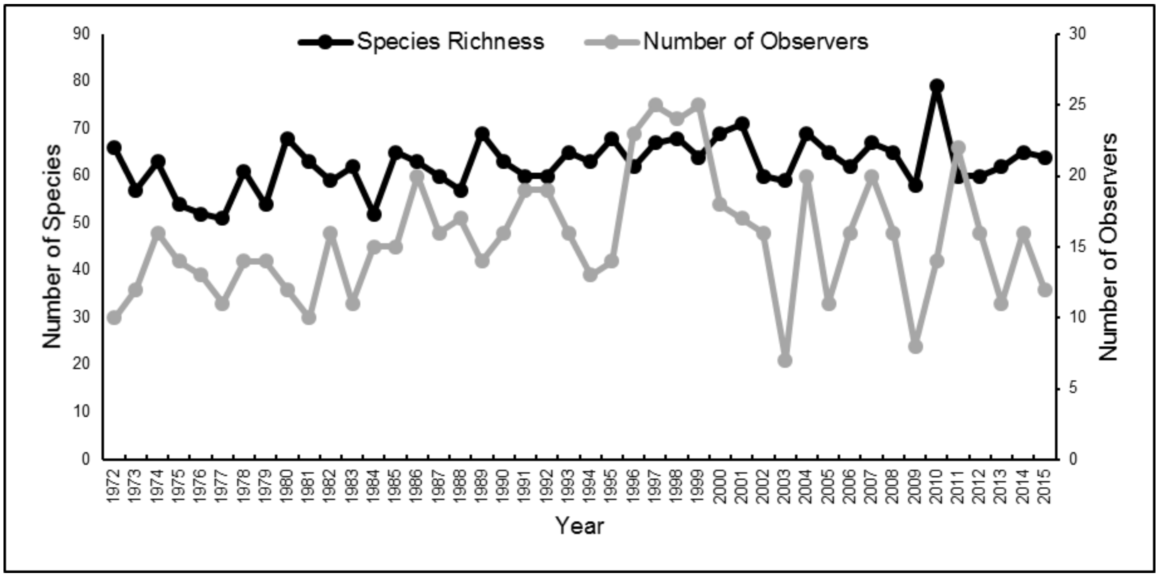


Figure 18. Number of bird species and observers during the Pipestem Christmas Bird Count between 1972 and 2015. Note that data include all count circle results and are not specific to Bluestone National Scenic River. Data retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Species Abundance

Species abundance refers to how many individuals are documented in a given survey/monitoring period. It needs to be noted, however, that all species have different detection probabilities, and measures of abundance reported here should be considered "naïve" estimates, as they do not account for these variable detection probabilities.

NPS Point Count Surveys (1998-Present)

The NPS-organized avian PCS in BLUE have identified 2,314 individuals of 64 species between 1998 and 2016. The total number of individuals observed each year has been variable, ranging from 97 individuals in 2013 to 181 individuals in 2011; the average number of birds detected during PCS from 1998-2016 was 128.6 (NPS unpublished data).

The most commonly detected species during the 18 field seasons were the red-eyed vireo (*Vireo olivaceus*; 404 individuals), scarlet tanager (*Piranga olivacea*; 219 individuals), Louisiana waterthrush (*Parkesia motacilla*; 175 individuals), wood thrush (*Hylocichla mustelina*; 143 individuals), and the blue jay (*Cyanocitta cristata*; 122 individuals). These five species have accounted for 45.9% of all observations during the NPS PCS surveys in BLUE. All five of these species were detected during every year of the PCS, and an additional four species were detected during all 18 years, albeit in lower numbers (Table 26).

Table 26. The most abundant (i.e., most commonly observed) bird species during National Park Service monitoring from 1998-2016. All nine species were observed in every year of the point count survey (NPS unpublished data).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
red-eyed vireo	23	34	29	24	22	18	20	25	20	22	15	23	18	23	19	23	21	25	404
scarlet tanager	11	3	16	12	13	13	13	13	9	15	10	11	23	11	9	9	14	14	219
Louisiana waterthrush	6	7	9	8	5	7	13	10	10	12	10	12	18	14	12	6	10	6	175
wood thrush	9	17	14	1	6	2	3	3	11	7	3	7	10	7	7	9	17	10	143
blue jay	1	13	5	7	9	5	7	7	8	13	4	3	3	11	7	5	7	7	122
tufted titmouse	3	9	6	8	10	6	3	4	9	1	5	6	2	2	6	5	6	8	99
worm-eating warbler	2	9	7	3	4	3	4	7	5	3	2	4	2	7	3	2	2	3	72
northern parula	7	3	5	6	6	6	5	7	2	1	3	2	6	1	1	1	2	2	66
Acadian flycatcher	5	4	9	3	4	2	1	8	2	1	2	5	5	2	1	2	2	2	60

The majority of the birds that were detected in the highest numbers, perhaps with the exception of the blue jay, are all species dependent upon intact, dense forests. The scarlet tanager is particularly sensitive to changes in forests in regards to fragmentation, and the Swainson's warbler is a secretive, forest-dependent species that is a species of conservation concern and is not easily observed. The fact that these species were detected frequently, and without any apparent declines in the park since 1998, highlights the importance of the largely intact forests of BLUE and is indicative of the overall health of these communities.

Pauley et al. (2003)

The Pauley et al. (2003) inventory efforts documented species abundance by total number of individuals observed for the Little Bluestone River and Indian Creek sites. Researchers visited Little Bluestone River and Indian Creek five times in 1998. At the Little Bluestone River site, total abundance counts per visit ranged from 111 individuals (14 July 1998) to 223 individuals (13 June 1998) (Figure 19), while the Indian Creek site ranged from 124 individuals (5 July 1998) to 159 individuals (29 June 1998) (Figure 20). The Little Bluestone River PCS site had a higher average abundance (164.8 individuals/visit) and a higher total number of birds observed (824 individuals) than the Indian Creek PCS site.

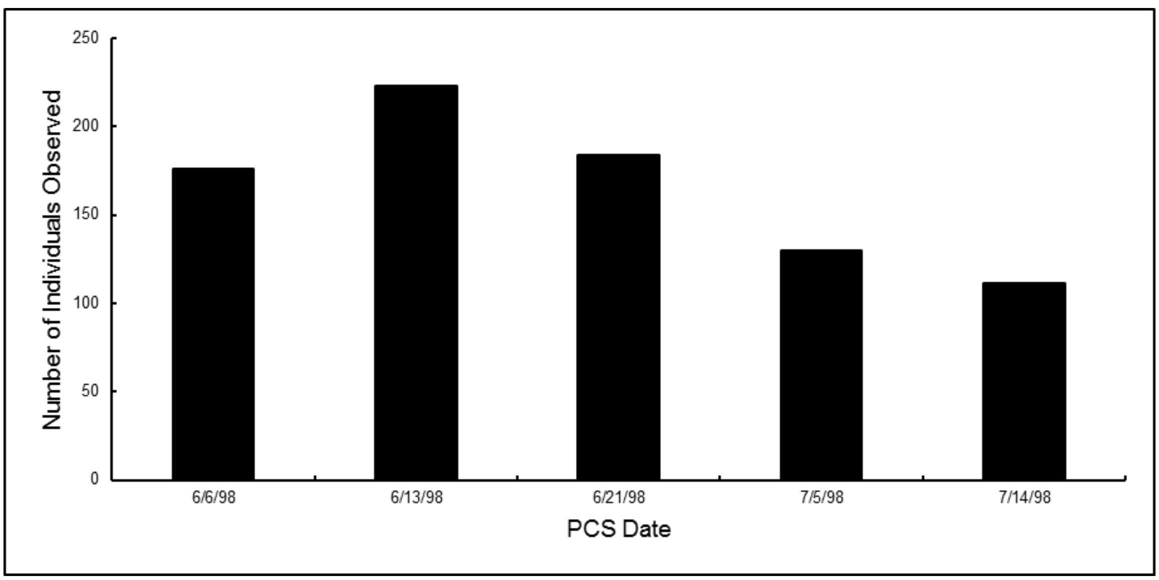


Figure 19. Number of individuals observed during the 1998 point count survey (PCS) efforts along the Little Bluestone River transect (Pauley et al. 2003). The solid red line represents the average number of individuals observed during the five PCS in 1998 (164.8 ind./visit).

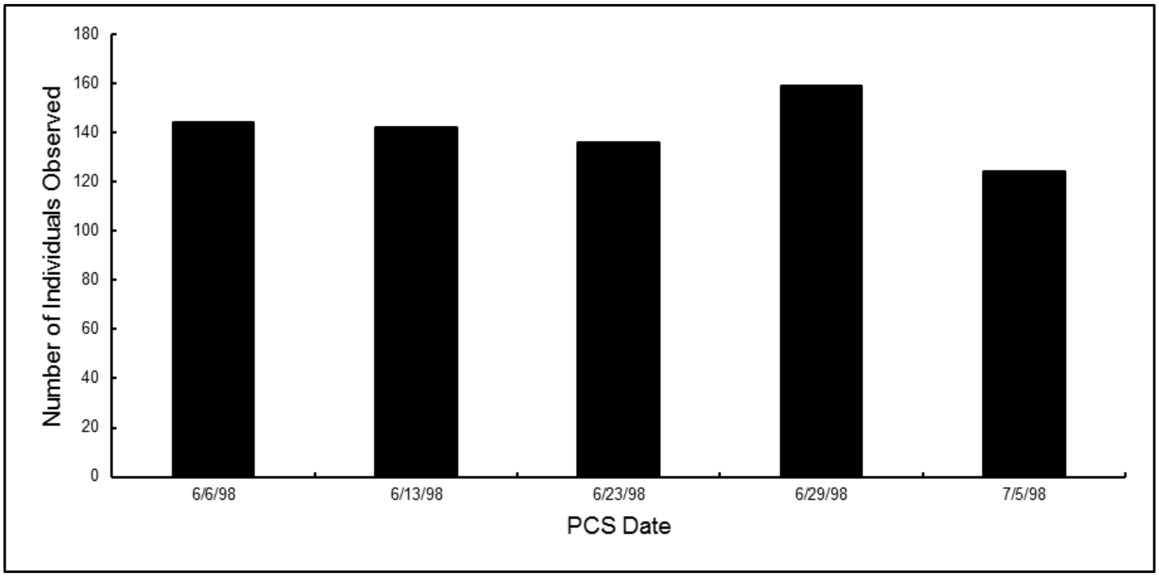


Figure 20. Number of individuals observed during the 1998 point count survey (PCS) efforts along the Indian Creek transect (Pauley et al. 2003). The solid red line represents the average number of individuals observed during the five PCS in 1998 (141 ind./visit). Survey dates were not the same as the Little Bluestone River PCS.

The Canada goose (*Branta canadensis*) was observed in the highest numbers along the Little Bluestone River transect (47 individuals, Table 27), despite being observed during just three of the five site visits. The red-eyed vireo was similar in abundance at the Little Bluestone River transect (45 individuals), and was the most commonly observed species on the Indian Creek transect, with 61 individuals observed in 1998 (Table 27). Other species observed in high numbers at both transect sites included the wood thrush and black-and-white warbler (*Mniotilta varia*).

Similar to the results of the NPS PCS in BLUE, the majority of the most frequently detected species during Pauley et al. (2003) were forest interior-dependent species. These repeated detections along the Little Bluestone River and Indian Creek continue to emphasize just how important and healthy this avian guild is in the BLUE area.

Pauley et al. (2003) also conducted raptor-specific surveys and waterfowl counts. The raptor surveys occurred at Little Bluestone River, Indian Creek, and Mountain Creek. The most commonly detected raptor species (visual or auditory) during Pauley et al. (2003) was the eastern screech owl (*Megascops asio*), which was detected 14 times across all locations (Table 24). The sharp-shinned hawk (*Accipiter striatus*), was detected nine times, while the barred owl (*Strix varia*) was detected eight times. The remaining raptor species were detected anywhere between one and six times during survey efforts (Table 24).

Table 27. The five most commonly observed species at the Little Bluestone River and Indian Creek sites during Pauley et al. (2003).

Site	Scientific Name	Common Name	# of Individuals
Little Bluestone River	*Branta canadensis*	Canada goose	47
	Vireo olivaceus	red-eyed vireo	45
	Passerina cyanea	indigo bunting	39
	Hylocichla mustelina	wood thrush	31
	Mniotilta varia	black-and-white warbler	30
Indian Creek	*Vireo olivaceus*	Red-eyed vireo	61
	Hylocichla mustelina	Wood thrush	58
	Mniotilta varia	Black-and-white warbler	45
	Seiurus aurocapilla	Ovenbird	44
	Spinus tristis	American goldfinch	38

The peak number of Canada geese detected during Pauley et al. (2003) was over two times greater than the peak number of any other waterfowl species, with 112 individuals observed in 1999 (Table 21). Other waterfowl species observed in high numbers included the mallard (*Anas platyrhynchos*; 44 individuals), lesser scaup (*Aythya affinis*; 36 individuals), wood duck (*Aix sponsa*; 16 individuals), and the hooded merganser (*Lophodytes cucullatus*; 15 individuals) (Table 25).

Marshall et al. (2013)

Marshall et al.'s (2013) streamside bird monitoring at Mountain Creek, Little Bluestone River, and the Jarrell Branch documented 1,107 detections from 2009-2012 (Appendix E). The most frequently detected species during the 4 years of monitoring was the Acadian flycatcher (*Empidonax virescens*), with 175 detections. The Acadian flycatcher was followed closely by the red-eyed vireo, which had 168 detections (Table 28). The five most commonly detected species during Marshall et al. (2013) made up 54.7% of all observations (Table 28). As has been mentioned previously, Marshall et al. (2013) sampled in streamside habitats, and likely detected streamside birds in higher numbers than bird species that may depend on other habitats.

Table 28. The five most commonly observed bird species during Marshall et al. (2013) monitoring at Mountain Creek, Little Bluestone River, and the Jarrell Branch from 2009-2012.

Scientific Name	Common Name	Number of Detections
Empidonax virescens	Acadian flycatcher	175
Vireo olivaceus	red-eyed vireo	168
Hylocichla mustelina	wood thrush	100
Seiurus aurocapilla	ovenbird	89
Parkesia motacilla	Louisiana waterthrush	72

One of the focal specialist species in the ERMN is the Louisiana waterthrush. This species is a migratory warbler and a forest interior obligate species (Mattsson and Cooper 2006) that breeds along streams in the Appalachian region (the only such species in the Eastern U.S.). The ERMN documents Louisiana waterthrush occupancy network-wide, as the species is considered an indicator of overall riparian ecological condition (Mattsson and Cooper 2006, Latta and Mulvihill 2010, Marshall et al. 2013). The species' possible utility as an indicator of overall stream health is part of the reason that the ERMN selected streamside birds for monitoring (Marshall et al. 2013). Seventy-two Louisiana waterthrushes were documented by Marshall et al. (2013) at the three sample sites from 2009-2012 (Table 28).

Pipestem CBC (1972-Present)

The CBC takes place over the winter months when many migratory and breeding species are no longer present in the area; the abundance estimates and species observed often look very different when compared to breeding or migratory season surveys. When looking at the average number of individuals of a particular species per year from 1972-2015, the dark-eyed junco had the highest annual average abundance with 265.9 individuals/year (Table 29). Other abundant bird species during the Pipestem CBC included the European starling (*Sturnus vulgaris*), Canada goose, rock pigeon (*Columba livia*), and the American robin (*Turdus migratorius*) (Table 29).

Table 29. Average annual abundance for the 10 most frequently observed species during the Pipestem Christmas Bird Count from 1972-2015. Data were retrieved from http://netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx.

Scientific Name	Common Name	Average # of Individuals/Year
Junco hyemalis	dark-eyed junco	265.9
Sturnus vulgaris	European starling	223.2
Branta canadensis	Canada goose	221
Anas platyrhynchos	mallard	110.7
Spinus tristis	American goldfinch	95.5
Passer domesticus	house sparrow	94
Cardinalis cardinalis	northern cardinal	90.5
Zonotrichia albicollis	white-throated sparrow	89.8
Baeolophus bicolor	tufted titmouse	86.6
Columba livia	rock pigeon	84

Species Distribution

The boundaries of BLUE remain fairly close to the Bluestone River, and accordingly, many of the avian surveys that have been completed in the park have been along the river or its tributaries (Figure 15). The riparian and streamside habitat is undoubtedly one of the most predominant and important avian communities in the park, and has been the focus of study for the Marshall et al. (2013) monitoring. The frequently sampled areas of the park have been along the Bluestone River, Little Bluestone River, Mountain Creek, Jarrell Branch, and Indian Creek/Branch. That being said, the NPS and ERMN monitoring in conjunction have done a good job of capturing the forest bird community of BLUE. Some species, such as the cerulean warbler (*Setophaga cerulea*) or worm-eating warbler (*Helmitheros vermivorum)*, have not been well sampled as their distribution lies outside of the habitats currently monitored in BLUE.

None of the avian studies in BLUE have focused specifically on differences in avian community structures in different habitat types or areas of the park. As a result, this measure relies on previous discussions of species abundance and distribution by transect or survey location which were previously summarized above. Trends or patterns in distribution need to be discerned with caution, as survey timing, methodology, and duration have been variable between research efforts.

Bird Community Index (BCI)

Bird Community Indices have been developed to better understand the health and biotic integrity of bird communities in specific regions, communities, or habitats. For streamside bird monitoring in the ERMN, Marshall et al. (2013) utilized a BCI developed by O'Connell et al. (1998a, b, 2000) that was based on the breeding bird communities of the central Appalachians. As described by Marshall et al. (2013, p. 23), the O'Connell et al. (1998a, b, 2000) BCI is

> *…based on 16 response guilds with each guild broadly classified as 'specialist' or 'generalist' depending on each guild's relationship to specific elements or biotic integrity (Table 30). Each species is assigned to a response guild and the BCI ranks the overall bird community detected at a site according to the proportional representation of the species in the response guilds.*

Table 30. Biotic integrity elements, guild categories, response guilds, and guild interpretations used in the O'Connell et al. (1998a, b, 2000) Bird Community Index of ecological integrity.

Biotic Integrity Element	Guild Category	Response Guild	Specialist	Generalist
Functional	tropic	omnivore	–	X
Functional	insectivore foraging behavior	bark prober	X	–
Functional	insectivore foraging behavior	ground gleaner	X	–
Functional	insectivore foraging behavior	upper-canopy forager	X	–
Functional	insectivore foraging behavior	lower-canopy forager	X	–
Compositional	origin	exotic/nonnative	–	X
Compositional	migratory	resident	–	X
Compositional	migratory	temperate migrant	–	X
Compositional	number of broods	single-brooded	X	–
Compositional	population limiting	nest predator/brood parasite	–	X
Structural	nest placement	canopy nester	X	–
Structural	nest placement	shrub nester	–	X
Structural	nest placement	forest-ground nester	X	–

Table 30 (continued). Biotic integrity elements, guild categories, response guilds, and guild interpretations used in the O'Connell et al. (1998a, b, 2000) Bird Community Index of ecological integrity.

Biotic Integrity Element	Guild Category	Response Guild	Specialist	Generalist
Structural	nest placement	open-ground nester	X	–
Structural	primary habitat	forest generalist	–	X
Structural	primary habitat	interior forest obligate	X	–

Bird Community Index scores were broken down into four ecological condition categories: highest integrity (60.1-77.0), high integrity (52.1-60.0), medium integrity (40.1-52.0), and low integrity (20.5-40.0). A high BCI score (i.e., the higher ecological condition categories) corresponds to communities that have a higher proportion of specialist avian species relative to generalist species.

BCI scores in BLUE from 2010-2012 were all high, with average values falling into the highest ecological integrity category for all sites (Figure 21). The park-wide average BCI score was 64 ±2.8, which was also above the threshold for the 'highest' ecological integrity category. Of the seven site visits in BLUE from 2010-2012, only once did a site have a BCI score that fell into the 'high' ecological integrity condition (Figure 21). These high scores reflect the overall quality of the largely unfragmented forests of the park, and the fact that the park is home to a robust group of forest interior specialist species for much of the year.

<u>Annual Waterfowl Harvest</u>

Waterfowl can be legally hunted and harvested in BLUE during a species' open hunting season (Table 23). Harvestable species that have been confirmed in BLUE include the northern pintail (*Anas acuta*), lesser scaup, American black duck (*Anas rubripes*), wood duck, redhead (*Aythya americana*), mallard, American coot (*Fulica americana*), common (*Mergus merganser*) and hooded mergansers, and Canada goose. Many of the harvested waterfowl species in BLUE also appear as species of conservation concern as defined previously in Table 22.

Currently, there are no available harvest summaries for the BLUE area. Until a harvest report is completed by either the WV DNR or a harvest summary study is initiated by another organization, this component represents a data gap and cannot be assessed for current condition.

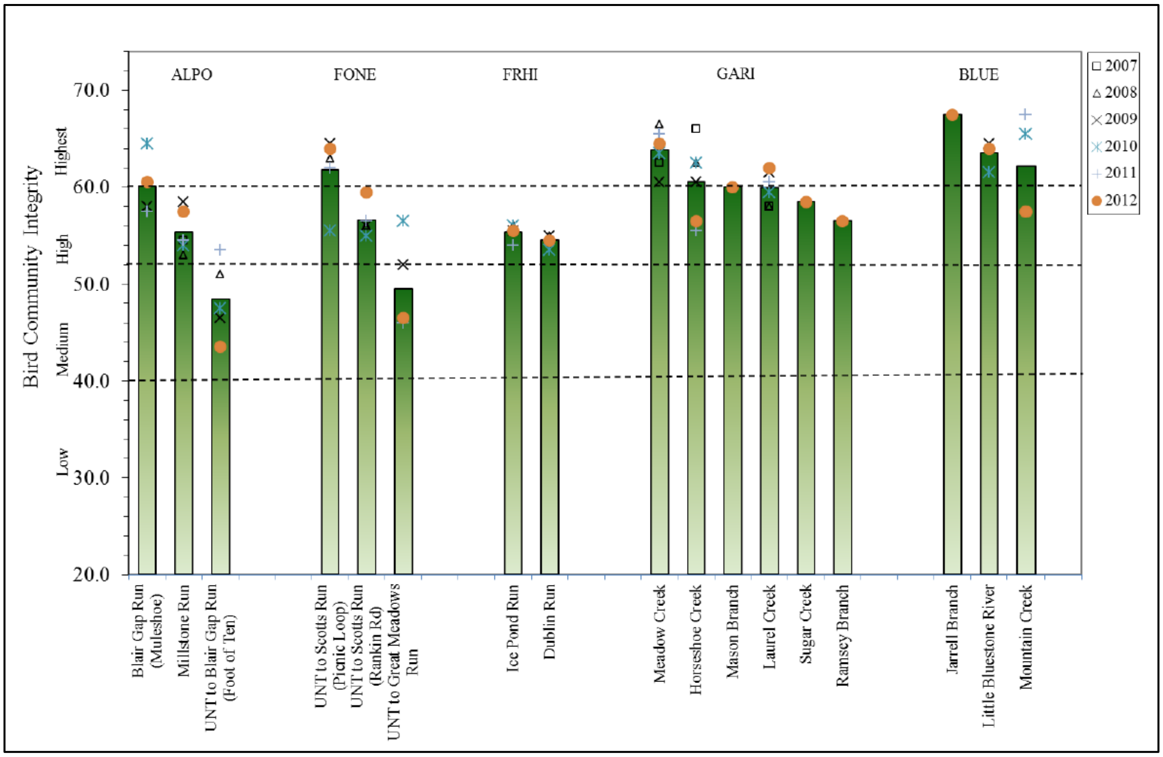


Figure 21. Bird community index of biotic integrity (O'Connell et al. 2000) for several Eastern Rivers and Mountains Network parks. Bird Community Index results for Bluestone National Scenic River are depicted on the far right of the graph. Bar height represents the mean of 1-6 years of sampling. Points depict values for individual years. Higher values indicate higher ecological integrity. Dashed horizontal lines depict thresholds between low, medium, high, and highest ecological integrity (reproduced from Marshall et al. 2013). ALPO = Allegheny Portage Railroad National Historic Site, FONE = Fort Necessity National Battlefield, FRHI = Friendship Hill National Historic Site.

Annual Turkey Harvest

The wild turkey exists in a wide variety of habitats across its native range (historically in 39 states in the U.S.), and was almost driven to extinction shortly after North America was colonized by Europeans (Dickson 1992). By 1920, wild turkey populations had been extirpated in 18 of the 39 states within the species' native range (Dickson 1992). Population numbers nationwide have returned to high levels, and hunting seasons exist for the species in nearly every state where the species is found. Much like the annual waterfowl harvest measure, there are currently no turkey harvest statistics specific to BLUE. However, the WV DNR summarizes annual spring and fall turkey harvests and reports results by county. The majority of BLUE falls within Summers County, with a small portion of the southern end of the park falling within Mercer County. The annual harvest results for both of these counties are reported below, with the caveat that these results may not truly be representative of expected harvest within BLUE boundaries. Instead, these harvest estimates provide reasonable insight into the overall harvestable turkey population in the region.

There are two primary turkey hunting seasons in West Virginia, the spring turkey hunt (between 17 April and 13 May in 2016), and the fall turkey hunt (from 8-15 October in 2016). Spring daily bag limits are one bearded turkey, with a season limit/possession limit of two bearded turkeys. In the fall, hunters may only take one turkey of either sex (WV DNR 2016a). Spring harvest in Summers County has ranged from 176 (2012) to 258 bearded turkeys (2013) (210.4 turkeys/year on average), while Mercer County has ranged from 146 (2012) to 186 bearded turkeys (2011) (168 turkeys/year on average) (Table 31). Fall harvests were lower for both counties. Summers County had between 26 (2015) and 73 (2012) turkeys harvested, with an average of 42.6 turkeys harvested per year. Mercer County only had two open fall seasons from 2011-2015, with 52 birds harvested in 2011 and two birds harvested in 2014.

Table 31. Annual turkey harvest in Mercer and Summers Counties from 2011-2015 (WV DNR 2016a). "C" represents a closed hunting season.

Season	Location	2011	2012	2013	2014	2015
Spring Season	Mercer County	186	146	177	170	161
	Summers County	210	176	258	209	199
Fall Season	Mercer County	52	C	C	2	C
	Summers County	31	73	42	41	26

Threats and Stressor Factors

NPS staff identified several threats to BLUE's bird communities, including climate change, water quality, timber plots outside the park, and cultivated agriculture upstream of the park. Climate change is one of the major forces affecting bird communities across the globe; this threat is becoming better understood as research and data continue to become available. Changes in the temperature and precipitation norms in the park could have both direct and indirect effects on the bird community of BLUE. An example of a direct impact to the bird community in the park includes potential shifts in the timing of spring plant phenology, while indirect impacts resulting from shifts in temperature and precipitation could include effects on the frequency, extent, and severity of insect outbreaks. These insect outbreaks often have lasting effects on communities, as tree mortality can influence the overall habitat structure and species composition of forest areas for many years.

Another climate-related threat facing breeding landbird populations is the shifting of species' reproductive phenology. Several bird species depend on temperature ranges or weather cycles to cue their breeding. As global temperatures change, some bird species have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring; American robins in the Colorado Rocky Mountains are now returning to their breeding grounds 14 days earlier compared to 1981 (NABCI 2009). A concern is that this shift in migration may be out of sync with food availability and could ultimately lead to lowered reproductive success and population declines (Jones and Cresswell 2010).

Migratory bird species face deteriorating habitat conditions along their migratory routes and on wintering grounds. Most of the birds that breed in the U.S. winter in the Neotropics (MacArthur

1959); deforestation in these wintering grounds has occurred at an annual rate up to 3.5% (Lanly 1982). While forest and habitat degradation does occur in the United States, it does not approach the level of degradation seen in the tropics (WRI 1989). Furthermore, Robbins et al. (1989) supported the suggestion that deforestation in the tropics has a more direct impact on Neotropical migrant populations than deforestation and habitat loss in the U.S.

Deteriorating habitat conditions are not restricted to migratory routes or wintering grounds, however, as several of the breeding habitats in BLUE are also at risk of degradation. In forested areas surrounding BLUE, most of the timber is considered harvestable, and active logging occurs near and adjacent to the park (Purvis 2002). Logging, and the roads associated with logging activity, increase soil exposure and erosion, which in turn increases sedimentation of streams in the area (Hebner 1991, Purvis 2002). Additionally, the removal of mature timber trees eliminates nesting and foraging habitat for many forest interior species, and creates additional edge habitats.

Degradation of the park's water quality could have impacts on BLUE's bird population, especially with the high observed levels of biotic integrity in these areas reported by Marshall et al. (2013). As previously discussed, logging activities increase sedimentation in area streams, and contributes to a reduction in overall stream quality. An additional water quality threat in the area are the agricultural practices that occur within the BLUE area. Approximately 20% of the land cover in BLUE's watershed is crop and pasture land (Sheeder et al. 2004), and agricultural land uses can contribute pollutants (e.g., chemicals, nutrients, fecal bacteria from livestock) and excess sediment to streams.

Data Needs/Gaps

Continuation of both the annual NPS-led PCS efforts and the ERMN streamside bird monitoring (Marshall et al. 2013) in the park would allow for long-term trend analysis for many observed species, and would allow managers to better monitor the health of the park's avian and vegetation communities. The NPS-led PCS efforts are especially important to continue as it represents the longest avian survey to take place in the park, with almost 20 years of data, and it also covers a much broader range of habitats than the ERMN streamside monitoring.

Annual monitoring of regional/local habitat changes within a specific distance of BLUE would allow BLUE managers to better detect and understand landscape level changes occurring around the park, specifically in regards to logging practices, strip mining, and land clearing/development. These potential changes would all directly impact the park's bird communities and could disrupt the otherwise continuous tracts of forest near the park.

Expansion of existing survey efforts could sample areas and groups of birds that are missed by current methodologies. For example, few data exist that pertain directly to bird species that utilize the Bluestone River, particularly during the non-breeding seasons. While not as large as the nearby Gauley River or New River, the Bluestone River likely supports several unique species during the winter months that are missed during previously established monitoring efforts. The stream and river corridors of BLUE are of high importance for many species in the park, as nine of the 11 species of conservation concern that occur in the park are directly tied to water-related habitats (Table 22). Expansion of survey efforts could also include sampling of the raptor communities in the park, as these species are often under-represented during traditional point count methodologies. The Bluestone River gorge may offer suitable nesting habitat for cliff dwelling raptors such as the peregrine falcon (*Falco peregrinus*) and additional investigations would be needed to verify its presence.

Annual harvest estimates for waterfowl and turkeys in BLUE and the surrounding area are needed in order to assess the current condition of those measures, and to determine the potential impacts that harvest may have on the park's game species.

<u>Overall Condition</u>

Species Richness

The BLUE project team assigned the species richness measure a *Significance Level* of 3 during project scoping. Determining the species richness condition is a bit unique, as higher species richness estimates do not always correlate to higher indices of quality. The presence of non-native species, generalist species, or vagrant species may increase the species richness estimate while not truly increasing the overall condition of the avian community. Instead, species richness must be assessed based on the expected species in the park, as well as making sure that focal communities and guilds (e.g., forest-dwelling species) remain intact and free from excessive generalist species.

Species richness values obtained from the various bird surveys completed in BLUE indicate species richness estimates that are about what is to be expected based on the size and location of the park. Yearly species richness estimates remained relatively constant throughout the NPS-led PCS. Similarly, results from Pauley et al. (2003) and Marshall et al. (2013) indicated relatively stable species richness estimates for the park.

The species richness estimates of native forest dwelling species remained high throughout the duration of all surveys, suggesting that the forest community in BLUE is in good condition. The most common and frequently detected species during the NPS PCS efforts were nearly universally forest-dwelling species. For these reasons, the *Condition Level* of species richness in BLUE was determined to be 1, indicating low current concern.

Species Abundance

The species abundance measure was assigned a *Significance Level* of 2 during project scoping. Abundance estimates obtained during NPS-led PCS efforts were variable, but overall species abundance estimates did not indicate any major declines or problematic trends. The majority of the most frequently detected bird species during the NPS PCS efforts were interior forest obligates, such as the scarlet tanager and red-eyed vireo. The persistent abundance of these species again highlights the overall health of both the forest communities and the forest-dependent species in the park. The absence of these species, or a dramatic reduction in annual abundance would likely indicate a shift in the overall health of the interior forest communities, and no such trend was apparent during the period of record for BLUE.

At present, there does not appear to be any major concern regarding the annual abundance of birds in BLUE. However, there is a lack of recent data available outside of the NPS-led PCS efforts. While

ERMN streamside bird monitoring is still ongoing, the results from 2012-2018 are yet to be summarized. A *Condition Level* of 1 was assigned for species abundance at this time; however, expansion of survey efforts and the summarization of recent ERMN monitoring data is needed to assign higher confidence in this assessment.

Species Distribution
A *Significance Level* of 2 was assigned to the species distribution measure. The data related to species distribution were not summarized outside of the species richness and species abundance measures, as the studies that have taken place in BLUE have reported richness and abundance by transect/location. As discussed previously, richness and abundance estimates have not varied much by date or locations, although the Little Bluestone River PCS results have been a bit higher than other locations on average. Avian species in BLUE appear to be closely tied to stream and river habitats, as is evidenced by the Marshall et al. (2013) selection of streamside bird habitats as a focal study area. The presence of several water-dependent species of conservation concern also highlights this priority area. However, as is true for all measures reported here, more recent data are needed to assess the current condition of this measure with high confidence. A *Condition Level* of 1, indicating low concern, was assigned to this measure, with moderate confidence.

Bird Community Index (BCI)
The bird community index measure was assigned a *Significance Level* of 3 during project scoping. This measure dealt primarily with the work of Marshall et al. (2013), as this was the only study in BLUE that reported a BCI. Overall, BCI scores in BLUE were high from 2010-2012, with average values falling into the highest ecological integrity category for all sites. The BCI values from BLUE were among some of the highest values obtained ERMN-wide by Marshall et al. (2013), indicating very high ecological integrity at BLUE. For these reasons, the bird community index measure was assigned a *Condition Level* of 0, indicating no current concern for this metric.

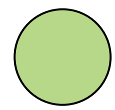
Annual Waterfowl Harvest
BLUE managers assigned the annual waterfowl harvest measure a *Significance Level* of 3 during project scoping. While legal waterfowl species can be harvested within BLUE boundaries, there has been no harvest summary report or survey of waterfowl hunters within the park. Until data exist regarding waterfowl harvest in BLUE, a *Condition Level* cannot be assigned to this measure.

Annual Turkey Harvest
A *Significance Level* of 3 was assigned to the annual turkey harvest measure. Similar to the annual waterfowl harvest measure, no data specific to BLUE exist for this measure. While annual harvest reports exist for the two counties that BLUE falls within, these data represent a wide variety of habitats and locations in the counties and likely do not correlate to the harvest within BLUE. Until park-specific data exist for turkey harvest in BLUE, a *Condition Level* cannot be assigned to this measure.

Weighted Condition Score
The birds component was assigned a *Weighted Condition Score* of 0.15, indicating good current condition (Table 32). The number of species and individuals associated with intact forests remained

high throughout the period of record, indicating that the critical forest community remains healthy and is supporting many birds. The absence of more recent data has reduced the overall confidence in this assessment. Because of this, a trend arrow was not assigned and a medium confidence border was applied to the condition graphic.

Table 32. Current condition of Bluestone National Scenic River's Bird Community.

Measures	Significance Level	Condition Level	WCS = 0.15
Species Richness	3	1	
Species Abundance	2	1	
Species Distribution	2	1	
Bird Community Index	3	0	
Annual Waterfowl Harvest	3	n/a	
Annual Turkey Harvest	3	n/a	

4.3.6. Sources of Expertise

- Matt Marshall, ERMN Program Manager
- Lenza Paul, BLUE Biological Science Technician

4.4 Mammals

4.4.1. Description

Mammals are some of the most visible and recognizable wildlife in eastern national parks. The mature forests, cliffs, and riparian areas of BLUE provide favorable habitat for many species, including common forest mammals such as white-tailed deer, raccoons, and squirrels. These same habitats are critically important foraging and summer roosting areas for many bat species in the park (Castleberry et al. 2007). Bat activity in the region is often associated with riparian zones, but edge habitats are also important, as insects are often abundant and the relatively open nature allows for clearer flight and echolocation paths (Schirmacher et al. 2007). BLUE supports several mammal species of conservation concern (NPS 2016b) (Table 33). Two of these species are federally protected, the Indiana bat (*Myotis sodalis*) as an endangered species and the northern myotis (*M. septentrionalis*) as a threatened species.

Table 33. Mammal species of concern occurring within Bluestone National Scenic River, along with their West Virginia state ranks (WVDNR 2015).

Scientific Name	Common Name	State Rank[a]
Cryptotis parva	least shrew	S2
Lasionycteris noctivagans	silver-haired bat	S2
Myotis leibii	eastern small-footed myotis	S1
Myotis septentrionalis	northern myotis/long-eared bat	S3
Myotis sodalis	Indiana bat	S1
Neotoma magister	Allegheny woodrat	S3
Sorex dispar	long-tailed shrew	S2S3
Sorex hoyi	American pygmy shrew	S2S3
Synaptomys cooperi	southern bog lemming	S3
Zapus hudsonius	meadow jumping mouse	S3

[a] S1 = extremely rare and critically imperiled, S2 = very rare and imperiled, S3 = may be somewhat vulnerable to extirpation

<u>Measures</u>

- Species richness
- Bat species richness
- Annual harvest numbers

4.4.2. Reference Condition/Values

Historic literature pertaining to West Virginia's mammals is scarce, and no information specific to BLUE's mammal populations was published until 2003 (Pauley et al. 2003). As a result, the reference condition for this component is currently undefined. The information presented in this assessment may be used as a baseline for assessing the condition of this resource in the future.

4.4.3. Data and Methods

From 1997-1999, Pauley et al. (2003) conducted a park-wide mammal inventory at BLUE utilizing various methods. Small mammals were captured with Sherman live traps, pitfalls, tomahawk traps, and snap traps. Bats were sampled with mist nets, beginning one hour before dusk and continuing until 10:00 pm (Pauley et al. 2003).

Castleberry et al. (2007) surveyed natural habitats at BLUE for bat species during the summers of 2003 and 2004. Both acoustic monitoring and live capture techniques were utilized. Mist net surveys were conducted in just one area for a total of approximately 20 net-hours. Sampling began at sunset and continued for approximately 5 hours (Castleberry et al. 2007). Acoustic surveys were conducted with an Anabat II detector during the 2-3 hours right after sunset at 40 locations in 2003 (July-Sept) and 44 locations in 2004 (May-Aug). However, considering that is difficult to distinguish between several *Myotis* species with similar echolocation call structures during acoustic surveys (Castleberry et al. 2007), this NRCA will focus on the more reliable mist net survey results.

Hunting harvest data for white-tailed deer and black bears (*Ursus americanus*) are reported at the county level by the WV DNR in annual Big Game Reports (WVDNR 2011, 2016a) and, more recently, in online press releases (WVDNR 2017c, 2018).

4.4.4. Current Condition and Trend

<u>Species Richness</u>

The species richness measures in this component refers to the total number of species present in a given study, survey, or other monitoring effort. It is important to note that a higher species richness estimate does not always correlate to a "healthier" community. The mature, largely unfragmented forests typical of the BLUE area may exhibit lower species richness estimates but could still be considered in good condition, as they provide and sustain critical habitat for some specialized species of wildlife. The fragmentation of these forests may encourage non-native species to move in, which would increase the species richness, but could lower the overall condition of the community.

According to NPSpecies (NPS 2016b), 41 mammal species have been confirmed as present in the park with two additional species considered probably present (Appendix F). Only one species, the house mouse (*Mus musculus*), is non-native to North America. However, non-native feral hogs have also been documented at Pipestem State Park (within BLUE boundaries) but are not yet on the NPSpecies list (Lenza Paul, BLUE Biological Science Technician, written communication, May 2018). Thirty-eight of the 41 confirmed mammal species were observed by Pauley et al. (2003). Anecdotal reports suggest that two additional species not currently on the NPSpecies list are occasionally seen along the park's streams: the American mink (*Neovison vison*) and the river otter (*Lontra canadensis*) (NPS 2016c). Given that West Virginia as a whole supports 66 native mammal species and BLUE does not contain the same number and type of habitats as the entire state, the current species richness is about what would be expected for the park.

Historically, several additional large mammals occurred in West Virginia and may have been present in what is now BLUE. These include eastern elk (*Cervus elaphus canadensis*), bison (*Bison bison*), eastern cougars (*Puma concolor couguar*), and gray wolves (*Canis lupus*). However, the last known sightings of native individuals of these species in the state (excluding reintroduction attempts) were all prior to 1900 (WVDNR 2001, 2008).

Bat Species Richness

NPSpecies (NPS 2016b) lists nine bat species as present within BLUE (Appendix F). Pauley et al. (2003) observed six species, while Castleberry et al. (2007) captured three species during mist netting (Table 34). Acoustic surveys by Castleberry et al. (2007) detected the apparent calls of six additional bat species, but the presence of these species within park boundaries was not confirmed by physical captures.

Table 34. Bat species documented by surveys at Bluestone National Scenic River, 1997-2004.

Scientific Name	Common Name	Pauley et al. (2003)	Castleberry et al. (2007)
Eptesicus fuscus	big brown bat	X	X
Lasionycteris noctivagans	silver-haired bat	–	a[a]
Lasiurus borealis	eastern red bat	X	a
Lasiurus cinereus	hoary bat	–	a
Myotis leibii	eastern small-footed myotis	X	a
Myotis lucifugus	little brown bat	X	X
Myotis septentrionalis	northern myotis	X	a
Myotis sodalis	Indiana bat	–	a
Perimyotis subflavus	tricolored bat	X	X

[a] a = acoustic detection only; not confirmed by physical capture.

The Indiana bat (left, USFWS photo by Adam Mann) and silver-haired bat (right, NPS photo by Sally King) are two bat species of conservation concern found at Bluestone National Scenic River.

Annual Harvest Numbers

In the absence of population size monitoring, harvest numbers and trends provide some insight into the condition of wildlife populations. In West Virginia, black bear and white-tailed deer harvest statistics are reported by county on an annual basis. Statewide, black bear harvest has generally increased since the mid-1980s (Figure 22). Harvests exceeded 3,000 individuals in 2015 (3,201 bears), 2016 (3,012 bears), and 2017 (3,160 bears) (WVDNR 2016a, 2017b, 2018).

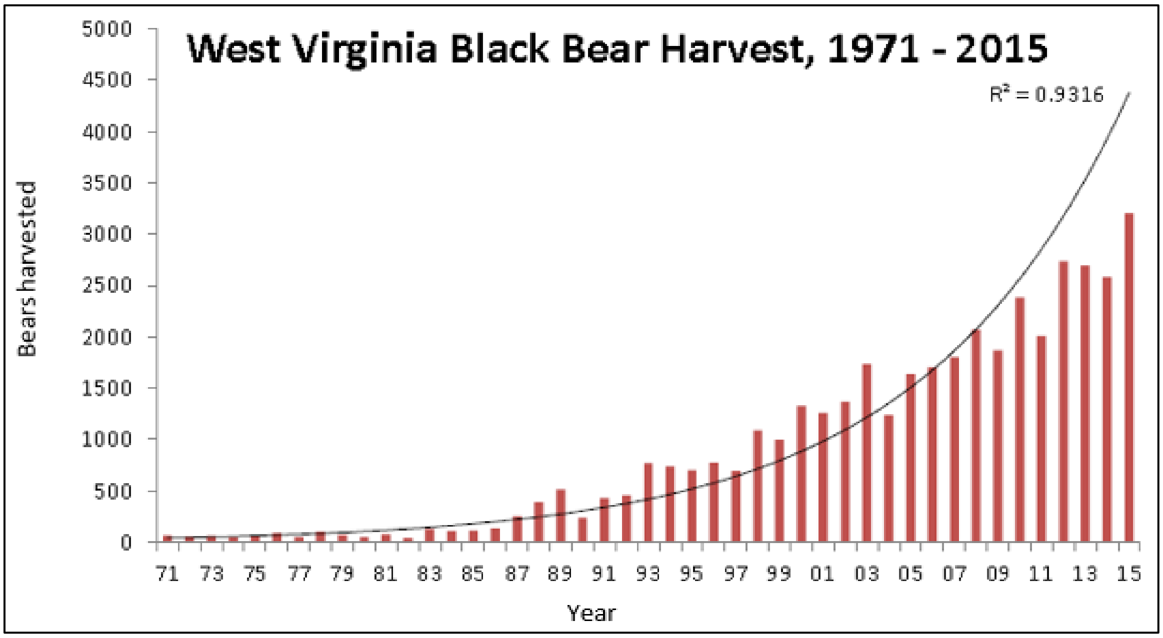


Figure 22. West Virginia black bear harvest, 1971-2015 (reproduced from WVDNR 2016a).

The counties that include BLUE (Mercer and Summers) have also experienced relatively stable or slightly above average black bear harvest numbers in recent years (Table 35). In Mercer County, harvest has exceeded 30 individuals in 4 of the last 7 years, reaching a record high in 2017 at 54 bears (WVDNR 2016a, 2017b, 2018). Summers County harvest numbers also experienced a record high in 2017 at 35 bears, although the 2016 harvest was nearly as high (Table 35). While numbers may fluctuate somewhat between years, these statistics do not raise any particular cause for concern regarding black bear population size in the BLUE region.

Table 35. Black bear harvest within the counties that include Bluestone National Scenic River, 2011-2017 (WVDNR 2016a, 2017b, 2018).

County	2011	2012	2013	2014	2015	2016	2017
Mercer	17	15	32	13	34	39	54
Summers	13	13	18	15	14	34	35

White-tailed deer harvest in West Virginia increased from the 1970s through the 1990s, peaking in 2002 (Figure 23). Numbers declined during the mid-2000s but appear to have stabilized between 100,000 and 150,000 deer harvested annually (WVDNR 2016a).

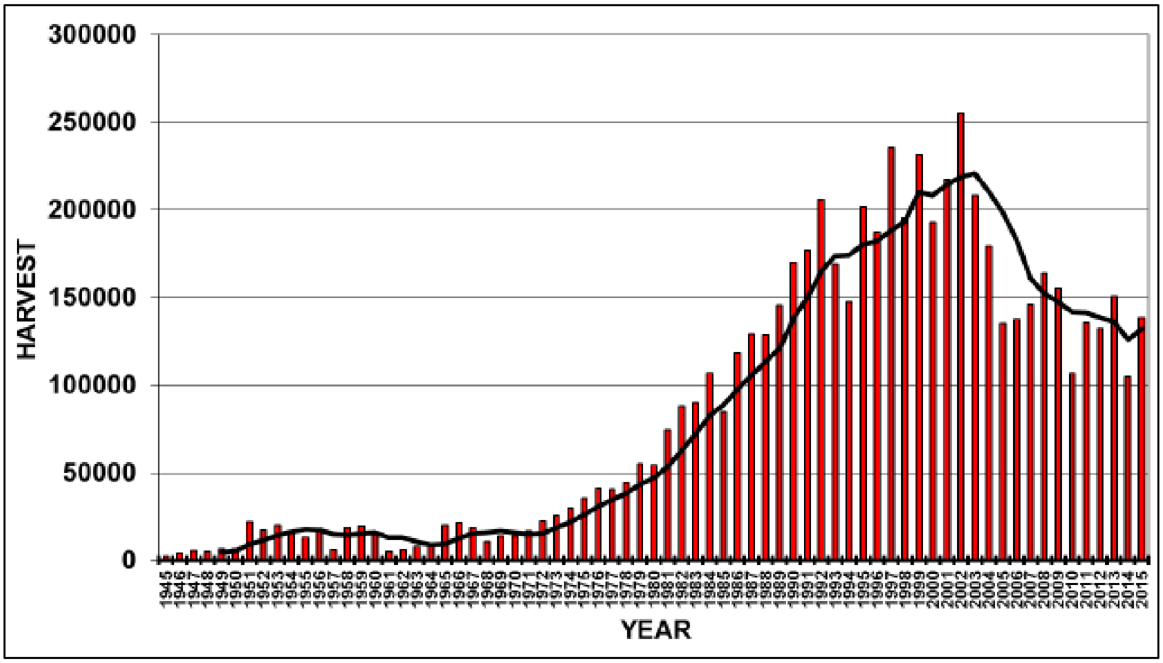


Figure 23. White-tailed deer harvest in West Virginia from 1945-2015 (reproduced from WVDNR 2016a).

In Mercer County, annual white-tailed deer harvest over the past 10 years (2007-2016) has ranged from 831 in 2010 to 2,241 in 2007, with an average of 1,584 deer (Table 36). The annual deer harvest in Summers County has typically been higher, ranging from 1,282 in 2010 to 2,902 in 2012, with an average of 2,216 deer (WVDNR 2011, 2016a, 2017c). In 2015, a special controlled hunt was held for the first time at Pipestem Resort State Park, adjacent to BLUE. From 16-18 November, 51 deer were harvested within state park boundaries (WVDNR 2016a). In general, harvest numbers likely fluctuate naturally over time, but current numbers and trends for the BLUE region do not raise any particular concerns with regards to the deer population.

Table 36. White-tailed deer harvest within the counties that include Bluestone National Scenic River, 2007-2016 (WVDNR 2011, 2016a, 2017c).

County	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mercer	2,241	1,631	1,685	831	1,324	1,359	1,760	1,110	2,111	1,789
Summers	2,245	2,758	2,632	1,282	1,519	2,902	2,771	2,027	2,339	1,684

Threats and Stressor Factors

Threats to mammals at BLUE include habitat fragmentation, adjacent land use, invasive species, climate change, hunting pressure, white-nose syndrome (WNS), and Bluestone Dam maintenance/operations. The impacts of dam operations/maintenance on mammal populations are related to influences on hydrologic regime and habitat, which are discussed in Chapters 4.2 and 4.10. As described in Chapter 4.1, fragmentation has been occurring in the BLUE region since logging began in the late 1800s (Vanderhorst et al. 2008). Timber harvest still occurs on private lands near BLUE and potentially on private inholdings within park boundaries. Other human uses, such as gas extraction development and recreational/residential development also contribute to habitat fragmentation. Such fragmentation often limits mammal species' movements and dispersal, influencing species abundance and density, genetic diversity, and interspecific interactions (Rentch 2006). Fragmentation also creates more "edge" areas, where wildlife are potentially vulnerable to increased predation, exposure to pathogens, and competition with non-native species (Rentch 2006).

Climate change could impact mammal populations directly (e.g., heat and/or water stress) and indirectly (e.g., altered habitats, food availability, pathogen presence/strength). Climate change may also impact seasonal cues that some mammals depend on to trigger behaviors (e.g., hibernation, breeding) (Bronson 2009). In a statewide assessment, Byers and Norris (2011) concluded that two West Virginia species of special concern at BLUE are particularly vulnerable to climate change: the Allegheny woodrat (*Neotoma magister*) and the Indiana bat. Due to its similar habitat needs, the northern myotis is also likely vulnerable to climate change (Sheila Colwell, NPS Wildlife Biologist, written communication, 26 April 2018).

Although not currently a concern, hunting pressure may pose a threat to the park's mammal populations. Hunting is allowed on park lands in accordance with WVDNR state regulations. Deer and bear hunting seasons generally extend from October through December, and some smaller mammals may be hunted throughout the fall and winter (squirrels, foxes, cottontail rabbits [*Sylvilagus floridanus*]), or year-round (skunk [*Mephitis mephitis*], Virginia opossum [*Didelphis virginiana*], woodchuck [*Marmota monax*], coyote [*Canis latrans*]) (WVDNR 2017a).

According to park managers, a small number of non-native feral hogs have been documented in the vicinity of Pipestem Resort State Park, near BLUE (Paul, personal communication, October 2016). Feral hogs damage forested habitats with their rooting behavior and compete for food sources with native wildlife (Campbell and Long 2009, McCoy 2016). Their disturbance of ground vegetation and litter layers could threaten small mammals that rely on these areas for food and shelter (Singer et al. 1984, Campbell and Long 2009). Feral hogs also carry diseases and parasites that could spread to other mammals, including some that impact humans (McCoy 2016).

White-nose syndrome, caused by the fungus *Pseudogymnoascus destructans*, has emerged as the greatest threat to bats in North America in the past decade (Blehert et al. 2008, Castle and Cryan 2010, Cryan et al. 2010). First detected in upstate New York in 2006, WNS has spread rapidly across the U.S., reaching as far west as Oklahoma and Nebraska in just 10 years (two isolated cases were confirmed in Washington State in 2016 and 2017; it is unknown how the disease traversed to the west coast and affected only two isolated counties) (Figure 24) (USFWS 2018b). Affected bats exhibit a white fungal growth on their external body surface, usually around the muzzle, ears, or wings, and experience frequent winter arousal when hibernating. These arousals deplete the bat's body fat prematurely and cause them to experience dehydration, wing damage, starvation, and frequently, death (Foley et al. 2011). It is estimated that WNS has killed more than 6 million bats in the eastern U.S. and Canada since 2006 (Baker et al. 2015). In 2015, the northern myotis was listed as a federally threatened species due to population declines caused by WNS (USFWS 2018a). Transmission primarily occurs from bat-to-bat during the winter months, as the fungus that causes the disease thrives in cold temperatures; it is unknown, however, how long the fungal spores can persist. Anthropogenic spread of WNS is also possible, as contaminated caving gear, clothing, or recreational equipment (e.g., ropes, packs) may facilitate spread of the fungus (Baker et al. 2015, USGS 2017a).

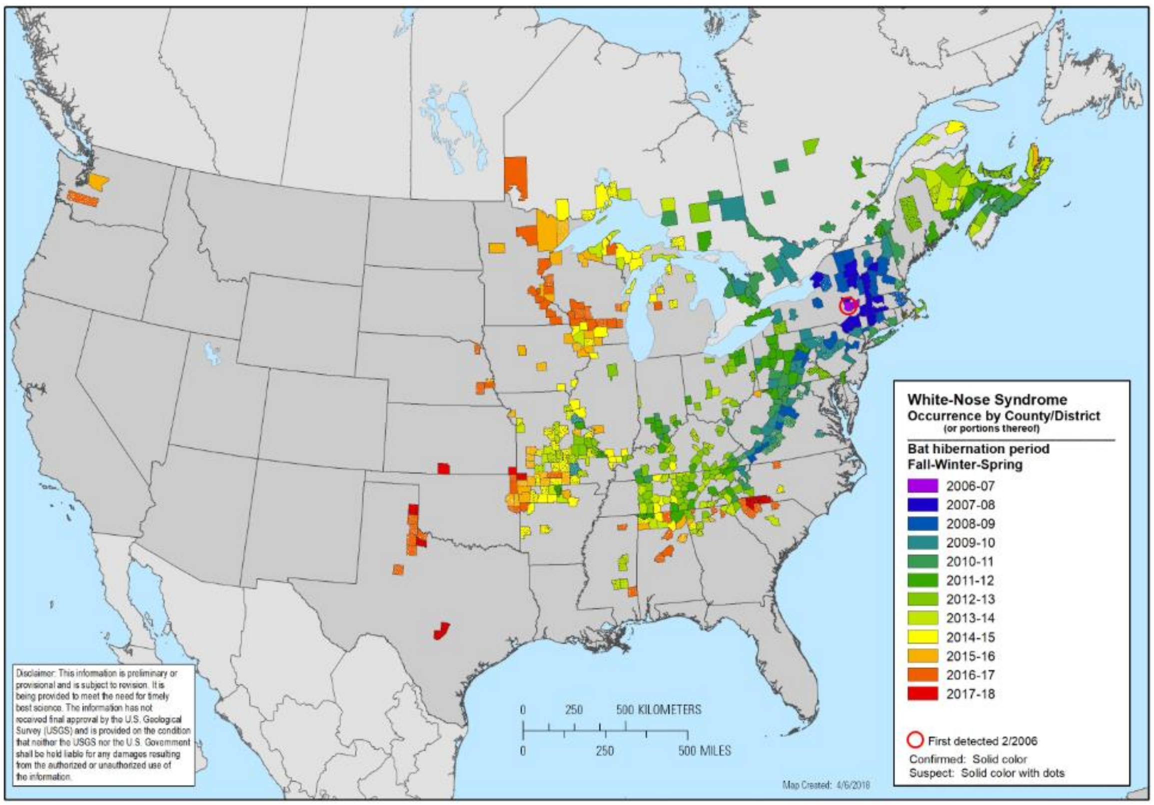


Figure 24. Counties and districts across the continental U.S. and Canada where white-nose syndrome has been confirmed, as of April 2018 (Reproduced from USFWS 2018b). Colors represent the year in which the disease was first detected.

In West Virginia, WNS was first detected in Pendleton County in 2009 (WVDNR 2015). By 2012, the disease had spread across the karst regions of the state, affecting multiple bat species. In 2010, Francl et al. (2012) already noted dramatic declines in capture rates for little brown bats (*Myotis lucifugus*), northern myotises, eastern small-footed myotises (*M. leibii*), Indiana bats, and tricolored bats (*Perimyotis subflavus*). Based on winter 2014-2015 surveys in the state, little brown bats experienced a 97% population decline and Indiana bats an 85% decline (WVDNR 2015). It is not known if WNS has impacted bat populations in the BLUE area.

Data Needs/Gaps

An updated inventory of BLUE mammal species would help to identify any trends in species richness or concerns regarding particular rare or sensitive species. Special attention is likely needed for bat species, given the impact of WNS on bat populations in other portions of the state. Bat inventory and monitoring efforts that utilize mist netting (i.e., physical captures) would be preferred, given the difficulties in distinguishing between several *Myotis* species with similar echolocation call structures during acoustic surveys.

Overall Condition

Species Richness

The project team assigned this measure a *Significance Level* of 3. Forty-one mammal species have been confirmed as present at BLUE, with an additional two species currently considered “probably present” (NPS 2016b). This represents 62% of all mammal species known to occur in the state of West Virginia. Only one confirmed mammal species is considered non-native. Given the relatively small size of the park, this species richness is considered good. Therefore, this measure is assigned a *Condition Level* of 0.

Bat Species Richness

The bat species richness measure was also assigned a *Significance Level* of 3. Surveys have confirmed six bat species as occurring at BLUE through physical capture (Pauley et al. 2003). An additional three species are likely to occur but have only been detected by acoustic surveys (Castleberry et al. 2007). However, no bat survey results have been published since 2007 and, particularly given the presence of WNS in the region, it is unclear whether all of these species are still present within the park. As a result, a *Condition Level* cannot be assigned for this measure.

Annual Harvest Numbers

A *Significance Level* of 3 was assigned for this measure. Although available harvest data are county-wide and not specific to BLUE boundaries, they can provide some insight into the condition of the park’s wildlife populations. At this time, the trends in harvest numbers do not do not raise any particular cause for concern regarding mammal populations in the BLUE region (*Condition Level* = 0).

Weighted Condition Score

The *Weighted Condition Score* for BLUE’s mammals is 0, indicating good condition (Table 37). Given the lack of consistent information for the species richness measures over time, particularly recent studies, it is not currently possible to identify any trends in condition and a medium confidence border has been applied.

Table 37. Current condition of Bluestone National Scenic River's Mammal Community.

Measures	Significance Level	Condition Level	WCS = 0.00
Species Richness	3	0	
Bat Species Richness	3	n/a	
Annual Harvest Numbers	3	0	

4.4.5. Sources of Expertise

- Sheila Colwell, NPS Wildlife Biologist
- Lenza Paul, NERI/GARI/BLUE Biological Science Technician

4.5. Herpetofauna

4.5.1. Description

Herpetofauna species are often used as indicator species in assessments of environmental health, particularly amphibian species that are highly sensitive to environmental change and degradation (Welsh and Ollivier 1998, Rentch 2006). Many herpetofauna species around the world are also in decline due to environmental stressors (Gibbons et al. 2000, Rentch 2006). Reptiles and amphibians are often understudied in protected areas, and have become a focal topic as protecting biodiversity has become a critical goal in NPS units (Scott and Seigel 1992).

The forests and aquatic habitats of BLUE support a diversity of herpetofaunal species, including one reptile species and five salamander species that are of special concern within the State of West Virginia (Pauley et al. 2003). All of these species of special concern are known to breed within the park016e (NPS Pauley et al. 2003, 2016b). Four of BLUE’s salamander species are endemic to the Appalachian Mountains: the black-bellied salamander (*Desmognathus quadramaculatus*), green salamander (*Aneides aeneus*), Cumberland Plateau salamander (*Plethodon kentucki*), and Wehrle’s salamander (*Plethodon wehrlei*) (WV DNR 2015). These endemic salamanders and several other species found at BLUE lack lungs and “breathe” through their skin and mouth lining, making them very sensitive to environmental contaminants and changes in moisture levels. Terrestrial salamanders typically have specific temperature, moisture, and humidity requirements that limit their distribution within the landscape (WV DNR 2015).

The green salamander (left, USGS photo by Alan Cressler) and Wehrle’s salamander (right, photo by Todd Pierson) are two of the Appalachian endemics that occur at Bluestone National Scenic River.

Most amphibians require standing water for breeding habitat (WV DNR 2015). Natural pools suitable for breeding are somewhat rare within BLUE, but artificial pools that form in ruts in or along roads and trails (i.e., as a result of human activity) have become important breeding habitats for the park’s amphibians (Pauley et al. 2003). During vertebrate surveys, Pauley et al. (2003) observed egg masses from several frog and salamander species in these “road-rut pools”. Habitats with rocks and/or open areas, including roads and trails, are valuable for reptiles and some amphibians that rely on solar radiation to warm their ectothermic (i.e., “cold-blooded) bodies (Pauley et al. 2003).

4.5.2. Measures

- Species richness
- Species abundance
- Species distribution

4.5.3. Reference Condition/Values

Very little is known about the herpetofauna community within BLUE. However, the most comprehensive source for the state (Green and Pauley 1987) shows that 34 amphibian and 22 reptile species have been documented in Summers and Mercer Counties, where BLUE is located. BLUE may not contain all the habitats that are found across both counties and therefore may not support all of these species; however, the number of species identified as present by Green and Pauley (1987) will serve as an informal reference condition for the species richness measure. The reference conditions for species abundance and distribution are undefined at this time. Information presented in the current condition section of this report may be used as a baseline for assessing condition in the future.

4.5.4. Data and Methods

A herpetofaunal inventory and sampling of BLUE was conducted from 1996-2000 by a team from Marshall University (Pauley et al. 2003). The objectives of this inventory were to document reptile and amphibian species diversity, abundance, distribution, and habitat types. Day and night-time searches were conducted across both terrestrial and aquatic habitats throughout BLUE. In addition to simple ground searches, team members utilized pitfall traps, dip nets in pools and ponds, minnow and turtle hoop traps in streams, and breeding chorus surveys for frogs and toads (Pauley et al. 2003). A total of 213 sites were inventoried across 16 different habitat types.

4.5.5. Current Condition and Trend

Species Richness

During inventory and sampling efforts at BLUE, Pauley et al. (2003) documented 28 amphibian species and 12 reptile species (Appendix G). The amphibians documented included eight frog species, one toad species, and 19 salamander species. Reptiles included two lizard species, two turtle species, and eight snake species. Three species represented new county records for Summers County: southern ravine salamander (*Plethodon richmondi*), Wehrle's salamander, and rough greensnake (*Opheodrys aestivus*; Figure 25). Based on habitat, researchers expected more species of turtles and possibly eastern hellbenders (*Cryptobranchus a. alleganiensis*) or mudpuppies (*Necturus m. maculosus*) to occur along the Bluestone River, but none were observed. Long-term residents of the area reported that eastern hellbenders were common in the river 20-30 years ago, but had not been seen in several years (Pauley et al. 2003).

Figure 25. Rough greensnake, a West Virginia species of conservation concern (WVDNR photo by Mark B. Watson).

Species Abundance

Pauley et al. (2003) observed a total of 1,564 individual reptiles and amphibians throughout their study period. The vast majority of individuals observed (~94%) were amphibians (Table 38). Among amphibians, salamanders were most abundant (66% of amphibian individuals), while snakes and turtles were nearly equally abundant among reptiles (45% of reptile individuals each). Five or fewer individuals were documented for three amphibian species (all salamanders) and for seven reptile species (primarily snakes). Researchers noted that a portion of their study period (1997-1999) was unusually dry in West Virginia and may have contributed to low observation numbers at some sites (Pauley et al. 2003). Species abundances by habitat type are provided in Appendix H (terrestrial habitats) and Appendix I (aquatic habitats).

Table 38. The abundance of herpetofauna categories documented at Bluestone National Scenic River by Pauley et al. (2003), along with the most abundant species in each category.

Herpetofauna	Individuals
Total reptiles	**98**
Total turtles	45
Eastern box turtle (Terrapene c. carolina)	40
Total lizards	9
Eastern fence lizard (Sceloporus undulatus)	6
Total snakes	44
Northern ringneck snake (Diadophis punctatus edwardsii)	13
Total amphibians	**1,466**
Total frogs and toads	494
Pickerel frog (Lithobates palustris)	148
Total salamanders	972
Red-spotted newt (Notophthalmus v. viridescens)	183

Species Distribution

Pauley et al. (2003) found more herpetofauna species in BLUE's terrestrial habitats (33 species) than in aquatic habitats (28 species), despite sampling a greater number of aquatic sites (Table 39). The difference is largely among reptile species, as only four reptiles were observed in aquatic habitats. However, more total individuals were observed at aquatic habitat sites than at terrestrial habitat sites (981 vs. 583) (Pauley et al. 2003). Forests supported the highest number of species (23), followed by rock outcrops (19). Amphibian abundance was highest in forests (262 individuals), followed by ephemeral pools and road-rut pools (232 individuals each). Reptile abundance was highest on trails/roads and banks (30 individuals) and in forests (29 individuals) (Table 39). In the case of forests and ephemeral pools, the high abundance may be related to the high number of inventories/site visits.able

Table 39. Number of herpetofauna species and total individuals observed by habitat type within Bluestone National Scenic River's (Pauley et al. 2003).

Habitat Type	Total Inventories	Species Richness		Total Individuals	
		Reptile	Amphibian	Reptile	Amphibian
Terrestrial	**191**	**11**	**22**	**69**	**514**
Forest	93	7	16	29	262
Rock outcrop	32	1	18	3	181
Trails/roads and banks	46	9	8	30	23
Emergent rocks or boulder fields	6	1	9	1	42
Field and rights-of-way	7	5	4	5	5
Old Field	7	1	1	1	1
Aquatic	**298**	**4**	**24**	**29**	**952**
Riparian zone	38	2	14	11	139
Ephemeral pool	81	2	12	3	232
First-order streams	68	0	14	0	157
Road-rut pool	37	2	10	4	232
Second-order streams	21	1	7	1	107
Permanent pool	20	0	7	0	76
Spring/seep	9	2	5	4	5
Bluestone River	16	3	2	5	N/A*
Wet meadow	6	1	2	1	N/A*
Third-order streams	2	0	2	0	4

*The number of individuals is unknown for these habitats because amphibian species were detected by calls only, no individuals were captured or visually observed.

The number and diversity of habitat types where a species was observed provides some insight into their distribution. Species found in a greater number of habitats, and in both terrestrial and aquatic types, likely have a wider distribution. At BLUE, the most widely distributed reptile was the eastern box turtle (*Terrapene c. carolina*), found in nine of the 16 habitat types (three terrestrial, six aquatic)

(Appendix J). The eastern fence lizard (*Sceloporus undulatus*) and northern ringneck snake (*Diadophis punctatus edwardsii*) were also widely distributed among terrestrial and aquatic habitat types (Pauley et al. 2003). Just one reptile, the rough greensnake, was found in a single habitat type.

Among amphibians, the most widely distributed species was the pickerel frog (*Lithobates palustris*), which was found in 13 habitat types (six terrestrial, seven aquatic) (Appendix J). The northern green frog (*Lithobates clamitans melanota*), red-spotted newt (*Notophthalmus v. viridescens*), and eastern American toad (*Anaxyrus a. americanus*) were also found in a high number of habitats. Five amphibian species (one frog, four salamanders) were limited to a single habitat type (Pauley et al. 2003).

Maps of the sampling locations where each herpetofauna species was encountered by Pauley et al. (2003) are included in Appendix K. While many species were distributed throughout the park, several were more common in the northern, downstream portion, including the common water snake (*Nerodia s. sipedon*), five-lined skink (*Eumeces fasciatus*), Allegheny Mountain dusky salamander (*Desmognathus ochrophaeus*), and black-bellied salamander. One species, the eastern fence lizard, was observed only in the southern, upstream portion of the park (Pauley et al. 2003).

<u>Threats and Stressor Factors</u>

Threats to BLUE’s herpetofauna include habitat alteration and fragmentation, impaired water quality, pathogens, recreational use, bait collection and release, illegal moss harvest, pesticides, and climate change. Habitat loss and alteration are considered a primary threat to herpetofauna populations. In North America, the loss of freshwater wetlands has been substantial (Dahl 2000). A reduction in these important aquatic habitats, along with an increase in landscape fragmentation, have been implicated in declining trends in aquatic biodiversity, particularly aquatic reptile and amphibian taxa (Bates et al. 2008). At BLUE, deciduous forests also support a high diversity of herpetofauna but are impacted by fragmentation, which impacts species movement/migration (Pauley et al. 2003). As mentioned in Chapter 4.1, fragmentation due to logging occurred in the BLUE region from the late 1800s through at least the 1950s (Rentch et al. 2005). Recreational trails, transportation corridors (roads and railways), and pipeline/powerline corridors also fragment the landscape, exposing forest edges to additional threats such as exotic species invasion, alteration of temperature/moisture regimes, and exposure to harsh weather conditions (Pauley et al. 2003, Rentch 2006). Within BLUE, the WVDNR mows some floodplain areas towards the north end of the park (described in Chapter 4.2), which contributes to fragmentation of forested habitat (Perez, written communication, April 2018).

With many of BLUE’s herpetofauna species dependent on aquatic habitat at some stage in their life cycles, drought is a major threat to these populations. Climate change has been implicated in widespread drought events, which are interspersed with deluges (Bates et al. 2008). This results in huge amounts of runoff, erosion, and occasional flooding that damage riparian areas and other important aquatic habitats, as well as degrading water quality (Bates et al. 2008). Riparian flooding during the summer may destroy vegetative cover utilized by young herpetofauna and could wash away larval amphibians and/or turtle nests (Purvis 2002). An overall increase in global temperatures associated with climate change, which contributes to extended periods of drought, will have a combined effect on biota by causing temperature and water stress (Bates et al. 2008). In West Virginia, amphibians have been identified as one of the taxonomic groups most vulnerable to climate change (Byers and Norris 2011), with some species already being negatively impacted within the state (Pauley 2006).

Ranavirus is a genus in the family Iridoviridae which can infect multiple species of amphibians and some reptiles (e.g., box turtles) (USGS 2016b). These viruses have been associated with die-offs of more than 20 species of amphibians and turtles in over 25 states across the U.S., and they are known to be present in West Virginia (WVDNR 2015, USGS 2016b). Mortality due to ranaviruses occurs mostly in larval amphibians, true frogs, and chorus frogs. Infected individuals may exhibit subtle or severe hemorrhages in ventral skin, often appearing as an irregular rash; onset of illness is sudden and frequently affects most individuals within a wetland (up to or exceeding 90%) (USGS 2016b). Observed outbreaks have often been within wetland ecosystems and cause mass die-off of frogs and salamanders, with the highest mortality rates occurring in juveniles (USGS 2016b).

Chytrid fungus, specifically *Batrachochytrium dendrobatidis* (*Bd*), is an amphibian pathogen that could potentially affect BLUE's populations. The pathogen has been identified as the cause of severe population declines on several continents, including North America (Piotrowski et al. 2004). A similar fungus, *Batrachochytrium salamandrivorans* (*Bsal*), impacts salamanders specifically but has not yet been documented in North America (Yap et al. 2015). Amphibians infected by *Bd* or *Bsal* develop chytridiomycosis, an infectious non-hyphal zoosporic fungus that causes roughening and reddening of the skin, convulsions, ulcers and hemorrhages, and sporadic death. Not all amphibians infected with *Bd* develop chytridiomycosis or die; environmental factors, such as pH of the environment, drought, and temperature at time of infection, may affect mortality rates. Some research indicates that *Bd* growth is inhibited by high temperatures (28°C [82°F]) and exposure of infected individuals to high temperatures may kill the fungus (Woodhams et al. 2003). If this is the case, the threat of chytrid at BLUE may abate somewhat during warmer summers or as average temperatures rise with global climate change. To date, chytrid fungus has not been detected in or near BLUE, but a black-bellied salamander captured near Quinnimont in the vicinity of NERI tested positive for the fungus in 2008 (Bartkus 2009).

Activities related to recreational fishing can threaten herpetofauna populations in several ways. Some salamanders, such as the black-bellied salamander, are collected for use as bait (Purvis 2002). Many amphibian species face competition or predation from non-native bait species (e.g., fish, crayfish) that are released, accidentally or intentionally, into aquatic habitats by visiting anglers. When bait species are introduced to smaller water bodies where they previously were not present, amphibians and their eggs are often exposed to a novel predation source that they are not adapted to (Kats and Ferrer 2003, WVDNR 2015). Introduced bait species that are not predators may still compete with native herpetofauna for habitat and food resources and may spread pathogens (WVDNR 2015). Other recreational activities, particularly off-road vehicle (ORV) use, can negatively impact herpetofauna species. ORV use, which can do significant damage to wildlife habitat, has increased in West Virginia and across the country over time (Pauley et al. 2003, Andrews et al. 2006). These vehicles disturb and destroy road-rut pools and can crush herpetofauna eggs, larvae, and adults (Pauley et al. 2003, Andrews et al. 2006).

Water quality impairment due to human activities often impacts aquatic herpetofauna. These impairments include contaminants (e.g., pesticides, mining waste, endocrine disrupting chemicals) and siltation/sedimentation (WVDNR 2015). Contaminants have been shown to significantly affect herpetofauna development, growth, reproduction, and immune system functions (Gibbons et al. 2000, Hayes et al. 2006). Pesticides and other chemicals may be ingested by herpetofauna if their prey species are contaminated (e.g., insects, other invertebrates) and can be absorbed directly through the skin of some amphibians (Smith et al. 2007, WVDNR 2015). Excess silt and sediment in water bodies can degrade aquatic habitat and may destroy food resources (Bilotta and Brazier 2008, WVDNR 2015).

Data Needs/Gaps

Information regarding BLUE's herpetofauna populations is largely limited to a single study from over 15 years ago (Pauley et al. 2003). Rentch (2006) recommended regular herpetofauna sampling within ERMN parks, particularly since the environmental sensitivity of many species could provide park managers with an "early warning" of environmental degradation. Sampling could be stratified by vegetative cover type and staggered over 3-5 years so that not all herpetofauna species are targeted every year (Rentch 2006). Each year in the rotation could focus on certain species with similar habitats that could be inventoried with similar methods. Given the difficulties in herpetofauna study (e.g., small size, seasonal and/or secretive behavior), focus should be on relative diversity and density/abundance rather than exact population numbers and distributions (Rentch 2006). In addition, regular disease surveillance would help managers detect the presence and potentially the impacts of pathogens such as chytrid fungus and ranavirus (WVDNR 2015).

Overall Condition

Species Richness

The NRCA project team assigned this measure a *Significance Level* of 3. Pauley et al. (2003) documented 28 amphibian and 12 reptile species at BLUE during 1996-2000 inventory and sampling efforts. These totals are below the number of species documented in Mercer and Summers County (34 amphibian, 22 reptile) (Green and Pauley 1987). However, BLUE may not contain all the same habitats as across both counties and therefore may not be capable of supporting all these species. It is also possible that the methodology and timing of Pauley et al. (2003) may have decreased the likelihood of encountering some species. No systematic surveys have occurred since 2000 to determine if herpetofauna species richness has changed over time. As a result, a *Condition Level* cannot be assigned.

Species Abundance

The abundance measure was also assigned a *Significance Level* of 3. Pauley et al. (2003) surveys showed that some herpetofauna species were relatively abundant at BLUE (Table 32) while others were rare. As with species richness, more recent data is not available to determine if species abundances have shifted since that time. Therefore, a *Condition Level* cannot currently be assigned for this measure.

Species Distribution
A *Significance Level* of 3 was also assigned for the distribution measure. Many of the park's herpetofauna were well distributed throughout the park and across habitat types, but some species appear to show limited distributions (Appendix K). Given the limited data, it is unclear if restricted distributions are related to limited habitat availability within BLUE or are simply due to species rarity. As with previous measures, a *Condition Level* could not be assigned, given the lack of recent data.

Weighted Condition Score
A *Weighted Condition Score* for BLUE's herpetofauna could not be calculated for BLUE's herpetofauna due to a lack of recent data and information (Table 40). The current condition and trend for the component are considered unknown at this time.

Table 40. Current condition of Bluestone National Scenic River's Herpetofauna Community.

Measures	Significance Level	Condition Level	WCS = N/A
Species Richness	3	n/a	
Species Abundance	3	n/a	
Species Distribution	3	n/a	

4.5.6. Sources of Expertise

- Lenza Paul, NERI/GARI/BLUE Biological Science Technician (Wildlife)
- John Perez, NERI/GARI/BLUE Biologist

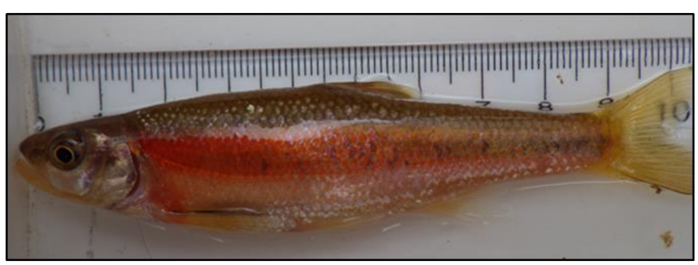
4.6. Aquatic Wildlife Community

4.6.1. Description

The aquatic wildlife community of BLUE includes aquatic animals that rely upon the park's rivers and streams, such as fish and aquatic macroinvertebrates. Aquatic macroinvertebrates are invertebrates that can be seen without the aid of a microscope (e.g., insects and their larvae, mussels, crayfish) (Marshall and Piekielek 2007a, WVDEP 2016a). Fish and aquatic macroinvertebrates have both been used as bioindicators of stream ecosystem health (Marshall et al. 2006, Faulk 2015, Tzilkowski et al. 2015). Since fish are more mobile and generally longer-lived than invertebrates, they are considered better indicators of watershed-scale health, while macroinvertebrates are more indicative of localized conditions (Marshall et al. 2006, Anderson and Petty 2015).

Benthic macroinvertebrates (BMI), which live on or within the stream bottom, have frequently been included in water quality monitoring efforts because they are very common, relatively easy to collect, and have consistent responses to human impacts on aquatic systems (Marshall et al. 2006, WVDEP 2016a). BMI are also vital components of stream ecosystems, as they are an important link in the food web, serving as a food source for many other organisms such as fish, herpetofauna, and birds (Tzilkowski et al. 2015, WVDEP 2016a). As a result, BMI were chosen as a Vital Sign for ERMN parks, including BLUE (Marshall and Piekielek 2007a).

Like BMI, fish are also relatively easy to collect and identify, and they are important within the food web, as both predators and prey (Marshall et al. 2006). The fish community of BLUE has been described as relatively "depauperate", compared to neighboring watersheds (Welsh et al. 2006, p. xix), although the Bluestone River does support nearly all of the warm-water game fish that occur in West Virginia (Marshall and Piekielek 2007b). However, many of these game species are non-native and were introduced to "improve" angling opportunities (Purvis 2002). The low native species richness is likely due to migration barriers downstream from the park, particularly the 7.0-7.6 m (23-25 ft) high Kanawha Falls (Messinger and Chambers 2001, Purvis 2002). These falls, along with others such as Sandstone Falls within NERI, have likely prevented the migration of additional fish species that are common further downstream in the Upper Ohio River System (Cincotta and Chambers 1999).

The native fish of Bluestone National Scenic River' include green sunfish (left, NPS photo) and rosyside dace (right, NPS photo courtesy of Evan Faulk).

4.6.2. Measures

- Fish species richness

- Percent native fish species
- Fish species relative abundance
- Aquatic macroinvertebrate species richness
- Benthic macroinvertebrate multimetric index of biotic integrity (MIBI)

4.6.3. Reference Condition/Values

The reference conditions for this component will vary between measures. For the three fish measures, information reported in Welsh et al. (2006) will serve as the reference. No reference condition could be identified for aquatic macroinvertebrate species richness, but reference ranges have been developed by Herlihy et al. (2008) and adopted by the EPA for the regional MIBI utilized by ERMN monitoring (described below). For the Southern Appalachian region where BLUE is located, streams with MIBI scores above 51 are considered in good condition, scores of 37-51 are fair condition, and scores below 37 are poor condition (Herlihy et al. 2008). For the purpose of this assessment, good condition will serve as the reference condition for BLUE.

4.6.4. Data and Methods

In the late 1990s, the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program studied the effects of environmental factors on the fish and BMI communities of the Kanawha River Basin, which includes the Bluestone River system (Chambers and Messinger 2001, Messinger and Chambers 2001). The study sampled fish and BMI at two sets of locations: fixed, indicator sites to reflect overall watershed conditions, and synoptic sites to investigate the impacts of coal mining in the West Virginia portion of the Kanawha Basin (Chambers and Messinger 2001). A fixed sampling site was located on the Bluestone River upstream of BLUE (near Spanishburg) and a synoptic site was located on the Little Bluestone River (near Jumping Branch), also upstream of the park boundary. Fish and BMI samples were collected at fixed sites in 1997 and at synoptic sites in 1998 (Chambers and Messinger 2001, Messinger and Chambers 2001). Fish were collected with electrofishing gear and BMI were sampled by disturbing substrate immediately upstream of a slack sampler (a fine-meshed net) (Figure 26). Benthic macroinvertebrate sampling results were used to calculate modified Hilsenhoff Biotic index (HBI) scores for each location to assess stream degradation (higher scores = more impairment) (Hilsenhoff 1988, Chambers and Messinger 2001). HBI scores are based on the average pollution tolerance values of the taxa present, on a scale of 0-10 (i.e., the most sensitive taxa have a value of zero and the least sensitive taxa have values closer to 10).

Figure 26. USGS researchers sampling benthic macroinvertebrate with a slack sampler (USGS photo by Dennis Sun).

Welsh et al. (2006) compiled historic fish community information and conducted sampling by electrofishing within the Bluestone River drainage in 2004-2005. The study's objectives were to document the diversity of fish species within BLUE and the Bluestone River drainage through a synthesis of historic and recent data, and to estimate fish species abundances within BLUE. Sampling was largely limited to the upper and lower reaches of BLUE, due to extremely low water levels from drought conditions and limited access in the middle portions of BLUE (Welsh et al. 2006; Figure 27). Thirteen of the sites sampled by Welsh et al. (2006) and six historically sampled sites fell within BLUE boundaries (Table 41); only the results from these sites are included in this NRCA.

Table 41. Sampling locations synthesized or surveyed by Welsh et al. (2006) within Bluestone National Scenic River boundaries. Stream locations are shown in Figure 27.

Site #	Year	Stream	Sampling Location
34	1978	Mountain Creek	0.4 km (0.25 mi) above mouth (confluence with Bluestone River)
35	1979	Bluestone River	Below mouth of Mountain Creek at end of Cty Rte 4
38	1979	Bluestone River	At confluence with Little Bluestone River
40	1979	Little Bluestone River	At mouth, upstream 0.4 km (0.25 mi)
47	1979	Mountain Creek	0.4 km (0.25 mi) above mouth (confluence with Bluestone River)
60	1996	Little Bluestone River	0.4 km (0.25 mi) above mouth
72	2004	Bluestone River	Upstream of Mountain Creek mouth/confluence
73	2004	Bluestone River	150 m upstream of Mountain Creek mouth
74	2004	Bluestone River	At mouth of Tony Hollow Run
75	2004	Bluestone River	Downstream of mouth of Little Bluestone River
76	2004	Bluestone River	0.4 km (0.25 mi) below Pipestem River Lodge
78	2004	Bluestone River	At mouth of Mountain Creek
79	2004	Bluestone River	At mouth of Little Bluestone River
82	2004	Little Bluestone River	At mouth
83	2004	Little Bluestone River	Upstream of mouth
84	2004	Mountain Creek	240 m above mouth
85	2004	Tony Hollow Run	250 m above mouth
86	2004	Tributary of Bluestone River	At mouth of unnamed tributary, upstream of mouth of Mountain Creek
87	2004	Tributary of Bluestone River	Upstream of mouth of Little Bluestone River

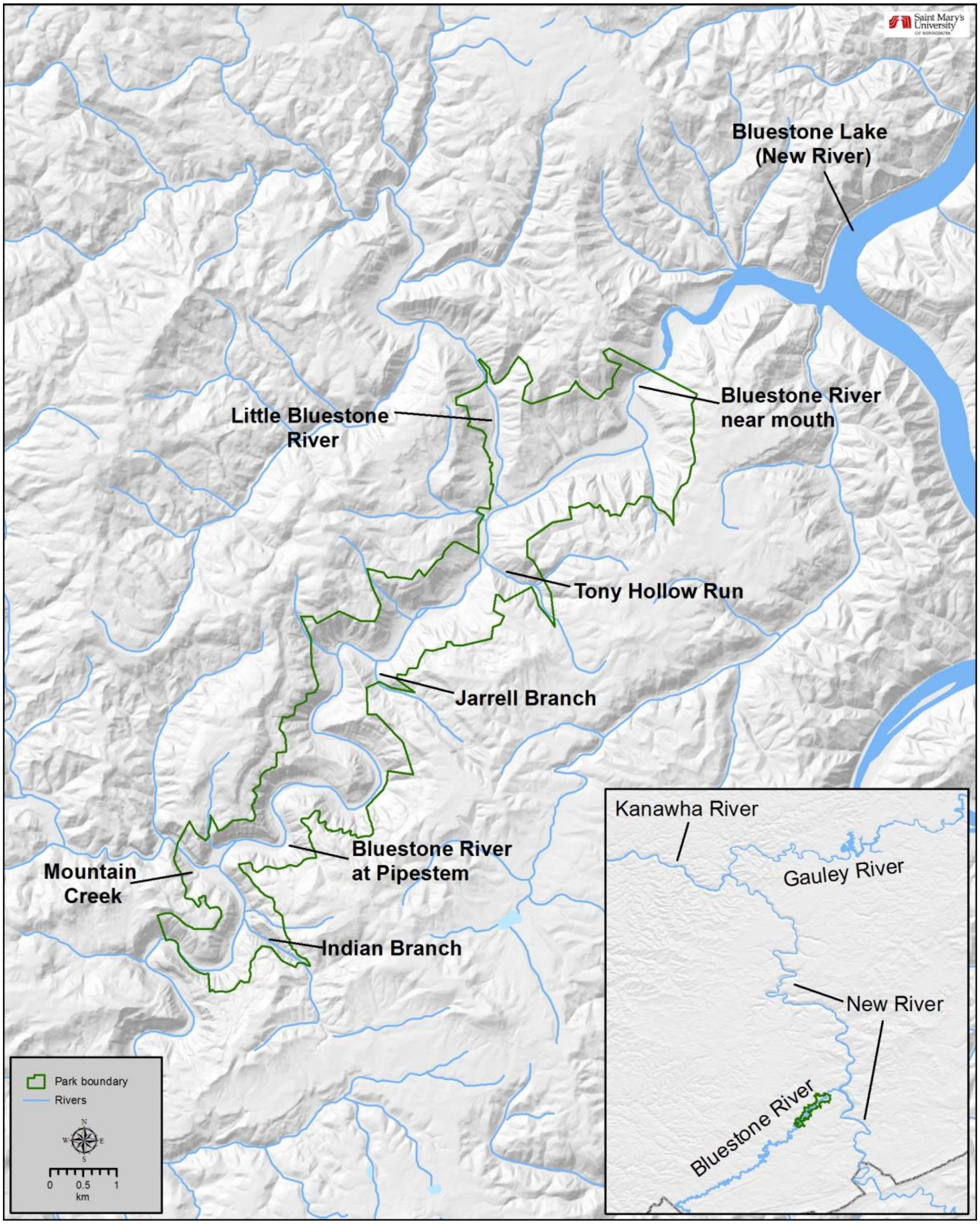


Figure 27. Streams/locations within Bluestone National Scenic River where aquatic wildlife community sampling has been conducted over time. The inset map shows the location of BLUE relative to other rivers in the region.

The ERMN began sampling BMI at network parks in 2008 as part of a wadeable streams monitoring protocol (Tzilkowski et al. 2010, 2015). Four stream reaches within BLUE were initially included in this monitoring: Mountain Creek, the Little Bluestone River, the Bluestone River near its mouth, and the Bluestone River at Pipestem (Figure 27). In 2014, the ERMN began sampling on the Jarrell Branch and Indian Branch and stopped sampling at the two Bluestone River locations (Caleb Tzilkowski, ERMN Aquatic Ecologist, written communication, 19 September 2017). BMI sampling was conducted on the Bluestone River in the fall but on its tributaries in the spring (March-early April), as researchers realized that many mid-sized streams in the region are frequently dry in the fall (Tzilkowski et al. 2010). BMI samples are collected using the USGS richest-targeted habitat (RTH) method (Moulton et al. 2002). An RTH is a habitat that is typically rich in BMI taxa (Tzilkowski et al. 2015); at BLUE, the RTH is riffle habitat (Andrew Weber, ERMN Hydrologic Technician, written communication, February 2018). This involves disturbance-removal sampling, similar to that used by Chambers and Messinger (2001). The data collected were used to calculate a regional MIBI designed for the Mid-Atlantic Highlands Region, where upland and lowland streams are often dominated by riffle habitat (Klemm et al. 2003). This MIBI consists of seven metrics, shown in Table 42.

Table 42. Metrics included in the Multimetric Index of Biotic Integrity utilized by Eastern Rivers and Mountains Network benthic macroinvertebrate sampling (Tzilkowski et al. 2015, based on Klemm et al. 2003).

Metric	Response to Decreasing Biotic Integrity
Ephemeroptera taxa richness	decrease
Plecoptera taxa richness	decrease
Trichoptera taxa richness	decrease
Collector-Filterer (feeding strategy) taxa richness	decrease
% of non-insect individuals	increase
Macroinvertebrate tolerance index (MTI) (abundance-weighted mean tolerance)	increase
% of individuals in the five most dominant taxa	increase

In 2012, the ERMN initiated a pilot project to evaluate the feasibility of including fish monitoring into the Vital Signs program (Faulk and Weber 2017). Four tributary streams within BLUE were sampled by electrofishing during 2014. Three sites (Indian Branch, Little Bluestone River, Mountain Creek) were visited three times and one site (Jarrell Branch) was visited only once because of limited access and an absence of fish on the first visit (Faulk and Weber 2017). The final report includes data on fish species richness, distribution, and abundance.

4.6.5. Current Condition and Trend

Fish Species Richness

Given the relatively low native fish species richness at BLUE (Welsh et al. 2006), low numbers of species alone are not necessarily indicative of poor condition. Rather, changes in species richness may indicate a cause for concern or need for further investigation. The NPS certified species list for BLUE (NPS 2016b) includes 32 confirmed species, nine species considered "probably present", and four species that occurred historically but are considered no longer present (Table 43). One of the confirmed species (bigmouth chub) and one of the historical species (candy darter [*Etheostoma osburni*]) are considered endemic (i.e., native to a limited geographic area). According to Welsh et al. (2006), 26 species were documented within BLUE boundaries by surveys conducted from 1978-1979 and in 1996. During 2004 sampling, Welsh et al. (2006) documented 30 species within park boundaries. This included 11 species not previously observed during historic surveys. However, seven species that had been present previously were not found in 2004 (Welsh et al. 2006). During 2014 sampling, Faulk and Weber (2017) found 23 fish species within BLUE boundaries, including two not currently on the certified species list (Table 43). Species richness was likely lower during 2014 sampling than during 2004 sampling because Faulk and Weber (2017) only sampled smaller tributaries and not the larger main stem of the Bluestone River.

Table 43. Fish species present, probably present, or historically present within Bluestone National Scenic River, according to NPSpecies (NPS 2016b). The last three columns indicate which species were documented by historic surveys (1978-79 and 1996, as reported by Welsh et al. 2006), in 2004 by Welsh et al. (2006), and in 2014 by Faulk and Weber (2017). Those species with the year "1996" listed in the "Historic" column were first documented in that year and had not been noted earlier.

Status in Park	Scientific Name	Common Name	Historic	Welsh et al. 2006	Faulk & Weber 2017
Confirmed present	Catostomus commersoni	white sucker	X	X	X
	Hypentelium nigricans	northern hog sucker	X	X	X
	Campostoma anomalum	central stoneroller	X	X	X
	Clinostomus funduloides	rosyside dace	–	X	X
	Cyprinella galactura[a]	whitetail shiner	X (1996)	X	X
	Cyprinella spiloptera	spotfin shiner	X (1996)	X	–
	Luxilus albeolus	white shiner	X	X	–
	Nocomis leptocephalus[a, c]	bluehead chub	–	–	X
	Nocomis platyrhynchus[b]	bigmouth chub	X	X	–
	Notropis hudsonius[a]	spottail shiner	–	X	–
	Notropis rubellus[a]	rosyface shiner	X	–	–
	Notropis telescopus[a]	telescope shiner	X	X	X

[a] Non-native

[b] Endemic

[c] Not yet on certified species list (first observed in 2014)

Table 43 (continued). Fish species present, probably present, or historically present within Bluestone National Scenic River, according to NPSpecies (NPS 2016b). The last three columns indicate which species were documented by historic surveys (1978-79 and 1996, as reported by Welsh et al. 2006), in 2004 by Welsh et al. (2006), and in 2014 by Faulk and Weber (2017). Those species with the year "1996" listed in the "Historic" column were first documented in that year and had not been noted earlier.

Status in Park	Scientific Name	Common Name	Historic	Welsh et al. 2006	Faulk & Weber 2017
Confirmed present (continued)	Notropis volucellus	mimic shiner	–	X	–
	Chrosomus oreas	mountain redbelly dace	–	X	X
	Pimephales notatus[a]	bluntnose minnow	X	X	X
	Rhinichthys atratulus3	eastern blacknose dace	–	–	X
	Rhinichthys cataractae	longnose dace	X	X	X
	Rhinichthys obtusus	western blacknose dace	–	X	–
	Semotilus atromaculatus	creek chub	X	X	X
	Ambloplites rupestris[a]	rock bass	X	X	X
	Lepomis auritus[a]	redbreast sunfish	–	X	–
	Lepomis cyanellus	green sunfish	–	X	X
	Micropterus dolomieu[a]	smallmouth bass	X	X	X
	Micropterus punctulatus[a]	spotted bass	X (1996)	X	–
	Micropterus salmoides[a]	largemouth bass	–	X	–
	Etheostoma blennioides	greenside darter	X	X	X
	Etheostoma caeruleum[a]	rainbow darter	X	X	X
	Etheostoma flabellare	fantail darter	X	X	X
	Etheostoma simoterum[a]	snubnose darter	–	–	X
	Percina caprodes	logperch	–	X	X
	Percina roanoka[a]	Roanoke darter	X	X	X
	Oncorhynchus mykiss[a]	rainbow trout	–	–	X
	Ameiurus natalis[a]	yellow bullhead	X	X	–
	Noturus insignis[a]1	margined madtom	–	X	X
	Pylodictis olivaris	flathead catfish	–	X	–
Probably present	Labidesthes sicculus[a]	brook silverside	–	–	–
	Dorosoma cepedianum[a]	gizzard shad	–	–	–
	Cyprinus carpio[a]	common carp	–	–	–
	Notemigonus crysoleucas[a]	golden shiner	–	–	–

[a] Non-native,

[b] Endemic,

[c] Not yet on certified species list (first observed in 2014)

Table 43 (continued). Fish species present, probably present, or historically present within Bluestone National Scenic River, according to NPSpecies (NPS 2016b). The last three columns indicate which species were documented by historic surveys (1978-79 and 1996, as reported by Welsh et al. 2006), in 2004 by Welsh et al. (2006), and in 2014 by Faulk and Weber (2017). Those species with the year "1996" listed in the "Historic" column were first documented in that year and had not been noted earlier.

Status in Park	Scientific Name	Common Name	Historic	Welsh et al. 2006	Faulk & Weber 2017
Probably present (continued)	Notropis atherinoides[a]	emerald shiner	–	–	–
	Lepomis gibbosus[a]	pumpkinseed	X	–	–
	Lepomis macrochirus[a]	bluegill	X	–	–
	Pomoxis annularis[a]	white crappie	–	–	–
	Pomoxis nigromaculatus[a]	black crappie	–	–	–
Historical	Luxilus chrysocephalus	striped shiner	X	–	–
	Etheostoma osburni[b]	candy darter	X	–	–
	Percina oxyrhynchus	sharpnose darter	X	–	–
	Ictalurus punctatus	channel catfish	X	–	–

[a] Non-native,

[b] Endemic,

[c] Not yet on certified species list (first observed in 2014)

Percent Native Fish Species

Of the 32 fish species confirmed present according to the BLUE certified species list, 47% are native (NPS 2016b). None of the species considered "probably present" are native. According to historic records (as reported by Welsh et al. 2006), 54% of the species documented were native. Of the 30 fish species observed specifically within BLUE boundaries by Welsh et al. (2006) during 2004 sampling, nearly 57% were native. In the three tributaries sampled by Faulk and Weber (2017), 52% of the fish species documented were native.

Smallmouth bass (left, NPS photo) and rock bass (right, USFWS photo) are two of the common non-native game fish found at Bluestone National Scenic River.

Fish Species Relative Abundance

Welsh et al. (2006) reported the number of fish of each species documented by sampling location, allowing for calculations of relative abundance. The most abundant species within BLUE boundaries during 2004 sampling were central stoneroller (*Campostoma anomalum*) at 35.6%, the endemic bigmouth chub at 15.0%, and the non-native rainbow darter (*Etheostoma caeruleum*) with 12.9% (Table 44). Together, these three species comprised 63.5% of all fish sampled. Seven species showed extremely low abundances, comprising 0.1% or less of sampled fish.

Table 44. Fish species relative abundance during 2004 sampling at Bluestone National Scenic River (Welsh et al. 2006).

Species	# of Sites (out of 13)	Total Individuals	% Relative Abundance
central stoneroller	11	975	35.6
bigmouth chub[b]	10	410	15.0
rainbow darter[a]	9	355	12.9
creek chub	6	138	5.0
Roanoke darter[a]	7	115	4.2
telescope shiner[a]	7	106	3.9
spottail shiner[a]	6	103	3.8
rock bass[a]	8	93	3.4
white shiner	5	74	2.7
whitetail shiner[a]	8	47	1.7
longnose dace	7	47	1.7
spotfin shiner	9	45	1.6
rosyside dace	4	41	1.5
logperch	5	35	1.3
northern hog sucker	5	33	1.2
smallmouth bass[a]	7	28	1.0
greenside darter	7	22	0.8
margined madtom[a]	4	21	0.8
green sunfish	4	11	0.4
fantail darter	4	10	0.4
western blacknose dace	4	7	0.3
redbreast sunfish[a]	3	8	0.3
bluntnose minnow[a]	4	5	0.2
white sucker	2	3	0.1
mountain redbelly dace	2	4	0.1

[a] Non-native

[b] Endemic

Table 44 (continued). Fish species relative abundance during 2004 sampling at Bluestone National Scenic River (Welsh et al. 2006).

Species	# of Sites (out of 13)	Total Individuals	% Relative Abundance
mimic shiner	1	2	<0.1
spotted bass[a]	1	1	<0.1
largemouth bass[a]	1	1	<0.1
yellow bullhead[a]	1	1	<0.1
flathead catfish	1	1	<0.1

[a] Non-native

[b] Endemic


A central stoneroller (left, NPS photo courtesy of Evan Faulk) and bigmouth chub (right, NPS photo).

Faulk and Weber (2017) also reported the number of fish of each species sampled by location. The most abundant species within the three tributaries sampled were rainbow darter at 32.5%, central stoneroller at 21.8%, and rosyside dace at 15.0% (Table 45). Together, these species accounted for 69.3% of all fish sampled. Three species, two of them non-native, were rare, comprising 0.1% or less of fish sampled. As with species richness, the results of Faulk and Weber (2017) and Welsh et al. (2006) are not directly comparable, as Welsh et al. (2006) sampled more sites covering a greater variety of stream habitats.

Table 45. Fish species relative abundance during 2014 sampling at Bluestone National Scenic River (Faulk and Weber 2017).

Species	# of Sites (out of 3)	Total Individuals	% Relative Abundance
rainbow darter[a]	2	629	32.5
central stoneroller	2	422	21.8
rosyside dace	3	289	15.0
creek chub	3	239	12.4
margined madtom[a]	2	64	3.3
bluehead chub[a]	2	40	2.1

[a] Non-native

Table 45 (continued). Fish species relative abundance during 2014 sampling at Bluestone National Scenic River (Faulk and Weber 2017).

Species	# of Sites (out of 3)	Total Individuals	% Relative Abundance
mountain redbelly dace	3	32	1.7
longnose dace	2	31	1.6
rock bass[a]	2	30	1.6
northern hog sucker	2	28	1.4
fantail darter	2	27	1.4
blacknose dace	3	23	1.2
bluntnose minnow[a]	1	16	0.8
snubnose darter[a]	1	16	0.8
smallmouth bass[a]	2	13	0.7
greenside darter	1	12	0.6
white sucker	1	7	0.4
telescope shiner[a]	2	3	0.2
green sunfish	3	4	0.2
rainbow trout[a]	2	4	0.2
Roanoke darter[a]	1	2	0.1
whitetail shiner[a]	1	1	<0.1
logperch	1	1	<0.1

[a] Non-native

Aquatic Macroinvertebrate Species Richness

Information regarding aquatic macroinvertebrate species richness within BLUE streams is somewhat limited. A comprehensive macroinvertebrate survey has not been conducted. The only data currently available are from ERMN BMI sampling. Two stream reaches were sampled consistently from 2009-2014, and four sites were sampled less frequently. Total taxa richness was calculated for two reaches of the Bluestone River in 2008, but only EPT taxa richness is available for those reaches from 2010-2012. Two additional reaches (Jarrell Branch and Indian Branch) were sampled for the first time in 2014. When sampled in 2008, the two sites on the Bluestone River supported 29 and 26 BMI taxa, 16 of which were from the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT), organisms commonly considered sensitive to degradation (Tzilkowski et al. 2010). From 2010-2012, the number of EPT taxa on these reaches ranged from 13-18, with the highest numbers observed near the river mouth (Table 46) (Tzilkowski et al. 2015). Jarrell Branch and Indian Branch, which are smaller tributaries, both yielded 26 BMI taxa each (NPS unpublished data). Sixteen taxa from Indian Branch and 13 from Jarrell Branch were EPT taxa. BMI taxa richness from Mountain Creek, a stream in the south (upstream) end of BLUE, ranged from 25 to 33 with an average of 28.5 and no clear trend over time. EPT taxa richness on Mountain Creek ranged from 14 to 22 with an average of 18.2 (Table 46). On the Little Bluestone River in the north-central portion of BLUE, BMI taxa richness ranged from

26 to 35 with an average of 30.3 and no clear trend (NPS unpublished data). EPT taxa richness ranged from 13 to 23, averaging 19.3.

Table 46. BMI taxa richness at sampling stream reaches within Bluestone National Scenic River (2008 data from Tzilkowski et al. 2010; 2009-2014 from NPS unpublished data, received from the Eastern Rivers and Mountains Network).

Site	Year	Taxa Richness	EPT Taxa Richness
Mountain Creek	2009	25	14
	2010	31	21
	2011	29	18
	2012	27	16
	2013	26	18
	2014	33	22
	Average	**28.5**	**18.2**
Little Bluestone River	2009	29	21
	2010	26	17
	2011	37	23
	2012	29	21
	2013	35	21
	2014	26	13
	Average	**30.3**	**19.3**
Bluestone River (PipestemTramway)	2008	29	16
	2010	–	13
	2011	–	15
	2012	–	14
Bluestone River (Mouth)	2008	26	16
	2010	–	13
	2011	–	18
	2012	–	18
Indian Branch	2014	26	16
Jarrell Branch	2014	26	13

Benthic Macroinvertebrate Multimetric Index of Biotic Integrity (MIBI)

Aquatic macroinvertebrate communities can be described or characterized in several ways. For example, communities may be assessed based on the presence or percentage of particularly sensitive or tolerant taxa, by taxa food-resource use (e.g., filterers, predators, shredders), or through a mathematical index of multiple attributes or metrics (Chambers and Messinger 2001). During the USGS study of the Kanawha Basin during the late 1990s, BMI sampling results were used to calculate modified HBI scores for each study site (Chambers and Messinger 2001). Lower HBI scores indicate low levels of stream degradation while higher scores indicate higher degradation. HBI scores throughout the Basin ranged from 2.84 to 5.80 with a mean of 4.44 (Chambers and Messinger 2001). The HBI scores for the Bluestone River near Spanishburg and for the Little Bluestone River near Jumping Branch were near the mean value (Figure 28, Figure 29).

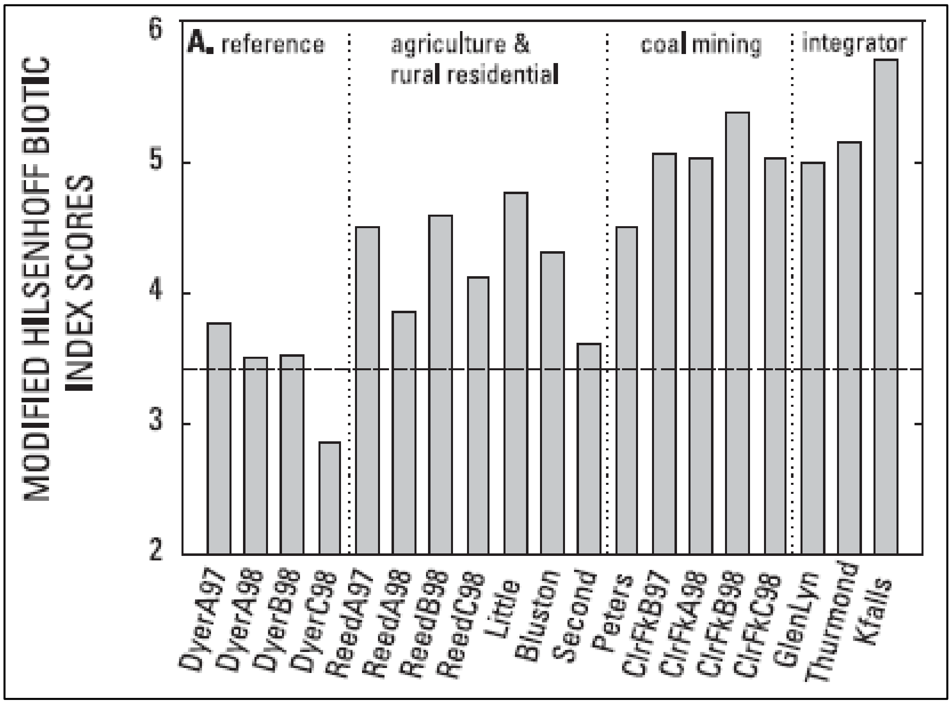


Figure 28. Modified Hilsenhoff Biotic Index (HBI) scores for fixed sampling locations throughout the Kanawha River Basin (Chambers and Messinger 2001). “Blueston”, near the center of the graph, represents the Bluestone River near Spanishburg location. The text above the columns shows land use in the watershed around each location.

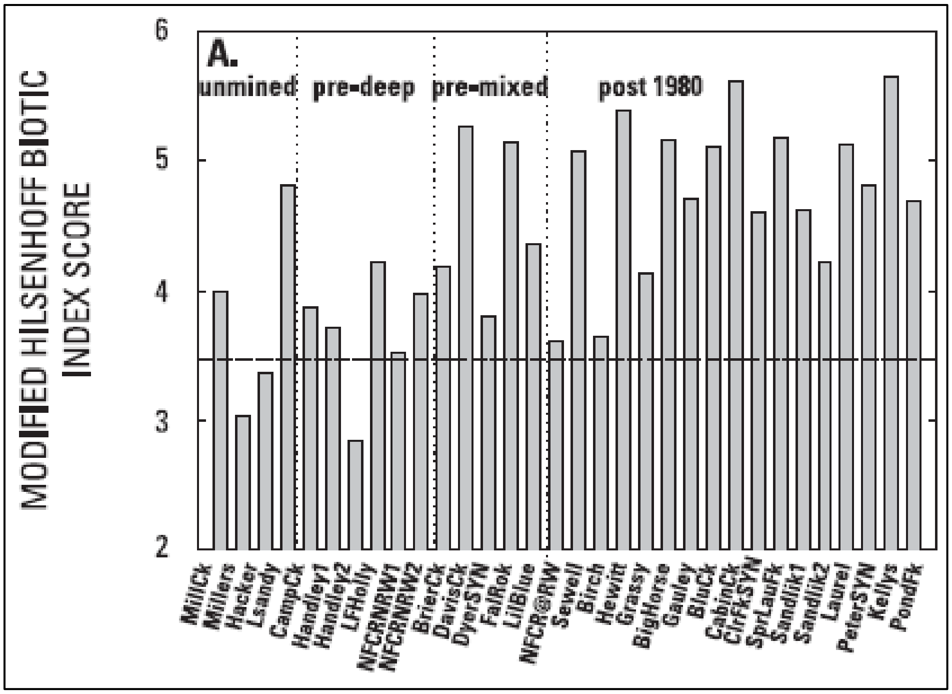


Figure 29. Modified Hilsenhoff Biotic Index (HBI) scores for synoptic sampling locations throughout the Kanawha River Basin (Chambers and Messinger 2001). “LilBlue”, towards the middle of the graph, represents the Little Bluestone River near Jumping Branch location. The text above the columns shows coal mining history (pre-mixed = deep and surface mining before 1980).

MIBI scores were calculated for the four ERMN sampling reaches within BLUE based on 4 years of results (2008, 2010-2012) from the Bluestone River and 5 years (2009-2013) from the tributary reaches (Tzilkowski et al. 2015). Overall, MIBI scores across all four sites ranged from 28.6 (Bluestone at Pipestem, 2011) to 63.2 (Little Bluestone River, 2013) (Table 47, Figure 30). The site on the Bluestone River near the mouth showed the narrowest range of MIBI scores (42.6-53.1) and the widest range of scores occurred at Bluestone River near Pipestem (28.6-51.7). The reach averages ranged from 38.7 (Bluestone at Pipestem) to 55.1 (Little Bluestone River). Based on these average MIBI scores, all of the sampled stream reaches fell within the fair condition range (37-51), with the exception of the Little Bluestone River, which was in the good condition range (>51). However, Tzilkowski et al. (2015) noted that the BLUE sampling reaches were considerably different (e.g., size, underlying geology) than the streams for which the MIBI was developed. Further research is needed to determine if these differences make the condition ranges utilized for other ERMN parks unsuitable for use at BLUE (Tzilkowski et al. 2015).

Table 47. Multimetric Index of Biotic Integrity (MIBI) scores and constituent metric results for samples from Bluestone National Scenic River, 2008-2013 (Tzilkowski et al. 2015). E = Ephemeroptera richness, P = Plecoptera richness, T = Trichoptera richness, CF = Collector-filterer richness, %NI = Percent non-insect individuals, %D5 = Percent of five most dominant taxa, MTI = Macroinvertebrate Tolerance Index.

Reach	Date	E	P	T	CF	% NI	% D5	MTI	MIBI
Bluestone River (mouth)	10/24/2008	5	4	7	6	7.2	66	4.27	44.4
	9/14/2010	5	3	5	6	7.5	60	4.01	42.6
	9/14/2011	8	2	8	5	3.8	69	4.39	45.8
	9/25/2012	8	2	8	6	0.9	67	4.15	53.1
	Average	**6.5**	**2.8**	**7.0**	**5.8**	**4.9**	**65.5**	**4.21**	**46.5**
Bluestone River (Pipestem Tramway)	10/24/2008	6	3	7	8	13.9	49	4.10	51.7
	9/14/2010	6	1	6	6	17.8	50	4.22	40.4
	9/14/2011	7	3	5	5	26.5	66	4.79	28.6
	9/25/2012	5	2	7	7	24.5	71	4.63	34.2
	Average	**6.0**	**2.3**	**6.3**	**6.5**	**20.7**	**59.0**	**4.44**	**38.7**
Mountain Creek	3/31/2009	5	5	4	3	6.9	70	3.64	38.8
	4/7/2010	8	7	6	5	1.3	69	2.76	60.0
	3/29/2011	6	7	5	5	1.1	76	3.65	52.3
	3/8/2012	7	5	4	4	1.7	64	3.56	48.5
	3/11/2013	7	7	4	4	0.9	63	2.80	54.2
	Average	**6.6**	**6.2**	**4.6**	**4.2**	**2.4**	**68.4**	**3.28**	**50.8**
Little Bluestone River	3/31/2009	10	7	4	3	1.2	78	4.77	43.2
	4/7/2010	8	5	4	4	1.5	66	2.54	49.2
	3/29/2011	11	8	4	5	1.2	66	4.26	58.2
	3/8/2012	10	8	3	5	0.6	61	3.02	61.7
	3/11/2013	10	7	4	5	2.5	53	2.96	63.2
	Average	**9.8**	**7.0**	**3.8**	**4.4**	**1.4**	**64.8**	**3.51**	**55.1**

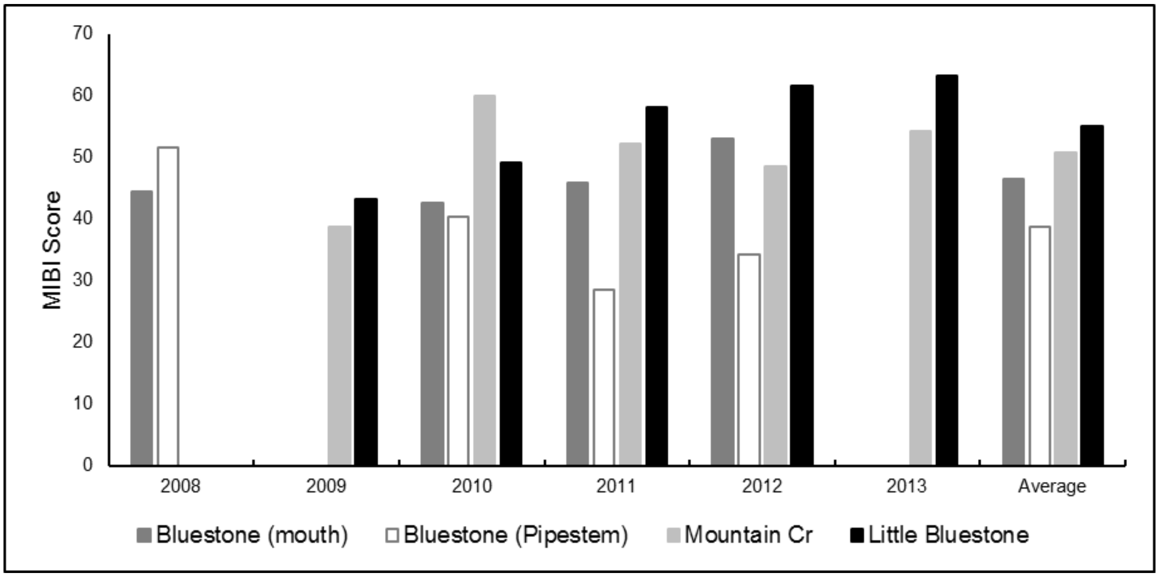


Figure 30. Multimetric Index of Biotic Integrity (MIBI) scores for Bluestone National Scenic River sampling reaches, 2008-2013 and averages for the period (Tzilkowski et al. 2015).

Threats and Stressor Factors

Threats to the aquatic wildlife community of BLUE include bait bucket releases, invasive aquatic plants, boat traffic, inundation due to Bluestone Dam operations, extreme weather/ hydrologic events, gas pipelines, pesticides, and upstream land use/development (e.g., agriculture, sewage discharge, logging, development). Land use/development and gas pipelines are primarily threats to aquatic life because of their impacts on water quality, which will be discussed in Chapter 4.7. However, the excess sediment often contributed to streams by logging, agriculture, and development can also fill in pools or small spaces that provide habitat for aquatic wildlife (Chambers and Messinger 2001, Purvis 2002, Bilotta and Brazier 2008). When suspended in the water, excess sediment can irritate and clog the respiratory organs of fish and aquatic invertebrates, stressing and potentially killing these organisms (Bilotta and Brazier 2008). In the Kanawha Basin, Chambers and Messinger (2001) found that aquatic invertebrate communities in watersheds with agricultural land use showed slight impairment over reference streams. Fish species have varying tolerances for pollution/degradation, with some showing more sensitivity to change than others (Messinger and Chambers 2001). Native fish occurring within BLUE that are considered intolerant of pollution include the rosyside dace, mountain redbelly dace (*Chrosomus oreas*), and greenside darter (*Etheostoma blennioides*) (Anderson and Petty 2015).

Recreational fishing in the region around BLUE has contributed to non-native species introductions in several ways. First is the intentional introduction of game fish such as bass, sunfish, and trout to “improve” recreational opportunities (Cincotta and Chambers 1999, Purvis 2002). Although stocking is not currently occurring in or near BLUE, it is likely the historic source of the redbreast sunfish (*Lepomis auritus*) and the three bass species in the Bluestone River. Non-native species have also been introduced through bait-bucket releases (i.e., anglers dumping out remaining bait at the end of the day) (Cincotta and Chambers 1999). Smaller fish within BLUE that are likely present due to bait-bucket introductions, either within park boundaries or downstream, include the margined madtom (*Noturus insignis*), telescope shiner (*Notropis telescopus*), and whitetail shiner (*Cyprinella galactura*) (Purvis 2002, Welsh et al. 2006). Although it has not been documented, it is likely that these non-native fish are having a negative impact on native species and may even out-compete some of the local endemics (Messinger and Chambers 2001, Purvis 2002). Watersheds such as the Bluestone and New Rivers that have naturally low fish species richness are often more vulnerable to successful invasion by non-native species than watersheds with higher species richness (Welsh et al. 2006). Bait-bucket releases are not only responsible for fish introductions but are also thought to be the source for non-native crayfish in the New River system (Purvis 2002, Swecker 2012). Lastly, boating can lead to non-native plant and invertebrate introductions if boats are not cleaned properly when moved between sites (Johnson et al. 2001, WVDNR 2014). Invasive species transferred by boats that threaten BLUE include non-native mussels and hydrilla (*Hydrilla verticillata*), a mat-forming aquatic plant known to occur in Summers County where BLUE is located (WVISWG 2011). Invasive aquatic plants and invertebrates can alter habitats and/or ecosystem processes in ways that could negatively impact native aquatic wildlife (Strayer 2010).

Extreme weather events, such as droughts or heavy rain, can cause extremely low or high water levels, which may negatively impact aquatic wildlife communities. While heavy rain and droughts are natural events in the BLUE region, these events may increase in frequency or intensity due to climate change and/or human activities (e.g., development, water diversions, land use change). Flooding, which may also contribute to landslides, can alter aquatic habitat by scouring away habitat features (e.g., gravel, woody debris, aquatic vegetation), eroding stream banks, or altering other stream morphology characteristics (Purvis 2002). Droughts reduce habitat availability; smaller streams may shrink to isolated pools or dry up completely, stranding any fish and aquatic invertebrates living there (Messinger and Chambers 2001, Boulton and Lake 2008). As water levels drop and pools become isolated, water quality often declines (e.g., higher water temperatures, lower dissolved oxygen, pH), which can further stress aquatic organisms (Boulton and Lake 2008). Previous research in West Virginia streams found that BMI density declined significantly during droughts (Kaller 2001). This decline could impact other wildlife that rely on BMI as a food source.

Data Needs/Gaps

Although some information regarding fish species composition and relative abundance at BLUE is available, the studies have not sampled consistent locations over time, making it difficult to recognize any changes that may be occurring within the fish community with confidence. Re-sampling of the locations surveyed by Welsh et al. (2006) and Faulk and Weber (2017) would help to identify any trends within the fish community. In addition, further research is needed to explore how non-native species (plants and animals) are impacting native aquatic wildlife and habitats (Welsh et al. 2006).

The continuation of ERMN BMI sampling will assist NPS staff in determining how BMI biotic integrity is influenced by stream conditions, weather patterns, habitat characteristics, and local land use (Marshall and Piekielek 2007a). With the exception of ERMN BMI sampling locations, little is known about the diversity of aquatic macroinvertebrates within BLUE streams. An inventory of all aquatic invertebrates within park boundaries would help managers better understand the park's biodiversity and may identify environmentally-sensitive organisms or species of conservation concern, such as mussels or crayfish. Mussels and crayfish are important components of West Virginia stream ecosystems, and many species are considered of conservation concern in the state (WVDNR 2015).

<u>Overall Condition</u>

Fish Species Richness

The NRCA project team assigned this measure a *Significance Level* of 3. While overall species richness in BLUE waters has not changed much over time, species composition has shifted somewhat. Several historically present species were not re-located during more recent surveys (Welsh et al. 2006, Faulk and Weber 2017) while new species, many non-native, have appeared. However, no fish sampling has been conducted since 2005 and species richness may have shifted during this time. As a result, this measure has not been assigned a *Condition Level*.

Percent Native Fish Species

A *Significance Level* of 3 was also assigned for this measure. The percentage of native fish species documented by various surveys at BLUE over time has been relatively stable, ranging from 52-57% (Welsh et al. 2006, Faulk and Weber 2017). This relatively high percentage of non-native species observed (nearly 50% in some cases), would certainly be cause for concern, but no more recent information is available to determine whether the percentage has remained high or if it has changed. Therefore, the level of concern cannot be determined at this time and a *Condition Level* has not been assigned.

Fish Species Relative Abundance

The relative abundance measure was assigned a *Significance Level* of 3. The most abundant fish during 2004 sampling was a native species (central stoneroller, 35.6%), and the three most abundant species comprised 63% of all individuals observed (Welsh et al. 2006). During 2014 sampling of three Bluestone tributaries, the most abundant fish was a non-native species (rainbow darter, 32.5%) and the three most abundant species comprised 69% of all individuals observed (Faulk and Weber 2017). This documented dominance by a non-native species and dominance by just a few species would be cause for concern. However, due to a lack of recent studies, it is unknown whether relative abundance has changed since 2005. As a result, a *Condition Level* has not been assigned.

Aquatic Macroinvertebrate Species Richness

This measure was also assigned a *Significance Level* of 3. Information regarding aquatic macroinvertebrate species richness within BLUE waters is limited to just a few sampling locations and a relatively short period of time. There are also no reference points or ranges for comparison to assess condition. Therefore, a *Condition Level* cannot be assigned at this time.

Benthic Macroinvertebrate Multimetric Index of Biotic Integrity (MIBI)

The MIBI measure was assigned a *Significance Level* of 3. The average MIBI scores for three of the four ERMN sampling reaches fell within the fair condition range (Mountain Creek, Bluestone River near the mouth and at Pipestem) and one average score was in the good condition range (Little Bluestone River) (Tzilkowski et al. 2015). As a result, this measure is assigned a *Condition Level* of 2. However, as mentioned previously, further research is needed to determine if certain characteristics of park streams (e.g., size, geology) make the MIBI condition ranges utilized for other ERMN parks unsuitable for use at BLUE (Tzilkowski et al. 2015).

Weighted Condition Score

A *Weighted Condition Score* was not calculated for BLUE's aquatic wildlife community due to a lack of recent data for a majority of the measures (Table 48). The condition and trend for this park resource are currently unknown.

Table 48. Current condition of Bluestone National Scenic River's Aquatic Wildlife Community

Measures	Significance Level	Condition Level	WCS = N/A
Fish species richness	3	n/a	
Percent native fish species	3	n/a	
Fish species relative abundance	3	n/a	
Aquatic macroinvertebrate species richness	3	n/a	
BMI MIBI	3	2	

4.6.6. Sources of Expertise

- Caleb Tzilkowski, ERMN Aquatic Ecologist
- Andrew Weber, ERMN Hydrologic Technician

4.7. Water Quality

4.7.1. Description

Surface water quality and hydrology were identified by the ERMN as high priorities both for Vital Signs monitoring and for park management (Marshall and Piekielek 2007a). Water quality and quantity have direct impacts on park wildlife and vegetation, including sensitive species (e.g., fish, aquatic invertebrates, amphibians), and also influence visitor use and enjoyment (e.g., water-based recreation) (Marshall and Piekielek 2007a).

The lower portion of the Bluestone River was designated as a Scenic River due to its free flowing condition and high quality waters, which support remarkable levels of biological diversity (Marshall and Piekielek 2007b). Of the 28.5 km (17.7 mi) of streams within BLUE, nearly 20 km (12.4 mi) have been identified by the State of West Virginia as Tier 3 or "outstanding national resource waters" (Sheeder et al. 2004, Tzilkowski et al. 2015). However, the entire stretch of the Bluestone River within park boundaries and a portion of one of its tributaries, Mountain Creek, are also classified as 303d impaired due to fecal coliform bacteria from unknown sources (NPS 2014). These water bodies typically meet the criteria to support fisheries, agricultural, and wildlife uses, but at times coliform bacteria levels are considered unsafe for water contact recreation (Sheeder et al. 2004, Tzilkowski et al. 2015). The Bluestone River is also 303d impaired for PCBs (polychlorinated biphenyls). The major tributary of the Bluestone River within BLUE, the Little Bluestone River, is not considered impaired and fully supports agricultural, wildlife, and recreation uses, as well as supporting a cold water recreational fishery (i.e., trout sustaining) (Sheeder et al. 2004, Webber 2012).

4.7.2. Measures

- Water temperature
- pH
- Dissolved oxygen
- Specific conductance
- Turbidity
- Fecal coliform bacteria

<u>Water Temperature</u>

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can temperature affect the ability of water to hold oxygen, but it also affects biological activity and growth within water systems (USGS 2015b). For example, water temperatures play a key role in the reproductive timing and success of river fish (Marshall et al. 2006). All aquatic organisms have a preferred or ideal temperature range for existence (USGS 2015b). As temperature increases or decreases too far past this range, the number of species and individuals able to survive eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water, making them more toxic to aquatic life (USGS 2015b).

pH

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2015b). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2015b). Chemicals in water can change the pH and harm animals and plants living in the water; monitoring pH can therefore be useful for detecting natural and human-caused changes in water chemistry (USGS 2015b).

Dissolved Oxygen

Dissolved oxygen (DO) is critical for organisms that live in water. In order to survive, fish and zooplankton filter out or "breathe" dissolved oxygen from the water (USGS 2015b). Oxygen enters water from the air, when atmospheric oxygen mixes with water at turbulent, shallow riffles in a waterway, or when released by algae and other plants as a byproduct of photosynthesis. As the concentration of DO decreases, it becomes more difficult for aquatic organisms to survive (USGS 2015b). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than warm water (USGS 2015b). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2015b).

Specific Conductance

Specific conductance (SpC) is a measure of the ability of water to conduct electrical current, which depends largely on the amount of dissolved ions in the water (Allan and Castillo 2007). Water with low amounts of dissolved ions (such as purified or distilled water) will have a low SpC, while water with high amounts of dissolved ions (such as sea water) will have a higher SpC (Allan and Castillo 2007). SpC is an important water quality parameter to monitor because high levels can indicate that water is unsuitable for drinking or aquatic life (USGS 2015b).

Turbidity

Turbidity assesses the amount of fine particle matter (such as clay, silt, plankton, microscopic organisms, or finely divided organic or inorganic matter) that is suspended in water by measuring the scattering effect that solids have on light that passes through water (USGS 2015b). For instance, the more light that is scattered, the higher the turbidity measurement will be. The suspended materials that make water turbid can absorb heat from sunlight, increasing the water temperature in waterways and reducing the concentration of dissolved oxygen in the water. The scattering of sunlight by suspended particles decreases photosynthesis by plants and algae, which contributes to decreased DO concentrations in the water (Bilotta and Brazier 2008). Suspended particles can also irritate and clog the respiratory organs of many fish and aquatic invertebrates (e.g., mussels, crustaceans), stressing and potentially killing these organisms (Bilotta and Brazier 2008).

Fecal Coliform Bacteria

Bacteria are commonly found in surface waterways and are mostly harmless to humans. However, certain bacteria, specifically those found in the intestinal tracts and feces of warm-blooded animals such as *E. coli*, can cause illness in humans (USGS 2011a). Fecal coliform bacteria are a subgroup of coliform bacteria that, when used in monitoring water quality, can indicate if fecal contamination has occurred in a specific waterway. Bacteria densities can be determined by counting colonies that grow on 0.45 micron filters incubated at 44.5°C (112.1°F) for 22-24 hours.

4.7.3. Reference Condition/Values

The reference conditions for water quality will be the West Virginia state standards for water bodies with an aquatic life designated use, unless otherwise indicated (Table 49). Many of these water quality standards also apply to other designated uses (e.g., contact recreation, wildlife use) and are protective of human health (WVDEP 2014).

Table 49. West Virginia state water quality standards for the fish and aquatic life designated use (unless otherwise noted) (WVDEP 2014).

Parameter	WV Standards
Water temperature	Temperature rise limited to no more than 2.8°C (5°F) above natural temperature, not to exceed 30.6°C (87°F) at any time during months of May through November and not to exceed 22.8°C (73°F) at any time during the months of December through April.
pH[a]	6.0-9.0; higher values due to photosynthetic activity may be tolerated
Dissolved oxygen[a]	≥5.0 mg/L
Turbidity[b]	No more than 10 NTUs (nephelometric turbidity units) over background turbidity when the background is 50 NTU or less, or no more than a 10% increase in turbidity (plus 10 NTU minimum) when the background turbidity is more than 50 NTUs.
Fecal coliform bacteria[c]	≤200/100 ml as a monthly geometric mean based on not less than 5 samples per month; also, ≤400/100 ml in more than ten percent of all samples taken during the month.

[a] Standard for aquatic life, human health, and other designated uses

[b] Standard for aquatic life and human health

[c] Human health standard for contact recreation; aquatic life standard not established

State turbidity standards are based on "background turbidity" levels, but such levels have not been determined for BLUE surface waters (Lisa Wilson, NPS Biological Science Technician, email communication, 27 January 2017). As a result, there is no numeric turbidity baseline/reference that can be used for this NRCA.

State and national standards are not available for SpC. However, SpC is related to concentration of total dissolved solids (TDS), and the EPA has recommended a TDS concentration <500 mg/L for drinking water (Sheeder et al. 2004). This recommended TDS concentration equates to an SpC of 325 µmhos or µS/cm. This value will be used as an informal reference condition for this NRCA, as values above this could indicate a need for further investigation and/or cause for concern.

4.7.4. Data and Methods

NPS (1995) presented the results of surface-water quality data retrievals for BLUE using six EPA national databases: Storage and Retrieval (STORET) water quality database management system, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Water Gages (GAGES), and Water Impoundments (DAMS). Although many of the sampling sites identified were either single-event or one-year intensive sampling efforts, six stations within BLUE had longer-term water quality records: Bluestone River (BLUE 0011), Bluestone River at Confluence (BLUE 0013), Little Bluestone River (BLUE 0015), Bluestone River at Pipestem (BLUE 0020), Bluestone River Near Pipestem, WV (BLUE 0024), and Mountain Creek (BLUE 0025) (Figure 31, left).

Various water quality parameters have been monitored at BLUE since the early 1990s, primarily due to concerns over coliform bacteria (Wilson and Purvis 2003). Samples have consistently been gathered at five locations, four within BLUE boundaries and one just northeast (downstream) of the park (Hebner 1991, Purvis 2009). Three sites are on the Bluestone River, and two are on tributaries (Little Bluestone River and Mountain Creek) (Figure 31, right). Main river sampling sites are at areas of high public contact while tributaries are sampled near their confluence with the Bluestone River, to adequately assess all pollutants entering the river at that point (Hebner 1991). Sampling typically occurs between April and October and includes the summer recreational season, when bacteria levels are a particular concern (Purvis 2009, NPS 2017c). Parameters measured include temperature, pH, dissolved oxygen, conductivity, turbidity, and fecal coliform (Purvis and Wilson 2007). Sampling results, focused primarily on fecal coliform, are presented by Hebner (1991), Sullivan (1993), Wilson and Purvis (2000, 2003), Purvis and Wilson (2007), and Purvis (2009). A Microsoft Access database (NPS 2017c) containing monitoring results (1991-2016) was provided to SMUMN GSS by park staff. Since the park baseline water quality report (NPS 1995) included data through 1995, only data from 1996-2016 in this Access database were used for this analysis. Results from the most recent 5 years available (2012-2016) will provide the best insight into current water quality conditions.

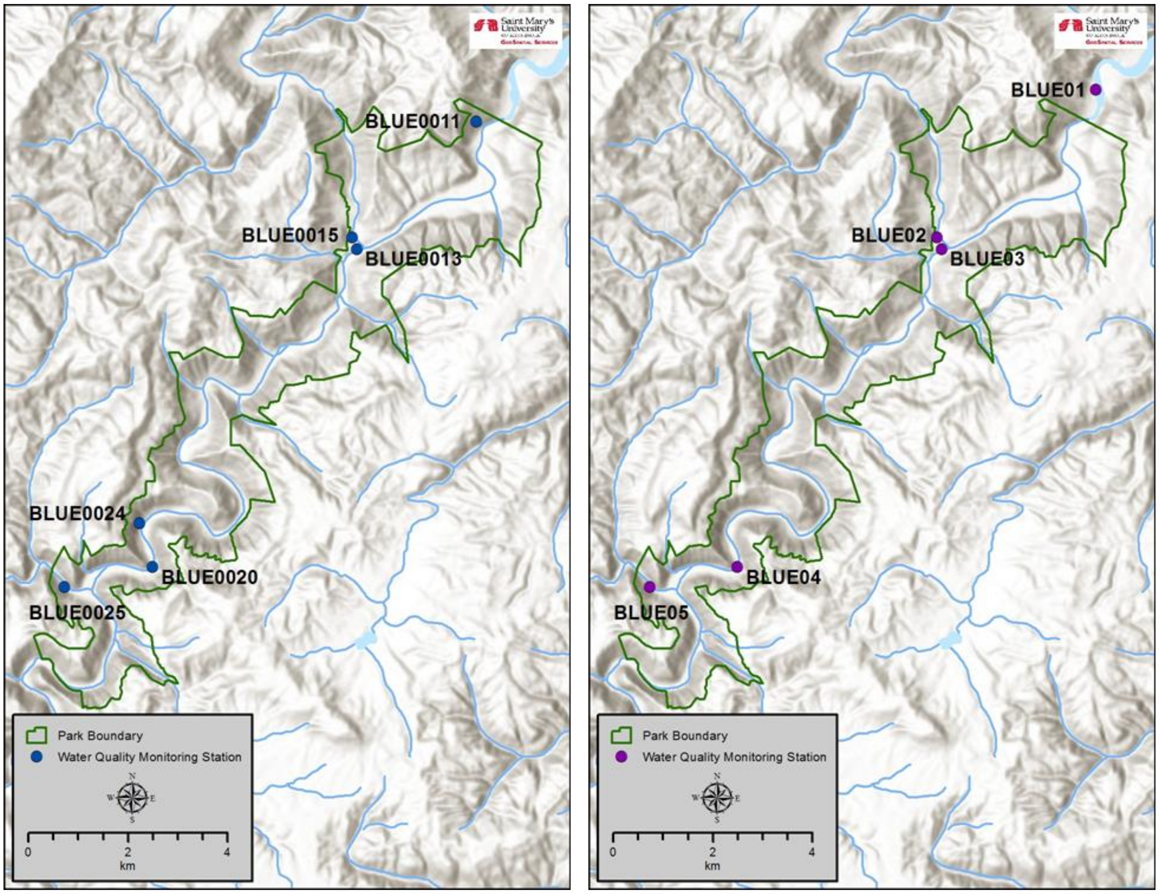


Figure 31. Locations of water quality monitoring stations from the park's baseline report (NPS 1995) (left) and stations used in more recent park monitoring (NPS 2017c) (right).

Since 2008, core water quality parameters (temperature, pH, DO, and SpC) have been sampled by ERMN as part of the wadeable stream monitoring program, in conjunction with benthic macroinvertebrate sampling (Tzilkowski et al. 2015). Four stream reaches have been monitored at BLUE: two on the Bluestone River, one on the Little Bluestone River, and one on Mountain Creek (Figure 32). Water quality sampling methods are based on USGS procedures, as outlined in Tzilkowski et al. (2010). Monitoring has occurred primarily in the spring (March-April), although some early samples were taken in the fall. ERMN also deployed continuous water quality monitors at two locations on the Bluestone River between August 2013 and October 2014. These monitors recorded water temperature and SpC observations every hour, although some gaps occurred when sensors malfunctioned or were exposed to the air due to low water levels (Tzilkowski, written communication, 16 February 2017). The upstream sampling location was less than 0.5 km (0.3 mi) above the confluence with Mountain Creek and the downstream location was approximately 3 km (1.9 mi) below the confluence with the Little Bluestone River (NPS 2017a).

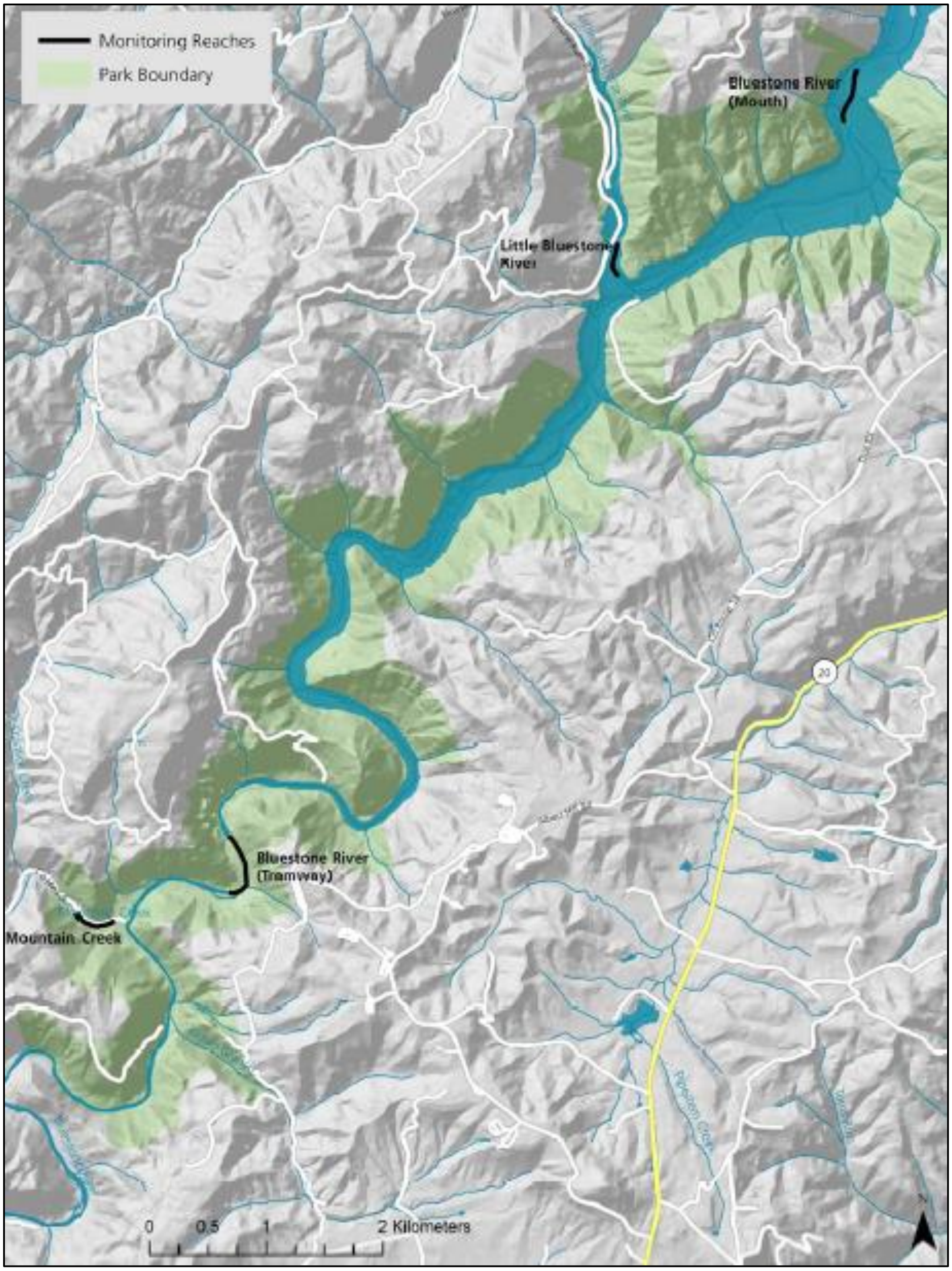


Figure 32. Stream reaches within Bluestone National Scenic River monitored by Eastern Rivers and Mountains Network (reproduced from Tzilkowski et al. 2015).

Webber (2012) collected data from two BLUE streams (Little Bluestone River and Mountain Creek) as part of a larger study to characterize water quality in ERMN wadeable streams. Parameters including temperature, pH, DO, turbidity, nutrients, and major ions (e.g., sulfate, chloride) were measured six times at each site during seasonal baseflow conditions in 2010-2011 (Webber 2012).

Webber (2012) classified each stream as reference (i.e., high quality), fair, or impaired, based on water chemistry and habitat criteria outlined by Waite et al. (2000).

4.7.5. Current Condition and Trend

Temperature

Historic observations (1950-1995) of water temperatures within BLUE ranged from 0-30.5°C (32-86.9°F), with site means from 13.9-19.8°C (57.0-67.6°F) (Table 50) (NPS 1995). Since state temperature standards vary with season and exact sampling dates for these historical observations were not provided, it is uncertain whether exceedances of the lower December-April standard occurred. However, all observations met the May-November standard of 30.6°C (87°F).

Table 50. Historic (pre-1996) water temperature observations (°C) for Bluestone National Scenic River sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Bluestone River at Pipestem S.P. (BLUE0020)	50 (1991-1995)	2.2	30.5	21.0	19.8
Bluestone River near Pipestem (BLUE0024)	209 (1950-1985)	0.0	29.0	15.0	13.9
Bluestone River above Little Bluestone confluence (BLUE0013)	50 (1991-1995)	2.7	29.0	21.0	19.4
Bluestone River (BLUE0011)	47 (1974-1989)	3.5	27.4	20.0	18.6
Mountain Creek near mouth (BLUE0025)	38 (1992-1995)	1.0	23.0	17.0	15.6
Little Bluestone River near mouth (BLUE0015)	51 (1991-1995)	2.3	27.0	18.0	16.8

Observations by Webber (2012) ranged from a low of 4.8°C (40.6°F) at Mountain Creek in the fall to a high of 22.1°C (71.8°F) in summer on the Little Bluestone River (Table 51). No observations exceeded either the December-April or May-November standards.

Table 51. Water temperature observations (°C) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012).

Site	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011
Little Bluestone River	20.9	6.0	9.0	22.1	9.5
Mountain Creek	20.5	4.8	8.8	20.7	8.9

ERMN sampling (Tzilkowski et al. 2015) showed higher water temperatures on the Bluestone River than on its tributaries (Figure 33), but this was primarily because river reaches were sampled in late summer whereas tributary reaches were sampled during spring. Observations from all reaches met the respective seasonal state standards.

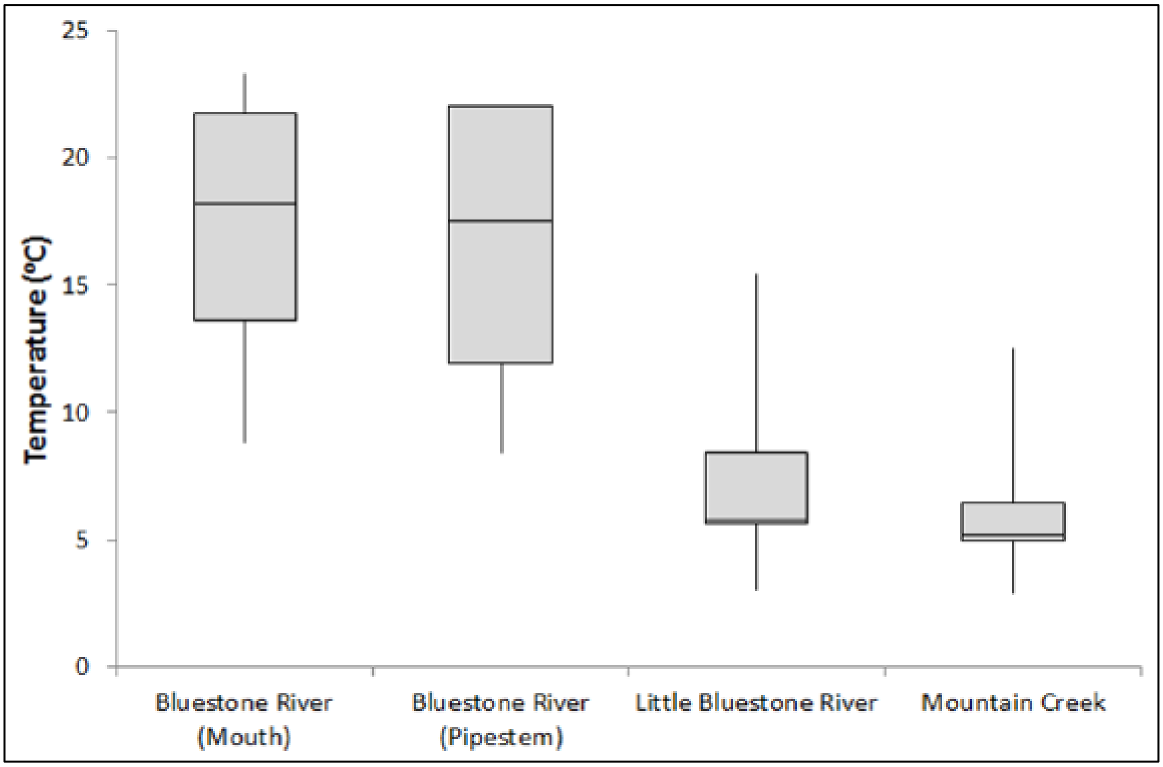


Figure 33. Water temperature ranges documented during Eastern Rivers and Mountains Network water quality sampling at Bluestone National Scenic River, 2008-2013 (reproduced from Tzilkowski et al. 2015). Bluestone River reaches were sampled four times whereas tributary reaches were sampled five times. The bottom and top of the boxes represent the 1st and 3rd quartiles respectively, whereas the band in each box is the median. “Whisker” ends represent minimum and maximum values.

Continuous water quality monitors deployed on the Bluestone River by ERMN in 2013-2014 recorded temperature ranges of 0-28.6°C (32-83.5°F) at the upstream location (above Mountain Creek) (Figure 34) and 0-28.4°C (32-83.1°F) at the downstream location (below the Little Bluestone River) (Figure 35) (NPS 2017a). As would be expected, rapid fluctuations were more common during the fall (October, November) and the spring (May) with steadier temperatures in early summer (June).

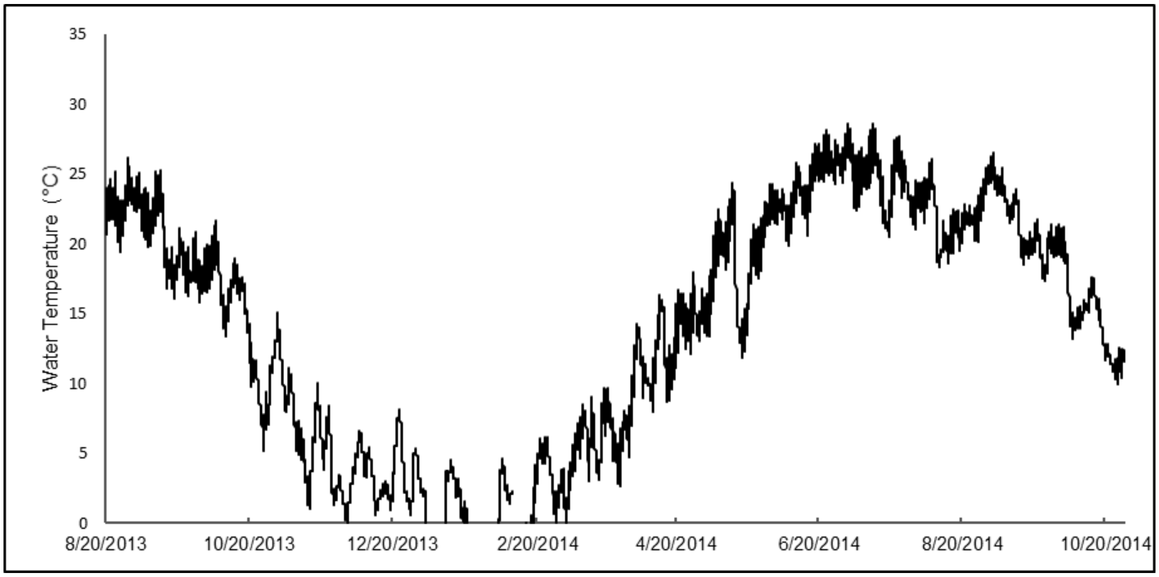


Figure 34. Continuous (hourly) water temperature observations at the upstream Bluestone River location, 2013-2014 (NPS 2017a).

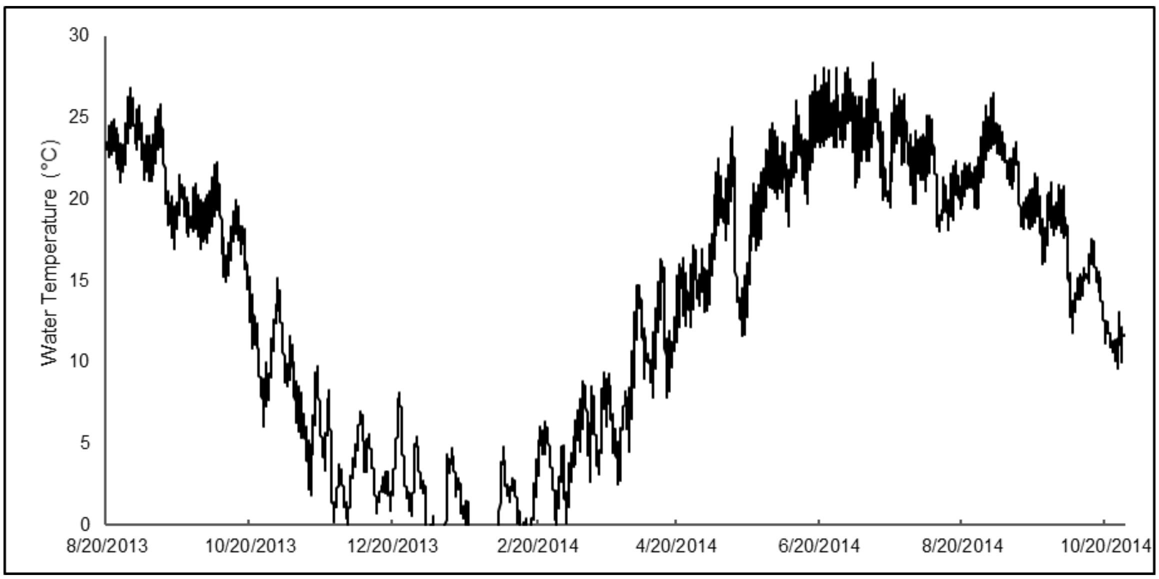


Figure 35. Continuous (hourly) water temperature observations at the downstream Bluestone River location, 2013-2014 (NPS 2017a).

During 1996-2011 park monitoring, water temperatures at the three Bluestone River monitoring locations ranged from 5.5-29.0°C (41.9-84.2°F), with means between 16.5-16.9°C (61.7-62.4°F) (NPS 2017c). Tributary water temperatures during the same period ranged from 4.0-25.0°C (39.2-77.0°F) with means of 14.4°C (57.9°F) for the Little Bluestone River and 14.0°C (57.2°F) for Mountain Creek (Table 52). Since 2012, Bluestone River site water temperatures have ranged from 9.1-26.0°C (48.4-78.8°F), with annual means in the 14-20°C (57-68°F) range (NPS 2017c). Tributary site water temperatures from 2012-2016 ranged from 6.8-20.0°C (44.2-68.0°F), with annual means generally between 12-15°C (53.6-59.0°F). However, annual means can be influenced by the timing and number of samples taken each year and should be compared with caution. All observations since 1996 have met state water quality standards.

Table 52. Water temperature results (°C) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Bluestone River below Mountain Creek (B04)	1996-2011 (79, Feb-Oct)	6.6	29.0	16.5
	Apr-Oct 2012 (3)	10.0	18.2	14.3
	Apr-Jun 2013 (3)	10.1	18.1	14.6
	Apr-Oct 2014 (5)	10.7	23.2	17.3
	Apr-Oct 2015 (5)	9.1	21.3	15.6
	Apr-Sept 2016 (3)	11.0	20.3	17.1
Bluestone River above Little Bluestone River (B03)	1996-2011 (81, Feb-Oct)	6.2	26.0	16.6
	Apr-Oct 2012 (3)	10.5	19.2	15.0
	Apr-Jun 2013 (3)	10.8	18.7	15.5
	Apr-Oct 2014 (5)	11.5	24.8	18.5
	Apr-Oct 2015 (5)	9.7	22.5	16.6
	Apr-Sept 2016 (3)	12.5	22.7	18.9
Bluestone River above Mouth (B01)	1996-2011 (80, Feb-Oct)	5.5	25.5	16.9
	Apr-Oct 2012 (3)	12.0	19.8	16.4
	Apr-Jun 2013 (3)	11.2	19.3	16.0
	Apr-Oct 2014 (5)	11.9	26.0	19.5
	Apr-Oct 2015 (5)	10.2	24.5	17.5
	Apr-Sept 2016 (3)	13.7	23.9	20.2
Mountain Creek (B05)	1996-2011 (80, Feb-Oct)	5.0	25.0	14.0
	Apr-Oct 2012 (3)	8.8	15.4	12.2
	Apr-Jun 2013 (3)	7.4	15.5	11.9
	Apr-Oct 2014 (5)	8.8	18.8	14.2
	Apr-Oct 2015 (5)	6.8	17.5	13.4
	Apr-Sept 2016 (3)	7.9	17.4	13.8
Little Bluestone River (B02)	1996-2011 (81, Feb-Oct)	4.0	22.0	14.4
	Apr-Oct 2012 (3)	8.9	16.3	12.8
	Apr-Jun 2013 (3)	8.6	16.7	13.1
	Apr-Oct 2014 (5)	9.6	20.0	14.9
	Apr-Oct 2015 (5)	7.8	19.3	14.8
	Apr-Sept 2016 (3)	9.0	18.5	14.6

pH

Historic pH observations on the Bluestone River and its tributaries within BLUE ranged from 6.2-10.8, with means from 7.2-8.4 (NPS 1995). The lowest and highest measurements occurred on Mountain Creek. While all measurements met the lower limit of the state standard (6.0), maximum values at five of the six sites exceeded the upper limit of 9.0 (Table 53).

Table 53. Historic (pre-1996) pH observations for Bluestone National Scenic River sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Bluestone River at Pipestem S.P. (BLUE0020)	49 (1991-1995)	6.9	10.1	8.4	8.4
Bluestone River near Pipestem (BLUE0024)	71 (1960-1985)	6.5	9.2	8.0	7.9
Bluestone River above Little Bluestone confluence (BLUE0013)	50 (1991-1995)	7.0	8.6	8.1	8.0
Bluestone River (BLUE0011)	47 (1974-1989)	6.5	9.2	7.7	7.8
Mountain Creek near mouth (BLUE0025)	38 (1992-1995)	6.2	10.8	7.6	7.5
Little Bluestone River near mouth (BLUE0015)	50 (1991-1995)	6.4	9.9	7.5	7.2

Readings taken by Webber (2012) on Bluestone River tributaries ranged from 6.9 to 8.0, all well within state standards (Table 54). Values on the two tributaries were consistently similar throughout the seasons.

Table 54. pH observations from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012).

Site	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011
Little Bluestone River	6.9	7.9	8.0	7.5	7.8
Mountain Creek	7.0	8.0	7.9	7.5	7.7

pH observations by Tzilkowski et al. (2015) on the Bluestone River were consistently around 8.5. Values on the tributaries were lower but within state standards, with the exception of one reading from Mountain Creek of 5.99 in March 2011 (Figure 36).

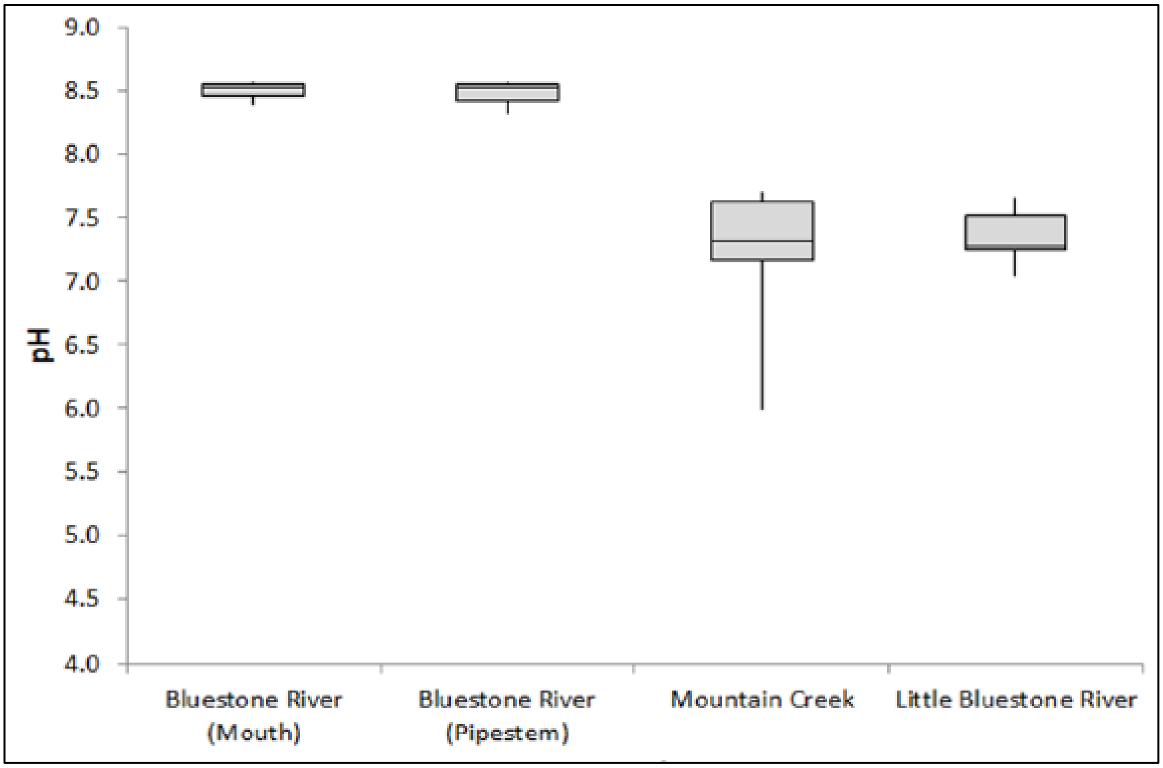


Figure 36. pH ranges documented during Eastern Rivers and Mountains Network water quality sampling at Bluestone National Scenic River, 2008-2013 (reproduced from Tzilkowski et al. 2015). "Whisker" ends represent minimum and maximum values.

Park monitoring from 1996-2011 documented that pH of Bluestone River water was between 7.1 and 9.2, with means around 8.0 (Table 55) (NPS 2017c). Only three observations were outside the state standard range of 6.0-9.0. Tributary pH values during this period ranged from 6.7 to 8.7, all within state standards, with means of 7.5. From 2012-2016, Bluestone River pH observations ranged from 7.9-8.9, with tributary observations between 7.5 and 8.1 (NPS 2017c). All 2012-2016 observations met state standards.

Table 55. pH results from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Bluestone River below Mountain Creek (B04)	1996-2011 (79)	7.4	9.2	8.1
	Apr-Oct 2012 (3)	8.1	8.4	8.3
	Apr-Jun 2013 (3)	7.9	8.1	8.0
	Apr-Oct 2014 (5)	8.1	8.3	8.2
	Apr-Oct 2015 (5)	7.9	8.3	8.2
	Apr-Sept 2016 (3)	8.3	8.5	8.4
Bluestone River above Little Bluestone River (B03)	1996-2011 (81)	7.4	9.0	7.9
	Apr-Oct 2012 (3)	8.1	8.3	8.2
	Apr-Jun 2013 (3)	7.9	8.2	8.0

Table 55 (continued). pH results from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Bluestone River above Little Bluestone River (B03) (continued)	Apr-Oct 2014 (5)	7.9	8.3	8.1
	Apr-Oct 2015 (5)	8.0	8.3	8.1
	Apr-Sept 2016 (3)	8.1	8.2	8.2
Bluestone River above Mouth (B01)	1996-2011 (80)	7.1	9.1	8.0
	Apr-Oct 2012 (3)	8.5	8.6	8.6
	Apr-Jun 2013 (3)	7.9	8.3	8.1
	Apr-Oct 2014 (5)	8.3	8.7	8.4
	Apr-Oct 2015 (5)	8.0	8.7	8.4
	Apr-Sept 2016 (3)	8.5	8.9	8.6
Mountain Creek (B05)	1996-2011 (80)	6.7	8.7	7.5
	Apr-Oct 2012 (3)	7.7	7.7	7.7
	Apr-Jun 2013 (3)	7.6	7.6	7.6
	Apr-Oct 2014 (5)	7.5	7.8	7.6
	Apr-Oct 2015 (5)	7.6	7.8	7.7
	Apr-Sept 2016 (3)	7.6	7.9	7.7
Little Bluestone River (B02)	1996-2011 (81)	6.9	8.1	7.5
	Apr-Oct 2012 (3)	7.8	7.9	7.8
	Apr-Jun 2013 (3)	7.6	7.9	7.8
	Apr-Oct 2014 (5)	7.7	8.1	7.9
	Apr-Oct 2015 (5)	7.7	8.0	7.9
	Apr-Sept 2016 (3)	7.6	8.1	7.9

Dissolved Oxygen

Historic observations of DO within BLUE ranged from 1.0-15.5 mg/L, with the lowest values occurring on the Bluestone mainstem in the early 1990s (Table 56) (NPS 1995). Minimum values at three stations (BLUE0013, BLUE0015, BLUE0020) fell below the state standard of 5.0 mg/L, but all means were well above this level.

Table 56. Historic (pre-1996) DO (mg/L) observations for Bluestone National Scenic River sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Bluestone River at Pipestem S.P. (BLUE0020)	42 (1991-1995)	1.0	14.2	9.7	9.6
Bluestone River near Pipestem (BLUE0024)	11 (1972-1979)	6.6	15.5	10.4	10.8

Table 56 (continued). Historic (pre-1996) DO (mg/L) observations for Bluestone National Scenic River sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Bluestone River above Little Bluestone confluence (BLUE0013)	42 (1991-1995)	1.2	13.5	8.0	8.1
Bluestone River (BLUE0011)	45 (1974-1989)	6.5	14.1	8.7	9.0
Mountain Creek near mouth (BLUE0025)	33 (1992-1995)	6.7	13.3	9.2	9.4
Little Bluestone River near mouth (BLUE0015)	44 (1991-1995)	3.0	13.3	9.0	8.9

All DO observations by Webber (2012) met the state standard, with the highest values occurring in the fall when temperatures were cooler (Table 57).

Table 57. DO observations (mg/L) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012).

Site	Summer 2010	Fall 2010	Summer 2011	Fall 2011
Little Bluestone River	6.5	11.2	9.3	11.6
Mountain Creek	7.2	12.4	9.9	11.5

All observations by Tzilkowski et al. (2015) met the state standard of ≥5.0 mg/L (Figure 37). Mean DO concentrations were higher but more variable on tributaries than on the mainstem Bluestone River.

From 1996-2011, park monitoring recorded DO ranges of 4.8-15.5 mg/l, with means of 8.6-9.4 mg/l on the Bluestone River and above 9 mg/l on its tributaries (Table 58) (NPS 2017c). One observation on the Bluestone River just above the Little Bluestone River confluence (July 2000) and one from the Little Bluestone River (September 2010) were below the state minimum standard during this period. More recently (2012-2016), park monitoring on the Bluestone River yielded DO ranges of 5.8-12.4 mg/l, with annual means in the 7-12 mg/l range. However, as with temperature, annual means can be influenced by the timing and number of samples taken each year and should be compared with caution. Recent DO observations from tributaries were between 6.9 and 11.9 mg/l, with annual means near or above 9 mg/l (NPS 2017c). All observations from 2012-2016 met the state standard of ≥5.0 mg/L.

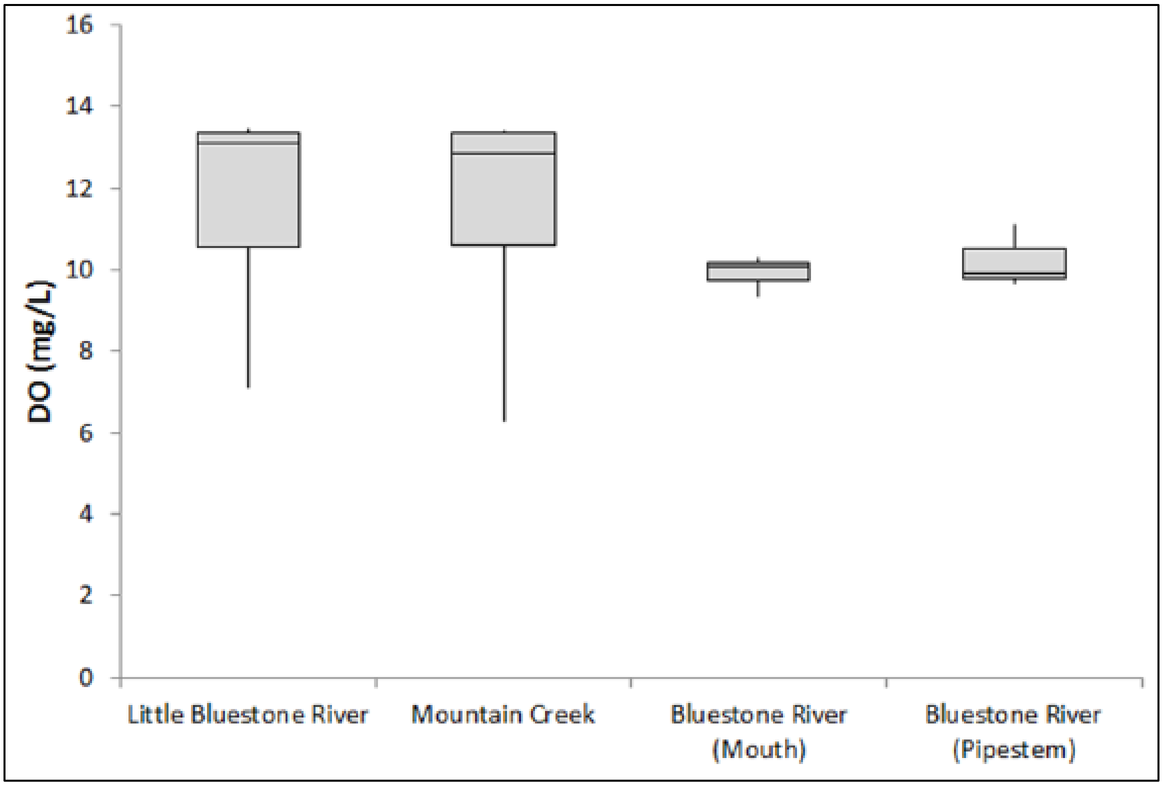


Figure 37. DO ranges documented during ERMN water quality sampling at Bluestone National Scenic River, 2008-2013 (reproduced from Tzilkowski et al. 2015).

Table 58. DO concentrations (mg/l) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Bluestone River below Mountain Creek (B04)	1996-2011 (78)	5.3	14.4	9.4
	Apr-Oct 2012 (3)	9.7	11.2	10.5
	Apr-Jun 2013 (3)	8.5	10.7	9.6
	Apr-Oct 2014 (5)	8.2	9.9	8.8
	Apr-Oct 2015 (5)	8.5	11.3	9.5
	Apr-Sept 2016 (3)	7.9	10.6	9.2
Bluestone River above Little Bluestone River (B03)	1996-2011 (80)	4.8	14.6	8.6
	Apr-Oct 2012 (3)	9.9	11.1	10.4
	Apr-Jun 2013 (3)	8.2	10.8	9.6
	Apr-Oct 2014 (5)	6.7	10.1	8.3
	Apr-Oct 2015 (5)	6.2	11.2	8.5
	Apr-Sept 2016 (3)	5.8	9.5	7.1
Bluestone River above Mouth (B01)	1996-2011 (79)	5.9	15.5	9.3
	Apr-Oct 2012 (3)	10.8	12.4	11.6
	Apr-Jun 2013 (3)	8.2	11.3	9.8
	Apr-Oct 2014 (5)	7.9	10.3	9.4

Table 58 (continued). DO concentrations (mg/l) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Bluestone River above Mouth (B01) (continued)	Apr-Oct 2015 (5)	8.3	11.2	9.6
	Apr-Sept 2016 (3)	8.7	11.6	9.8
Mountain Creek (B05)	1996-2011 (79)	5.1	15.2	9.5
	Apr-Oct 2012 (3)	10.6	11.8	11.0
	Apr-Jun 2013 (3)	9.2	11.4	10.2
	Apr-Oct 2014 (5)	7.7	11.0	9.2
	Apr-Oct 2015 (5)	8.5	11.9	9.8
	Apr-Sept 2016 (3)	7.2	11.4	9.2
Little Bluestone River (B02)	1996-2011 (80)	4.6	14.8	9.2
	Apr-Oct 2012 (3)	9.9	11.4	10.7
	Apr-Jun 2013 (3)	8.8	11.3	10.0
	Apr-Oct 2014 (5)	7.8	10.0	9.0
	Apr-Oct 2015 (5)	7.7	11.3	9.3
	Apr-Sept 2016 (3)	6.9	10.6	8.9

Specific Conductance

Historic (pre-1996) SpC measurements at BLUE ranged from 30-480 µS/cm, with means from 89.0-264.4 µS/cm (Table 59) (NPS 1995). The highest single observation and mean were from the Bluestone River near Pipestem, between 1960 and 1985. Although no state standard exists for SpC, the informal reference condition of 325 µS/cm (based on EPA criteria for TDS in drinking water) was exceeded at all sites except the Little Bluestone River (BLUE0013).

Table 59. Historic (pre-1996) SpC (µS/cm) observations for Bluestone National Scenic River sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Bluestone River at Pipestem S.P. (BLUE0020)	46 (1991-1995)	90	390	267.5	256.1
Bluestone River near Pipestem (BLUE0024)	80 (1960-1985)	113	480	269	264.4
Bluestone River above Little Bluestone confluence (BLUE0013)	47 (1991-1995)	101	380	249	249.4
Bluestone River (BLUE0011)	29 (1974-1989)	85	380	245	235.0
Mountain Creek near mouth (BLUE0025)	37 (1992-1995)	50	370	140	155.8
Little Bluestone River near mouth (BLUE0015)	48 (1991-1995)	30	175	79.5	89.0

The informal reference condition for SpC used in this assessment was exceeded three times on Mountain Creek during Weber's (2012) sampling (Table 60). All samples from the Little Bluestone River were well below 325 µS/cm.

Table 60. SpC observations (µS/cm) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012).

Site	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011
Little Bluestone River	89.9	209.1	174.0	74.2	189.1	149.7
Mountain Creek	131.7	348.0	322.0	127.0	372.0	399.0

The majority of Bluestone River SpC measurements taken by Tzilkowski et al. (2015) documented levels in the 350-425 µS/cm range, with medians above the informal 325 µS/cm reference (Figure 38). Observations from tributaries were much lower, generally below 150 µS/cm.

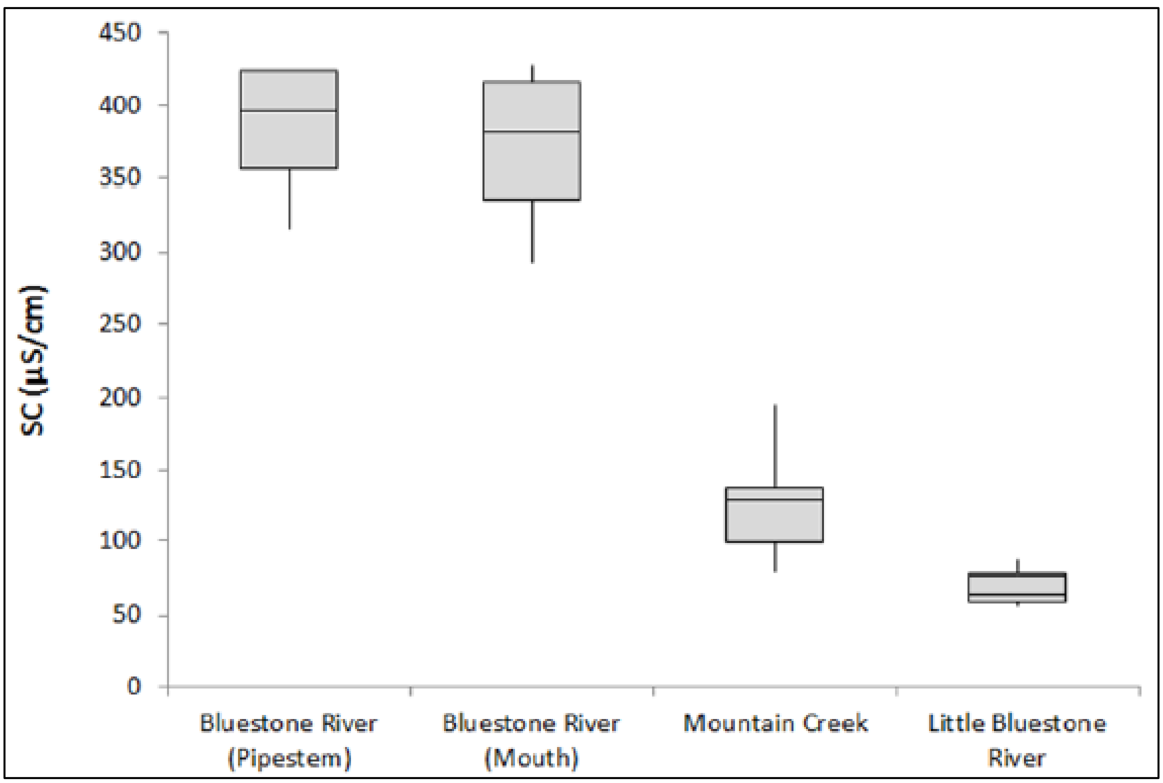


Figure 38. SpC ranges documented during Eastern Rivers and Mountains Network water quality sampling at Bluestone National Scenic River, 2008-2013 (reproduced from Tzilkowski et al. 2015).

Continuous water quality monitors deployed by ERMN in 2013-2014 recorded SpC ranges of 113.5-434.0 µS/cm at the upstream sampling location (Figure 39) and 120.4-467.8 µS/cm at the downstream location (Figure 40), with observations frequently exceeding the informal 325 µS/cm reference level (NPS 2017a). The highest readings occurred primarily in the summer and fall but with occasional peaks during the spring.

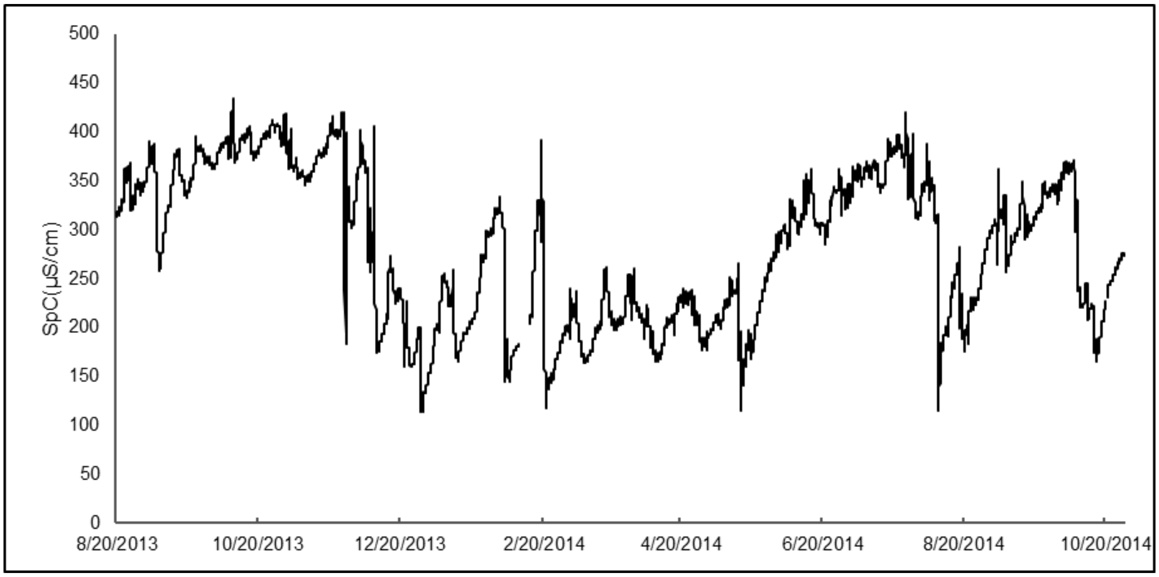


Figure 39. Continuous (hourly) SpC observations at the upstream Bluestone River location, 2013-2014 (NPS 2017a).

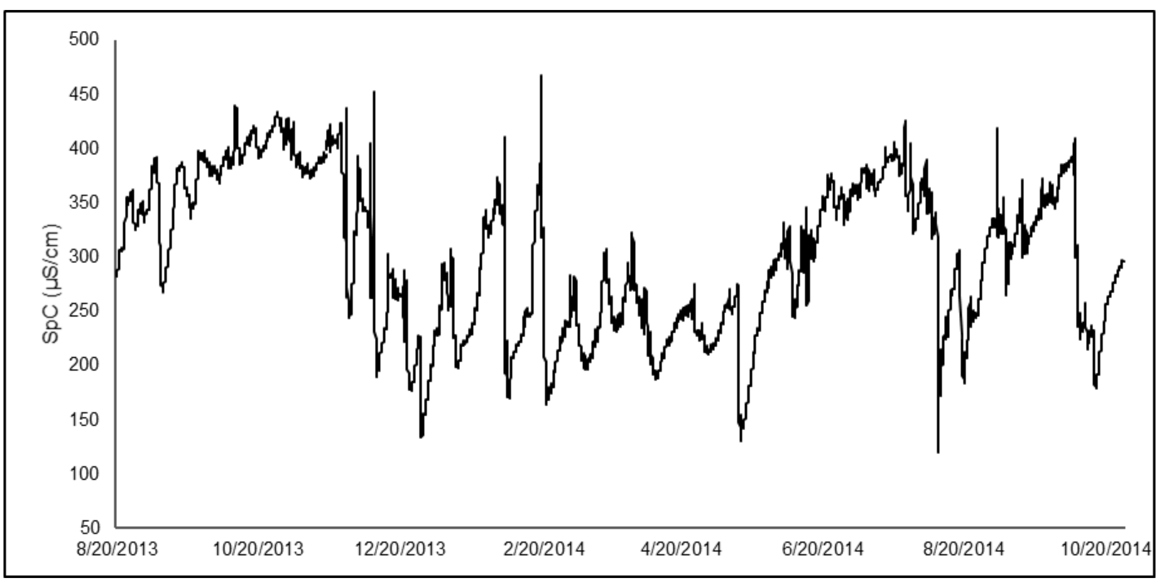


Figure 40. Continuous (hourly) SpC observations at the downstream Bluestone River location, 2013-2014 (NPS 2017a).

Park monitoring from 1996-2011 found that SpC on the Bluestone River ranged from 79.0-390.0 µS/cm, with means between 205 and 213 µS/cm (Table 61) (NPS 2017c). Thirty-four observations (out of 240) exceeded the informal reference condition of 325 µS/cm. Observations on tributaries from 1996-2011 ranged from 35.0-380.0 µS/cm, with means below 151 µS/cm (NPS 2017c). Only four observations from Mountain Creek exceeded 325 µS/cm. More recently (2012-2016), SpC observations on the Bluestone River ranged from 95.8-403.9 µS/cm, with six observations above 325 µS/cm (two at each station) and annual means in the 126-294 µS/cm range. Annual means are influenced by the timing and number of samples taken each year, as SpC may shift with heavy precipitation and flow levels. SpC observations on tributaries during 2012-2016 ranged from 39.3-281.8 µS/cm, with annual means below 178 µS/cm (NPS 2017c).

Table 61. Field conductivity results (µS/cm) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Bluestone River below Mountain Creek (B04)	1996-2011 (79)	84.5	390.0	212.4
	Apr-Oct 2012 (3)	182.1	227.0	198.2
	Apr-Jun 2013 (3)	126.0	166.3	152.0
	Apr-Oct 2014 (5)	172.7	367.4	242.0
	Apr-Oct 2015 (5)	101.2	295.8	188.5
	Apr-Sept 2016 (3)	198.4	390.7	293.9
Bluestone River above Little Bluestone River (B03)	1996-2011 (81)	84.3	368.1	212.5
	Apr-Oct 2012 (3)	159.4	240.6	192.1
	Apr-Jun 2013 (3)	121.3	163.2	142.7
	Apr-Oct 2014 (5)	133.1	351.1	227.2
	Apr-Oct 2015 (5)	100.8	308.2	190.2
	Apr-Sept 2016 (3)	194.8	377.6	291.4
Bluestone River above Mouth (B01)	1996-2011 (80)	79.0	360.2	205.6
	Apr-Oct 2012 (3)	182.2	202.0	189.8
	Apr-Jun 2013 (3)	102.0	155.5	126.6
	Apr-Oct 2014 (5)	159.2	352.6	235.3
	Apr-Oct 2015 (5)	95.8	312.6	189.9
	Apr-Sept 2016 (3)	195.6	403.9	292.8
Mountain Creek (B05)	1996-2011 (79)	48.0	380.0	150.4
	Apr-Oct 2012 (3)	97.1	218.7	139.4
	Apr-Jun 2013 (3)	82.0	117.3	98.8
	Apr-Oct 2014 (5)	103.8	281.8	171.4
	Apr-Oct 2015 (5)	57.3	214.8	126.9
	Apr-Sept 2016 (3)	123.9	224.2	177.1

Table 61 (continued). Field conductivity results (µS/cm) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Little Bluestone River (B02)	1996-2011 (81)	35.0	194.3	85.7
	Apr-Oct 2012 (3)	67.2	84.2	73.7
	Apr-Jun 2013 (3)	47.5	70.7	60.7
	Apr-Oct 2014 (5)	45.2	127.5	89.2
	Apr-Oct 2015 (5)	39.3	135.5	82.5
	Apr-Sept 2016 (3)	55.2	167.8	106.0

Turbidity

The units for turbidity measurements vary depending on the equipment used for sampling, although this distinction was not recognized until 2004 (USGS 2017b). Since 2004, measurements taken with a device using white or broadband light are presented in Nephelometric Turbidity Units (NTUs) while those taken with devices using infrared, monochromatic light are measured in Formazin Turbidity Units (FTU) (USGS 2017b). These two units are not directly comparable. Historically, the U.S. Army Corps of Engineers (USACE) measured turbidity in FTU while the NPS has used NTU (Wilson, written communication, April 2017). Historic observations of turbidity within BLUE ranged from 0.4-89.0 NTU (NPS 1995). Mean values showed a much narrower range of 4.4-8.5 NTU, with medians between 2.9 and 5.8 NTU (Table 62).

Table 62. Historic (pre-1996) turbidity observations for Bluestone National Scenic River sampling locations (NPS 1995).

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Bluestone River at Pipestem S.P. (BLUE0020)	39 (1992-1995)	1.2 NTU	89.0 NTU	3.4 NTU	8.0 NTU
Bluestone River near Pipestem (BLUE0024)	1 (1980)	17.0 FTU	17.0 FTU	–	–
Bluestone River above Little Bluestone confluence (BLUE0013)	40 (1992-1995)	0.8 NTU	84.0 NTU	4.8 NTU	8.5 NTU
Bluestone River (BLUE0011)	14 (1974-1978)	0.5 FTU	25.0 FTU	5.8 FTU	8.3 FTU
Mountain Creek near mouth (BLUE0025)	37 (1992-1995)	0.4 NTU	22.0 NTU	2.9 NTU	4.4 NTU
Little Bluestone River near mouth (BLUE0015)	40 (1992-1995)	0.4 NTU	26.0 NTU	2.9 NTU	5.9 NTU

On Bluestone River tributaries, Webber (2012) observed turbidities in the 0.1-4.8 FTU range, with the majority of values below 1.0 FTU (Table 63).

Table 63. Turbidity observations (FTU) from Bluestone River tributaries within Bluestone National Scenic River, 2010-2011 (Webber 2012).

Site	Spring 2010	Summer 2010	Fall 2010	Spring 2011	Summer 2011	Fall 2011
Little Bluestone River	0.9	0.8	0.2	4.8	0.7	0.1
Mountain Creek	0.7	0.3	0.1	1.2	4.7	0.2

Turbidities on the Bluestone River during 1996-2011 park monitoring were highly variable, ranging from 0.6-604.0 NTU, with means in the 25-30 NTU range (Table 64) (NPS 2017c). Higher values were likely following rain/runoff events, when sediment was washed into streams. Tributary turbidities showed a narrower range during this period, from 0.2-129.0 NTU, and lower means. More recently (2012-2016), Bluestone River turbidities ranged from 1.1-59.1 NTU, with annual means varying from 2.4 to 18.6 NTU. As with previous measures, annual means can be influenced by the timing and number of samples taken each year and should be compared with caution. Turbidities on tributaries during this time ranged from 0.5-12.9 NTU, with all annual means below 8.0 NTU (NPS 2017c).

Table 64. Turbidity results (NTU) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Bluestone River below Mountain Creek (B04)	1996-2011 (79)	0.6	387.0	25.9
	Apr-Oct 2012 (3)	1.1	16.7	7.2
	Apr-Jun 2013 (3)	6.7	32.8	17.6
	Apr-Oct 2014 (5)	2.7	7.0	4.8
	Apr-Oct 2015 (5)	2.2	57.9	18.5
	Apr-Sept 2016 (3)	1.8	3.2	2.6
Bluestone River above Little Bluestone River (B03)	1996-2011 (81)	1.0	307.0	25.9
	Apr-Oct 2012 (3)	1.3	7.6	4.2
	Apr-Jun 2013 (3)	6.1	32.8	17.1
	Apr-Oct 2014 (5)	3.1	6.6	4.7
	Apr-Oct 2015 (5)	1.9	59.0	18.6
	Apr-Sept 2016 (3)	1.4	15.4	7.1
Bluestone River above Mouth (B01)	1996-2011 (80)	0.6	604.0	29.2
	Apr-Oct 2012 (3)	1.1	4.8	2.8
	Apr-Jun 2013 (3)	5.9	31.7	16.4
	Apr-Oct 2014 (5)	1.9	5.2	3.6
	Apr-Oct 2015 (5)	1.6	59.1	18.4
	Apr-Sept 2016 (3)	1.4	3.7	2.4

Table 64 (continued). Turbidity results (NTU) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean
Mountain Creek (B05)	1996-2011 (80)	0.2	103.0	7.9
	Apr-Oct 2012 (3)	0.5	2.8	1.7
	Apr-Jun 2013 (3)	4.0	7.7	6.2
	Apr-Oct 2014 (5)	1.1	4.3	2.3
	Apr-Oct 2015 (5)	0.8	8.9	4.7
	Apr-Sept 2016 (3)	1.8	3.0	2.2
Little Bluestone River (B02)	1996-2011 (81)	0.3	129.0	11.0
	Apr-Oct 2012 (3)	0.7	4.0	2.1
	Apr-Jun 2013 (3)	4.5	10.6	7.2
	Apr-Oct 2014 (5)	1.1	4.2	2.4
	Apr-Oct 2015 (5)	0.8	12.9	5.6
	Apr-Sept 2016 (3)	1.4	6.8	3.5

Fecal Coliform Bacteria

Historic (pre-1996) fecal coliform measurements from BLUE waters ranged widely from 0.5-4,325.0 FC/100ml, with means from 151.7-241.9 FC/100 ml (NPS 1995). Fecal coliform concentrations were lower in Mountain Creek than in either the Bluestone River or the Little Bluestone River during this time period Table 65).

Table 65. Historic (pre-1996) fecal coliform observations (FC/100ml) for Bluestone National Scenic River sampling locations (NPS 1995). FC = fecal coliforms.

Site	# of Observations (Time Period)	Minimum	Maximum	Median	Mean
Bluestone River at Pipestem S.P. (BLUE0020)	31 (1991-1995)	8	4,325	40.0	220.5
Bluestone River above Little Bluestone confluence (BLUE0013)	31 (1991-1995)	2	3,580	41.0	241.9
Mountain Creek near mouth (BLUE0025)	21 (1992-1995)	0.5	1,310	37.0	151.7
Little Bluestone River near mouth (BLUE0015)	25 (1991-1995)	17	1,400	114.0	241.9

Fecal coliform observations have also been highly variable during park monitoring, with values on the Bluestone River between 1996 and 2011 ranging from 3-55,000 FC/100 ml (Table 66) (NPS 2017c). Means for all three Bluestone River sites were above 1,000 FC/100 ml, with 20-28% of samples at each site exceeding 400 FC/100 ml. On tributaries during this period, coliform measurements ranged from 1-18,000 FC/100 ml, with higher values on the Little Bluestone River than on Mountain Creek. Approximately 10% of samples from the Little Bluestone River and 9% of

Mountain Creek samples exceeded 400 FC/100 ml (NPS 2017c). From 2012-2016, fecal coliform observations on the Bluestone River were between 2-2,250 FC/100 ml, with annual means in the 9-582 FC/100 ml range. Four observations (7%) exceeded 400 FC/100 ml (Table 66), with three of these occurring in July 2015. Coliform bacteria levels on tributaries during this time ranged from 3-277 FC/100 ml; only one measurement from Mountain Creek exceeded 200 FC/100 ml (NPS 2017c).

Table 66. Fecal coliform bacteria results (FC/100 ml) from park monitoring efforts, 1996-2016 (NPS 2017c).

Location	Time Period (Samples)	Minimum	Maximum	Mean	Samples ≥200	Samples ≥400
Bluestone River below Mountain Creek (B04)	1996-2011 (76)	3	26,000	1,084	26	21
	Apr-Oct 2012 (3)	5	183	66.0	0	0
	Apr-Jun 2013 (3)	23	270	118.3	1	0
	Apr-Oct 2014 (5)	10	43	27.4	0	0
	Apr-Oct 2015 (5)	14	2,250	582.2	2	2
	Apr-Sept 2016 (3)	5	20	10.3	0	0
Bluestone River above Little Bluestone River (B03)	1996-2011 (81)	4	55,000	1,289	24	19
	Apr-Oct 2012 (3)	8	70	28.7	0	0
	Apr-Jun 2013 (3)	13	320	130.7	1	0
	Apr-Oct 2014 (5)	8	304	77.8	1	0
	Apr-Oct 2015 (5)	10	2,050	491.6	2	1
	Apr-Sept 2016 (3)	3	15	9	0	0
Bluestone River above Mouth (B01)	1996-2011 (77)	4	44,000	1,232	22	16
	Apr-Oct 2012 (3)	2	19	9.0	0	0
	Apr-Jun 2013 (3)	15	340	138	1	0
	Apr-Oct 2014 (5)	5	21	10.2	0	0
	Apr-Oct 2015 (5)	8	1,900	430.6	2	1
	Apr-Sept 2016 (3)	3	6	4.0	0	0
Mountain Creek (B05)	1996-2011 (77)	3	2,100	138.7	12	7
	Apr-Oct 2012 (3)	3	77	30.3	0	0
	Apr-Jun 2013 (3)	28	94	53.3	0	0
	Apr-Oct 2014 (5)	7	277	81.2	1	0
	Apr-Oct 2015 (5)	6	140	48.2	0	0
	Apr-Sept 2016 (3)	7	32	19.0	0	0
Little Bluestone River (B02)	1996-2011 (78)	1	18,000	433.9	14	8
	Apr-Oct 2012 (3)	6	39	17.7	0	0
	Apr-Jun 2013 (3)	13	103	52.0	0	0
	Apr-Oct 2014 (5)	6	39	22.6	0	0
	Apr-Oct 2015 (5)	11	107	40.2	0	0
	Apr-Sept 2016 (3)	4	62	24.0	0	0

Threats and Stressor Factors

Threats to BLUE's water quality include upstream agricultural use and logging; residential and other development; inadequately treated sewage; pesticides, road de-icers, and industrial chemicals (e.g., fracking waste disposal sites); bilge waste from boats on Bluestone Lake; and atmospheric deposition. One of the greatest water quality concerns is high fecal coliform bacteria levels, which have led to the 303d impaired listing for the Bluestone River and its tributary, Mountain Creek (Tzilkowski et al. 2015). While some bacteria may come from livestock and wildlife, it is likely that the primary contributor is inadequately treated sewage (i.e., human waste) (Purvis and Wilson 2007). Many communities and households in the region around the park lack adequate septic or sewage systems for the proper treatment of human and other domestic wastes (Purvis 2002, 2009). This is largely due to the longstanding poverty in the area and the high cost of building sewer lines in rocky, densely forested terrain (Purvis 2002).

Surrounding land use can have a significant impact on the surface water quality of protected areas, especially at BLUE, where the majority of the watershed lies outside park boundaries (Marshall and Piekielek 2007a). Land cover within the BLUE watershed is primarily forested, with approximately 20% of land in agriculture (crops and pasture) (Figure 41) (Sheeder et al. 2004). Agricultural land uses can contribute pollutants (e.g., chemicals, nutrients, fecal bacteria from livestock) and excess sediment to streams. Agricultural sources are responsible for much of the phosphorous, nitrogen, and sediment discharged into U.S. waterways (Purvis 2002). In forested areas surrounding BLUE, most of the timber is considered harvestable, and active logging occurs near and adjacent to the park (Purvis 2002). Logging, and the roads associated with logging activity, increase soil exposure and erosion, which in turn increases sedimentation of streams in the area (Hebner 1991, Purvis 2002).

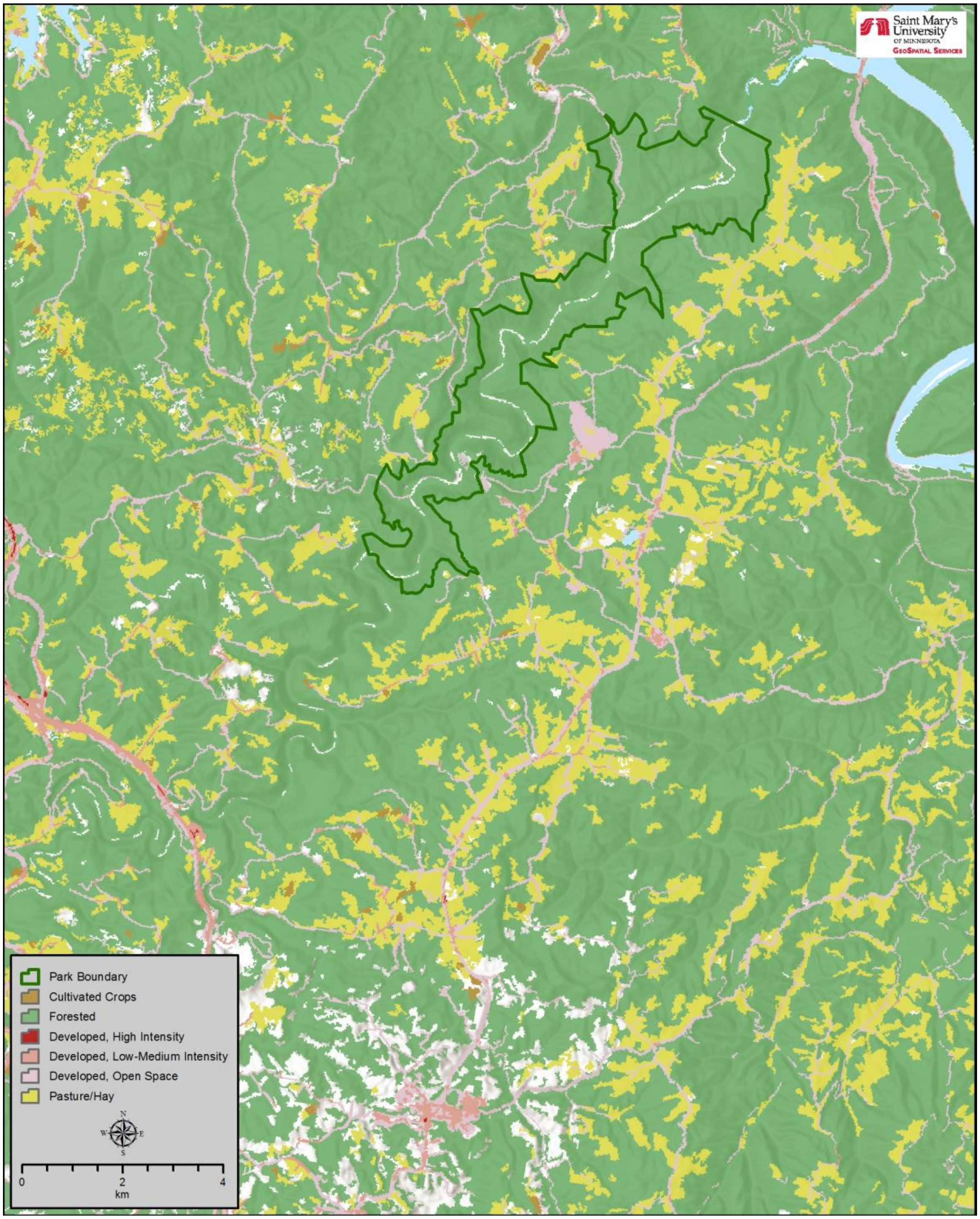


Figure 41. Land use in and around Bluestone National Scenic River, 2011 (USGS 2011b).

Increasing residential and recreational development is a concern in the area, due to interest in vacation homes and recreational infrastructure (Marshall and Piekielek 2007a). Construction and clearing for these developments can increase runoff, contributing sediment to surface waters. The Bluestone watershed also collects discharges of treated wastewater from eight sewage treatment plants associated with existing upstream developments (Purvis 2002). One sewer overflow system in the drainage releases a mix of stormwater runoff and untreated wastewater directly into streams during heavy rain events (Purvis 2002). De-icing solutions (e.g., salts) used on roads associated with developments may pollute park waters as well, particularly with chloride (Webber 2012).

Although there are currently no gas wells within BLUE boundaries, the park's water quality is still threatened by exploration and extraction activity. The park lies on the southeastern edge of the Marcellus Shale, a major gas-bearing rock formation (NPS 2009). According to WVDEP, there are active gas wells approximately 13 km (8.1 mi) to the west and 14 km (8.7 mi) to the south of BLUE (Figure 42) (WVDEP 2016b). During drilling and extraction, there is a risk that drilling fluids, gas, or waste fluids may spill or leak, potentially contaminating nearby waters (Purvis 2002, NPS 2009). Trucks, pipelines, and pumping stations required for the transportation of gas and waste products may also spill or leak. A major natural gas pipeline currently crosses the park and the Bluestone River in the vicinity of Lilly (Purvis 2002). The liquid wastes from oil and gas extraction operations (primarily brine) are often pumped back into the ground by separate injection wells (EPA 2016b). Although these wells are designed to carry the waste fluids to deep underground formations that are isolated from groundwater sources, there is a risk of leaks or spills at or near the surface, which could contaminate surface waters and/or shallow groundwater. The closest injection well to the park is just 9.2 km (5.7 mi) to the southwest (Figure 42) (WVDEP 2016b).

Bluestone Lake, a reservoir created by the Bluestone Dam, is just downstream of BLUE's northern boundary. Occasionally, the reservoir "backs up" during periods of high water, causing water from the lake to encroach upstream into the park (Vanderhorst et al. 2008). Bluestone Lake is a popular site for recreational boating; bilge and other wastes from boats can contaminate the lake's waters (Milliken and Lee 1990). During lake back-ups, these contaminants may reach into BLUE.

Atmospheric wet deposition (e.g., rain, snow, fog) in the region around BLUE is likely acidic. The mean annual pH of wet deposition measured at Babcock State Park (approximately 42 km [26 mi] north of BLUE) in 2014-2015 was below 5.1 (Figure 43) (NADP 2016b). The normal pH of rain is around 5.6 (NADP 2014). The low pH of precipitation/deposition in the region may decrease the pH of (i.e., acidify) the park's surface waters. Human-related contributors to acidic deposition include motor vehicles, electric power generation (e.g., coal-burning facilities), and industrial/chemical plants (NADP 2014).

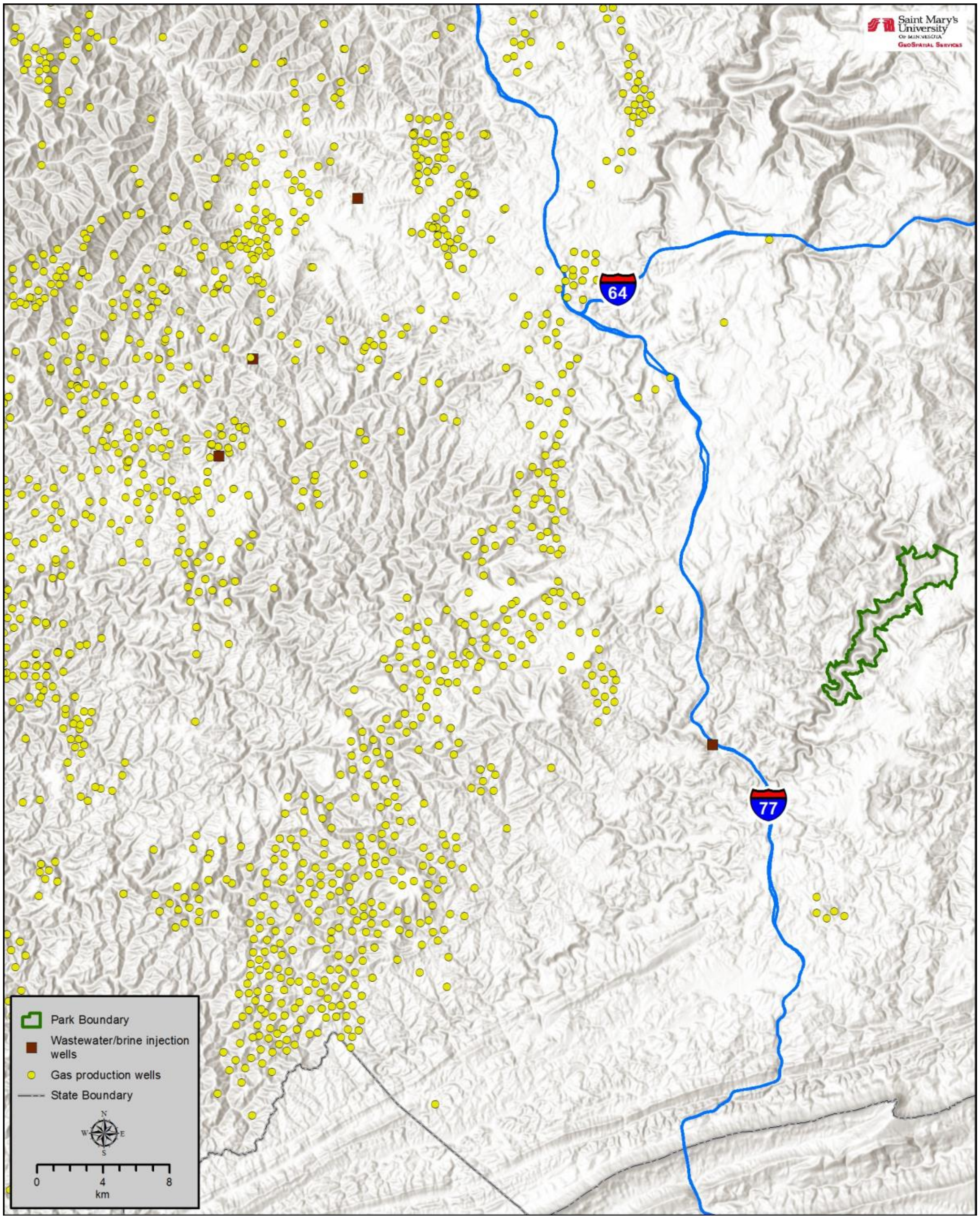


Figure 42. Active gas production and wastewater/brine injection wells in the vicinity of Bluestone National Scenic River (WVDEP 2016b).

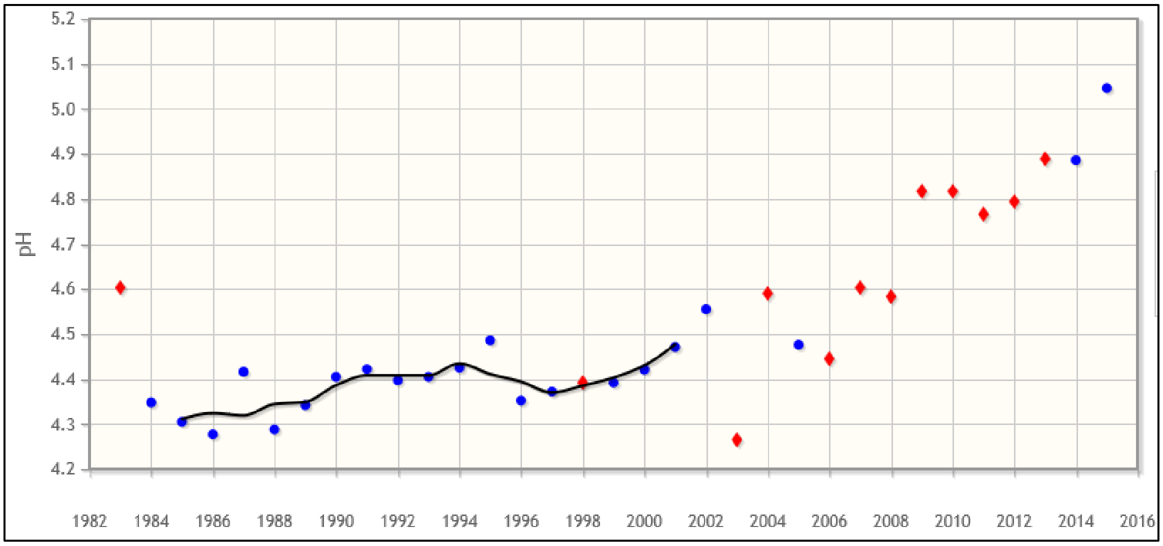


Figure 43. Annual mean pH of wet atmospheric deposition at National Trends Network Site WV04, Babcock State Park (NADP 2016b). Red diamonds represent years when National Atmospheric Deposition Program's data completeness criteria (valid samples and precipitation amounts for 75% of time period) were not met. The black line represents a smoothed 3-yr moving average.

<u>Data Needs/Gaps</u>

While some data are available for all selected water quality measures, more frequent and consistent monitoring would provide further insight into current water quality conditions and any changes over time. However, this is challenging given the remoteness and limited access to many areas of the park. If budgets allow, the deployment of additional automated water quality monitoring equipment to collect continuous data (similar to the ERMN 2013-2014 temperature and SpC observations) would be particularly useful. This could enable researchers to link fluctuations in water quality parameters to seasonal changes or particular events (e.g., precipitation events). In addition, existing water quality data could be compared to stream flow/discharge data and to park geologic maps to look for any patterns or relationships between these factors. Bedrock geology has been shown to influence water quality, particularly pH and specific conductance, in other areas of the Appalachians (Johnson and Reynolds 1977, Silsbee and Larson 1982).

<u>Overall Condition</u>

Temperature

The NRCA project team assigned this measure a *Significance Level* of 2. All water temperature observations taken since 1996 during park monitoring have met state water quality standards, as did observations by Webber (2012) and Tzilkowski et al. (2015). Therefore, this measure is currently of no concern (*Condition Level* = 0).

pH

This measure was assigned a *Significance Level* of 3. Historically, some pH readings from BLUE streams slightly exceeded the state standard range of 6.0-9.0. However, all park monitoring observations since 2012, along with Webber (2012) and Tzilkowski et al. (2015) observations, have met state standards. As a result, pH is assigned a *Condition Level* of 0.

Dissolved Oxygen
A *Significance Level* of 3 was assigned for the DO measure. Sufficient DO levels are critical for the survival of aquatic organisms (USGS 2015b). All park monitoring observations since 2012, as well as measurements by Webber (2012) and Tzilkowski et al. (2015), met the state standard of ≥5.0 mg/L. Therefore, DO is also currently of no concern (*Condition Level* = 0).

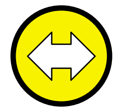
Specific Conductance
This measure was assigned a *Significance Level* of 3. Several SpC measurements by Webber (2012) from Mountain Creek exceeded the informal reference condition of 325 µS/cm (based on EPA criteria for TDS in drinking water), as did many measurements reported by Tzilkowski et al. (2015). According to ERMN continuous data from the Bluestone River (NPS 2017a), nearly 43% of downstream measurements and 38% of upstream measurements were above 325 µS/cm. During 2012-2016 park monitoring, six observations (~10%) from the Bluestone River were above 325 µS/cm, but all tributary measurements met the informal reference condition (NPS 2017c). As a result, SpC is currently considered of moderate concern (*Condition Level* = 2).

Turbidity
The turbidity measure was also assigned a *Significance Level* of 3. A numeric turbidity reference condition could not be determined for BLUE surface waters, since the "background turbidity" is unknown. However, all three Bluestone River sites have experienced maximum turbidities above 50 NTU in 2015 and above 30 NTU in 2013. Based on these results and the concern of park staff, turbidity is assigned a *Condition Level* of 2 at this time.

Fecal Coliform Bacteria
The NRCA project team assigned this measure a *Significance Level* of 3. Elevated coliform bacteria levels can pose a threat to the health of park visitors and staff. Fecal coliform bacteria measurements have been highly variable during park monitoring, with observations from the Bluestone River during 2012-2016 ranging from 2 to 2,250 FC/100 ml (NPS 2017c). Four observations (7%) during this period exceeded 400 FC/100 ml. Park monitoring measurements from the Little Bluestone River and Mountain Creek were lower, with only one observation from Mountain Creek exceeding 200 FC/100 ml. This measure is currently of moderate concern (*Condition Level* = 2).

Weighted Condition Score
The *Weighted Condition Score* for BLUE's water quality is 0.35, indicating moderate concern (Table 67). Although water temperatures, pH, and DO are well within state standards and currently of no concern, the remaining measures have shown levels of concern during recent (2012-2016) park monitoring. SpC and turbidity observations on the Bluestone River have exceeded informal reference conditions on occasion, and sporadic elevated fecal coliform bacteria levels on the Bluestone River may pose a threat to human health. As there is no clear or consistent decline or improvement in the selected measures, a stable/unchanging trend is assigned.

Table 67. Current condution of Bluestone National Scenic River's Water Quality.

Measures	**Significance Level**	**Condition Level**	**WCS = 0.35**
Temperature	2	0	
pH	3	0	
Dissolved Oxygen	3	0	
Specific Conductance	3	2	
Turbidity	3	2	
Fecal coliform bacteria	3	2	

4.7.6. Sources of Expertise

- Caleb Tzilkowski, ERMN Aquatic Ecologist
- Lisa Wilson, NPS Biological Science Technician

4.8. Air Quality

4.8.1. Description

Air pollution can significantly affect natural resources, their associated ecological processes, and the health of park visitors. In the Clean Air Act (CAA), Congress set a national goal “to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic or historic value” (42 U.S.C. §7470(2)). This goal applies to all units of the National Park System. The act includes special provisions for 48 park units, called “Class I” areas under the CAA; all other NPS areas are designated as Class II, including BLUE. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas which can allow for more development (NPS 2004). Additional authority to consider and protect air quality in Class II parks is provided by Title 54 (54 USC 100101(a) et seq.), commonly known as the NPS Organic Act.

Parks designated as Class I and II airsheds use the EPA’s National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. EPA standards are designed to protect human health and the health of natural resources (EPA 2016e). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008). In addition, the ERMN has identified ozone and atmospheric deposition as Vital Signs for all network parks, including BLUE (Marshall and Piekielek 2007a).

4.8.2. Measures

- Nitrogen deposition
- Sulfur deposition
- Mercury deposition
- Ozone
- Visibility

<u>Atmospheric Deposition of Sulfur and Nitrogen</u>

Sulfur and nitrogen are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2012). While in the atmosphere, these emissions form compounds that may be transported long distances, eventually settling out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (NPS 2008, EPA 2012). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2012). Deposition of sulfur and nitrogen can have significant effects on ecosystems including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water and vegetation (NPS 2008, reviewed in Sullivan et al. 2011b, 2011d).

Atmospheric Deposition of Mercury

Sources of atmospheric mercury include anthropogenic sources such as fuel combustion and evaporation (especially coal-fired power plants), waste disposal, mining, industrial sources, along with natural sources such as volcanoes and evaporation from enriched soils, wetlands, and oceans (EPA 2008). Atmospheric deposition of mercury from coal-burning power plants has been identified as a major source of mercury to remote ecosystems (Landers et al. 2008). Mercury is a potential problem for ecosystems in regions with heavy current or historic coal use.

Mercury deposited into rivers, lakes, and oceans can accumulate in various aquatic species, resulting in exposure to wildlife and humans that consume them (EPA 2008). Mercury exposure can cause liver, kidney, and brain (neurological and developmental) damage (EPA 2008). High concentrations in birds, mammals, and fish can result in reduced foraging efficiency, survival, and reproductive success (Mast et al. 2010, Eagles-Smith et al. 2014).

Ozone

Ozone occurs naturally in the earth's upper atmosphere where it protects the earth's surface against ultraviolet radiation (EPA 2012). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides (NO_x) and VOCs in the presence of heat and sunlight (NPS 2008). Ozone precursors are emitted from both anthropogenic and natural source types, including power plants, industry, motor vehicles, oil and gas development, forest fires, and other sources (Beitler 2006, EPA 2008).

Ozone is one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth defects for sensitive plants in natural ecosystems. Specific defects include reduced photosynthesis, premature leaf loss, and reduced biomass; prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (NPS 2008). Plant species occurring in BLUE that are known to be sensitive to ozone include green ash, white ash, tulip tree, American sycamore, and Virginia pine (*Pinus virginiana*) (Kohut 2007).

At high concentrations, ozone can aggravate respiratory and cardiovascular diseases in humans through reduced lung function, increased acute respiratory problems, and elevated susceptibility to respiratory infections (EPA 2016d). Visitors and staff engaging in aerobic activities in the park (e.g., hiking), as well as children, the elderly, and people with heart and lung diseases are especially sensitive to elevated ozone concentrations.

Visibility (Particulate Matter)

Air pollution, especially PM, influences a visitor's ability to view scenic vistas and landscapes at parks (NPS 2007). PM is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. It largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2016f). There are two particle size classes of concern: $PM_{2.5}$ – fine particles found in smoke and haze, which are 2.5 micrometers or less in diameter; and PM_{10} – coarse particles found in wind-blown dust, which have diameters between 2.5 and 10 micrometers (EPA 2012). Fine particles are a major cause of reduced visibility (haze) in many national parks and wilderness areas (EPA 2012). $PM_{2.5}$ can either be directly emitted from sources (e.g., forest fires) or they can form when gas emissions from power plants, industry, and/or vehicles react in the air (EPA 2016f). Particulate matter can either absorb or scatter light, causing the clarity, color, and distance seen by humans to decrease, especially during humid conditions when additional moisture is present in the air. $PM_{2.5}$ is also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2016f). Exposure to these particles can cause airway irritation, coughing, and difficulty breathing (EPA 2016f).

4.8.3. Reference Condition/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (NPS 2015b). This approach is discussed by indicator in the following paragraphs and the ratings are summarized in Table 68 and Table 69.

Table 68. National Park Service Air Resources Division air quality index values for wet deposition of nitrogen or sulfur, ozone, particulate matter, and visibility (NPS 2015b).

Condition Level	Human Health Risk from O3 (ppb)	Vegetation Health Risk from O3 (ppm-hrs)	Wet Deposition of N or S (kg/ha-yr)	Visibility (dv* above natural conditions)
Significant Concern	≥71	>13	>3	>8
Moderate Concern	55–70	7-13	1–3	2–8
Good Condition	≤55	<7	<1	<2

*a unit of visibility proportional to the logarithm of the atmospheric extinction; one deciview (dv) represents the minimal perceptible change in visibility to the human eye.

Table 69. National Park Service Air Resources Division air quality assessment matrix for mercury status (NPS 2015b). GC = Good Condition, MC = Moderate Concern, and SC = Significant Concern.

Predicted Methylmercury Concentration Rating	Mercury Wet Deposition Rating				
	Very Low (<3 µg/m2/yr)	Low (≥3–<6 µg/m2/yr)	Moderate (≥6–<9 µg/m2/yr)	High (≥9–<12 µg/m2/yr)	Very High (≥ 12 µg/m2/yr)
Very Low (< 0.038 ng/L)	GC	GC	GC	MC	MC
Low (≥0.038–< 0.053 ng/L)	GC	GC	MC	MC	MC
Moderate (≥0.053–<0.075 ng/L)	GC	MC	MC	MC	SC
High (≥0.075–<0.12 ng/L)	MC	MC	MC	SC	SC
Very High (≥0.12 ng/L)	MC	MC	SC	SC	SC

Ozone

The primary NAAQS for ground-level ozone is set by the EPA, and is based on human health effects. The 2008 NAAQS for ozone was a 3-year average 4th-highest daily maximum 8-hour ozone concentration of 75 parts per billion (ppb) (NPS 2015b). On 1 October 2015, the EPA strengthened the national ozone standard by setting the new level at 70 ppb (EPA 2015). The NPS ARD recommends a benchmark for *Good Condition* ozone status in line with the updated Air Quality Index (AQI) breakpoints (NPS 2015b).

Current condition for human health risk from ozone is based on the estimated 5-year average 4th-highest daily maximum 8-hour ozone average concentration in ppb (NPS 2015b). Ozone concentrations ≥71 ppb are assigned a *Significant Concern*, from 55–70 ppb are assigned *Moderate Concern*, and <55ppb are assigned a *Good Condition* (NPS 2015b).

In addition to being a concern to human health, long-term exposures to ozone can cause injury to ozone-sensitive plants (EPA 2014). The W126 metric relates plant response to ozone exposure and is a better predictor of vegetation response than the metric used for the primary (human-health based) standard (EPA 2014). The W126 metric measures cumulative ozone exposure over the growing season in "parts per million-hours" (ppm-hrs) and is used for assessing the vegetation health risk from ozone levels (EPA 2014).

The W126 condition thresholds are based on information in the EPA's Policy Assessment for the Review of the Ozone NAAQS (EPA 2014). Research has found that for a W126 value of:

- ≤7 ppm-hrs, tree seedling biomass loss is ≤2% per year in sensitive species; and
- ≥13 ppm-hrs, tree seedling biomass loss is 4–10% per year in sensitive species.

The NPS ARD recommends a W126 of <7 ppm-hrs to protect most sensitive trees and vegetation. Levels below this guideline are considered *Good Condition*, 7-13 ppm-hrs is *Moderate Condition*, and >13 ppm-hrs is considered to be of *Significant Concern* (NPS 2015b).

Atmospheric Deposition of Sulfur and Nitrogen

Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Wet deposition is used as a surrogate for total deposition (wet plus dry), because wet deposition is the only nationally available monitored source of nitrogen and sulfur deposition data (NPS 2015b). Values for nitrogen (from ammonium and nitrate) and sulfur (from sulfate) wet deposition are expressed as amount of nitrogen or sulfur in kilograms deposited over a 1 ha (2.5 ac) area in 1 year (kg/ha/yr). The NPS ARD selected a wet deposition threshold of 1.0 kg/ha/yr as the level below which natural ecosystems are likely protected from harm. This is based on studies linking early stages of aquatic health decline correlated with 1.0 kg/ha/yr wet deposition of nitrogen both in the Rocky Mountains (Baron et al. 2011) and in the Pacific Northwest (Sheibley et al. 2014). Parks with ≤1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds are assigned *Good Condition*, those with 1-3 kg/ha/yr are assigned *Moderate Concern*, and parks with depositions ≥3 kg/ha/yr are assigned *Significant Concern* (NPS 2015b).

Mercury Deposition

The condition of mercury was assessed using estimated 3-year average mercury wet deposition (micrograms per m2 per year [μg/m2/yr]) and the predicted surface water methylmercury concentrations (nanograms per liter [ng/L]) at NPS I&M parks (NPS 2015b). It is important to consider both mercury deposition inputs and ecosystem susceptibility to mercury methylation when assessing mercury condition because atmospheric inputs of elemental or inorganic mercury must be methylated before it is biologically available and able to accumulate in food webs (NPS 2015b). Thus, mercury condition cannot be assessed according to mercury wet deposition alone. Other factors, like environmental conditions conducive to mercury methylation (e.g., dissolved organic carbon, wetlands, pH), must also be considered (NPS 2015b). Mercury wet deposition and predicted methylmercury concentration are considered concurrently in the mercury status assessment matrix displayed previously (Table 60) to determine park-specific mercury/toxics status (NPS 2015b).

Visibility

Visibility conditions are assessed in terms of a Haze Index, a measure of visibility (termed deciviews [dv]) that is derived from calculated light extinction and represents the minimal perceptible change in visibility to the human eye (NPS 2013b). Conditions measured near 0 dv are clear and provide excellent visibility, and as dv measurements increase, visibility conditions become hazier (NPS 2013b). The NPS ARD assesses visibility condition status based on the deviation of the estimated current visibility on mid-range days from estimated natural visibility on mid-range days (i.e., those estimated for a given area in the absence of human- caused visibility impairment, EPA-454/B003-005) (NPS 2015b). The NPS ARD chose reference condition ranges to reflect the variation in visibility conditions across the monitoring network. Visibility on mid-range days is defined as the mean of the visibility observations falling within the 40th and 60th percentiles (NPS 2015b). A visibility condition estimate of <2 dv above estimated natural conditions indicates a *Good Condition*, estimates ranging from 2-8 dv above natural conditions indicate *Moderate Concern*, and estimates >8 dv above natural conditions indicate *Significant Concern* (NPS 2015b).

Visibility trends are computed from the Haze Index values on the 20% haziest days and the 20% clearest days, consistent with visibility goals in the CAA and Regional Haze Rule, which include improving visibility on the haziest days and allowing no deterioration on the clearest days (NPS 2015b). Although this legislation provides special protection for NPS areas designated as Class I, the NPS applies these standard visibility metrics to all units of the NPS. If the Haze Index trend on the 20% clearest days is deteriorating, the overall visibility trend is reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days is reported as the overall visibility trend (NPS 2015b).

4.8.4. Data and Methods

<u>NPS Data Resources</u>

Although data on air quality parameters have not been actively collected within park boundaries, data collected at several regional monitoring stations for various parameters can be used to estimate air quality conditions in BLUE. NPS ARD provides estimates of ozone, wet deposition (nitrogen, sulfur, and mercury), and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over the most recent 5 years (2011–2015). Estimates and condition data for BLUE were obtained from the NPS Air Quality by park data products page (http://www.nature.nps.gov/air/data/products/parks/index.cfm).

On-site or nearby data are needed for a statistically valid trends analysis. There are no on-site or near-enough representative monitors for such an assessment of ozone, $PM_{2.5}$, and nitrogen, sulfur and mercury deposition trends at this time. For visibility trend analysis, monitoring data from an Interagency Monitoring of Protected Visual Environments Program (IMPROVE) station is required (NPS 2015b). An IMPROVE monitoring site considered representative of a Class II park has to be within ± 30.48 m (100 ft) or 10% of maximum and minimum elevation of the park and at a distance of no more than 150 km (93 mi) (NPS 2015b). No currently operational IMPROVE visibility monitoring locations meet these criteria for BLUE. Although the IMPROVE monitor in the James River Face Wilderness Area (Monitor ID: JARI1) near Natural Bridge, VA, is within the requisite distance, it does not meet the elevation requirements.

Other Air Quality Data Resources

The EPA Air Trends Database provides annual average summary data for ozone and $PM_{2.5}$ concentrations near BLUE (EPA 2016a). The nearest $PM_{2.5}$ monitor is located in Beckley, WV (Site ID: 54-081-0002) and data was collected at this site by the West Virginia Air Pollution Control Commission through March 2015 (Figure 44). This station is located approximately 30.5 km (19 mi) northwest of BLUE. The nearest active ozone monitor is in the small town of Sam Black Church, WV (Site ID: 54-025-0003), around 43 km (27 mi) northeast of BLUE, and has been active since 1999 (Figure 44).

The National Atmospheric Deposition Program–National Trends Network (NADP-NTN) database provides annual average summary data for nitrogen and sulfur concentration and deposition across the U.S. (NADP 2016b). The NADP-NTN monitoring site closest to BLUE is located at Babcock State Park (site ID: WV04), approximately 42 km (26 mi) north of BLUE (Figure 44). This site has collected deposition data for the region since 1983 and is currently active in monitoring (NADP 2016b). Data summaries for this monitor are available on the NADP-NTN website (NADP 2016b).

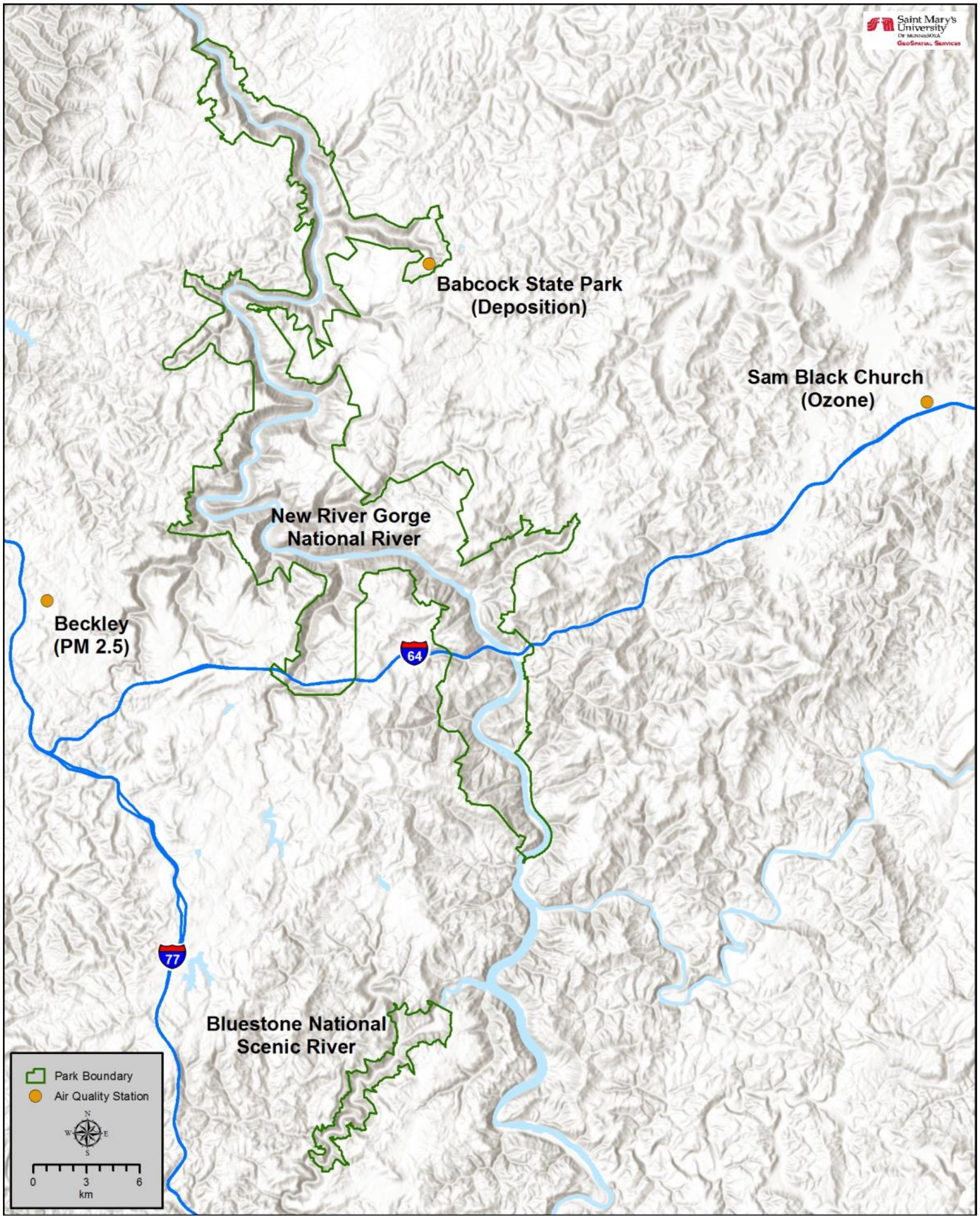


Figure 44. Locations of air quality monitoring stations in relation to Bluestone National Scenic River.

The NADP Mercury Deposition Network (MDN) provides weekly summary data for mercury deposition and concentration (NADP 2016a). Wet mercury deposition trends are evaluated using pollutant concentrations in precipitation (micro equivalents/liter) so that yearly variations in precipitation amounts do not influence trend analyses. Trends are computed for parks with a representative NADP-MDN wet deposition monitor that is within 16 km (10 mi) of park boundaries (NPS 2015b). BLUE does not have any NADP-MDN monitors within 190 km (118 mi). Predicted methylmercury concentrations in surface water were obtained from a model that predicts surface water methylmercury concentrations for hydrologic units throughout the U.S. based on relevant water quality characteristics (pH, sulfate, and total organic carbon) and wetland abundance (USGS 2015a).

Special Air Quality Studies

Kohut (2007) employed a biologically-based method to evaluate the risk of foliar injury from ozone at parks within the 32 Vital Signs Networks, the Appalachian National Scenic Trail, and the Natchez Trace National Scenic Trail. The assessment allowed resource managers at each park to better understand the risk of ozone injury to vegetation within their park and permits them to make a better informed decision regarding the need to monitor the impacts of ozone on plants.

Sullivan et al. (2011b, 2011d) identified ecosystems and resources at risk to acidification and excess nitrogen enrichment in national parks. These reports provided a relative risk assessment of acidification and nutrient enrichment impacts from atmospheric nitrogen and sulfur deposition for parks in 32 I&M networks. Ecosystem sensitivity ratings to acidification from atmospheric deposition were based on percent sensitive vegetation types, number of high-elevation lakes, length of low-order streams, length of high-elevation streams, average slope, and acid-sensitive areas within the park (Sullivan et al. 2011b). Ecosystem sensitivity ratings to nutrient enrichment effects were based on percent sensitive vegetation types and number of high-elevation lakes within the park (Sullivan et al. 2011d).

Pardo et al. (2011) synthesized current research relating atmospheric nitrogen deposition to effects on terrestrial and aquatic ecosystems in the U.S. and identified empirical critical loads for atmospheric nitrogen deposition.

4.8.5. Current Condition and Trend

Nitrogen Deposition

Five-year interpolated averages of nitrogen (from nitrate and ammonium) wet deposition are used to estimate condition for deposition. The most recent 5-year (2011–2015) estimate for nitrogen deposition at BLUE is 3.0 kg/ha/yr (NPS 2015a). Based on the NPS ratings for air quality conditions (see Table 58), this falls in the *Moderate Concern* range. A comparison to previous 5-year estimates shows that nitrogen deposition has decreased slightly and then stabilized over recent years (Figure 45).

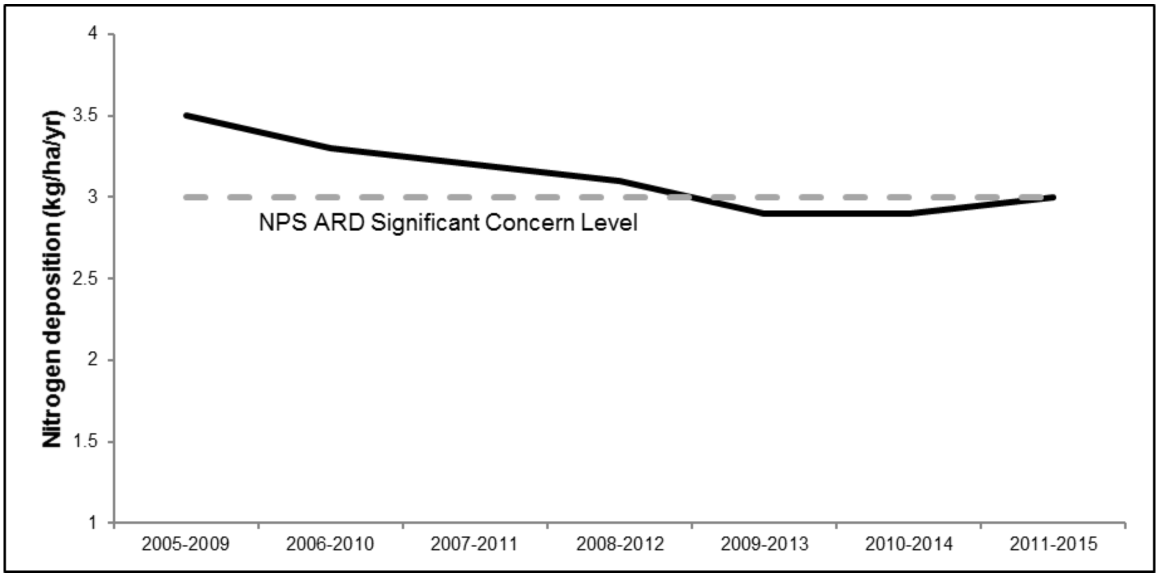


Figure 45. Estimated 5-year averages of nitrogen wet deposition (kg/ha/yr) at Bluestone National Scenic River (NPS 2015a).

In addition to assessing wet deposition levels, critical loads can also be a useful tool in determining the extent of deposition impacts (i.e., nutrient enrichment) to park resources (Pardo et al. 2011). A critical load is defined as the level of deposition below which harmful effects to the ecosystem are not expected (Pardo et al. 2011). For the Eastern Temperate Forest, the ecoregion where BLUE is located, Pardo et al. (2011) suggested critical loads for total nitrogen deposition (wet plus dry) of 4-8 kg/ha/yr to protect lichen, 8 kg/ha/yr to protect hardwood forests, and <17.5 kg/ha/yr to protect herbaceous species. The lowest critical load level (4.0 kg/ha/yr) is identified as an appropriate management goal because it will protect the full range of vegetation in the park (Pardo et al. 2011). The 2011-2015 estimated deposition at BLUE of 3.0 kg/ha/yr was below the minimum ecosystem critical load for the ecoregion, suggesting that sensitive vegetation elements may not be at risk for harmful effects. Similarly, Sullivan et al. (2011c) ranked BLUE as at very low risk of nutrient enrichment from nitrogen deposition, due to moderate pollutant exposure and very low levels of ecosystem sensitivity.

Concentrations (mg/L) of nitrogen compounds in wet deposition can also be used to evaluate overall trends in deposition. Since atmospheric wet deposition can vary greatly depending on the amount of precipitation that falls in any given year, it can be useful to examine concentrations of pollutants, which factor out the variation introduced by precipitation. Figure 46 shows that nitrate concentrations fluctuated but were somewhat stable during the 1980s and 1990s, and then decreased during the 2000s (NADP 2016b). Ammonium concentrations appear relatively stable from the 1980s through 2002. Levels have fluctuated since that time, showing no clear increasing or decreasing trend (Figure 47) (NADP 2016b).

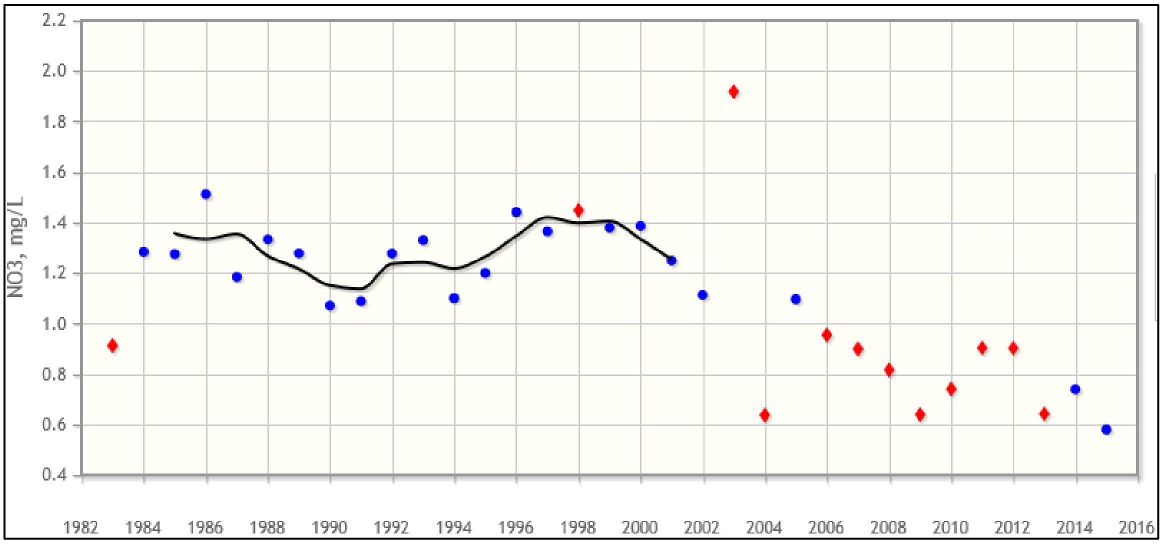


Figure 46. Annual weighted mean concentration of nitrate in wet deposition from Babcock State Park (National Trend Network Site WV04) (NADP 2016b). The black line represents a smoothed 3-yr moving average. Red diamonds represent years when National Atmospheric Deposition Program's data completeness criteria (valid samples for 75% of the period) were not met and, therefore, were not included in trend line calculations.

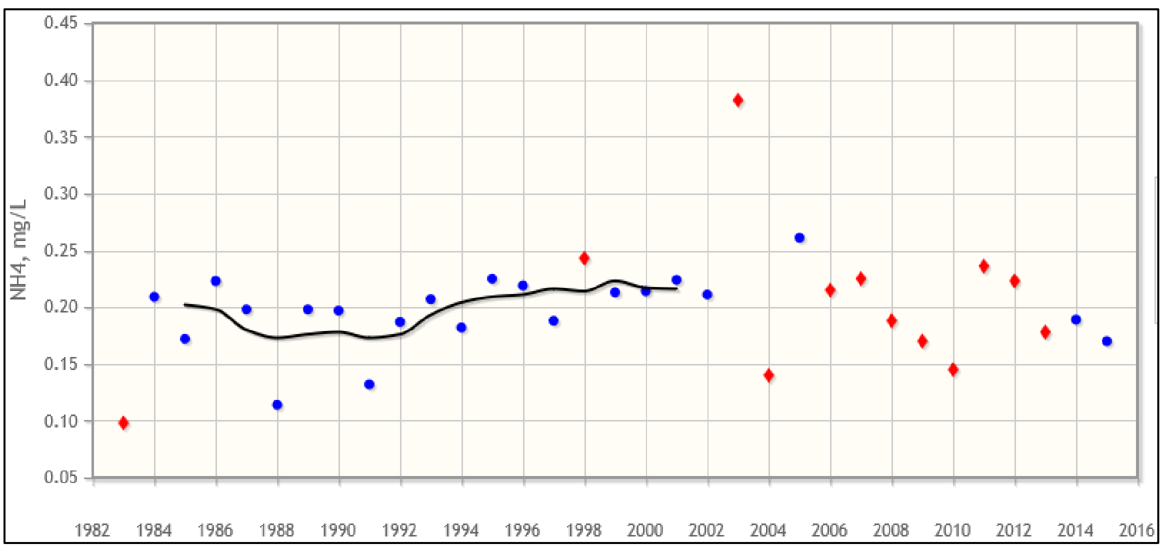


Figure 47. Annual weighted mean concentration of ammonium in wet deposition from Babcock State Park (National Trend Network Site WV04) (NADP 2016b). The black line represents a smoothed 3-yr moving average.

In contrast to the nutrient enrichment assessment discussed previously, Sullivan et al. (2011a) ranked BLUE as being at a high risk of acidification from acidic (nitrogen and sulfur) deposition, due to high pollutant exposure and very high levels of ecosystem sensitivity.

Sulfur Deposition

Five-year interpolated averages of sulfur (from sulfate) wet deposition are used to estimate condition for deposition. The most recent 5-year (2011–2015) estimate for sulfur wet deposition at BLUE is 2.1 kg/ha/yr (NPS 2015a). While this normally falls in the Moderate Concern range, the NPS ARD has elevated BLUE to *Significant Concern* due to very high ecosystem sensitivity to acidification effects (according to Sullivan et al. 2011a). A comparison to previous estimates suggests that sulfur deposition is decreasing at BLUE (Figure 48).

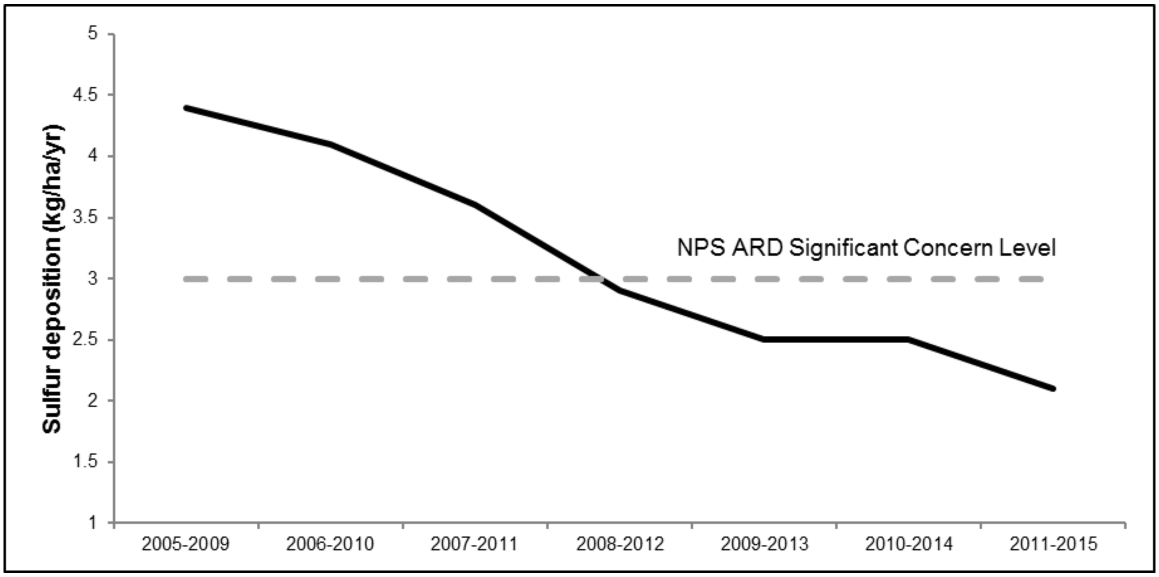


Figure 48. Estimated 5-year averages of sulfur wet deposition (kg/ha/yr) at Bluestone National Scenic River (NPS 2015a).

As with nitrogen, concentrations (mg/L) of sulfur compounds in wet deposition can also be used to evaluate overall trends in deposition. Figure 49 shows that the sulfate concentration in the BLUE region has declined over time, dropping to 0.5 mg/L in 2015 (NADP 2016b).

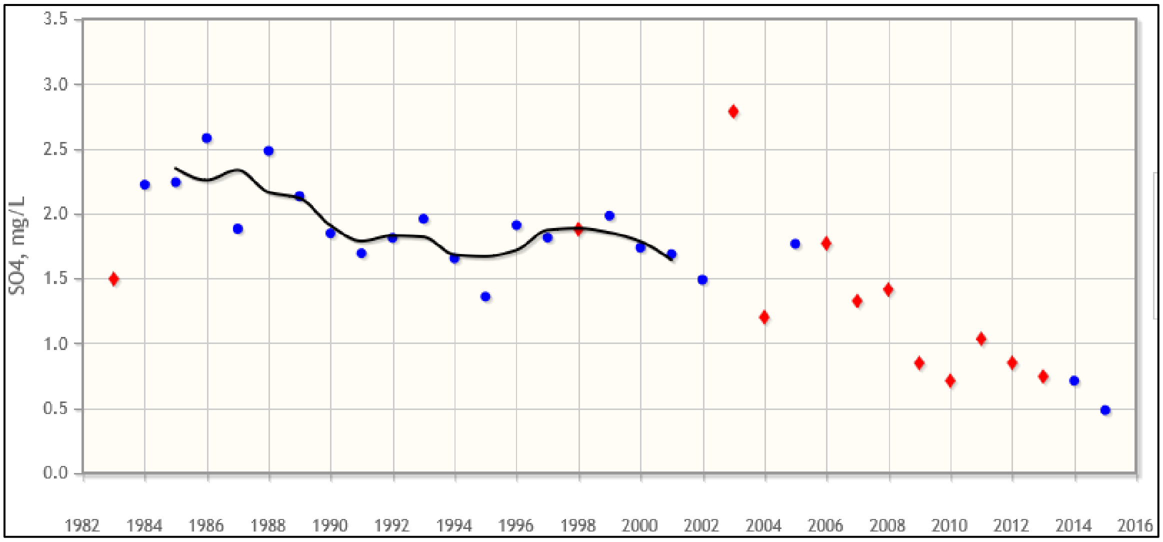


Figure 49. Annual weighted mean concentration of sulfate in wet deposition from Babcock State Park (National Trend Network Site WV04) (National Trend Network Site WV04) (NADP 2016b). The black line represents a smoothed 3-yr moving average. Red diamonds represent years when National Atmospheric Deposition Program's data completeness criteria (valid samples for 75% of the period) were not met and, therefore, were not included in trend line calculations.

Mercury Deposition

The 2012-2014 wet mercury deposition estimate is moderate for BLUE, ranging from 8.1-8.3 $\mu g/m^2/yr$, but predicted methylmercury concentrations in surface waters are low, estimated at 0.04 ng/l (NPS 2016a). When compared to the NPS ARD mercury status assessment matrix (Table 69), these estimates result in a condition of *Moderate Concern*. However, confidence in this assignment is low, given a lack of park-specific contaminant data.

Based on interpolations by the MDN, mercury deposition levels in the BLUE area in 2014 were likely in the 7-11 µg/m2 range (Figure 50). Also based on interpolations, as displayed in Figure 51, total mercury concentrations in the BLUE area in 2014 were likely 7-9 ng/L (NADP 2017).

The NPS ARD has measured mercury wet deposition at 16 parks across the U.S. (NPS 2013a). The location closest to BLUE where monitoring has occurred is Shenandoah National Park (SHEN), approximately 240 km (150 mi) northeast of BLUE. According to an analysis of mercury concentrations in precipitation, concentrations at SHEN have been relatively stable, increasing by an average of just 0.1 ng/l/yr from 2000-2009 (NPS 2013a).

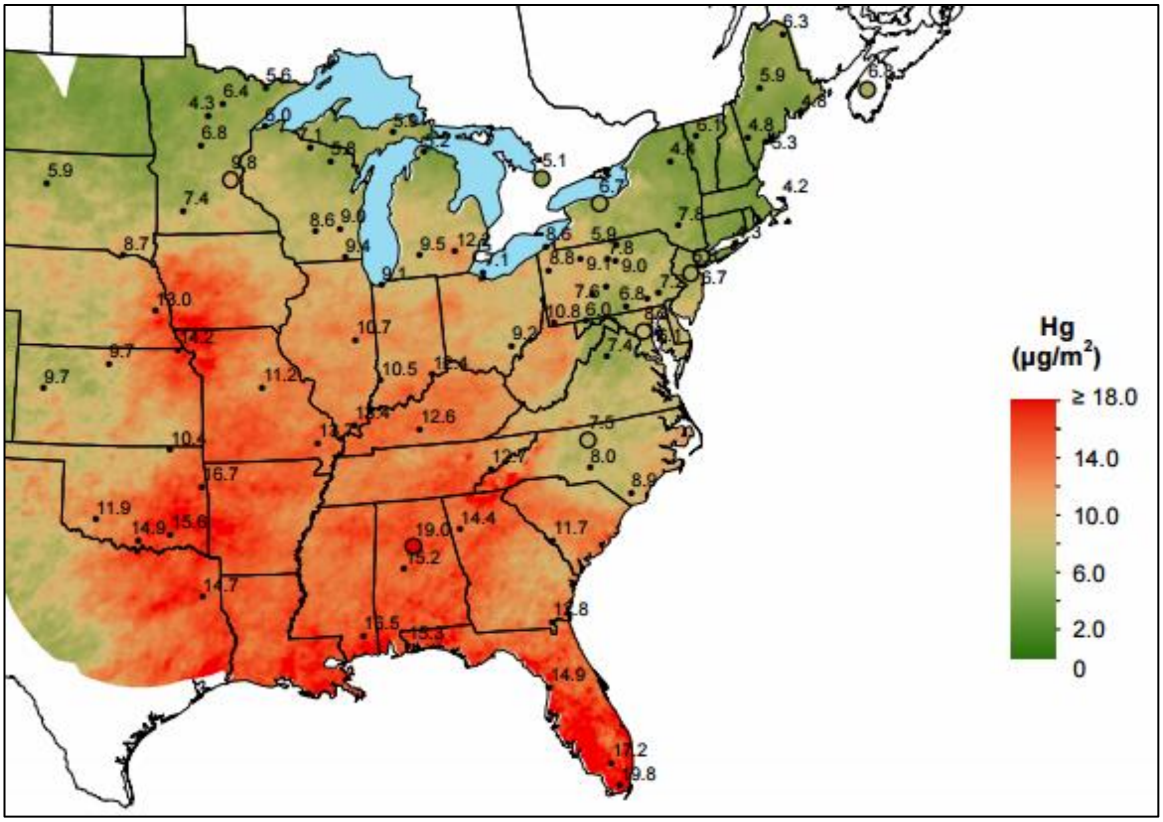


Figure 50. Total annual mercury wet deposition in 2015 (NADP 2017).

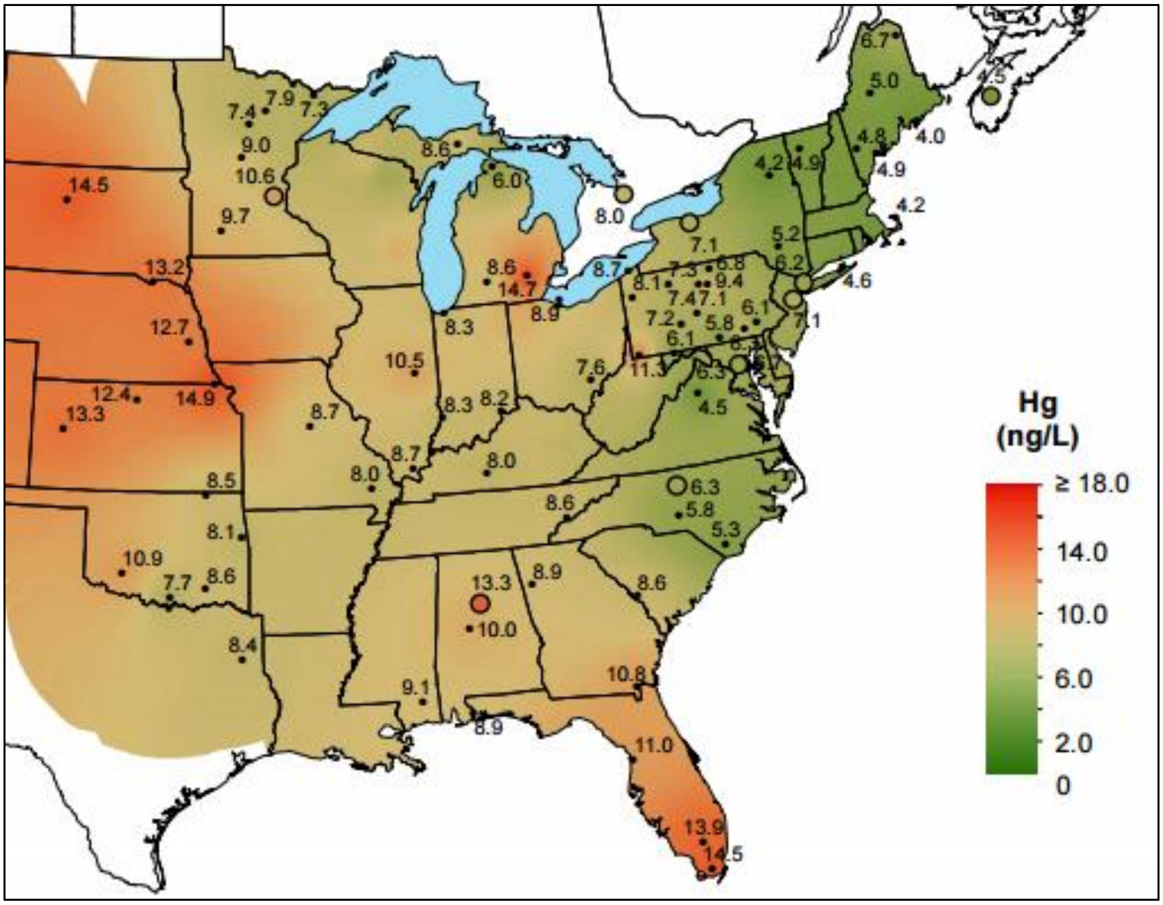


Figure 51. Total mercury concentrations in 2015 (NADP 2017).

Ozone

Historically, ozone has been somewhat of a concern in the BLUE region. Kohut (2007) determined that the risk of ozone exposure at the park was moderate, with concentrations estimated (through kriging) to exceed 80 ppb many times annually between 1995 and 1999. During these same years, the estimated W126 value remained above 30 ppm-hrs, and exceeded 50 ppm-hrs in 1998 and 1999 (Kohut 2007).

The condition of human risk from ozone in NPS units is determined by calculating the 5-year average of the 4th-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2013b). The most recent 5-year (2011–2015) estimated average for 4th-highest 8-hour ozone concentration at BLUE was 63.1 ppb (NPS 2015a). This is within the *Moderate Concern* range (Figure 52). A comparison to previous estimates suggests that ozone conditions are improving at BLUE, as 5-year average estimates have declined annually from a high of 71.8 ppb for 2005-2009 (NPS 2015a).

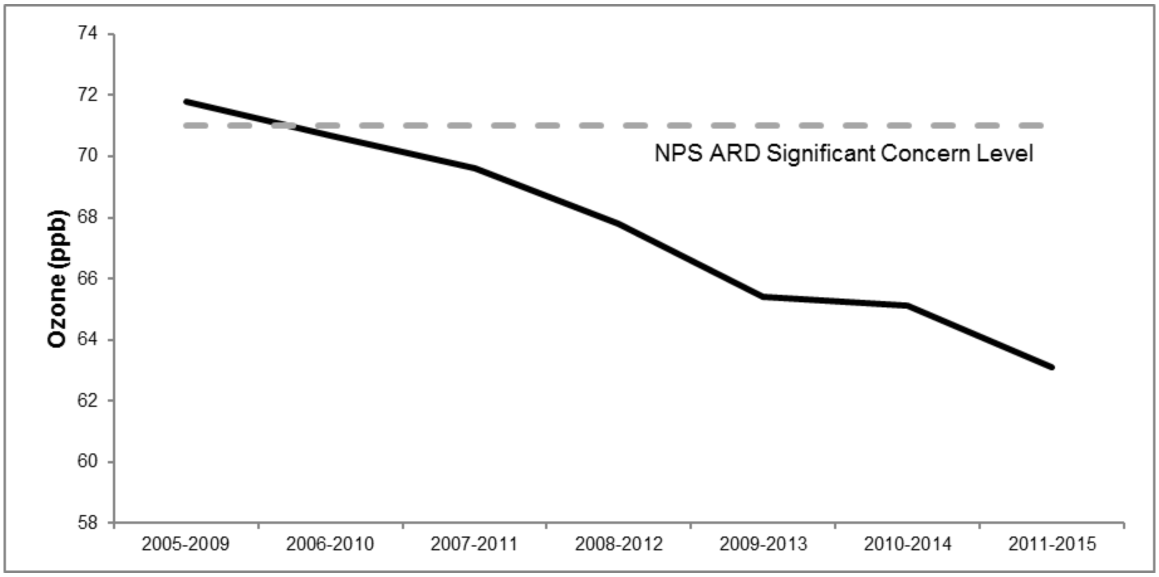


Figure 52. Estimated 5-year averages of the 4th-highest daily maximum of 8-hour average ozone concentrations for Bluestone National Scenic River (NPS 2015a).

The apparent improvement in ozone condition is supported by data from the nearest year-round ozone monitor (in Sam Black Church, WV), which show ozone concentrations fluctuating over time but with a general decreasing trend (Figure 53) (EPA 2016a).

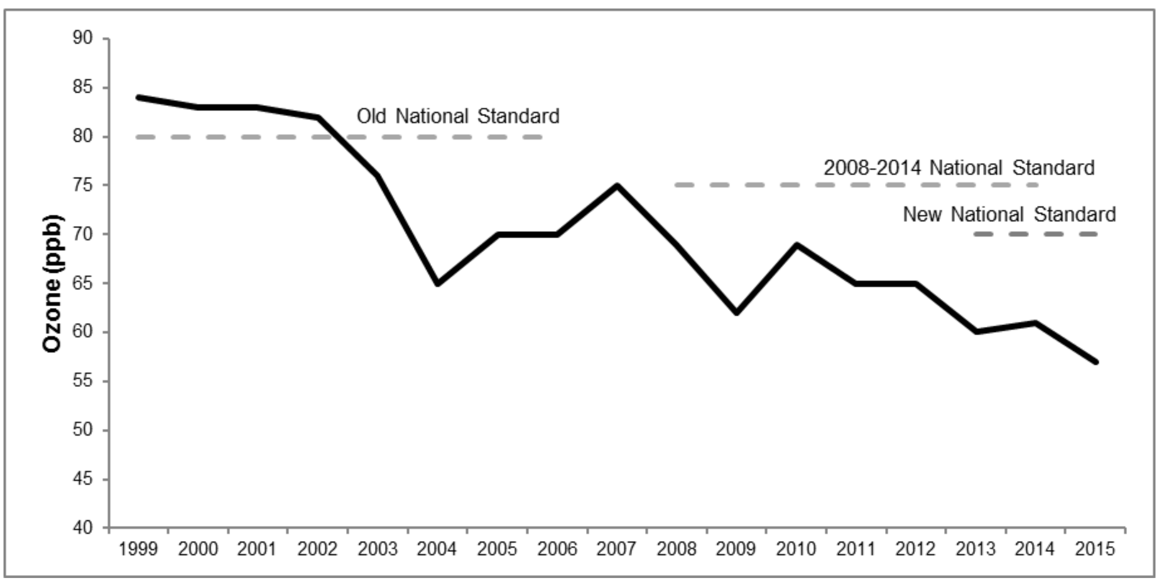


Figure 53. Annual 4th-highest 8-hour maximum ozone concentrations (ppb) at the Sam Black Church, West Virginia monitoring site (Site ID: 54-025-0003), 1999-2015 (EPA 2016a).

Vegetation health risk from ground-level ozone condition is determined by estimating a 5-year average of annual maximum 3-month, 12-hour W126 values. The 2011–2015 estimated W126 metric of 6.9 ppm-hrs falls at the top of the *Good Condition* category (NPS 2015a). Again, a comparison to previous estimates suggests that ozone conditions are improving (Figure 54). With the most recent estimate, BLUE's W126 value has fallen in the Good Condition range (<7 ppm-hrs) for the first time.

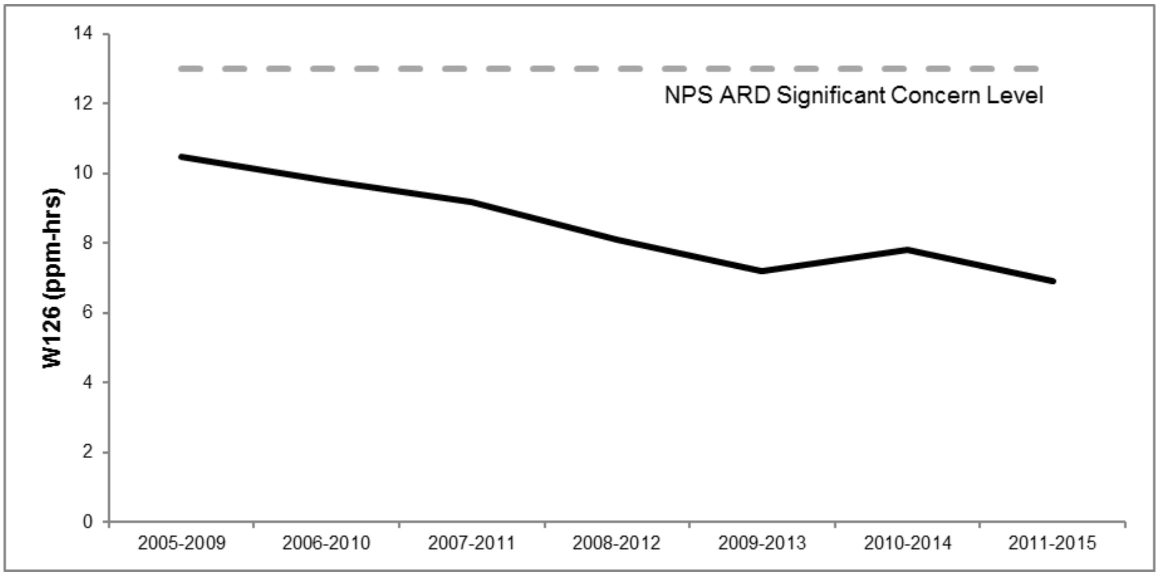


Figure 54. Estimated 5-year averages of the W126 ozone metric for Bluestone National Scenic River (NPS 2015a).

Visibility

Five-year estimated averages of visibility on mid-range days minus natural condition visibility on mid-range days are used to estimate condition for visibility. The 2011–2015 estimated visibility on mid-range days for BLUE was 8.3 dv above estimated natural conditions (NPS 2015a). This estimate falls into the *Significant Concern* category based on NPS criteria for air quality assessment. Comparing the most recent mid-range estimate to previous NPS ARD estimates of visibility suggests that conditions may be improving at BLUE. The 2005-2009 estimated visibility was 12.0 dv above estimated natural conditions, but the 5-year average has declined every year since, although it is still just above the significant concern threshold (>8 dv) (Figure 55).

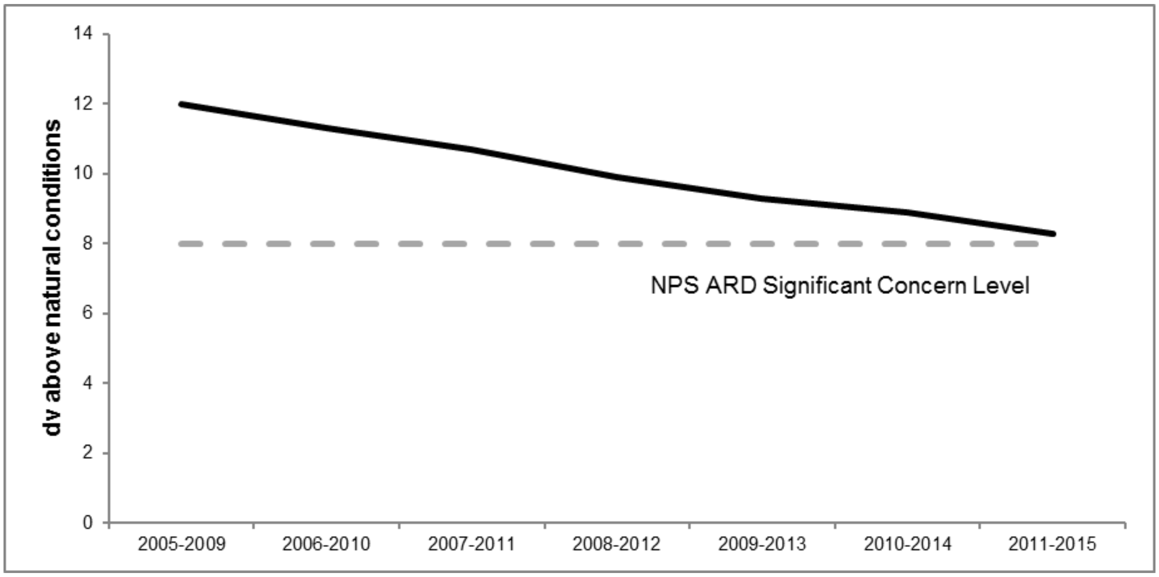


Figure 55. Estimated 5-year averages of visibility (dv above natural conditions) on mid-range days at Bluestone National Scenic River (NPS 2015a).

$PM_{2.5}$ is a major contributor to visibility impairment. Annual average 24-hour $PM_{2.5}$ concentrations are available from a station in Beckley, WV for 1999-2015. This station is located northwest of BLUE, in a more developed area than that around BLUE. Observations from the station suggest that $PM_{2.5}$ concentrations have decreased in the region (Figure 56). The EPA NAAQS for $PM_{2.5}$ uses the 3-year average 98th percentile 24-hour $PM_{2.5}$ concentration to assess human health risk. The station's most recent 3-year average (2013-2015) 98th percentile 24-hour $PM_{2.5}$ concentration of 11.2 µ/m^3 meets the EPA standard of <35 µg/m^3 (EPA 2016e).

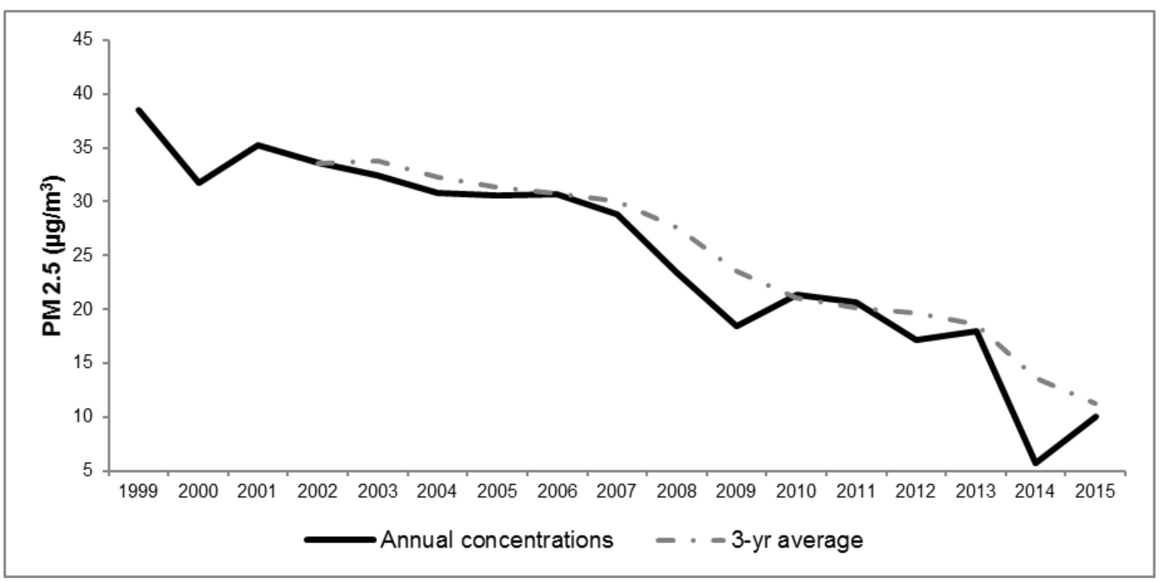


Figure 56. Annual 24-hour particulate matter ($PM_{2.5}$) concentrations (98th percentile) for the Bluestone National Scenic River region, 1999-2015 (EPA 2016a). The monitoring station is located in Beckley, West Virginia (Site ID: 54-081-0002).

Threats and Stressor Factors

Threats to BLUE's air quality include power plant and vehicle emissions, dust from mountaintop removal mining, and prescribed burning. Power plants are a major source of greenhouse gas emissions in the U.S. (EPA 2012). Coal-fired power plants also produce mercury, sulfur dioxide, and PM, which can cause a visible haze in the air (EPA 2012, NPS 2013a). The use of coal for power generation is declining across the country, with numerous facilities converting to natural gas, but a coal-burning power plant is still active near St. Paul, Virginia, approximately 135 km (84 mi) southwest of BLUE (Dominion 2016).

Transportation sources account for a significant portion of nitrogen oxide and VOC emissions in the U.S. and also produce some particulate pollution and sulfur dioxides (Small and Kazimi 1995). These emissions can contribute to ozone formation and impact visibility. Although vehicle traffic within the majority of the park is minimal, it likely increases on state park lands during peak visitation periods.

Mountaintop removal (MTR) coal mining uses heavy excavation equipment and explosives to remove vegetation, dirt, and rock in order to access coal seams (Kurth et al. 2014). This blasting and equipment operation generates PM (e.g., rock and coal dust) that can impair air quality. Fuel use by vehicles and equipment at the site, often diesel-powered, also generates air pollutants, including PM and VOCs (Kurth et al. 2014). While mining companies are required to "reclaim" sites following MTR, the result is nearly always open, grassy fields rather than the diverse forests that existed previously (EPA 2011). This forest loss alone can impact air quality, as trees are known to capture and store carbon dioxide and can remove pollutants such as sulfur dioxides, nitrogen dioxides, and ozone from the atmosphere (McPherson et al. 1994, Wickham et al. 2013). As of 2014, numerous surface coal mines, many of them MTR sites, were active to the west and north of BLUE (Figure 57).

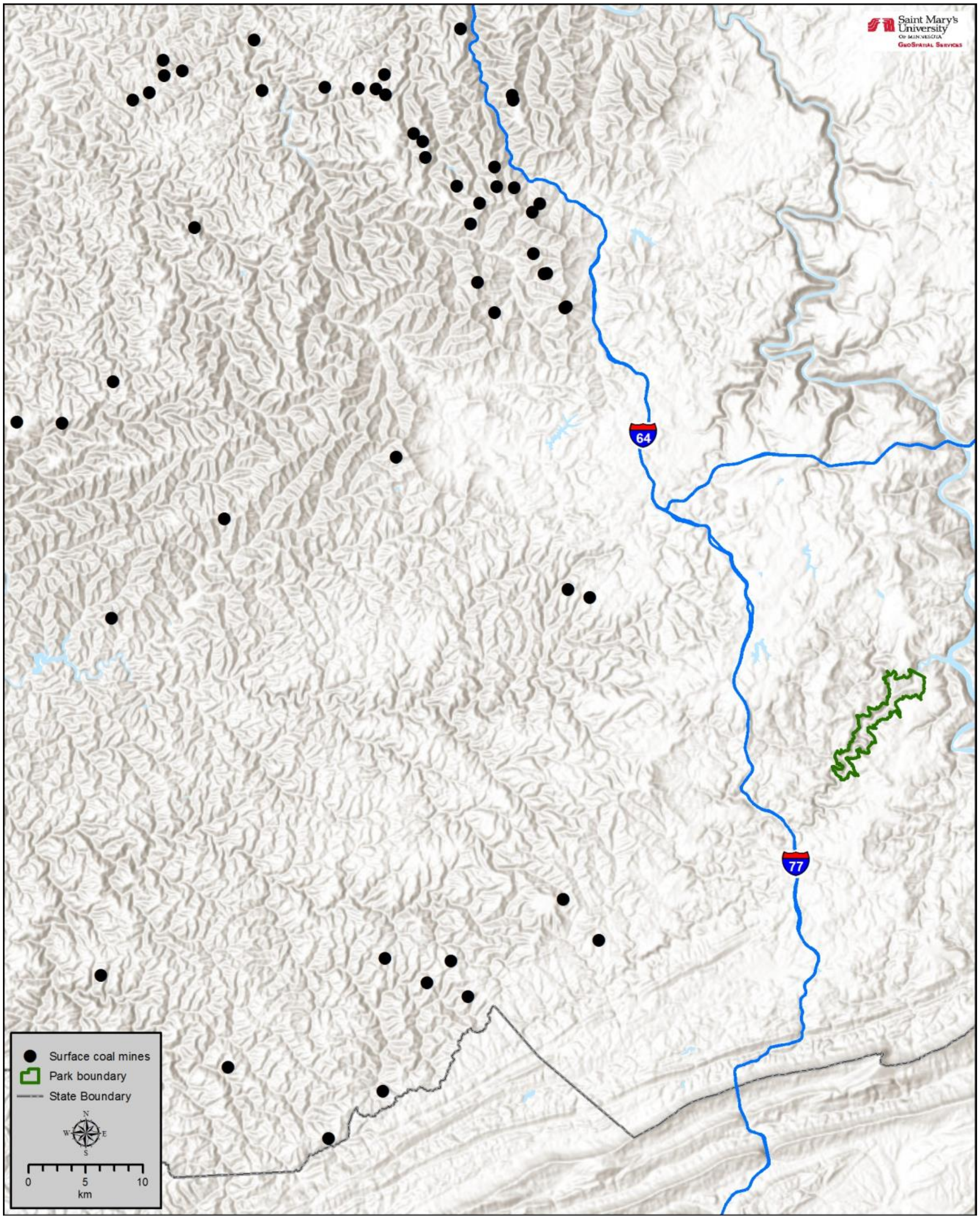


Figure 57. Surface coal mines (active as of 2016) in the Bluestone National Scenic River region (WVDEP 2017).

Prescribed burning and wildfires produce air pollutants, including PM, carbon monoxide, and VOCs, which can contribute to ozone formation (Wotawa and Trainer 2000, Lee et al. 2005). Air pollution from fires typically impairs visibility and can travel long distances. For example, forest fires in

Canada have been shown to impact air quality in the eastern U.S., including as far south as Tennessee (Wotawa and Trainer 2000, Lee et al. 2005).

Air pollutants such as ozone and particulates are strongly influenced by weather shifts (e.g., heat waves, droughts) (EPA 2012). According to the EPA and the Intergovernmental Panel on Climate Change (IPCC), warmer temperatures associated with global climate change are expected to negatively affect air quality (EPA 2012). For example, the EPA (2012) projects that climate change could increase summertime average ground-level ozone concentrations in many areas by 2-8 ppb.

Data Needs/Gaps

If budget and personnel limitations allow, on-site monitoring of atmospheric deposition (sulfur, nitrogen, and mercury) and visibility will help managers better understand air quality conditions in the park. Studies of mercury concentrations in park waters and wildlife (e.g., fish, birds, bats) may also provide insight into the impact this contaminant is having on the park.

Overall Condition

Nitrogen Deposition

The project team assigned this measure a *Significance Level* of 3. The most recent 5-year nitrogen deposition estimate (2011–2015) for the park fell within the NPS ARD's *Moderate Concern* range. Five-year averages have been decreasing slightly over time (Figure 45), as have nitrate concentrations in wet deposition (Figure 46). While BLUE is considered to be at very low risk of nutrient enrichment from nitrogen deposition, it is at high risk of acidification from acidic (nitrogen and sulfur) deposition, partially due to very high levels of ecosystem sensitivity (Sullivan et al. 2011a, 2011c). As a result, nitrogen deposition is assigned a *Condition Level* of 2.

Sulfur Deposition

Sulfur deposition was also assigned a *Significance Level* of 3. Although the most recent 5-year sulfur deposition estimate for BLUE fell within the Moderate Concern range, the NPS ARD elevated the rating to *Significant Concern*, due to very high ecosystem sensitivity. Five-year deposition averages and sulfate concentrations in wet deposition have been decreasing in recent years (Figure 48, Figure 49). However, this measure is still assigned a *Condition Level* of 3.

Mercury Deposition

A *Significance Level* of 3 was assigned for mercury deposition. Based on the NPS ARD mercury status assessment matrix (Table 69), which incorporates estimated mercury wet deposition and predicted methylmercury concentrations, BLUE is currently in the *Moderate Concern* range. Therefore, a *Condition Level* of 2 is assigned for this measure.

Ozone

The project team also assigned this measure a *Significance Level* of 3. The most recent 5-year estimated average for 4^{th}-highest 8-hour ozone concentration at BLUE was in the *Moderate Concern* range for human health. Ozone concentrations appear to be improving (decreasing) in the region (Figure 52, Figure 53). Vegetation health risk (as measured by W126 values) just improved into the

Good Condition range for the first time with the most recent estimate (2011-2015). Overall, ozone is assigned a *Condition Level* of 2.

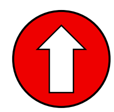
Visibility

Visibility was assigned a *Significance Level* of 3. The most recent estimated visibility average for mid-range days for BLUE fell in the *Significant Concern* range. Five-year averages have been improving slightly since 2009 (Figure 55), but this measure is still assigned a *Condition Level* of 3.

Weighted Condition Score

The *Weighted Condition Score* for BLUE's air quality is 0.80, indicating significant concern (Table 70). Conditions appear to be improving among all the selected measures, but visibility and sulfur deposition are still of high concern. A medium confidence border is applied due to the use of estimates/interpolations, as park-specific data is lacking.

Table 70. Current condition of Bluestone National Scenic River's Air Quality.

Measures	Significance Level	Condition Level	WCS = 0.80
Nitrogen Deposition	3	2	
Sulfur Deposition	3	3	
Mercury Deposition	3	2	
Ozone	3	2	
Visibility	3	3	

4.8.6. Sources of Expertise

- Holly Salazer, NPS Northeast Region Air Resources Coordinator

4.9. Dark Night Skies

4.9.1. Description

A natural lightscape is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS NSNSD 2015). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural resource processes such as plant phenology (NPS 2006, NPS NSNSD 2015). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS NSNSD 2015). In addition to the ecological importance of dark night skies, park visitors expect skies to be free of light pollution and allow for star observation.

BLUE is located in Summers County in south-central West Virginia. The park is relatively isolated from nearby communities, with the nearest cities (Pipestem, Lerona, Camp Creek) being small and unincorporated (Figure 58). Larger West Virginia cities within an hour or two drive from the park include Hinton, Beckley, Bluefield, and Princeton. While no major highways or roads travel through BLUE, the park is located between West Virginia HWY 20 (east of the park) and Interstate 77 and U.S. HWY 19 (west of the park).

The resource of a dark night sky is important to the NPS for a variety of reasons. First, the preservation of natural lightscapes (the intensity and distribution of light on the landscape at night) will keep the nocturnal photic environment within the range of natural variability. Excursions outside this natural range may result in a modification to natural ecosystem function, especially to systems involving the behavior and survival of nocturnal animals (NPS NSNSD 2015). The natural night sky is therefore one of the physical resources under which natural ecosystems have evolved. Second, the “scenery” of national park areas does not just include the daytime hours (NPS NSNSD 2015). Third, the history and culture of many civilizations are steeped in interpretations of night sky observations, whether for scientific, religious, or time-keeping purposes (NPS NSNSD 2015). As such, the natural night sky may be a very important cultural resource, especially in areas where evidence of aboriginal cultures is present. Fourth, the recreational value of dark night skies is important to campers and backpackers, allowing the experience of having a campfire or “sleeping under the stars” (NPS NSNSD 2015). And lastly, night sky quality is an important wilderness value, contributing to the ability to experience a feeling of solitude in a landscape free from signs of human occupation and technology (NPS NSNSD 2015).

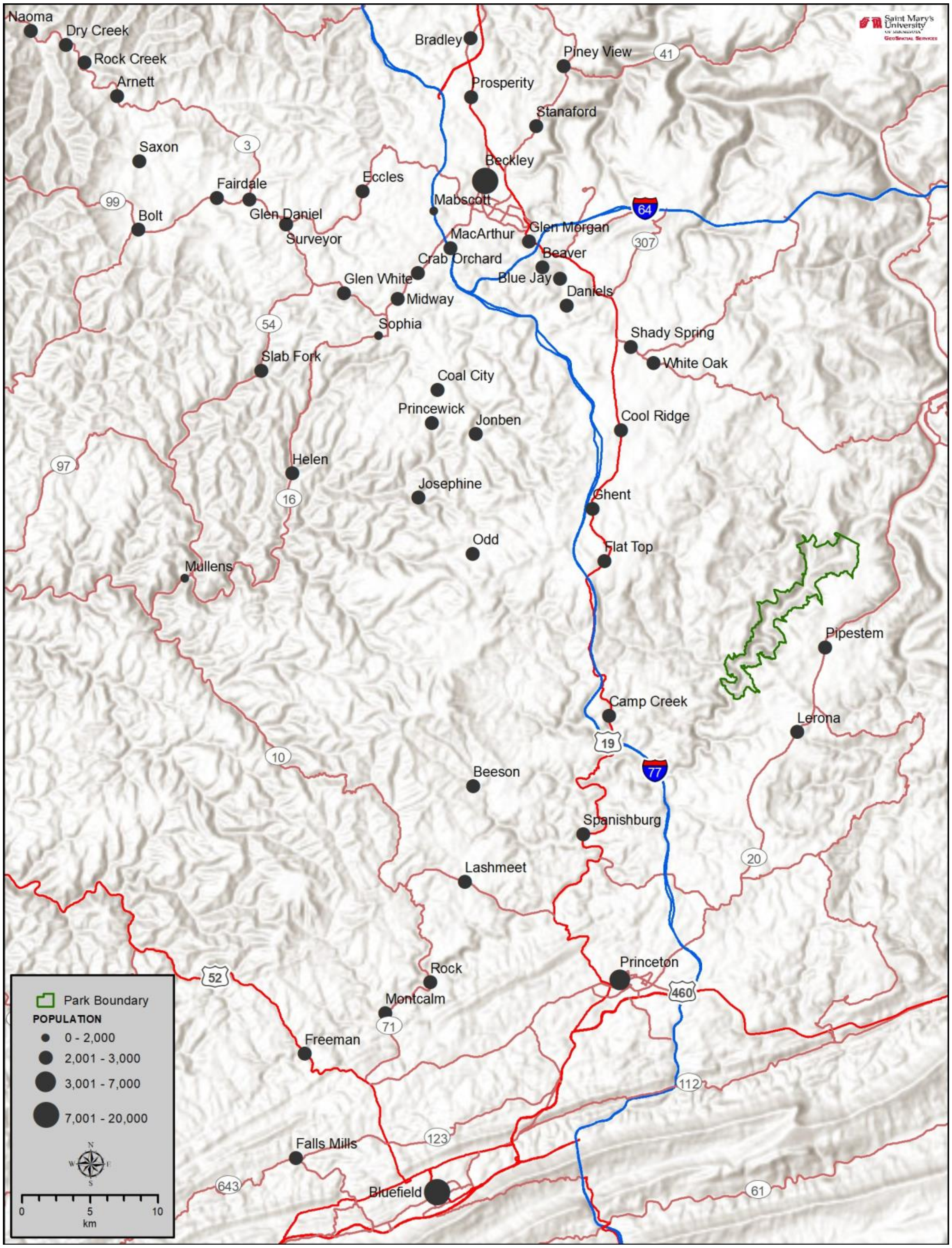


Figure 58. Location of Bluestone National Scenic River and nearby communities and roads that may contribute anthropogenic light to the night sky.

4.9.2. Measures

The dark night sky at BLUE was assessed using the suite of measures that the NPS Natural Sounds and Night Sky Division (NSNSD) uses to define the night sky conditions in a park unit. Selection of the standard NSNSD measures ensures that this assessment aligns with NSNSD standards. The suite of measures that the NSNSD typically uses to define the condition of dark night skies include:

- Sky luminance over the hemisphere in high resolution (thousands of measurements comprise a data set), reported in photometric luminance units (V magnitudes per square arc second [mag/arcsec^2] or milli-candela per square meter [mCd/m^2]) or relative to natural conditions, often shown as a sky brightness contour map of the entire sky. V magnitude (mags) is a broadband photometric term in astronomy, meaning the total flux from a source striking a detector after passing through a "Johnson-Cousins V" filter. It is similar to the "CIE photopic" broadband function for wavelengths of light to which the human eye is sensitive (Bessell 1990);
- Integrated measures of anthropogenic sky glow from selected areas of sky that may be attributed to individual cities or towns (known as city light domes), reported in milli-Lux of hemispheric illuminance or vertical illuminance;
- Integration of the entire sky illuminance measures, reported either in milli-Lux of total hemispheric (or horizontal) illuminance, milli-Lux of anthropogenic hemispheric (or horizontal) illuminance, V-magnitudes of the integrated hemisphere, or ratio of anthropogenic illuminance to natural illuminance;
- Vertical illuminance from individual (or groups of) outdoor lighting fixtures at a given observing location (such as the Wilderness boundary), in milli-Lux;
- Visual observations by a human observer, such as Bortle Class and Zenith limiting magnitude (ZLM);
- Integrated synthesized measure of the luminance of the sky within 50 degrees of the Zenith, as reported by the Unihedron Sky Quality Meter (SQM), in mag/arcsec2.

The NPS NSNSD has not conducted a field visit to BLUE as of this writing. In the absence of these data, the NPS NSNSD recommends the use of the anthropogenic light ratio (ALR) as a measure of the quality of the photic environment and lightscape within a park (Moore et al. 2013). The ALR measures the average anthropogenic sky luminance as a ratio of natural conditions. This measure is easily modeled using GIS and provides a robust and descriptive metric (Moore et al. 2013). For this assessment, the ALR model for the BLUE area will be used to assess current condition.

4.9.3. Reference Condition/Values

NPS staff identified the absence of anthropogenic light as the preferred reference condition. This condition can be defined as the absence of artificial light in terms of sky luminance and illuminance at the observer's location from anthropogenic sources as follows:

> *No portion of the sky background brightness exceeds natural levels by more than 200 percent, and the sky brightness at the Zenith does not exceed natural Zenith sky brightness by*

> *more than 10 percent. The ratio of anthropogenic hemispheric illuminance to natural hemispheric illuminance from the entire night sky does not exceed 20 percent. The observed light from a single visible anthropogenic source (light trespass) is not observed as brighter than the planet Venus (0.1 milli-Lux) when viewed from within any area of the park designated the naturally dark zone* (Dan Duriscoe, NPS NSNSD, pers. comm., 2011).

Achieving this reference condition for preserving natural night skies is well summarized in the NPS Management Policies (NPS 2006, p. 7) in section 4.10 as follows:

> *The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light.*

Implementing this directive in BLUE requires that facilities within the park meet outdoor lighting standards that provide for the maximum amount of environmental protection while meeting human needs for safety, security, and convenience. This means that outdoor lights within the park:

- produce zero light trespass beyond the boundary of their intended use;
- be of an intensity that meets the minimum requirement for the task, but does not excessively exceed that requirement;
- be of a color that is toward the yellow or orange end of the spectrum to minimize sky glow;
- be controlled intelligently, preventing unnecessary dusk to dawn bright illumination of areas.

4.9.4. Data and Methods

The NPS NSNSD has developed a geographic information system (GIS) model derived from data from the 2001 World Atlas of Night Sky Brightness (Cinzano et al. 2001), which depicts *zenith* sky brightness (the brightness of the sky directly above the observer) (Moore et al. 2013). A neighborhood analysis is then applied to the World Atlas to determine the anthropogenic sky brightness over the *entire* sky. Anthropogenic light up to 200 km (124 mi) from parks can have an impact on a park's night sky quality. Finally, the modeled anthropogenic light over the entire sky is presented as a ratio (ALR) over the natural sky brightness (Dursicoe 2016).

4.9.5. Current Condition and Trend

<u>Background for NPS Night Sky Division's Suite of Measures</u>

Anthropogenic light in the night environment can be very significant, especially on moonless nights. Unshielded lamps mounted on tall poles have the greatest potential to cause light pollution, since light directly emitted by the lamp has the potential to follow an unobstructed path into the sky or the distant landscape. This type of light spill has been called glare, intrusive light, or light trespass (Narisada and Schreuder 2004). The dark-adapted human eye will see these individual light sources as extremely bright points in a natural environment. These sources also have the potential to illuminate the landscape, especially vertical surfaces aligned perpendicular to them, often to a level that approaches or surpasses moonlight. The brightness of such objects may be measured as the amount of light per unit area striking a "detector" or a measuring device, or entering the observer's pupil. This type of measure is called illuminance (Ryer 1997).

Illuminance is measured in lux (metric) or foot-candles (English), and is usually defined as luminous flux per unit area of a flat surface (1 lux = 1 lumen/m^2). However, different surface geometries may be employed, such as a cylindrical surface or a hemispheric surface. Integrated illuminance of a hemisphere (summed flux per unit area from all angles above the horizon) is a useful, unbiased metric for determining the brightness of the entire night sky. Horizontal and vertical illuminance are also used; horizontal illuminance weights areas near the Zenith much greater than areas near the horizon, while vertical illuminance preferentially weights areas near the horizon, and an azimuth of orientation must be specified (Ryer 1997).

Direct vertical illuminance from a nearby anthropogenic source will vary considerably with the location of the observer, since this value varies as the inverse of the square of the distance from light source to observer (Ryer 1997). Therefore, measures of light trespass are usually made in sensitive areas (such as public campgrounds).

Anthropogenic light which results in an upward component will be visible to an observer as "sky glow". This is because the atmosphere effectively scatters light passing through it. The sky is blue in daytime because of Rayleigh scattering by air molecules, which is more effective for light of shorter wavelengths. For this reason, bluish light from outdoor fixtures will produce more sky glow than reddish light. Larger particles in the atmosphere (aerosols and water vapor droplets) cause Mie scattering and absorption of light, which is not as wavelength-dependent and is more directional. When the air is full of larger particles, this process gives clouds their white appearance and produces a whitish glow around bright objects (e.g., the sun and moon). The pattern of sky glow as seen by a distant observer will appear as a dome of light of decreasing intensity from the center of the city on the horizon. As the observer moves closer to the source, the dome gets larger until the entire sky appears to be luminous (Garstang 1989).

Light propagated at an angle near the horizon will be effectively scattered and the sky glow produced will be highly visible to an observer located in the direction of propagation. Predictions of the apparent light dome produced by a sky glow model demonstrate this (Luginbuhl et al. 2009). Light reflected off surfaces (e.g., a concrete road or parking area) becomes visible light pollution when it is scattered by the atmosphere above it, even if the light fixture has a "full cutoff" design and is not visible as glare or light trespass to a distant observer. For this reason, the intensity and color of outdoor lights must be carefully considered, especially if light-colored surfaces are present near the light source.

Light domes from many cities, as they appear from a location within Joshua Tree National Park, are shown in Figure 59 and Figure 60, as a grayscale and in false color. This graphic demonstrates that the core of the light dome may be tens or hundreds of times brighter than the extremities. A logarithmic scale for sky luminance and false color are commonly used to display monochromatic images or data with a very large dynamic range, and are used extensively in reports of sky brightness by the NSNSD.

Figure 59. Grayscale representation of sky luminance from a location in Joshua Tree National Park (Figure provided by Dan Duriscoe, NPS NSNSD).

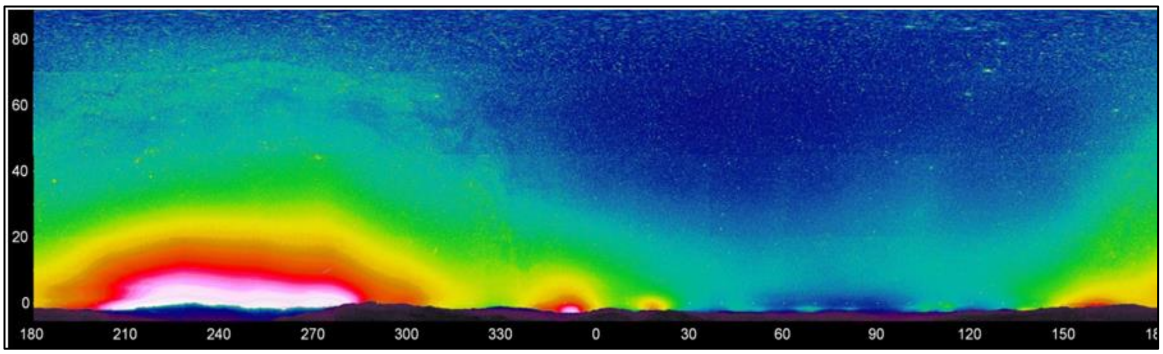


Figure 60. False color representation of Figure 59 after a logarithmic stretch of pixel values (Figure provided by Dan Duriscoe, NPS NSNSD).

The brightness (or luminance) of the sky in the region of the light domes may be measured as the number of photons per second reaching the observer for a given viewing angle, or area of the sky (such as a square degree, square arc minute, or square arc second). The NSNSD utilizes a digital camera with a large, dynamic range, monochromatic charge-coupled device (CCD) detector and an extensive system of data collection, calibration, and analysis procedures (Duriscoe et al. 2007). This system allows for the accurate measurement of both luminance and illuminance, since it is calibrated on standard stars that appear in the same images as the data and the image scale in arc seconds per pixel is accurately known. Sky luminance is reported in astronomical units of V-magnitudes per square arc second, and in engineering units of milli-candela per square meter. High resolution imagery of the entire night sky reveals details of individual light domes that may be attributed to anthropogenic light from distant cities or nearby individual sources. These data sets may be used for both resource condition assessment and long-term monitoring.

Figure 59 and Figure 60 contain information on natural sources of light in the night sky as well as anthropogenic sources. The appearance of the natural night sky may be modeled and predicted in terms of sky luminance and illuminance over the hemisphere, given the location, date, time, and the relative brightness of the natural airglow (the so-called "permanent aurora" which varies in intensity over time) (Roach and Gordon 1973). The NSNSD has constructed such a model, and uses it in analysis of data sets to remove the natural components. This results in a more accurate measure of anthropogenic sky glow (Figure 61). Figure 62 represents “total sky brightness” while Figure 63 displays “anthropogenic sky glow” or “net light pollution.” This is an important distinction, especially in areas where anthropogenic sky glow is of relatively low intensity.

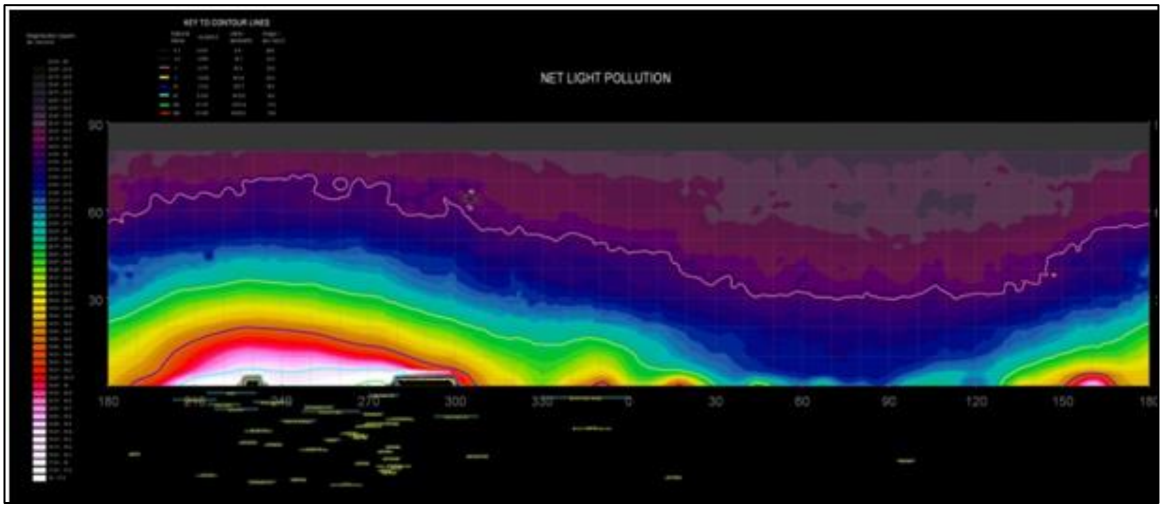


Figure 61. Contour map of anthropogenic sky glow at a location in Joshua Tree National Park, analogous to Figure 60 with natural sources of light subtracted (Figure provided by Dan Duriscoe, National Park Service Night Sky Division).

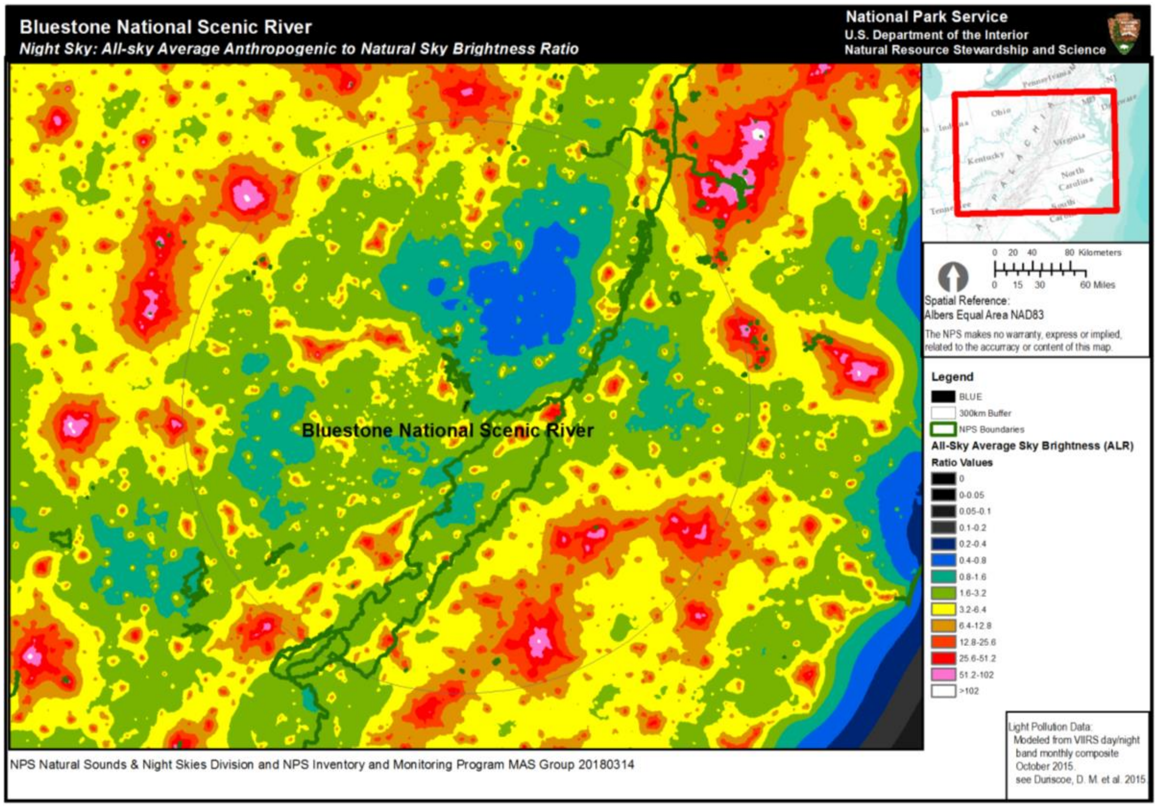


Figure 62. Modeled all-sky average sky brightness (ALR) in and around Bluestone National Scenic River. BLUE's boundary is outlined in black and is just above the text label for the park. Figure provided by National Park Service Natural Sounds and Night Sky Division.

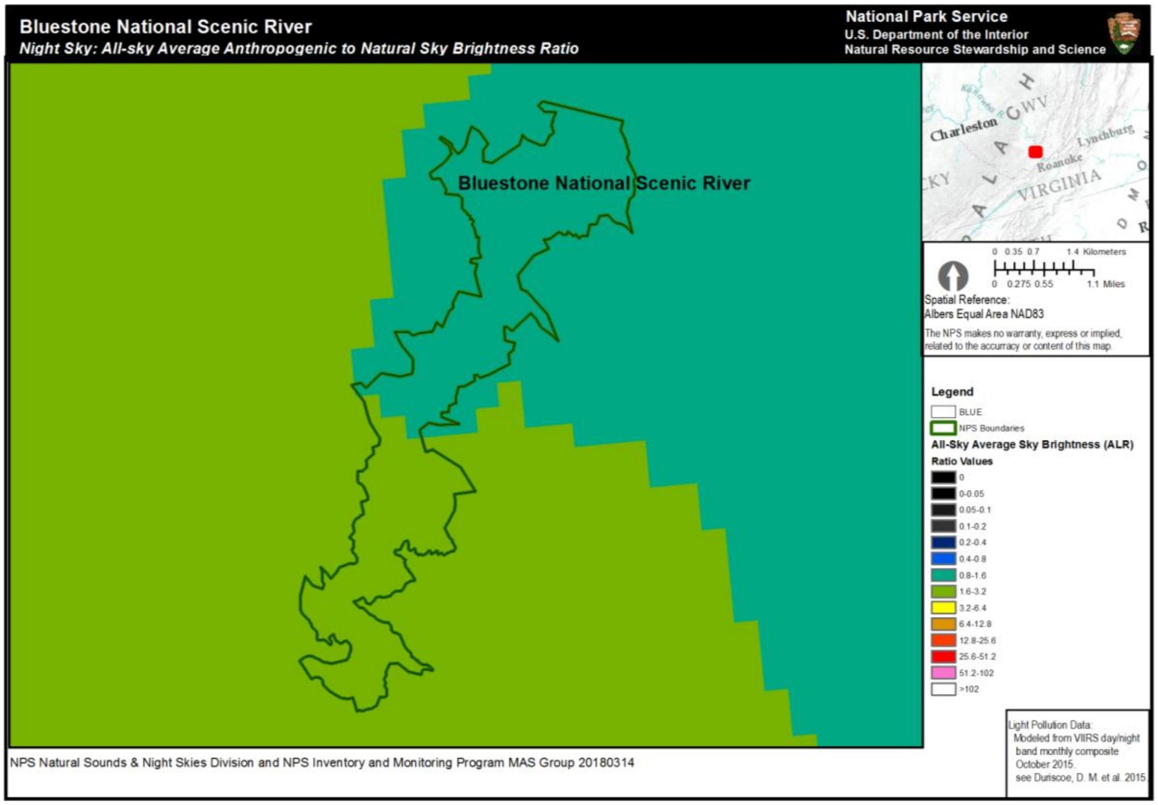


Figure 63. Modeled all-sky average sky brightness (ALR) for Bluestone National Scenic River. This figure is a close up visual of the park as displayed in Figure 62. Figure provided by National Park Service Natural Sounds and Night Sky Division.

The accurate measurement of both anthropogenic light in the night sky and the accurate prediction of the brightness and distribution of natural sources of light allows for the use of a very intuitive metric of the resource condition - a ratio of anthropogenic to natural light, the ALR identified previously (Moore et al. 2013). Both luminance and illuminance for the entire sky or a given area of the sky may be described in this manner (Hollan 2010). This so-called “light pollution ratio” is unitless and is always referenced to the brightness of a natural moonless sky under average atmospheric conditions, or, in the case of the NSNSD data, the atmospheric conditions determined from each individual data set. The ALR is derived from ground–based measurements when available, or from a GIS model (calibrated to ground-based measurements in the park) when field based data are measures are not available (Moore et al. 2013).

A quick and moderately accurate method of quantifying sky brightness near the Zenith is the use of a Unihedron SQM. The Unihedron SQM is a single-channeled hand-held photometric device. A single number in magnitudes per square arc second is read from the front of the device after its photodiode and associated electronics are pointed at the Zenith and the processor completes its integration of photon detection. Because the meter is relatively inexpensive and easy to use, a database of measures has grown since its introduction (see http://unihedron.com/projects/darksky/database/index.php). The NSNSD produces values from each data set as both a synthesized value derived from the high-resolution images and by hand held measures with a Unihedron SQM. The performance of the SQM has been tested and reviewed by Cinzano et al. (2001). While fairly accurate and easy to use, the value it produces is biased toward the Zenith. Therefore, the robustness of data collected in this manner is limited to areas with relatively bright sky glow near the Zenith, corresponding to severely light polluted areas. While not included in the reference condition, a value of about 21.85 would be considered “pristine”, providing the Milky Way is not overhead and/or the natural airglow is not unusually bright when the reading is taken (Moore et al. 2013).

Visual observations are important in defining sky quality, especially in defining the aesthetic character of night sky features. A published attempt at a semi-quantitative method of visual observations is described in the Bortle Dark Sky Scale (Bortle 2001). Observations of several features of the night sky and anthropogenic sky glow are synthesized into a 1-9 integer interval scale, where class 1 represents a “pristine sky” filled with easily observable features and class 9 represents an “inner city sky” where anthropogenic sky glow obliterates all the features except a few bright stars. Bortle Class 1 and 2 skies possess virtually no observable anthropogenic sky glow (Bortle 2001).

NPS Night Sky Division Suite of Measures

The NSNSD has not made a field visit to BLUE. However, the NSNSD was able to use GIS-modeling to show ALR values for the Eastern U.S. and BLUE (Figure 62, Figure 63). A condition level can be assigned to the modeled ALR data, based on a threshold applied spatially to the park (Moore et al. 2013). This threshold is dependent on whether the park is considered to be urban or non-urban (Moore et al. 2013). The distinction between urban (Level 2) and non-urban (Level 1) parks is based on the relative proximity of the park (and its borders) to Urban Areas as defined by the 2010 U.S. Census (Moore et al. 2013). For parks managed as wilderness, the designated condition is based on ALR level that exists in more than 90% of the wilderness area (Moore et al. 2013). As 90% of BLUE’s property occurs outside of urban areas, the park is classified as a non-urban (Level 1) park.

In interpreting the results of the model, for both urban and non-urban parks, the condition (green, amber, red) corresponds to the ALR level that represents the median condition (in at least half the park’s area) for the park’s landscape (Moore et al. 2013). This median condition reflects the probable night sky quality that park visitors will experience at any location within the park (Moore et al. 2013). It is also probable that the majority of wildlife and habitats within the park exist under this quality of night sky (Moore et al. 2013). The NPS NSNSD recommendations for ALR condition are given in Table 71. The median ALR value for BLUE is 1.60, which puts the park in the moderate condition category for non-urban (Level 1) parks (Moore et al. 2013, NPS 2015). These ALR values and condition levels are the product of a model, and may not be fully accurate representations of current night sky conditions in the park. A NSNSD team visit is needed to accurately quantify the quality of night skies in BLUE.

Table 71. National Park Service Natural Sounds and Night Sky Division recommendations for condition levels for modeled Anthropogenic Light Ratio (ALR) values (Moore et al. 2013).

Landscapes	Good Condition (Green)	Moderate Condition (Amber)	Poor Condition (Red)
Non-urban (Level 1) parks	< 0.33	0.33–2.00	> 2.00
Urban (Level 2) parks	< 2.00	2.00–18.00	> 18.00
Areas Managed as Wilderness	< 0.33	0.33–2.00	> 2.00

Threats and Stressor Factors

Bluestone State Park and Pipestem Resort State Park are the two nearest sources of potential light trespass and pollution in BLUE. Sources of anthropogenic light in those areas include the lights and spotlights at the top of the Pipestem tram, campground and other infrastructure lights, and traffic within those parks. Additionally, anticipated construction at the Bluestone Dam in the next 10 years will increase light pollution in the Bluestone State Park area. Nighttime boat traffic on Bluestone Lake, which is located to the east of BLUE, may also contribute marginal sources of light pollution in the park.

Other sources of light pollution in the BLUE area include traffic lights from highways/freeways, cell phone tower lights, and power line lighting. Contributing to these typical light sources are air transparency (haze, smoke) conditions, which are often degraded in the area due to local weather patterns and proximity to the mountains which trap and concentrate air contaminants from coal-fired power plants and vehicle emissions (Emmott et al. 2005, Emmott and Porter 2008). While quite a distance from major cities, the light glow from larger cities such as Beckley, Princeton, or Bluefield West Virginia, or even Roanoke, Virginia may lessen the quality of night skies in the park.

Data Needs/Gaps

The NPS NSNSD has never visited BLUE to collect data. The night sky condition data collected by the NPS NSNSD would provide a more comprehensive suite of measures that are more conducive to developing desired conditions or making management decisions than the modeled data currently available for BLUE. Along with periodic park monitoring visits, the NPS NSNSD could assess and track external light source impacts within BLUE.

Overall Condition

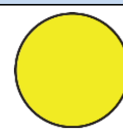
Anthropogenic Light Ratio (ALR)

During scoping meetings, the NRCA team assigned the NPS NSNSD suite of measures a *Significance Level* of 3. While NPS NSNSD has not conducted a field visit to BLUE ALR data modeled by the NPS NSNSD can be used as a surrogate for the Average Natural Sky Luminance data collected during their field visits (Moore et al. 2013). The modeled ALR data for BLUE was 1.60, which places it at the moderate condition level, as recommended by Moore et al. (2013). To align the *Condition Level* for this measure with what was suggested in Moore et al. (2013), a *Condition Level* of 2 was assigned to this measure.

Weighted Condition Score

A *Weighted Condition Score* of 0.67 was calculated for the dark night sky component, which, when following the scoring benchmark defined in Chapter 3, indicates Significant Concern (Table 72). However, due to only one measure being scored for this component, and because the *Condition Level* of that measure aligned with a Moderate Concern designation by Moore et al. (2013), the condition graphic for this component has been adjusted to one of moderate concern. An additional consideration that factored into the condition shift to Moderate Concern was that BLUE lies on the edge of perhaps the darkest areas in the entire region (Figure 62). While current night sky conditions in the park are by no means ideal, when compared to the overall night sky conditions in the region the BLUE night skies appear to be in a much better state. No current trend could be identified for this component, as all the data available were the result of modeling and not on-the-ground surveys. A visit to the park by the NPS NSNSD is needed to accurately measure the current condition of night skies in the park, and to elevate the confidence in condition designation (currently condition designation is of medium confidence).

Table 72. Current condition of Bluestone National Scenic River s Dark Night Skies.

Measures	Significance Level	Condition Level	WCS = 0.67
Anthropogenic Light Ratio	3	2	

4.9.6. Sources of Expertise

National Park Service Night Sky Division members Dan Duriscoe and Jeremy White were instrumental in putting together much of the background narrative for this component. Sharolyn Anderson, also of the NPS NSNSD, provided the modeled ALR figures and data used in this assessment.

4.10. Surface Water Hydrology

4.10.1. Description

Surface hydrology (i.e., water flow regime) is a primary driver of riverine ecological systems, influencing habitat conditions, species distribution, geophysical characteristics, and ecosystem processes within a river system (Marshall et al. 2006). Flows can also be linked to water quality parameters, as high flows due to surface runoff may contribute contaminants to a river system (Hebner 1991, Purvis 2002). Hydrology encompasses a number of parameters, including discharge (magnitude and timing), velocity, and water level/elevation. These parameters are influenced by the climate and physical context (e.g., geologic substrate, landscape structure, gradient) in which a river system occurs (Marshall et al. 2006).

Hydrology is particularly important to BLUE, since the Bluestone River's free-flowing nature was a key reason for the park's designation as a National Scenic River (Purvis 2002). Because the Bluestone River and its tributaries are unimpounded, the system experiences a natural, seasonal flow regime, with high flows during late winter and early spring and low flows typically in late summer and early fall (Hebner 1991, Wilson et al. 2006). Annual and seasonal variations in discharge due to the river system's unregulated flow create a variety of shifting microhabitats, which contribute to overall riverine biodiversity (Poff et al. 1997, Marshall et al. 2006). The natural character of BLUE's rivers and streams attract many visitors, including anglers who are drawn by the Bluestone River's high-quality warm-water fishery (Wilson et al. 2006).

The free-flowing Bluestone River, between Pipestem Resort State Park and the Little Bluestone confluence (SMUMN GSS photo by Andy Nadeau).

4.10.2. Measures

- Annual peak discharge
- Annual mean discharge
- Annual minimum discharge
- Timing and amount of precipitation

4.10.3. Reference Condition/Values

The reference condition for discharge measures will be the period of record (July 1950-present) for the USGS stream gage on the Bluestone River near Pipestem (Gage 03179000). For precipitation, the most recent 30-year normals (1981-2010) will serve as the reference condition. The weather stations closest to BLUE with 30-year normals (i.e., averages) available are Princeton (GHCND:USC00467207) and Bluestone Lake (GHCND:USC00460939).

4.10.4. Data and Methods

Surface hydrology data most relevant to the Bluestone River are from the USGS stream gage on the Bluestone River near Pipestem Resort State Park (Figure 64). Annual mean discharge, daily mean discharge, and peak streamflow data for this gage were obtained from the USGS National Water Information System (NWIS) (USGS 2016a). The gage's period of record extends from July 1950 through the present. Annual discharge measures will be based on the water year (October-September) as opposed to the calendar year. Discharge data are presented in cubic meters per second (cms).

Precipitation data for the two weather stations closest to BLUE (Figure 64) were downloaded from the National Centers for Environmental Information's (NCEI) climate data online database (NCEI 2015b, a, 2017a, b). This included 30-year normals and monthly precipitation for each of the past 10 years (2007-2016). Since the Princeton station is upstream of BLUE, it is more likely to reflect conditions further up the watershed from the park, where most of the water in the Bluestone River system comes from. The Bluestone Lake station is closer to the park and could better reflect precipitation towards the downstream end of BLUE, but rainfall here may have a proportionally smaller impact on Bluestone River hydrology.

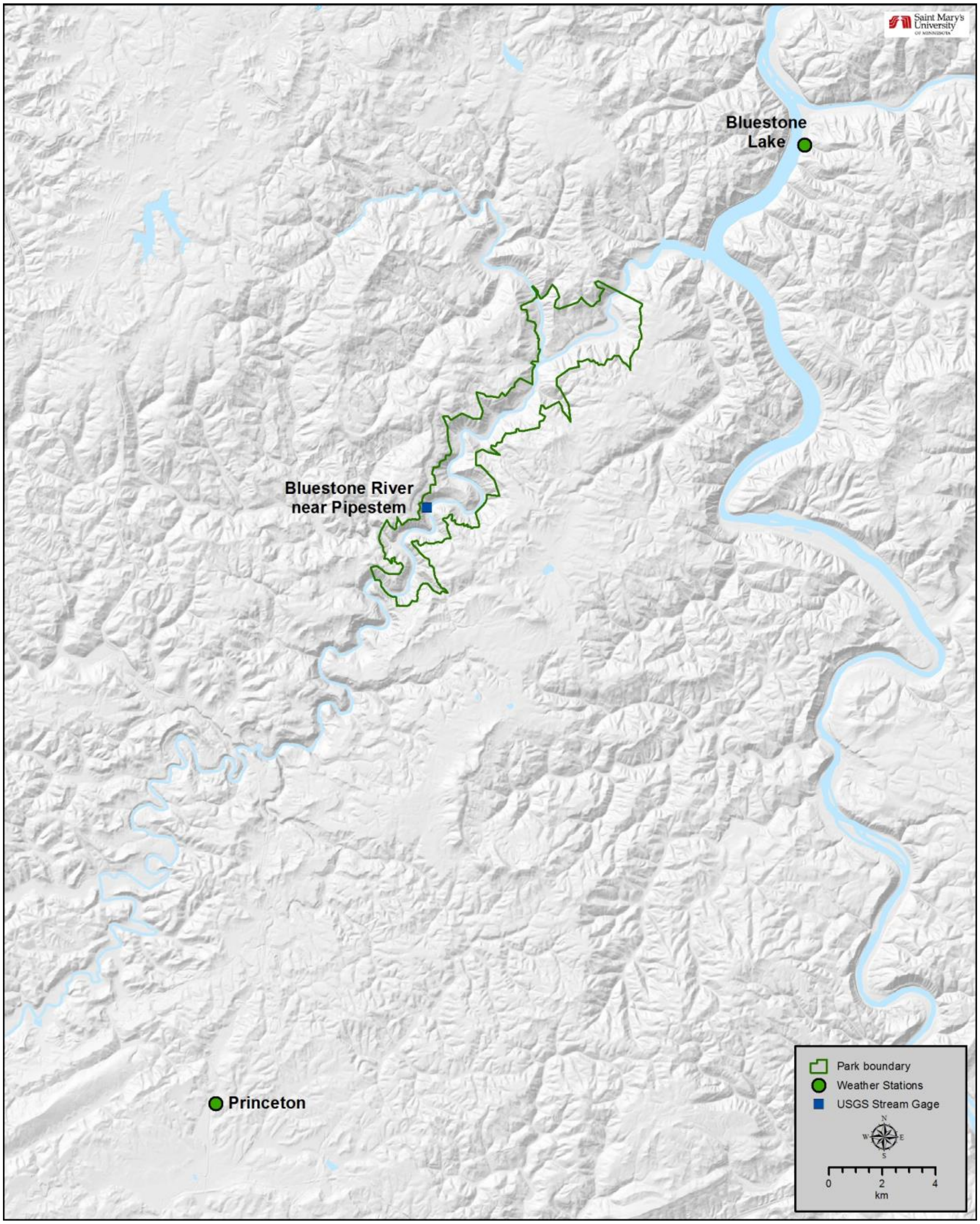


Figure 64. The location of the USGS stream gage near Pipestem and the two weather stations closest to Bluestone National Scenic River.

4.10.5. Current Condition and Trend

Annual Peak Discharge

Annual peak discharge is the highest flow at a stream gage during each water year. Over the period of record for the Bluestone River near Pipestem gage (water years 1951-2016), annual peak discharge ranged from 46.2 cms (20 January 1988) to 642.8 cms (13 March 2010) with a mean of 257.9 cms (± 15.2 standard error [S.E.]) (Figure 65) (USGS 2016a). Peak discharge typically occurred between December and May. Over the past 10 years (2007-2016), the mean annual peak discharge has been 290.0 cms (± 51.5 S.E.), above the average for the period of record. However, the mean for the past 5 years of 240.7 cms (± 57.4 S.E.) is below the period-of-record average (USGS 2016a). Data for the entire period of record show that peak discharge on the Bluestone River has been variable between years. The data do not show a significant difference or clear trend (increasing or decreasing) in peak discharge over time. However, five of the ten highest annual peak discharges have occurred since 2003.

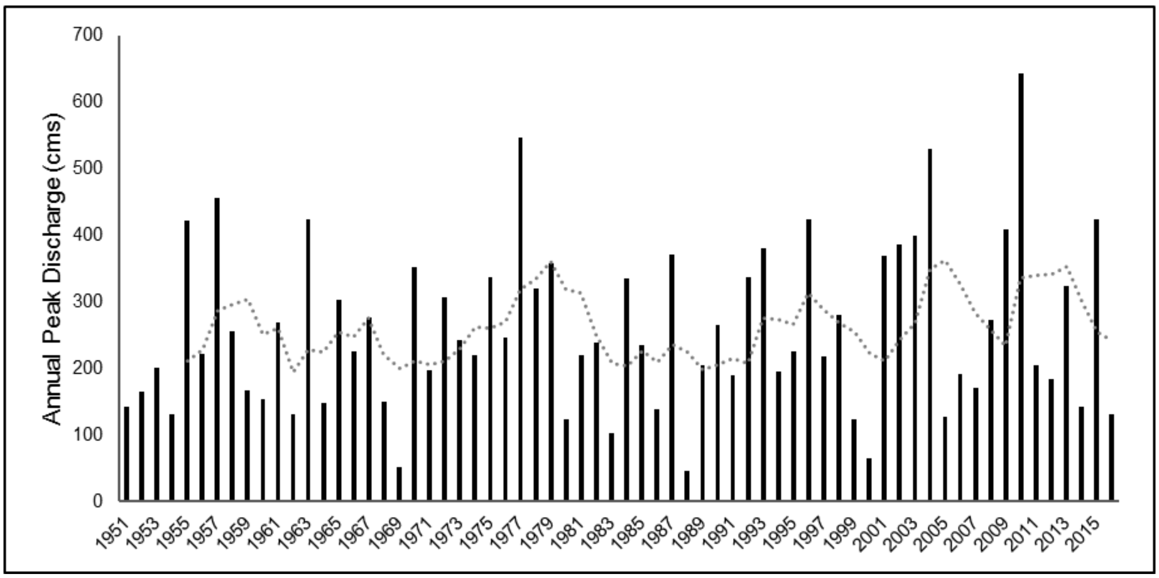


Figure 65. Annual peak discharge (cms) for the Bluestone River near Pipestem (USGS 03179000) (USGS 2016a). The dotted gray line represents the 5-year moving average. Note that the years represent water years (October-September) rather than calendar years.

Annual Mean Discharge

Annual mean discharge at the Bluestone River near Pipestem over the period of record ranged from 5.0 cms (1988) to 21.9 cms (2003) with a mean of 13.4 cms (± 0.5 S.E.) (Figure 66) (USGS 2016a). Over the past decade, annual mean discharge has averaged 13.3 cms (± 0.9 S.E.), while the average for the past 5 years was 14.1 cms (± 1.1 S.E.), slightly above the period-of-record average. As with annual peak discharge, mean discharge was variable between years with no clear trends over the past 40-45 years.

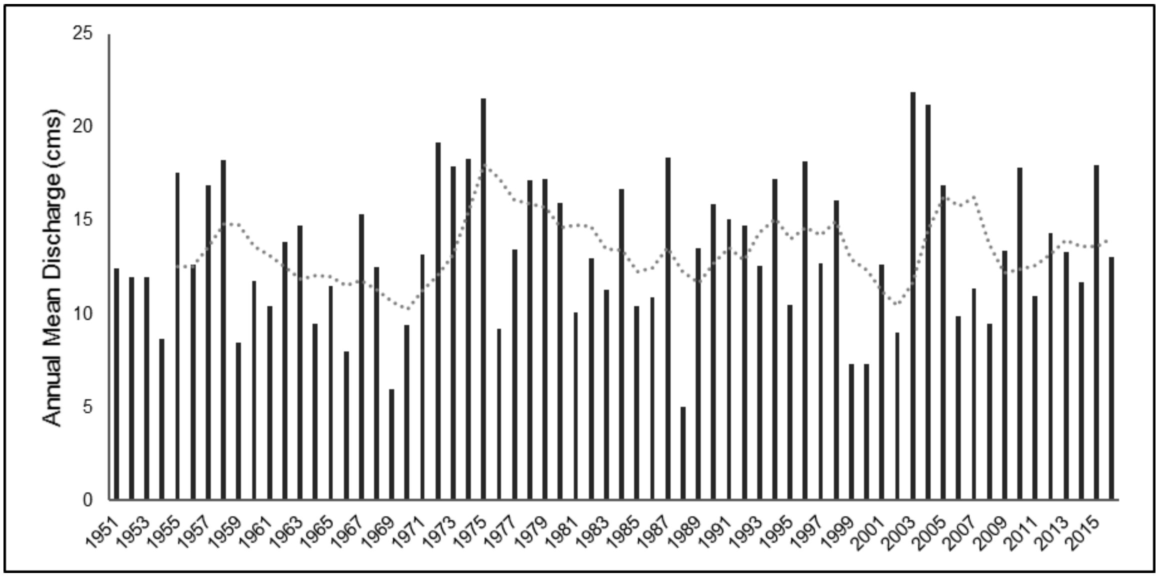


Figure 66. Annual mean discharge (cms) for the Bluestone River near Pipestem (USGS 03179000) (USGS 2016a). The dotted gray line represents the 5-year moving average. Note that the years represent water years (October-September) rather than calendar years.

<u>Timing and Amount of Precipitation</u>

Stream flow in the BLUE vicinity is primarily fed by precipitation falling within the watershed. In the southern West Virginia region, precipitation is relatively evenly distributed throughout the year, but with the largest amounts falling in the late spring and summer (Knight et al. 2015). During the warmer months, heating is often uneven over the region's irregular terrain, contributing to the formation of numerous thunderstorms over the mountains (Knight et al. 2015). The most recent 30-year (1981-2010) annual precipitation normal for the Princeton weather station was 97.5 cm/yr (38.4 in/yr) (NCEI 2015a), and the 30-year normal for the Bluestone Lake station was slightly higher at 98.1 cm/yr (38.6 in/yr) (NCEI 2015b).

Over the past decade, annual precipitation at the Princeton station ranged from 78.0-125.0 cm (30.7-49.2 in) with a mean of 100.4 cm (39.5 in) (Figure 67) (NCEI 2017b). This mean is approximately 3.0 cm (1.2 in) above the 30-year normal. A nearly equal number of years have fallen above and below the 30-year normal during this time (2013 has been excluded due to missing data for December).

In terms of monthly precipitation, the wettest month on average over the past decade was May, with a mean of 11.4 cm (4.5 in) (Figure 68) (NCEI 2017b). This differed from the 30-year normal, when July was the wettest month, with 11.1 cm (4.4 in) (NCEI 2015a). In general, the spring months (March, April May) were wetter from 2007-2016 than the 30-year monthly normals, while the summer months were drier (Figure 68). Decembers over the past decade have also seen substantially more precipitation than the 30-year normal (9.0 cm [3.5 in] vs. 7.3 cm [2.9 in]) (NCEI 2015a, 2017b).

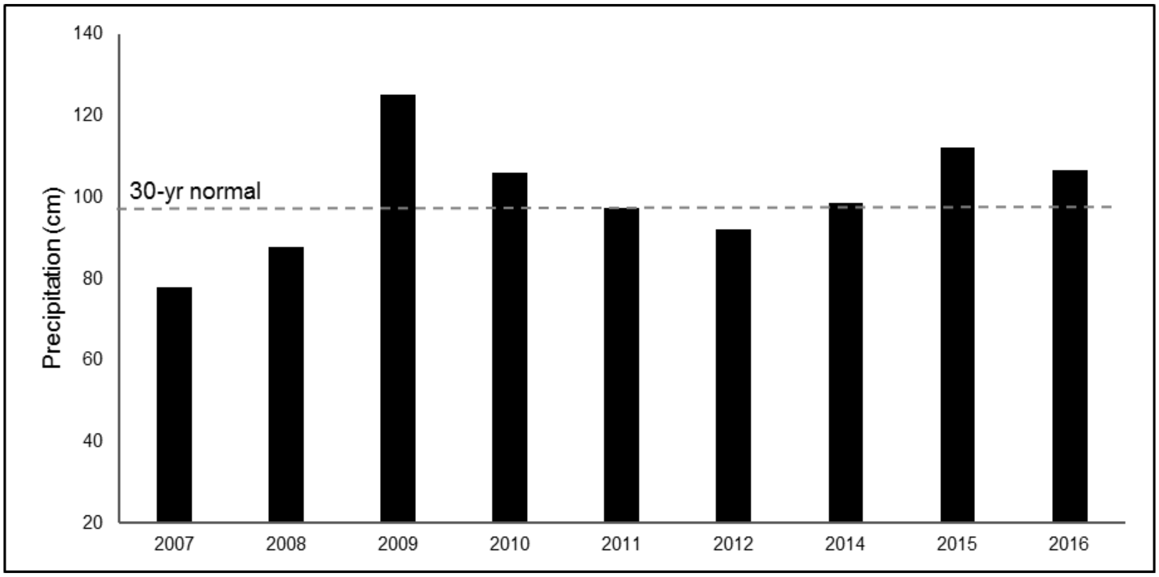


Figure 67. Total annual precipitation at the Princeton, West Virginia weather station, 2007-2016, compared to the 30-year normal (1981-2010) (NCEI 2015a, 2017b). Note that 2013 is excluded due to missing data for December.

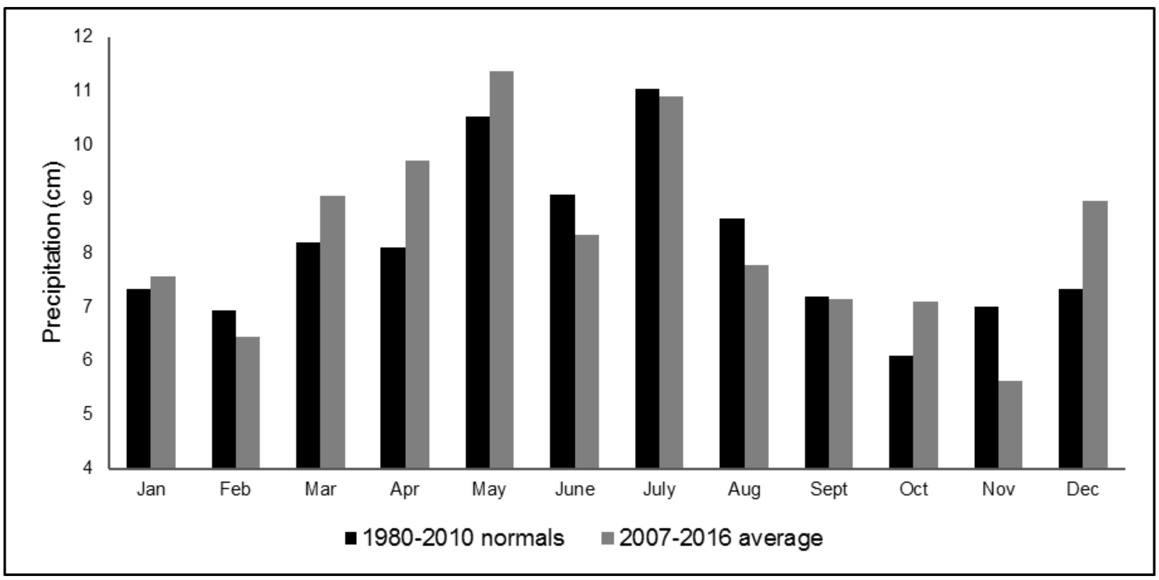


Figure 68. A comparison of monthly precipitation normals (1981-2010) for the Princeton, West Virginia weather station to monthly averages for the period 2007-2016 (NCEI 2015a, 2017b).

From 2007-2016, annual precipitation at the Bluestone Lake weather station ranged from 81.4 cm (32.0 in) to 121.8 cm (48.0 in) with a mean of 102.8 cm (40.5 in) (Figure 69) (NCEI 2017a). This mean is 4.7 cm (1.9 in) greater than the station's 30-year normal. Similar to the Princeton station, an equal number of years were above and below the 30-year normal during this time.

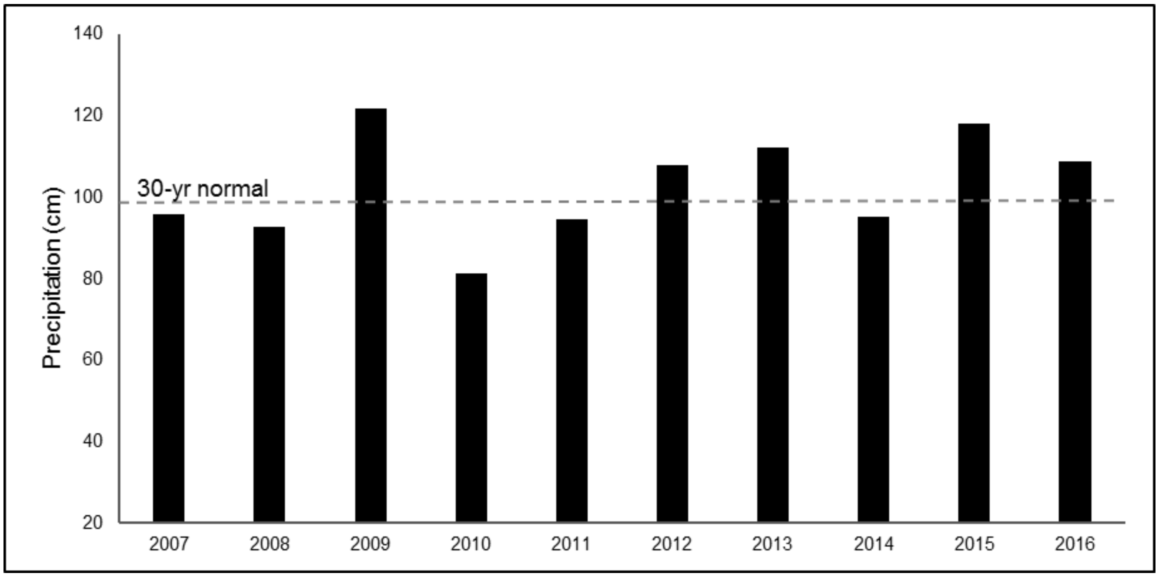


Figure 69. Total annual precipitation at the Bluestone Lake, West Virginia weather station, 2007-2016, compared to the 30-year normal (1981-2010) (NCEI 2017a).

The wettest month on average at the Bluestone Lake station over the past decade was also May, with a mean of 10.8 cm (4.3 in) (Figure 70) (NCEI 2017a). December was a close second at 10.3 cm (4.1 in). The wettest month under the 30-year normals was July with 11.2 cm (4.4 in) (NCEI 2015b). Nine of the 12 months, including March through June and August through October, experienced higher monthly precipitation during the past decade when compared to 30-year normals (NCEI 2015b, 2017a).

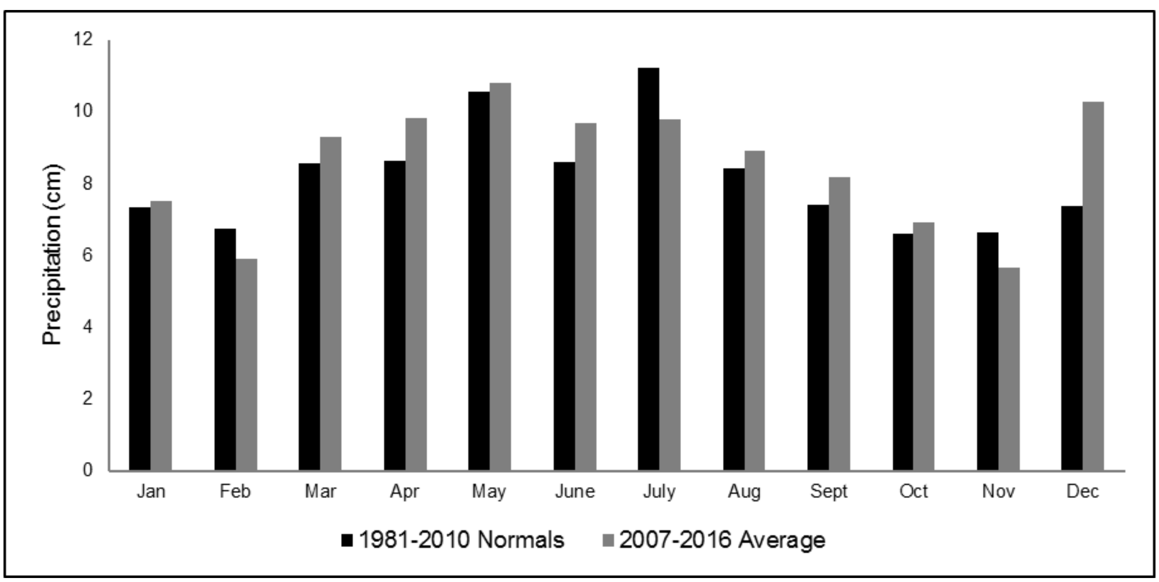


Figure 70. A comparison of monthly precipitation normals (1981-2010) for the Bluestone Lake, West Virginia weather station to monthly averages for the period 2007-2016 (NCEI 2015b, 2017a).

Threats and Stressor Factors

Threats to BLUE's surface water hydrology include climate change, extreme weather events, dam operations, and changes in upstream land use/development. Urban development typically involves an increase in impervious surface area (e.g., roads, parking lots) and a reduction in precipitation infiltration. This often results in increased storm runoff (amount and velocity) and a higher potential for flash flooding (Purvis 2002). High stormflows can also cause bank erosion and increased sedimentation, which can alter stream hydrology (Marshall et al. 2006). If further development were to occur upstream of BLUE, peak discharges could increase and may cause flood damage to riparian communities along the Bluestone River. Logging in upstream areas could also increase peak flows, storm flows, and the likelihood of catastrophic events such as floods and landslides (Purvis 2002).

Extreme weather events have the potential to impact surface hydrology in and around BLUE. Droughts, for example, would reduce stream discharge, while heavy or long-lasting precipitation events would increase discharge, potentially causing floods. Heavy rain from tropical storms and hurricanes occasionally reach West Virginia, causing high flows and flooding (Davey et al. 2006). Extreme precipitation events impacting the New River watershed (east and south of BLUE) but not the Bluestone River may indirectly affect the park's surface hydrology by raising water levels in Bluestone Lake, causing water to back up into the park.

Climate, especially precipitation, is one of the primary influences on surface hydrology (Poff et al. 1997, Marshall et al. 2006). As a result of global climate change, precipitation is expected to increase (6-11%) by 2100 in the region around BLUE (Gonzalez 2015). An increase in the frequency and intensity of extreme precipitation events is also expected, with the frequency of 20-year storms projected to increase to once every 4-6 years (Walsh et al. 2014, Gonzalez 2015). Together, higher precipitation levels and an increased frequency of large storms could lead to increased flooding (Horton et al. 2014, Gonzalez 2015). These changes in precipitation patterns, if they do occur, would likely alter discharges on the Bluestone River.

Maintenance, construction, or malfunctions at Bluestone Dam just downstream of the park could influence the Bluestone River's hydrology. Bluestone Dam has been operational since 1949; while it's primary purpose is flood control, operators also attempt to maintain a steady recreational pool behind the dam (Bluestone Lake) (Purvis 2002). Enabling legislation for BLUE recognized the importance of the dam and acknowledged that nothing in the park's designation will "affect or impair" the management of the dam/reservoir project to accomplish its purposes of flood control and recreation (16 U.S. Code § 1274). In recent decades, the dam has been renovated to handle a larger flood surge (i.e., stabilizing anchors added, dam height increased) (Purvis 2002, Steelhammer 2016). While these renovations did not alter baseline lake levels, they do increase Bluestone Lake's encroachment back into BLUE during extremely high inflows (Purvis 2002). The USACE is now considering a 10-year project to modify the dam's stilling basin, which would prevent erosion of bedrock behind the dam during high flows that could destabilize the structure (Steelhammer 2016). During this project, Bluestone Lake levels would be expected to fluctuate more frequently, as outflow from the dam would sometimes be reduced (Steelhammer 2016). This could impact the amount and duration of water backing up into the Bluestone River and potentially the flow rate of the river.

Data Needs/Gaps

The period of record for the gage on the Bluestone River near Pipestem is sufficient for an analysis of surface hydrology at that location on the river (July 1950-present). However, little is known about the hydrology of the Bluestone River at the downstream (north) end of the park, below its confluence with the Little Bluestone River and in the area where water backs up into the park from Bluestone Lake. The collection of discharge measurements from the Bluestone River closer to the downstream end of BLUE would help park managers better understand any influence that Bluestone Lake back-ups may have on surface hydrology in the park.

Overall Condition

Annual Peak Discharge

The NRCA project team assigned this measure a *Significance Level* of 3. Peak discharge on the Bluestone River at the Pipestem gage has been variable between years over the period of record. While there is no significant difference or clear trend in annual peak discharge over time, five of the ten highest annual peak discharges have occurred since 2003 (USGS 2016a). Therefore, a *Condition Level* of 1 is assigned, indicating low concern.

Annual Mean Discharge

The annual mean discharge measure was assigned a *Significance Level* of 2. Mean discharge on the Bluestone River is also variable between years but with no clear trends over the past 40-45 years (USGS 2016a). This measure is assigned a *Condition Level* of 0, as it is of no concern at this time.

Annual Minimum Discharge

This measure was assigned a *Significance Level* of 1. Measures with a *Significance Level* of 1 are not discussed in the current condition section of the text, rather they are briefly summarized in the Overall Condition section. To determine annual minimum discharge, GSS analysts downloaded mean daily discharge data and identified the lowest daily discharge value for each water year.

Annual minimum discharge during the period of record ranged from 0.2 cms (1955) to 1.7 cms (2004) with a mean of 0.74 cms (± 0.04 S.E.) (Figure 71) (USGS 2016a). Minimum discharge typically occurred between mid-July and October. Over the past 10 years (2007-2016), the mean annual minimum discharge has been 0.79 cms (± 0.07 S.E.), while the average for the past 5 years was 0.98 cms (± 0.07 S.E.), which is above the period-of-record average (USGS 2016a). While minimum discharge shows interannual variation, the 5-year moving average for the period of record suggests that minimum discharge since the early 1970s has been higher on average than during the 1950s and 1960s (Figure 71). Therefore, this measure is of low concern (*Condition Level* = 1).

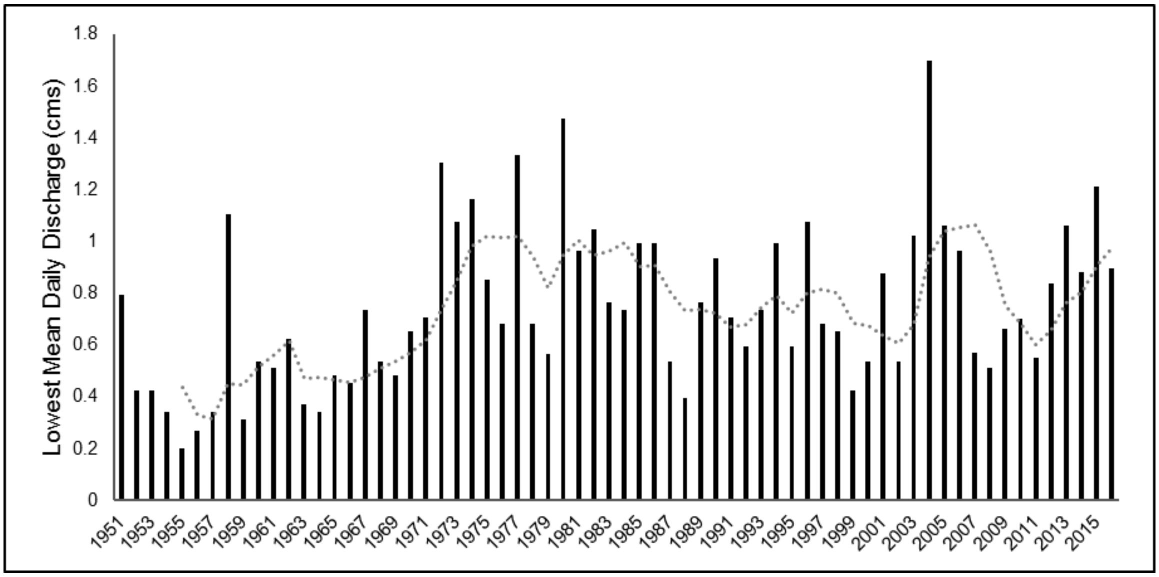


Figure 71. The lowest mean daily discharge (cms) by water year (October-September) for the Bluestone River near Pipestem (USGS 03179000) (USGS 2016a). The dotted gray line represents the 5-year moving average.

Timing and Amount of Precipitation

A *Significance Level* of 2 was assigned for the precipitation measure. Over the past decade (2007-2016), average annual precipitation at the Princeton and Bluestone Lake weather stations near BLUE has been slightly above the 30-year normals (NCEI 2015a, b, 2017b, a). Variation can be high between years, with a nearly equal number of years falling above and below the 30-year normal during this time. Monthly precipitation averages for both stations during the past decade have also varied from the 30-year normals, with the spring months and December receiving more precipitation and some of the summer months receiving less (Figure 68, Figure 70). As a result, this measure is currently of moderate concern (*Condition Level* = 2).

Weighted Condition Score

The *Weighted Condition Score* for BLUE's surface water hydrology is 0.33, indicating good condition (Table 73). Although variable between years, discharge measures on the Bluestone River have been relatively stable over time. The timing of precipitation (i.e., monthly totals) over the past decade has varied from the 30-year normals and may impact surface hydrology, if the shift continues.

Table 73. Current condition of Bluestone National Scenic River's Surface Water Hydrology.

Measures	Significance Level	Condition Level	WCS = 0.33
Annual Peak Discharge	3	1	
Annual Mean Discharge	2	0	
Annual Minimum Discharge	1	1	
Timing & Amount of Precipitation	2	2	

4.10.6. Sources of Expertise

- Caleb Tzilkowski, ERMN Aquatic Ecologist
- Lisa Wilson, NPS Biological Science Technician

5. Discussion

Chapter 5 provides an opportunity to summarize assessment findings and discuss the overarching themes or common threads that have emerged for the featured components. The data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also addressed is how condition analysis relates to the overall natural resource management issues of the park.

5.1. Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps exist for most key resource components assessed in this NRCA. Table 74 provides a detailed list of the key data gaps by component. Each data gap or need is discussed in further detail in the individual component assessments (Chapter 4).

Table 74. Identified data gaps or needs for the featured components in Bluestone National Scenic River.

Component	Data Gaps/Needs
Upland Forest Communities	➢ Continuation and expansion of monitoring efforts aimed at monitoring vegetation communities in BLUE. ➢ Additional research is needed into the current poor oak regeneration in the park and factors that may be contributing. ➢ More information is needed regarding the area's soil biota and the role they play in ecological processes that influence the health of BLUE's upland forests.
Riparian Vegetation Communities	➢ Continuation of the ERMN vegetation monitoring program. ➢ Additional surveys are needed to document the numbers, locations, and status of rare plants in BLUE's riparian areas.
Birds	➢ Continuation of the annual NPS PCS efforts and the ERMN streamside bird monitoring is recommended. ➢ Annual monitoring of regional and local habitat change within a set distance from BLUE would allow managers to better understand landscape level changes to avian communities and habitats. ➢ Expansion of existing survey efforts to sample unique habtiats and species groups is needed. ➢ Annual harvest estimates for waterfowl and turkeys in BLUE and the surrounding areas is needed to better understand annual take for those species.
Mammals	➢ An updated inventory of mammalian species in BLUE is needed. ➢ Additional research is needed on the park's bat population, particularly investigating the impacts of WNS and the presence of rare or sensitive species.
Herpetofauna	➢ Information regarding the park's herpetofauna is limited to a single, 15-year old study. Regular sampling intervals within the park is needed. ➢ Investigation into the prevalence of disease (e.g, chytrid fungus, ranavirus) in the park would allow managers to better understand the current health of herpetofauna species in BLUE.

Table 74 (continued). Identified data gaps or needs for the featured components in Bluestone National Scenic River.

Component	Data Gaps/Needs
Aquatic Wildlife Community	➢ Re-sampling of the locations surveyed by Welsh et al. (2006) and Faulk and Weber (2017) would help to identify any trends within the fish community. ➢ Further research is needed to explore how non-native plants and animals are impact native aquatic wildlife and habitats. ➢ Sampling of fish species composition and abundance has not occurred at consistent locations over time – this makes it difficult to recognize changes within the fish communities in BLUE.
Water Quality	➢ More frequent and consistent water quality monitoring would provide further insight into current conditions and any changes that may occur over time. ➢ Additional automated water quality monitoring equipment, although expensive, would allow for continuous data collection in the future.
Air Quality	➢ On-site monitoring of atmospheric deposition (sulfur, nitrogen, and mercury) and visibility, as budget and personnel limitations allow ➢ Studies of mercury concentrations in park waters and wildlife (e.g., fish, birds, bats) to identify any impacts this contaminant may be having on the park
Dark Night Skies	➢ The NPS NSNSD has not visited BLUE. A visit is needed to provide accurate, on-the-ground data. Currently, the only data that exist for BLUE are the result of GIS modeling.
Surface Water Hydrology	➢ Little is known about the hydrology of the Bluestone River at the downstream (north) end of the park, below its confluence with the Little Bluestone River, and in the area where water backs up into the park from Bluestone Lake. ➢ Collection of discharge measurements from Bluestone River closer to the downstream portion of BLUE would help managers better understand any influence that backups from Bluestone Lake may have on surface hydrology in the park.

Several of the park's data needs involve the continuation or expansion of monitoring programs to accumulate enough data for identification of trends over time (e.g., upland forest communities, riparian vegetation communities, birds). However, many of the identified data gaps for BLUE center on the need for the establishment of an annual (or at least standardized) monitoring or inventory effort (e.g., mammals, herpetofauna, air quality, dark night skies). Many of the existing data sets for these resources are outdated, while components such as dark night skies and air quality do not have data specific to BLUE; the data used in those assessments relied on either regional projections and trends or the best professional judgement of experts. Many components in the park are in need of expanded data sets in order to have an accurate assessment of current condition that is based more on data and less on professional judgement.

5.2. Component Condition Designations

Table 75 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Table 76 and Table 77). It is important to remember that the graphics represented are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols in Table 75) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing datasets and monitoring information and/or the expertise of NPS staff, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

For featured components with available data and fewer data gaps, assigned conditions varied. Three components were considered to be in good condition: birds, mammals, and surface water hydrology. Of those three components, however, only the surface water hydrology component had enough data to assess a current trend with high confidence. Three components (upland forest communities, water quality, dark night skies) were of moderate concern; upland forest communities and dark night skies lacked sufficient data to assign a current trend, while water quality had enough recent data to confidently assign a stable trend. Only the riparian vegetation communities and air quality components were determined to be of significant concern. The current trend of air quality in BLUE was determined to be improving (a designation assigned with moderate confidence), but trend was not able to be determined for riparian vegetation communities due to a lack of contemporary data. Condition could not be determined for two components: herpetofauna and aquatic wildlife communities.

Table 75. Summary of current condition and condition trend for featured Natural Resource Condition Assessment components.

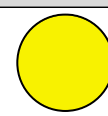
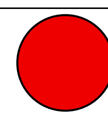
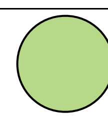
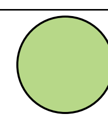
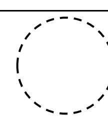
Component	WCS	Condition
Upland Forest Communities	0.44	
Riparian Vegetation Communities	0.67	
Birds	0.15	
Mammals	0.00	
Herpetofauna	N/A	

Table 75 (continued). Summary of current condition and condition trend for featured Natural Resource Condition Assessment components.

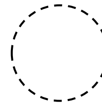
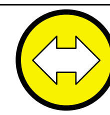
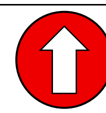
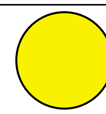
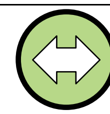
Component	WCS	Condition
Aquatic Wildlife Community	N/A	
Water Quality	0.35	
Air Quality	0.80	
Dark Night Skies	0.67	
Surface Water Hydrology	0.33	

Table 76. Description of symbology used for individual component assessments.

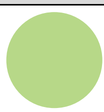
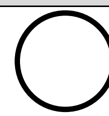
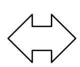
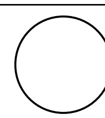
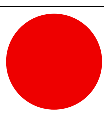
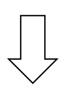
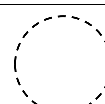
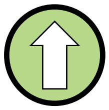
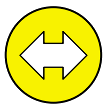
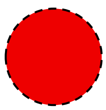
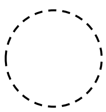
Condition Status		Trend in Condition		Confidence in Assessment	
Condition Icon	**Condition Icon Definition**	**Trend Icon**	**Trend Icon Definition**	**Confidence Icon**	**Confidence Icon Definition**
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 77. Example indicator symbols and descriptions of how to interpret them.

Symbol Example	Verbal Description
	Resource is in good condition; its condition is improving; high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment (explanation is required if a trend symbol or a medium/high confidence band is shown).

5.3. Park-wide Condition Observations

Despite the variety of habitats at BLUE, many of the resources discussed in this report are interrelated and share similar management concerns (e.g., data gaps, threats from outside the park, critical communities). The park protects 16.9 km (10.5 mi) of the free-flowing Bluestone River and large tracts of undeveloped and continuous forests on streamside habitats. The threats/stressors, data needs, and priority habitats of BLUE are critical to park managers in order to fully understand the many ecosystems present in the park.

5.3.1. Vegetation Communities

The condition of vegetation communities often provides insight into overall terrestrial ecosystem health (Perles et al. 2010). The native vegetation communities of BLUE are vital resources for the park, providing habitat for wildlife and performing critical ecological functions. The extensive upland forests in BLUE are dominated by oak, maple, and hickory species, and can be divided into 12 unique upland forest community types (Vanderhorst et al. 2008). These forests provide habitat for many plant species, with over 500 taxa documented within these areas (Appendix A).

The park's riparian communities support high plant diversity and are primarily wooded, with species such as eastern hemlock, American sycamore, and river birch, but also include some open areas with herbaceous vegetation, particularly where flooding disturbance is frequent. In addition to common and widespread riparian specices, a number of rare species, including the federally-threatened Virginia spiraea are found in the park (Norris 1992, Vanderhorst et al. 2008). Further, one of the 10 unique riparian vegetation community types that occurs in the park has been ranked as "Critically Imperiled Globally (G1)" by NatureServe (2011).

The current condition of the park's vegetation communities varied. The upland forests in the park were determined to be of moderate concern, although data relating to reference condition and pertaining to several metrics (rare plant EOs, oak regeneration, soil biota) were lacking. These deficiencies somewhat reduced the overall confidence in the condition designation, and prevented the designation of a current trend. The upland areas in BLUE cover the majority of the park's total area, and there is no indication that this extent is declining. The species richness estimates in BLUE indicate that the upland forests are home to a diversity of species, although there is some concern that the number and proportion of exotic species in the park may be increasing and that the proportion of total cover of exotic/invasive species may be above average for the area. At the time of writing, approximately 8.5% of all plant taxa documented in BLUE's upland forests are exotic. Recruitment and tree mortality are both of concern in the park's upland forests. From 2013-2016, the mean annual tree mortality rate in BLUE's upland forest monitoring plots was 1.7%/year (ERMN 2017), which is slightly higher than reported for other eastern forests (0.3-1.6%/year) and a small increase from the 2009-2012 rate in BLUE (~1.4%) (Perles et al. 2014b, 2016). The 2013-2016 mean annual tree recruitment rate for BLUE upland forest monitoring plots (0.7%/year) was lower than nearby NERI's rate (~0.9%) and less than half of the park's annual tree mortality rate (ERMN 2017). Several key tree species showed no recruitment at all, including scarlet, black, chestnut, and northern red oak (Perles et al. 2016).

Riparian communities in BLUE were identified as an area of significant concern. Similar to the upland forest communities component, there were some deficiencies in the available data, particularly in regards to reference condition and rare plant EOs. Because of this, no trend was assigned to the community. While there is no current evidence that the riparian areas of the park are shrinking, these areas cover such a small percentage of the park's total area (8%) and they are especially vulnerable to natural and anthropogenic changes. These areas are rich in plant species, with over 450 different taxa and 20 taxa determined to be rare. However, the proportion of exotic plant species in the park's riparian areas is moderately high (14.4%), especially when compared to the propotion of exotic plant species found in the upland areas of BLUE (8.5%). These exotic (and invasive) species also cover an unexpectedly large proportion of area in the riparian areas, as Vanderhorst et al. (2008) documented that invasive species covered over 30% of the landscape in three different riparian vegetation community types. The proportion of exotic and invasive species in the riparian areas was determined to be over 10 times higher than what was documented in the park's upland vegetation communities.

5.3.2. Wildlife

Animals featured as NRCA components included birds, mammals, amphibians and reptiles (under the herpetofauna component), and the broad group of organisms that inhabit the aquatic areas of BLUE (under the aquatic wildlife community component). Both the birds and mammals components were determined to be in good current condition. The absence of more recent avian survey data reduced the overall confidence in the bird assessment. Because of this, a trend arrow was not assigned and a medium confidence border was applied to the condition graphic. BLUE is home to large expanses of continuous, dense forests, free from fragmentation that is exhibited elsewhere in the Appalachian Mountains. These stretches of forest provide vital habitats for forest interior species such as the red-eyed vireo and scarlet tanager, both of which were among the most frequently detected species in the park during annual monitoring. The species richness estimates of forest dwelling bird species remained high throughout the duration of all surveys in BLUE, indicating that the forest community in BLUE is in good condition. In fact, the most common and frequently detected species during the NPS PCS efforts were nearly universally forest-dwelling species. Similarly, BCI values from BLUE were among some of the highest values obtained ERMN-wide by Marshall et al. (2013), indicating very high ecological integrity at BLUE. One unique aspect of BLUE is that turkey and waterfowl are hunted in the park during their respective legal seasons. Harvest numbers in BLUE are currently unknown. The utilization of the park for harvest is a difficult situation for managers to balance, as it requires NPS staff to strike a delicate balance between conservation of species and habitat and visitor experience (i.e., hunting success/opportunities).

Much like the birds component, the dense forests, cliffs, and riparian areas of BLUE provide critical habitat for the mammal species in the park. The mammals of BLUE include two bat species that are federally listed as either threatened (northern myotis) or endangered (Indiana bat), and several species identified as species of conservation concern. The overall species richness values observed in BLUE were about what was expected given the location of the park, and the species observed represent about 62% of all mammal species in West Virginia. Additional bat research is needed in BLUE in order to more accurately assess the current condition of that community, as the most recent bat survey is over 10 years old and WNS is known to have impacted bat species in other areas of the state. Similarly, research is needed to determine annual harvest rates for legally harvested mammals in the park. Currently, no harvest data specific to BLUE exist, and without these data managers cannot accurately determine the effects that annual hunts may have on local populations.

The remaining two wildlife components, herpetofauna and aquatic wildlife communities, were not assigned a current condition due to data gaps. The forests and aquatic habitats of BLUE likely support many species of herpetofauna, as four endemic salamander species have been documented in the park, as have several amphibian and reptilian species of conservation concern. Unfortunately, reptiles and amphibians are often understudied in protected areas, despite recently becoming a focal topic as protecting biodiversity has become a critical goal in NPS units (Scott and Seigel 1992). This trend has largely remained true in BLUE, as the only inventory of herpetofauna in the park occurred over 20 years ago. Because of the absence of data, a current condition and trend was not assigned to the herpetofauna component.

The aquatic wildlife community component was created to assess the other wildlife groups that utilize the park’s rivers and streams (e.g., fish and aquatic macroinvertebrates). These species were not represented in other components, and park managers felt their inclusion was critical as fish and aquatic macroinvertebrates are excellent bioindicators of stream and river health (Marshall et al. 2006, Faulk 2015, Tzilkowski et al. 2015). Unfortunately, contemporary data relating to many wildlife communities in BLUE are lacking and a current condition or trend could not be assigned. The fish community of BLUE has been described as “depauperate” when compared to neighboring watersheds (Welsh et al. 2006, p. xix), and is comprised of many non-native game fish that were introduced to improve angling opportunities. Native fish species richness was relatively low during the last thorough inventory in BLUE (2004-05), but the community is in need of an updated sampling effort to determine if this is still the case. Benthic macroinvertebrates have been sampled more recently in BLUE, and the MIBI measure was the only measure in this component to have enough data to assign a Condition Level. The average MIBI score for three of the four sampling reaches in BLUE indicated that those streams were in fair condition, and the fourth sampling reach was in good condition. However, these MIBI scores were treated with caution, as further research is needed to determine if certain characteristics of park streams (e.g., size, geology) make the MIBI condition ranges utilized for other ERMN parks unsuitable for use at BLUE.

5.3.3. Environmental Quality

Environmental quality is important in maintaining healthy, functioning ecosystems. The health of terrestrial and aquatic organisms can be substantially affected by the condition of air and water quality. The water quality of the many streams and rivers in BLUE was determined to be of moderate concern, although the weighted condition score for the component was very near to the upper threshold of the good condition designation. The confidence in the assessment of current condition was high, as sampling efforts have occurred on an annual basis since the 1990s and provide baselines for comparison. Conditions of the individual metrics in the water quality component were split between being of no concern (temperature, pH, DO), and being of moderate concern (specific conductance, turbidity, fecal coliform bacteria). Although water temperatures, pH, and DO were well within state standards and currently of no concern, the remaining measures have shown levels of concern during recent (2012-2016) park monitoring. SpC and turbidity observations on the Bluestone River have exceeded informal reference conditions on occasion, and sporadic elevated fecal coliform bacteria levels on the Bluestone River may pose a threat to human health. As there is no clear or consistent decline or improvement in the selected measures, a stable/unchanging trend was assigned.

Air quality was determined to be of significant concern in BLUE, largely due to high levels of sulfur deposition and poor visibility in the area. Although the most recent 5-year sulfur deposition estimate for BLUE fell within the moderate concern range, the NPS ARD elevated the rating to significant concern, due to very high ecosystem sensitivity. The most recent estimated visibility average for mid-range days for BLUE fell in the NPS ARD’s significant concern range. Nitrogen deposition in BLUE fell into the NPS ARD’s moderate concern range. While BLUE is considered to be at very low risk of nutrient enrichment from nitrogen deposition, it is at high risk of acidification from acidic (nitrogen and sulfur) deposition, partially due to very high levels of ecosystem sensitivity (Sullivan et al. 2011a, 2011c).

Despite not having any on-the-ground dark night skies data from within BLUE’s boundaries, NPS managers felt strongly about including dark night skies as a priority resource for this NRCA. The NPS NSNSD was able to use modeled ALR data for BLUE and the surrounding regions to estimate the current night sky conditions. Using that modeled data, it was determined that the night skies around BLUE are currently of moderate concern. However, BLUE lies on the edge of perhaps the darkest areas in the entire region (Figure 62). While current night sky conditions in the park are by no means ideal, when compared to the overall night sky conditions in the region, the BLUE night skies appear to be in a much better state. No current trend could be identified for this component, as all the data available were the result of modeling and not on-the-ground surveys. A visit to the park by the NPS NSNSD is needed to accurately measure the current condition of night skies in the park, and to elevate the confidence in condition designation (currently condition designation is of medium confidence).

5.3.4. Physical Characteristics

The surface water hydrology component for BLUE was determined to be of good condition, with a stable current trend. The Bluestone River and its tributaries are unimpounded, and the system experiences a natural, seasonal flow regime, with high flows during late winter and early spring and low flows typically in late summer and early fall (Hebner 1991, Wilson et al. 2006). Discharge rates in BLUE (annual peak, mean, and miniumum) have been variable over the period of record, with no apparent increasing or decreasing trend. Stream flow in the BLUE vicinity is primarily fed by precipitation falling within the watershed. Precipitation can be highly variable between years, and the average annual precipitation in the BLUE are from 2007-2017 was above the 30-year normals for the area (NCEI 2015a, b, 2017b, a). Because of this elevated average and potential shifts in seasonal patterns, precipitation was the only measure of surface water hydrology that was scored as being of *Moderate Concern*.

5.3.5. Park-wide Threats and Stressors

The various priority natural resources highlighted in this NRCA are all subject to their own unique threats and stressors. However, several universal threats and stressors stood out in multiple components in this document. These common park-wide threats and stressors (climate change, exotic species, habitat fragmentation, and degradation to water quality) are discussed below and emphasize how, despite each community being unique, they are all linked in many ways.

<u>Climate Change</u>

Climate is a key driving factor in the ecological and physical processes influencing vegetation in parks throughout the ERMN (Davey et al. 2006). As a result of global climate change, temperatures are projected to increase across the eastern United States over the next century (Horton et al. 2014). Additionally, warming temperatures will likely alter the habitat suitability of certain areas for some plant species (Fisichelli et al. 2014). As the impacts of climate change and related stressors compound over time, forests will experience more widespread changes in tree species composition, with cascading effects on other plants and wildlife (Fisichelli et al. 2014).

Climate change may alter the frequency and intensity of extreme weather events that already threaten BLUE’s forests, such as tornadoes/wind storms, ice storms, and droughts (Dale et al. 2001, Rentch 2006). Evidence suggests that the storm conditions contributing to tornado formation have increased with warming temperatures and will continue to do so under projected future climate changes (Dale et al. 2001). Higher temperatures also increase evaporation and transpiration (by plants), causing less water to be available for plants and increasing moisture stress (Dale et al. 2001), particularly for species adapted to wet environments.

Climate, especially precipitation, is one of the primary influences on surface hydrology (Poff et al. 1997, Marshall et al. 2006). As a result of global climate change, precipitation is expected to increase

(6-11%) by 2100 in the region around BLUE (Gonzalez 2015). An increase in the frequency and intensity of extreme precipitation events is also expected, with the frequency of 20-year storms projected to increase to once every 4-6 years (Walsh et al. 2014, Gonzalez 2015). Together, higher precipitation levels and an increased frequency of large storms could lead to increased flooding (Horton et al. 2014, Gonzalez 2015). These changes in precipitation patterns, if they do occur, would likely alter discharges on the Bluestone River.

Wildlife communities are likely to be impacted by climate change in a variety of ways. As global temperatures change, some bird species in the U.S. have adjusted by moving their home range north (Hitch and Leberg 2007). Other species have adjusted their migratory period and have begun returning to their breeding grounds earlier in the spring. These shifts could result in migratory periods becoming out of sync with food availability, which may result in lower fitness and reproductive success for the species. Mammalian species are likely to be impacted by climate change by experiencing heat and/or water stress, altered habitats, reduced food availability, and altered seasonal cues that some mammals need to trigger certain behaviors (e.g., reproduction, hibernation). BLUE is home to several mammalian species that are particularly vulnerable to climate change-related impacts, such as as the Allegheny woodrat and Indiana bat – both of which are species of concern in West Virginia.

With many of BLUE's herpetofauna species dependent on aquatic habitat at some stage in their life cycles, drought is a major threat to these populations. Climate change has been implicated in widespread drought events, which are interspersed with deluges (Bates et al. 2008). This results in huge amounts of runoff, erosion, and occasional flooding that damage riparian areas and other important aquatic habitats, as well as degrading water quality (Bates et al. 2008). Riparian flooding during the summer may destroy vegetative cover utilized by young herpetofauna and could wash away larval amphibians and/or turtle nests (Purvis 2002). An overall increase in global temperatures associated with climate change, which contributes to extended periods of drought, will have a combined effect on biota by causing temperature and water stress (Bates et al. 2008). In West Virginia, amphibians have been identified as one of the taxonomic groups most vulnerable to climate change (Byers and Norris 2011), with some species already being negatively impacted within the state (Pauley 2006).

Climate affects the spread of invasive plant species and pathogens as well, which also threaten BLUE (Fisichelli et al. 2014). The warmer temperatures associated with climate change are likely to increase the survival, reproduction, and dispersal/distribution of some forest pests and pathogens (Dale et al. 2001). An increase in drought frequency and/or intensity as a result of climate change would likely make forests more vulnerable to these pests and pathogens (Dale et al. 2001).

<u>Exotic Species</u>

Exotic invasive plants are among the greatest threats to forests worldwide, including those in BLUE. Of particular concern is the ability of these plants to outcompete native plants and disrupt ecosystem processes, such as nutrient cycling and disturbance regimes (Mooney et al. 2005, Perles et al. 2014b). Exotic plant species have occurred in the park since its establishment, and invasives such as multiflora rose have been the dominant species in certain areas of the park for some time (Norris

1992). According to recent monitoring, the average cover of invasive plant species in BLUE's riparian communities (14.1%) is much higher than in the park's upland forests (<2%) (ERMN 2017). The Bluestone River and recreational trails near the floodplain may serve as pathways for the invasion and spread of these exotic species (Richardson et al. 2007, Perles et al. 2014b). Additionally, invasive cover has been documented at over 10% in some areas of the park's successional upland forest communities (Vanderhorst et al. 2008).

Exotic insect, fungal, and bacterial pests pose a serious threat to many communities in BLUE. Plant pests are capable of altering entire vegetation communities by changing the species composition and structure of large areas; they can also be responsible for reductions in overall species diversity (Keefer 2009). The HWA has resulted in hemlock stands with declining crown vigor and increasing tree mortality in NPS units around BLUE, and BLUE staff have observed significant declines of hemlocks within the park. While the insect infestation is being treated in the park, it remains an intensive (labor and cost) process and is only a temporary solution. Another plant pest, the EAB, attacks only ash trees and is always fatal for the affected trees. The EAB has the potential to dramatically impact several globally rare vegetation and riparian areas in BLUE and continued monitoring and treatment in these areas is likely needed to preserve these communities. Oak trees are the primary host species of the gypsy moth, an insect pest that has been present in BLUE since the early 1990s (Weese 1992). While gypsy moths have not been responsible for major instances of defoliation or mortality in BLUE, the species defoliated approximately 40,450 ha (100,000 ac) of forests in West Virgina in 2015 (USFS and WVDA 2016).

Exotic pathogens are also threatening many communities and species in BLUE. The butternut canker is a fungal disease that has been decimating butternut trees throught the U.S. The effects of this disease have been so severe that the butternut has been extirpated from several areas in the south and has been listed as a species of federal concern by the USFWS (Schlarbaum et al. 1998). Butternut canker is not the only fungal pathogen affecting communities in West Virginia, as WNS (a fungal disease affecting bat species) has been decimating bat populations across the U.S. In West Virginia, WNS was first detected in Pendleton County in 2009 (WVDNR 2015). By 2012, the disease had spread across the karst regions of the state, affecting multiple bat species. Based on 2015 data, little brown bats experienced a 97% population decline and Indiana bats an 85% decline (WVDNR 2015). While not confirmed in BLUE, WNS is likely to affect the bat species of the park in the near future.

Many exotic animal species are present in BLUE and the surrounding areas. The feral hog has been documented in small numbers near Pipestem Resort State Park, but has not yet been observed in the park. Feral hogs damage forested habitats with their rooting behavior and compete for food sources with native wildlife (Campbell and Long 2009, McCoy 2016). Their disturbance of ground vegetation and litter layers could threaten small mammals that rely on these areas for food and shelter (Singer et al. 1984, Campbell and Long 2009). Feral hogs also carry diseases and parasites that could spread to other mammals, including some that impact humans (McCoy 2016).

Recreational users of BLUE and the surrounding area have contributed greatly to the presence of exotic species in the aquatic communities in BLUE. Exotic game fish such as bass, sunfish, and trout species have been intentionally introduced to improve angling and recreational opportunities. The

Bluestone River watershed has naturally low fish species richness and is more vulnerable to successful invasion by non-native species than watersheds with higher species richness (Welsh et al. 2006). Unintentional introductions of exotic species in the Bluestone River have also occurred, primarily through bait bucket releases from anglers. Species such as the margined madtom, telescope shiner, and whitetail shiner have been documented in the park and are likely the result of these bait bucket releases. The establishment of an exotic crayfish species in the New River system is also thought to be the result of an unintentional bait bucket release (Purvis 2002, Swecker 2012). Boating traffic has contributed to the overall number of exotic species, as boats that were not cleaned properly when moved between bodies of water have transported exotic species such as mussels, aquatic vegetation, and other invertebrates. These exotic species change the structure of the aquatic communities of BLUE, and may outcompete or prey upon native species.

Habitat Fragmentation

While the landscape of BLUE consists of dense stands of continuous forest and river gorges, the surrounding areas are being developed, managed, and used in manners that often threaten the ecological integrity of some communities in the park. Forest fragmentation has been occurring in the region around BLUE since commercial logging began in the late 1800s, aided by the 1872 construction of the Chesapeake and Ohio Railroad in Summers County (Rentch et al. 2005, Vanderhorst et al. 2008). Large commercial timber harvests continued through the 1940s and 1950s (Rentch et al. 2005). Recreational trails, transportation corridors (roads and railways), and pipeline corridors also fragment the landscape, exposing the forest edges to additional threats such as exotic species invasion and exposure to harsh weather conditions (Rentch 2006, Perles et al. 2014b). Other human uses, such as gas extraction development and recreational/residential development also contribute to habitat fragmentation. Within BLUE, the WVDNR manages several parcels of land jointly with the NPS within the park's legislative boundary. As part of their objective to maintain wildlife habitat and create hunting opportunities for state residents, the WVDNR mows some areas within the floodplain towards the north end of the park (Vanderhorst et al. 2008). However, these open areas tend to be weedy and offer opportunities for invasive plant species to become established (Vanderhorst et al. 2008; Perez, personal communication, October 2016). The openings also fragment the floodplain forest, exposing the forests to the risks associated with fragmentation (e.g., exposure to harsh weather conditions, alterations to interspecific interactions, etc.) (Rentch 2006).

Habitat fragmentation creates barriers to species dispersal, which can influence interspecific interactions, genetic and species diversity, and species density and abundance (Rentch 2006). In BLUE, deciduous forests support a high diversity of herpetofauna and interior-dependent avian species, but fragmentation may affect the ability of species to move freely between habitat types or to migrate (Pauley et al. 2003). Mammalian movement and dispersal in BLUE could be limited by fragmentation of the surrounding landscape, which would influence species abundance and density, genetic diversity, and interspecific interactions (Rentch 2006). Fragmentation also creates more "edge" areas, where wildlife are potentially vulnerable to increased predation, exposure to pathogens, and competition with non-native species (Rentch 2006).

Degradation to BLUE's Water Quality

Nearby land use and development has a significant impact on surface water quality in BLUE, where the majority of the watershed lies outside park boundaries (Marshall and Piekielek 2007a). Agricultural land uses contribute pollutants (e.g., chemicals, nutrients, fecal bacteria from livestock) and excess sediment to streams, and are responsible for much of the phosphorous, nitrogen, and sediment discharged into U.S. waterways (Purvis 2002). In forested areas surrounding BLUE, most of the timber is considered harvestable, and active logging occurs near and adjacent to the park (Purvis 2002). Logging, and the roads associated with logging activity, increase soil exposure and erosion, which in turn increases sedimentation of streams in the area (Hebner 1991, Purvis 2002). Construction and clearing for residential/recreational developments typically involves an increase in impervious surface area (e.g., roads, parking lots) and a reduction in precipitation infiltration; this can increase runoff and contribute sediment to surface waters. The Bluestone watershed also collects discharges of treated wastewater from eight sewage treatment plants associated with existing upstream developments (Purvis 2002). One sewer overflow system in the drainage releases a mix of stormwater runoff and untreated wastewater directly into streams during heavy rain events (Purvis 2002). De-icing solutions (e.g., salts) used on roads associated with developments may pollute park waters as well, particularly with chloride (Webber 2012).

There are currently no gas wells within BLUE boundaries, but the park's water quality is still threatened by nearby exploration and extraction activity. BLUE is located on the southeastern edge of the Marcellus Shale, a major gas-bearing rock formation (NPS 2009). According to the WVDEP (2016b), there are active gas wells approximately 13 km (8.1 mi) to the west and 14 km (8.7 mi) to the south of BLUE. Drilling and extraction activities increase the risk of drilling fluids, gas, or waste fluids spilling or leaking into nearby waters (Purvis 2002, NPS 2009). Trucks, pipelines, and pumping stations required for the transportation of gas and waste products may also spill or leak. A major natural gas pipeline currently crosses the park and the Bluestone River in the vicinity of Lilly (Purvis 2002). The liquid wastes from oil and gas extraction operations (primarily brine) are often pumped back into the ground by separate injection wells (EPA 2016b). Although these wells are designed to carry the waste fluids to deep underground formations that are isolated from groundwater sources, there is a risk of leaks or spills at or near the surface, which could contaminate surface waters and/or shallow groundwater. The closest injection well to the park is just 9.2 km (5.7 mi) to the southwest (Figure 42) (WVDEP 2016b).

Degradation of the park's water quality could have impacts on BLUE's bird population, especially with the high observed levels of biotic integrity in these areas reported by Marshall et al. (2013). Additionally, the excess sediment introduced to streams by logging, agriculture, and development can fill in pools or small spaces that provide habitat for aquatic wildlife species (Chambers and Messinger 2001, Purvis 2002, Bilotta and Brazier 2008). When suspended in the water, excess sediment can irritate and clog the respiratory organs of fish and aquatic invertebrates, stressing and potentially killing these organisms (Bilotta and Brazier 2008). Fish species have varying tolerances for pollution/degradation, with some showing more sensitivity to change than others (Messinger and Chambers 2001). Native fish occurring within BLUE that are considered intolerant of pollution include the rosyside dace, mountain redbelly dace, and greenside darter (Anderson and Petty 2015).

5.3.6. Overall Conclusions

Despite the park's relatively small size, BLUE is a diverse park with a variety of rare and unique resources, from dense stands of continuous upland forest to the rugged and ancient Bluestone River gorge. Continued monitoring of the park's priority resources, combined with management efforts directed at minimizing disturbance potential, will aid many of these natural communities and ensure their continued presence in the park. Additional monitoring in regards to the many shared threats and stressors in the area, particularly climate change, will strengthen park manager's overall understanding of the interrelated nature of the ecosystems and communities within the park. BLUE possesses tremendous opportunity for scientific study, and continuing advancements in the scientific understanding of BLUE's resources will not only benefit the park, but also other locales in the Appalachian Mountains with shared resources.

Literature Cited

Allan, J. D., and M. M. Castillo. 2007. Stream ecology: Structure and function of running waters. Springer Netherlands, Dordrecht, The Netherlands.

American Ornithologists' Union (AOU). 1995. Fortieth supplement to the American Ornithologists' Union Check-list of North American Birds. The Auk 112(3):819-830.

Anderson, A. M., and J. T. Petty. 2015. Fish based index of biotic integrity for wadeable warm water streams in West Virginia. West Virginia Department of Environmental Protection, Charleston, West Virginia.

Andrews, K. M., J. W. Gibbons, and D. M. Jochimsen. 2006. Literature synthesis of the effects of roads and vehicles on amphibians and reptiles. Report Number FHWA-HEP-08-005. U.S. Department of Transportation, Federal Highway Administration, Washington. D.C.

Animal and Plant Health Inspection Service (APHIS). 2009. Emerald Ash Borer: The green menace. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington, D.C.

Baker, G. M., S. J. Taylor, S. Thomas, K. Lavoie, R. Olson, H. A. Barton, M. Denn, S. C. Thomas, R. Ohms, K. L. Helf, and others. 2015. Cave ecology inventory and monitoring framework. Natural Resource Report NPS/NRSS/NRR–2015/948. National Park Service, Fort Collins, Colorado.

Baron, J. S., C. T. Driscoll, J. L. Stoddard, and E. E. Richer. 2011. Empirical critical loads of atmospheric nitrogen deposition for nutrient enrichment and acidification of sensitive US lakes. BioScience 61(8):602-613.

Bartkus, C. J. 2009. The occurrence of *Batrachochytrium dendrobatidis* in salamander populations of West Virginia. Thesis. Marshall University, Huntington, West Virginia.

Bates, B. C., Z. W. Kundzewicz, S. Wu, and J. P. Palutikof. 2008. Climate change and water. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Beitler, J. 2006. Tracking nature's contribution to pollution. NASA's Earth Observing System, Project Science Office, Greenbelt, Maryland.

Bessell, M. S. 1990. UBVRI Passbands. Publications of the Astronomical Society of the Pacific 102:1181-1199.

Bilotta, G. S., and R. E. Brazier. 2008. Understanding the influence of suspended solids on water quality and aquatic biota. Water Research 42:2849-2861.

Binkley, D., and R. Fisher. 2012. Ecology and management of forest soils. Johm Wiley & Sons Ltd, West Sussex, United Kingdom.

Blakesley, J. A., D. C. Pavlacky, and D. Hanni. 2010. Monitoring bird populations in Wind Cave National Park. Technical report M-WICA0901. Rocky Mountain Bird Observatory, Brighton, Colorado.

Blehert, D. S., A. C. Hicks, M. Behr, C. U. Meteyer, B. M. Berlowski-Zier, E. L. Buckles, J. T. H. Coleman, S. R. Darling, A. Gargas, R. Niver, and others. 2008. Bat white-nose syndrome: An emerging fungal pathogen? Science 323(5911):227.

Bortle, J. E. 2001. Introducing the Bortle dark-sky scale. Sky & Telescope 101(2):126-129.

Boulton, A. J. and P. S. Lake. 2008. Effects of drought on stream insects and its ecological consequences. Pages 81-102 *in* J. Lancaster and R. A. Briers, editors. Aquatic insects: Challenges to populations. CAB International, Wallingford, United Kingdom.

Braun, E. L. 1950. The mixed mesophytic forest region. Chapter 4 *in* Deciduous Forests of Eastern North America. The Blakiston Company, Philadelphia, Pennsylvania.

Busing, R. T. 2005. Tree mortality, canopy turnover, and woody detritus in old cove forests of the southern Appalachians. Ecology 86(1):73-84.

Byers, E., and S. Norris. 2011. Climate change vulnerability assessment of species of concern in West Virginia. West Virginia Division of Natural Resources, Elkins, West Virginia.

Campbell, T. A., and D. B. Long. 2009. Feral swine damage and damage management in forested ecosystems. Forest Ecology and Management 257:2319-2326.

Carter, L. M., J. W. Jones, L. Berry, V. Burkett, J. F. Murley, J. Obeysekera, P. J. Schramm, and D. Wear. 2014. Southeast and the Caribbean. Pages 396-417 *in* J. M. Melilo, T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United Sates: The third national climate assessment. U.S. Global Change Research Program, Washington, D.C.

Castle, K. T., and P. M. Cryan. 2010. White-nose syndrome in bats: A primer for resource managers. Park Science 27(1):20-25.

Castleberry, S. B., K. V. Miller, and W. M. Ford. 2007. Survey of bat communities in the New River Gorge National River, Gauley River National Recreation Area, and Bluestone National Scenic River: Species occurrence, relative abundance, distribution, and habitat use. Technical Report NPS/NER/NRTR—2007/101. National Park Service, Philadelphia, Pennsylvania.

Chambers, D. B., and T. Messinger. 2001. Benthic invertebrate communities and their responses to selected environmental factors in the Kanawha River Basin, West Virginia, Virginia, and North Carolina. Water-Resources Investigations Report 01-4021. U.S. Geological Survey, Charleston, West Virginia.

Cicero, C., and N. K. Johnson. 1998. Molecular phylogeny and ecological diversification in a clade of New World songbirds (genus *Vireo*). Molecular Ecology 7(10):1359-1370.

Cincotta, D. A., and D. B. Chambers. 1999. Recent Changes in the distribution of fish species in the New River basin in West Virginia and Virginia. Pages 98-106 *in* New River Symposium, Boone, North Carolina.

Cinzano, P., F. Falchi, and C. D. Elvidge. 2001. The first world atlas of artificial sky brightness. Monthly Notices of the Royal Astronomical Society 328:689-707.

Cryan, P. M., C. U. Meteyer, J. G. Boyles, and D. S. Blehert. 2010. Wing pathology of white-nose syndrome in bats suggests life-threatening disruption of physiology. BMC Biology 8(1):135-142.

Dahl, T. E. 2000. Status and trends of wetlands in the conterminous United States, 1986 to 1997. U.S. Fish and Wildlife Service, Washington, D.C.

Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, and others. 2001. Climate change and forest disturbances. BioScience 51(9):723-734.

Davey, C. A., K. T. Redmond, and D. B. Simeral. 2006. Weather and climate inventory: National Park Service, Eastern Rivers and Mountains Network National Park Service, Fort Collins, Colorado.

Dickson, J. G. 1992. The Wild Turkey: Biology and Management. Stockpole Books, Mechanicsburg, Pennsylvania.

Dominion. 2016. Virginia City hybrid energy center. Availacble at: https://www.dom.com/about-us/making-energy/coal-oil-and-gas/virginia-city-hybrid-energy-center. (accessed 19 December 2016).

Duriscoe, D. M., C. B. Luginbuhl, and C. A. Moore. 2007. Measuring night-sky brightness with a wide-field CCD camera. Publications of the Astronomical Society of the Pacific 119:192-213.

Dursicoe, D. 2016. Photometric indicators of visual night sky quality derived from all-sky brightness maps. Journal of Quantitative Spectroscopy and Radiative Transfer 181.

Eagles-Smith, C. A., J. A. Willacker, Jr. , and C. M. Flanagan Pritz. 2014. Mercury in fishes from 21 national parks in the Western United States – Inter- and intra-park variation in concentrations and ecological risk. Open-File Report 2014–1051. U.S. Geological Survey, Reston, Virginia.

Eastern Rivers and Mountains Inventory & Monitoring Network (ERMN). 2017. Vegetation data for GARI and BLUE NRCAs. Excel spreadsheet received from Stephanie Perles, 18 January 2017. Distributed by National Park Service. University Park, Pennsylvania.

Emmott, R. G., N. Murdock, P. Flaherty, and J. W. Ranney. 2005. Appalachian Highlands Inventory and Monitoring Network: Vital Signs Monitoring Plan. National Park Service, Appalachian Highlands Network, Asheville, North Carolina.

Emmott, R. G., and E. Porter. 2008. Air quality monitoring. Resource Brief. National Park Service, Appalachian Highlands I&M Network, Asheville, North Carolina.

Environmental Protection Agency (EPA). 2008. National air quality: Status and trends through 2007. EPA-454/R-08-006. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, North Carolina.

Environmental Protection Agency (EPA). 2010. Environmental Dataset Gateway (EDG). Avaolable at: https://edg.epa.gov/metadata/catalog/main/home.page. (accessed 03 February 2016).

Environmental Protection Agency (EPA). 2011. The effects of mountaintop mines and valley fills on aquatic ecosystems of the Central Appalachian coalfields. EPA/600/R-09/138F. Environmental Protection Agency, National Center for Environmental Assessment, Washington, D.C.

Environmental Protection Agency (EPA). 2012. Our nation's air: Status and trends through 2010. EPA 454/R-12-001. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina.

Environmental Protection Agency (EPA). 2013. Primary distinguishing characteristics of Level III Ecoregions of the continental United States. Environmental Protection Agency Unpublished Report, Washington, D.C.

Environmental Protection Agency (EPA). 2014. Policy assessment for the review of the Ozone National Ambient Air Quality Standards. Second External Review Draft. Environmental Protection Agency, Office of Air Quality Planning and Standards, Ambient Standards Group, Research Triangle Park, North Carolina.

Environmental Protection Agency (EPA). 2016a. Air data: Interactive map. Avaialble at: https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=5f239fd3e72f424f98ef3d5def547eb5&extent=-146.2334,13.1913,-46.3896,56.5319. (accessed 7 November 2016).

Environmental Protection Agency (EPA). 2016b. Class II oil and gas related injection wells. Avaialble at: https://www.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells. (accessed 26 January 2017).

Environmental Protection Agency (EPA). 2016c. Environmental Monitoring & Assessment Program master glossary: Stressor. Avaialble at: https://archive.epa.gov/emap/archive-emap/web/html/mglossary.html#ss. (accessed 31 October 2017).

Environmental Protection Agency (EPA). 2016d. Health effects of ozone pollution. Avaialble at: https://www.epa.gov/ozone-pollution/health-effects-ozone-pollution. (accessed 16 March 2016).

Environmental Protection Agency (EPA). 2016e. National Ambient Air Quality Standards (NAAQS). Avaialble at: https://www.epa.gov/criteria-air-pollutants/naaqs-table. (accessed 16 March 2016).

Environmental Protection Agency (EPA). 2016f. Particulate matter (PM). Avaialble at: https://www.epa.gov/pm-pollution. (accessed 16 March 2016).

Faulk, E. A. 2015. Patterns in distribution of stream fishes in the Eastern Rivers And Mountains Network: A multi-species occupancy approach. Thesis. Pennsylvania State University, State College, Pennsylvania.

Faulk, E. A., and A. S. Weber. 2017. Eastern Rivers and Mountains Network stream fish monitoring program: Summary of 2013-2014 pilot sampling. National Park Service, Fort Collins, Colorado.

Fisichelli, N. A., S. R. Abella, M. Peters, and F. J. Krist. 2014. Climate, trees, pests, and weeds: Change, uncertainty, and biotic stressors in Eastern U.S. national park forests. Forest Ecology and Management 327:31-39.

Fisichelli, N. A. 2015. Climate, trees, pests, and weeds: Change, uncertainty, and biotic stressors at Bluestone National Scenic River. National Park Service, Climate Change Response Program, Fort Collins, Colorado.

Foley, J., D., Clifford, K. T. Castle, P. M. Cryan, and R. S. Ostfeld. 2011. Investigating and managing the rapid emergence of white-nose syndrome, a novel, fatal, infectious disease of hibernating bats. Conservation Biology 25(2):223-231.

Fortney, R. H., S. L. Stephenson, and H. S. Adams. 1995. Reconnaissance vegetation study of the Bluestone, New, and Gauley River gorges. National Park Service, Glen Jean, West Virginia.

Francl, K. E., W. M. Ford, D. W. Sparks, and V. Brack. 2012. Capture and reproductive trends in summer bat communities in West Virginia: Assessing the impact of white-nose syndrome. Journal of Fish and Wildlife Management 3(1):33-42.

Garstang, R. H. 1989. Night-sky brightness at observatories and sites. Publications of the Astronomical Society of the Pacific 101:306-329.

Gibbons, J. W., D. E. Scott, T. J. Ryan, K. A. Buhlman, T. D. Tuberville, B. S. Metts, J. L. Greene, T. Mills, Y. Leiden, S. Poppy, and others. 2000. The global decline of reptiles, déjà vu amphibians. BioScience 50(8):653-666.

Gonzalez, P. 2015. Climate change summary, Bluestone National Scenic River, West Virginia National Park Service, Washington, D.C.

Grafton, W. N. 1993. Vascular flora on the lower sections of Gauley, Meadow, and Bluestone Rivers. National Park Service, Glen Jean, West Virginia.

Green, N. B., and T. K. Pauley. 1987. Amphibians and reptiles in West Virginia. University of Pittsburgh Press, Pittsburgh, Pennsylvania.

Hayes, T. B., P. Case, S. Chui, D. Chung, C. Haeffele, K. Haston, M. Lee, V. P. Mai, Y. Marjuoa, J. Parker, and others. 2006. Pesticide mixtures, endocrine disruption, and amphibian declines: Are we underestimating the impact? Environmental Health Perspectives 114(Supplement 1):40-50.

Hebner, S. W. 1991. Bluestone National Scenic River and Gauley River National Recreation Area: Fecal coliform study, April-September 1991. National Park Service, Glen Jean, West Virginia.

Herlihy, A. T., S. G. Paulsen, J. Van Sickle, J. L. Stoddard, C. P. Hawkins, and L. L. Yuan. 2008. Striving for consistency in a national assessment: the challenges of applying a reference-condition approach at a continental scale. Journal of the North American Benthological Society 27(4):860-877.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society 7(1):65-68.

Hitch, A. T., and P. L. Leberg. 2007. Breeding distributions of North American bird species moving north as a result of climate change. Conservation Biology 21(2):534-539.

Hollan, J. 2010. What is light pollution and how do we quantify it? N. Copernicus Observatory and Planetarium, Brno, Czech Republic.

Hoover, G. A. 2001. Entomological notes: Gypsy moth. Penn State University, State College, Pennsylvania.

Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz. 2014. Northeast. Pages 371-395 *in* J. M. Melillo, T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: The third national climate assessment. U.S. Global Change Research Program, Washington, D.C.

Hutto, R. L. 1998. Using landbirds as an indicator species group. Pages 75-92 *in* Avian conservation: research and management. Island Press, Washington, D.C.

Johnson, A. H., and R. C. Reynolds. 1977. Chemical character of headwater streams in Vermont and New Hampshire. Water Resources Research 13(2):469-473.

Johnson, L. E., A. Ricciardi, and J. T. Carlton. 2001. Overland dispersal of aquatic invasive species: A risk assessment of transient recreational boating. Ecological Applications 11(6):1789-1799.

Jones, T., and W. Cresswell. 2010. The phenology mismatch hypothesis: Are declines of migrant birds linked to uneven global climate change? Journal of Animal Ecology 79(1):98-108.

Kaller, M. D. 2001. Effects of sediment upon benthic macroinvertebrates in forested northern Appalachian streams. Thesis. West Virginia University, Morgantown, West Virginia.

Kats, L. B., and R. P. Ferrer. 2003. Alien predators and amphibian declines: Review of two decades of science and the transition to conservation. Diversity and Distributions 9:99-110.

Keefer, J. S. 2009. Invasive species early detection. Resource Brief. National Park Service, Eastern Rivers and Mountains Network, University Park, Pennsylvania.

Klemm, D. J., K. A. Blocksom, F. A. Fulk, A. T. Herlihy, R. M. Hughes, P. R. Kaufmann, D. V. Peck, J. L. Stoddard, W. T. Thoeny, and M. B. Griffith. 2003. Development and evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for regionally assessing Mid-Atlantic Highlands streams. Environmental Management 31(5):656-669.

Knight, P., K. Imhoff, and A. Person. 2015. Weather of Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River: Eastern Rivers and Mountains Network summary report for 2014. Natural Resource Data Series NPS/ERMN/NRDS—2015/812. National Park Service, Fort Collins, Colorado.

Kohut, R. J. 2007. Ozone risk assessment for Vital Signs Monitoring Networks, Appalachian National Scenic Trail, and Natchez Trace National Scenic Trail. Natural Resource Report NPS/NRPC/ARD/NRTR–2007/001. National Park Service, Fort Collins, Colorado.

Kurth, L. M., M. McCawley, M. Hendryx, and S. Lusk. 2014. Atmospheric particulate matter size distribution and concentration in West Virginia coal mining and non-mining areas. Journal of Exposure Science and Environmental Epidemiology 24:405-411.

Landers, D. H., S. Simonich, D. Jaffe, L. Geiser, D. H. Campbell, A. Schwindt, C. Schrek, M. Kent, W. Hafner, H. E. Taylor, and others. 2008. The fate, transport, and ecological impacts of airborne contaminants in Western National Parks (USA). Final Report EPA/600/R-07/138. Environmental Protection Agency, Office of Research and Development, NHEERL, Western Ecology Division, Corvallis, Oregon.

Lanly, J. P. 1982. Tropical forest resources. FAO Forestry Paper 30. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.

Latta, S. C., and R. S. Mulvihill. 2010. The Louisiana waterthrush as an indicator of headwater stream quality in Pennsylvania. *in* S. Majumadar, T. Master, R. Ross, M. Brittinghan, R. Mulvihill, and J. Huffman, editors. Avian ecology and conservation: A Pennsylvania focus with national implications. Pennsylvania Academy of Sciences, Easton, Pennsylvania.

Lee, S., K. Baumann, J. J. Schauer, R. J. Sheesley, L. P. Naeher, S. Meinardi, D. R. Blake, E. S. Edgerton, A. G. Russell, and M. Clements. 2005. Gaseous and particulate emissions from prescribed burning in Georgia. Environmental Science and Technology 39(23):9049-9056.

Link, W. A., and J. R. Sauer. 1998. Estimating population change from count data: Application to the North American breeding bird survey. Ecological Applications 8(2):258-268.

Lorimer, C. G. 1980. Age structure and disturbance history of a southern Appalachian virgin forest. Ecology 61(5):1169-1184.

Lorimer, C. G. 1993. Causes of the oak regeneration problem. Pages 14-39 *in* D. Loftis and C. E. McGee, editors. Oak regeneration: Serious problems, practical recommendations. U.S. Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.

Luginbuhl, C. B., D. M. Duriscoe, C. W. Moore, A. Richman, G. W. Lockwood, and D. R. Davis. 2009. From the ground up II: Sky glow and near-ground artificial light propagation in Flagstaff, Arizona. Publications of the Astronomical Society of the Pacific 121:204-212.

MacArthur, R. H. 1959. On the breeding distribution pattern of North American migrant birds. Auk 76(3):318-325.

Manning, D. R. 2016. Early detection of invasive species – surveillance monitoring and rapid response. Eastern Rivers and Mountains Network 2013-2015 summary report. Natural Resource Data Series NPS/ERMN/NRDS—2016/1032. National Park Service, Fort Collins, Colorado.

Marshall, M. R., K. S. Lubinski, and W. A. Lellis. 2006. Structure and functioning of large river ecosystems in the Eastern Rivers and Mountains Network: Conceptual models and Vital Signs monitoring National Park Service, Philadelphia, Pennsylvania.

Marshall, M. R., and N. B. Piekielek. 2007a. Eastern Rivers and Mountains Network ecological monitoring plan. Natural Resource Report NPS/ERMN/NRR—2007/017. National Park Service, Fort Collins, Colorado.

Marshall, M. R., and N. B. Piekielek. 2007b. Eastern Rivers and Mountains Network Park Natural Resource Summary. Appendix D *in* Eastern Rivers and Mountains Network ecological monitoring plan. National Park Service, Eastern Rivers and Mountains Network, University Park, Pennsylvania.

Marshall, M. R., B. Mattsson, K. K. Callahan, and T. Master. 2012. Streamside bird monitoring protocol for the Eastern Rivers and Mountain Network, version 2.0. Natural Resource Report NPS/ERMN/NRR–2012/592. National Park Service, Fort Collins, Colorado.

Marshall, M. R., B. Mattsson, K. K. Callahan, and T. Master. 2013. Streamside bird monitoring: Eastern Rivers and Mountains Network 2007–2012 summary report. Natural Resource Data Series NPS/ERMN/NRDS—2013/449. National Park Service, Fort Collins, Colorado.

Mast, M. A., D. J. Manthorne, and D. A. Roth. 2010. Historical deposition of mercury and selected trace elements to high-elevation National Parks in the Western U.S. inferred from lake-sediment cores. Atmospheric Environment 44:2577-2585.

Mattsson, B. J., and R. C. Cooper. 2006. Louisiana waterthrushes (*Seiurus motacilla*) and habitat assessments as cost-effective indicators of in-stream biotic integrity. Freshwater Biology 51:1941-1958.

McClure, M. S., S. M. Salom, and K. S. Shields. 2001. Hemlock woolly adelgid. FHTET-2001 - 03. U.S. Forest Service, Forest Health Technology Enterprise Team, Morgantown, West Virginia.

McCoy, J. 2016. Government agencies seek to stamp out WV's feral hogs. Charleston Gazette-Mail, Charleston, West Virginia.

McPherson, E. G., D. J. Nowak, and R. A. Rowntree. 1994. Chicago's urban forest ecosystem: Results of the Chicago Urban Forest Climate Project. General Technical Report NE-186. U.S. Forest Service, Radnor, Pennsylvania.

Messinger, T., and D. B. Chambers. 2001. Fish communities and their relation to environmental factors in the Kanawha River Basin, West Virginia, Virginia, and North Carolina, 1997–98. Water-Resources Investigations Report 01-4048. U.S. Geological Survey, Charleston, West Virginia.

Miller, K. M., F. W. Dieffenbach, J. P. Campbell, W. B. Cass, J. A. Comiskey, E. R. Matthews, B. J. McGill, B. R. Mitchell, S. J. Perles, S. Sanders, and others. 2016. National parks in the eastern United States harbor important older forest structure compared with matrix forests. Ecosphere 7(7):e01404.

Milliken, A. S., and V. Lee. 1990. Pollution impacts from recreational boating: A bibliography and summary review. Rhode Island Sea Grant, Narragansett, Rhode Island.

Mooney, H. A., R. Mack, J. A. McNeely, L. E. Neville, P. J. Schei, and J. K. Waage. 2005. Invasive alien species: A new synthesis. Island Press, Washington, D.C.

Moore, C. A., F. Turina, and J. White. 2013. Recommended indicators and thresholds of night sky quality for NPS State of the Parks reports. Interim Guidance – July 2013. National Park Service, Natural Sounds & Night Skies Division, WASO – Natural Resource Stewardship & Science, Lakewood, Colorado.

Morrison, M. L. 1986. Bird populations as indicators of environmental change. Current Ornithology 3:429-451.

Moulton, S. R., J. G. Kennen, R. M. Goldstein, and J. A. Hambrook. 2002. Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program. Open-File Report 02-150. U.S. Geological Survey, Reston, Virginia.

Narisada, K. and D. Schreuder. 2004. Light Pollution Handbook. Springer Publishing, Dordrecht, The Netherlands.

National Atmospheric Deposition Program (NADP). 2014. Acid rain. Avaialble at: http://nadp.sws.uiuc.edu/educ/acidrain.aspx. (accessed 9 February 2016).

National Atmospheric Deposition Program (NADP). 2016a. National Atmospheric Deposition Program - Mercury Deposition Network. Avaialble at: http://nadp.sws.uiuc.edu/data/sites/map/?net=MDN. (accessed 9 August 2016).

National Atmospheric Deposition Program (NADP). 2016b. Wet deposition trend plots (NTN Site WV04). Avaialble at: http://nadp.sws.uiuc.edu/data/ntn/plots/ntntrends.html?siteID=WV04. (accessed 4 November 2016).

National Atmospheric Deposition Program (NADP). 2017. Annual MDN maps. Avaialble at: http://nadp.sws.uiuc.edu/mdn/annualmdnmaps.aspx. (accessed 20 March 2017).

National Centers for Environmental Information (NCEI). 2015a. 1981-2010 climate normals for Princeton, WV. Avaialble at: https://www.ncdc.noaa.gov/cdo-web/datatools/normals. (accessed 11 July 2017).

National Centers for Environmental Information (NCEI). 2015b. 1981-2010 Normals for Bluestone Lake, WV. Avaialble at: https://www.ncdc.noaa.gov/cdo-web/datatools/normals. (accessed 25 August 2016).

National Centers for Environmental Information (NCEI). 2017a. Global summary of the month climate data: Bluestone Lake. Avaialble at: https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00460939/detail. (accessed 11 July 2017).

National Centers for Environmental Information (NCEI). 2017b. Global summary of the month climate data: Princeton. Avaialble at: https://www.ncdc.noaa.gov/cdo-web/datasets/GSOM/stations/GHCND:USC00467207/detail. (accessed 11 July 2017).

National Coal Heritage Area (NCHA). 2016. National Coal Heritage Area: Welcome. Avaialble at: http://www.coalheritage.org/Default.aspx. (accessed 8 December 2016).

National Park Service (NPS). 1995. Baseline water quality data inventory and analysis: Bluestone National Scenic River. National Park Service, Water Resources Division, Fort Collins, Colorado.

National Park Service (NPS). 2004. Air resources management: Definitions. Avaialble at: http://www.nature.nps.gov/Rm77/air/define.cfm (accessed 16 March 2016).

National Park Service (NPS). 2006. Management policies 2006. National Park Service, Washington, D.C.

National Park Service (NPS). 2007. Visibility monitoring: Overview. Avaialble at: https://www.nature.nps.gov/air/monitoring/vismon.cfm. (accessed 14 June 2017).

National Park Service (NPS). 2008. Air Atlas summary tables for I & M parks. Avaialble at: http://www.nature.nps.gov/air/permits/ARIS/networks/docs/SummariesAirAtlasRevised11072003.pdf. (accessed 16 March 2016).

National Park Service (NPS). 2009. Development of the natural gas resources in the Marcellus Shale: New York, Pennsylvania, Virginia, West Virginia, Ohio, Tennessee, and Maryland. National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2011. General Management Plan: New River Gorge National River. National Park Service, Glen Jean, West Virginia.

National Park Service (NPS). 2013a. Air quality in national parks: Trends (2000-2009) and conditions (2005-2009). Natural Resource Report NPS/NRSS/ARD/NRR—2013/683. National Park Service, Air Resources Division, Denver, Colorado.

National Park Service (NPS). 2013b. Methods for determining air quality conditions and trends for park planning and assessment. National Park Service, Air Resources Division, Denver, Colorado.

National Park Service (NPS). 2014. Hydrographic & impairment statistics. Avaialble at: http://nature.nps.gov/water/HIS/index.cfm. (accessed 11 November 2016).

National Park Service (NPS). 2015a. Air quality conditions & trends by park. Avaialble at: http://www.nature.nps.gov/air/data/products/parks/index.cfm. (accessed 8 August 2016).

National Park Service (NPS). 2015b. Draft National Park Service air quality analysis method: September 2015. Natural Resources Report NPS/ARD/NRR-2015/XXX. National Park Service, Air Resources Division, Denver, Colorado.

National Park Service (NPS). 2015c. Listing of acreage (summary). National Park Service, Fort Collins, Colorado.

National Park Service (NPS). 2016a. 2012-2014 mercury deposition estimates. National Park Service, Air Resources Division Unpublished Report, Denver, Colorado.

National Park Service (NPS). 2016b. BLUE Certified Species List: NPSpecies. Avaialble at: https://irma.nps.gov/NPSpecies/Search/SpeciesList/BLUE. (accessed 15 November 2016).

National Park Service (NPS). 2016c. Bluestone National Scenic River: Mammals. Avaialble at: https://www.nps.gov/blue/learn/nature/mammals.htm. (accessed 8 May 2018).

National Park Service (NPS). 2016d. Bluestone National Scenic River: Things to do. Avaialble at: https://www.nps.gov/blue/planyourvisit/things2do.htm. (accessed 28 September 2017).

National Park Service (NPS). 2016e. Things to do: Hiking. Avaialble at: https://www.nps.gov/blue/planyourvisit/hiking.htm. (accessed 28 April 2017).

National Park Service (NPS). 2017a. ERMN continuous water quality monitoring data, 2013-2014. Available at https://irma.nps.gov/aqwebportal/. (accessed 16 February 2017).

National Park Service (NPS). 2017b. NPS stats: Annual park recreation visitation. Avaialble at: https://irma.nps.gov/Stats/Reports/Park. (accessed 28 September 2017).

National Park Service (NPS). 2017c. Park water quality database. Distributed by National Park Service. Glen Jean, West Virginia.

National Park Service Natural Sounds and Night Skies Division (NPS NSNSD). 2015. Night sky monitoring report metrics. Avaialble at: http://sierranights.com/nightsky/dataPageExplain.htm. (accessed 8 February 2016).

National Weather Service (NWS). 2012. Derecho event of June 29th, 2012. Avaialble at: https://www.weather.gov/rlx/SVR062912. (accessed 20 April 2017).

Natural Resources Conservation Service (NRCS) and National Park Service (NPS). 2013. Soil survey of Bluestone National Scenic River, West Virginia. Natural Resources Conservation Service, Washington, D.C.

NatureServe. 2011. Ecological association comprehensive report: *Quercus* (*rubra*, *alba*)/*Carpinus caroliniana* - (*Halesia tetraptera*)/*Maianthemum racemosum* Forest. Avaialble at: http://explorer.natureserve.org/servlet/NatureServe?searchCommunityUid=ELEMENT_GLOBAL.2.793418. (accessed 23 October 2017).

NatureServe. 2016. Element occurrence data standard. Avaialble at: http://www.natureserve.org/conservation-tools/standards-methods/element-occurrence-data-standard. (accessed 22 April 2016).

Norris, S. J. 1992. Rare species survey of Bluestone Scenic River. West Virginia Natural Heritage Program, Elkins, West Virginia.

North American Bird Conservation Initiative (NABCI). 2009. The state of the birds, United States of America. U.S. Department of the Interior, Washington, D.C.

North American Bird Conservation Initiative (NABCI), U. S. C. 2010. The State of the Birds: 2010 report on climate change. U.S. Department of the Interior, Washington, D.C.

Nowacki, G. J., and M. D. Abrams. 2008. The demise of fire and "mesophication" of forests in the eastern United States. BioScience 58(2):123-138.

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 1998a. A bird community index of biotic integrity for the Mid-Atlantic Highlands. Environmental Monitoring and Assessment 51:145-156.

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 1998b. The bird community index: A tool for assessing biotic integrity in the Mid-Atlantic Highlands. Report 98-4 of the Penn State Cooperative Wetlands Center. The Pennsylvania State University, University Park, Pennsylvania.

O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. Ecological Applications 10:1706-1721.

Oxley, E. 1975. Floristics and vegetation of the gorge region of Indian Branch. West Virginia Division of Natural Resources Unpublished Report, South Charleston, West Virginia.

Pardo, L. H., M. E. Fenn, C. L. Goodale, L. H. Geiser, C. T. Driscoll, E. B. Allen, J. S. Baron, R. Bobbink, W. D. Bowman, C. M. Clark, and others. 2011. Effects of nitrogen deposition and empirical nitrogen critical loads for ecoregions of the United States. Ecological Applications 21(8):3049-3082.

Pauley, T. K., M. B. Watson, and R. A. Canterbury. 2003. Vertebrates of the Bluestone National Scenic River. National Park Service, Glen Jean, West Virginia.

Pauley, T. K. 2006. Upland wetlands: Amphibians and reptiles. West Virginia Division of Natural Resources, Natural Heritage Program Unpublished Report, Elkins, West Virginia.

Perles, S. J., K. K. Callahan, and M. R. Marshall. 2010. Condition of vegetation communities in Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River: Eastern Rivers and Mountains Network summary report 2007–2009. Natural Resource Data Series NPS/ERMN/NRDS—2010/036. National Park Service, Fort Collins, Colorado.

Perles, S. J., T. Wagner, B. Irwin, D. R. Manning, K. K. Callahan, and M. R. Marshall. 2012. Long-term forest health monitoring program in the Eastern Mountains and Rivers Network, evaluation of the statistical power to detect temporal trends. Natural Resource Technical Report NPS/ERMN/NRTR–2012/637. National Park Service, Fort Collins, Colorado.

Perles, S. J., D. R. Manning, K. K. Callahan, and M. R. Marshall. 2014a. Condition of soils in Eastern Rivers and Mountains Network Parks. Natural Resource Technical Report NPS/ERMN/NRTR—2014/891. National Park Service, Fort Collins, Colorado.

Perles, S. J., D. R. Manning, K. K. Callahan, and M. R. Marshall. 2014b. Forest health monitoring in the Eastern Rivers and Mountains Network: 2009-2012 summary report. Natural Resource Report NPS/ERMN/NRR— 2014/803. National Park Service, Fort Collins, Colorado.

Perles, S. J., J. Finley, D. R. Manning, and M. R. Marshall. 2014c. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, version 3. Natural Resource Report NPS/ERMN/NRR—2014/758

Perles, S. J., D. R. Manning, K. K. Callahan, and M. R. Marshall. 2016. Forest dynamics in National Parks in the Eastern Rivers and Mountains Network. Natural Resource Report NPS/ERMN/NRR—2016/1182. National Park Service, Fort Collins, Colorado.

Piotrowski, J. S., S. L. Annis, and J. E. Longcore. 2004. Physiology of *Batrachochytrium dendrobatidis*, a chytrid pathogen of amphibians. Mycologia 96(1):9-15.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience 47(11):769-784.

Purvis, J. M. 2002. Water resources management plan: New River Gorge National River, Gauley River National Recreation Area, Bluestone National Scenic River, West Virginia. National Park Service, Glen Jean, West Virginia.

Purvis, J. M., and L. Wilson. 2007. Water quality monitoring program 2004-2006: New River Gorge National River, Bluestone National Scenic River, Gauley River National Recreation Area. National Park Service, Glen Jean, West Virginia.

Purvis, J. M. 2009. Water quality monitoring program 2007-2008: New River Gorge National River, Bluestone National Scenic River, Gauley River National Recreation Area. National Park Service, Glen Jean, West Virginia.

Rentch, J. S., R. H. Fortney, S. L. Stephenson, H. S. Adams, W. N. Grafton, R. B. Coxe, and H. H. Mills. 2005. Vegetation patterns within the Lower Bluestone River Gorge in southern West Virginia. Castanea 70(3):184-203.

Rentch, J. S. 2006. Structure and functioning of terrestrial ecosystems in the Eastern Rivers and Mountains Network: Conceptual models and Vital Signs monitoring. Technical Report NPS/NER/NRR-2006/007. National Park Service, Northeast Region, Philadelphia, Pennsylvania.

Richardson, D. M., P. M. Holmes, K. J. Esler, S. M. Galatowitsch, J. C. Stromberg, S. P. Kirkman, P. Pysek, and R. J. Hobbs. 2007. Riparian vegetation: Degradation, alien plant invasions, and restoration prospects. Diversity and Distributions 13:126-139.

Roach, F. E., and J. L. Gordon. 1973. The Light of the Night Sky. D. Reidel Publishing Company, Dordrecht, Holland.

Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings of the National Academy of Sciences of the United States of America 86:7658-7662.

Royo, A. A., and W. P. Carson. 2006. On the formation of dense understory layers in forests worldwide: Consequences and implications for forest dynamics, biodiversity, and succession. Canadian Journal of Forest Research 36:1345-1362.

Runkle, J. R. 1998. Changes in southern Appalachian canopy tree gaps sampled thrice. Ecology 79(5):1768-1780.

Runkle, J. R. 2000. Canopy tree turnover in old-growth mesic forests of eastern North America. Ecology 81(2):554-567.

Ryer, A. 1997. The Light Measurement Handbook. International Light, Inc., Newburyport, Massachusetts.

Schirmacher, M. R., S. B. Castleberry, W. M. Ford, and K. V. Miller. 2007. Habitat associations of bats in south-central West Virginia. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 61:46-52.

Schlarbaum, S. E., F. Hebard, P. C. Spaine, and J. C. Kamalay. 1998. Three American tragedies: Chestnut blight, butternut canker, and Dutch elm disease. Pages 45-54 *in* K. O. Britton, editor.

Exotic pests of eastern forests conference proceedings, 1997 April 8-10. U.S. Forest Service and Tenneseee Exotic Pest Plant Council, Nashville, Tennessee.

Scott, N. J., and R. A. Seigel. 1992. The management of amphibian and reptile populations: Species priorities and methodological and theoretical constraints. Pages 343-368 *in* D. R. McCullough and R. H. Barrett, editors. Wildlife 2001: Populations. Elsevier Publishing Company, London, United Kingdom.

Sheeder, S., B. Evans, and K. Corradini. 2004. Water quality information and regulations summary for the Eastern Rivers and Mountains Network. Appendix C *in* M. R. Marshall and N. B. Piekielek, editors. Eastern Rivers and Mountains Network ecological monitoring plan. National Park Service, Fort Collins, Colorado.

Sheibley, R. W., M. Enache, P. W. Swarzenski, P. W. Moran, and J. R. Foreman. 2014. Nitrogen deposition effects on diatom communities in lakes from three National Parks in Washington state. Water, Air, and Soil Pollution 225:1857.

Sibley, C. G., and J. E. Ahlquist. 1983. Phylogeny and classification of birds based on the data of DNA-DNA hybridization. Current Ornithology:245-292.

Silsbee, D. G., and G. L. Larson. 1982. Water quality of streams in the Great Smoky Mountains National Park. Hydrobiologia 89(2):97-115.

Singer, F. J., W. T. Swank, and E. E. Clebsch. 1984. Effects of wild pig rooting in a deciduous forest. The Journal of Wildlife Management 48(2):464-473.

Small, K. A., and C. Kazimi. 1995. On the costs of air pollution from motor vehicles. University of California Transportation Center, Berkeley, California.

Smith, P. N., G. P. Cobb, C. Godard-Codding, D. Hoff, S. T. McMurry, T. R. Rainwater, and K. D. Reynolds. 2007. Contaminant exposure in terrestrial vertebrates. Environmental Pollution 150:41-64.

Steelhammer, R. 2016. More construction could be in store for Bluestone Dam. Charleston Gazette-Mail, Charleston, West Virginia.

Stoddard, J. L., D. P. Larsen, C. P. Hawkins, R. K. Johnson, and R. J. Norris. 2006. Setting expectations for the ecological condition of streams: The concept of reference condition. Ecological Applications 16(4):1267-1276.

Strayer, D. L. 2010. Alien species in fresh waters: Ecological effects, interactions with other stressors, and prospects for the future. Freshwater Biology 55(Suppl. 1):152-174.

Streets, B. P., J. P. Vanderhorst, C. Good, and G. Short. 2008. Floristic inventory of Bluestone National Scenic River, West Virginia. Technical Report NPS/NER/NRTR—2008/105. National Park Service, Philadelphia, Pennsylvania.

Strickler, L. K. 2014. Hemlock woolly adelgid control project annual report 2012: New River Gorge National River, Gauley River National Recreation Area, and Bluestone National Scenic River. Natural Resource Report NPS/NERI/NRR—2014/818. National Park Service, Fort Collins, Colorado.

Strickler, L. K. 2016. Hemlock management summary 2016. National Park Service Unpublished Report, Glen Jean, West Virginia.

Sullivan, R. J. 1993. Bluestone National Scenic River and Gauley River National Recreation Area: Water quality monitoring program, April-October 1992. National Park Service Glen Jean, West Virginia.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011a. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Eastern Rivers and Mountains Network (ERMN). Natural Resource Report NPS/NRPC/ARD/NRR–2011/355. National Park Service, Denver, Colorado.

Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring National Parks to acidification effects from atmospheric sulfur and nitrogen deposition: Main Report. Natural Resource Report NPS/NRPC/ARD/NRR–2011/349, National Park Service, Denver, Colorado.

Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011c. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: Eastern Rivers and Mountains Network (ERMN). National Park Service, Denver, Colorado.

Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011d. Evaluation of the sensitivity of inventory and monitoring National Parks to nutrient enrichment effects from atmospheric nitrogen deposition: Main Report. Natural Resource Report NPS/NRPC/ARD/NRR—2011/313. National Park Service, Denver, Colorado.

Swecker, C. D. 2012. The status and distribution of invasive crayfishes and their effects on native crayfish communities in West Virginia. Thesis. Marshall University, Huntington, West Virginia.

The H. John Heinz III Center for Science Economics and the Environment. 2008. The state of the nation’s ecosystems 2008: Measuring the land, waters, and living resources of the United States. Island Press, Washington, D.C.

Toews, D. P. L., and D. E. Irwin. 2008. Cryptic speciation in a Holarctic passerine revealed by genetic and bioacoustic analysis. Molecular Ecology 17(11):2691-2705.

Tzilkowski, C. J., K. K. Callahan, M. R. Marshall, and A. S. Weber. 2010. Integrity of benthic macroinvertebrate communities in Bluestone National Scenic River, Gauley River National Recreation Area, and New River Gorge National River: Eastern Rivers and Mountains Network

2009 summary report. Natural Resource Data Series NPS/ERMN/NRDS—2010/026. National Park Service, Fort Collins, Colorado.

Tzilkowski, C. J., M. R. Marshall, and A. S. Weber. 2015. Eastern Rivers and Mountains Network wadeable stream monitoring: Water quality and benthic macroinvertebrate summary report (2008–2013). Natural Resource Data Series NPS/ERMN/NRDS—2015/769. National Park Service, Fort Collins, Colorado.

U.S. Fish and Wildlife Service (USFWS). 2018a. Northern long-eared bat (*Myotis septentrionalis*). Avaialble at: https://www.fws.gov/Midwest/endangered/mammals/nleb/index.html. (accessed 16 May 2018).

U.S. Fish and Wildlife Service (USFWS). 2018b. White-nose syndrome occurence map - by year (2018). Avaialble at: https://www.whitenosesyndrome.org/. (accessed 7 May 2018).

U.S. Forest Service (USFS) and West Virginia Department of Agriculture (WVDA). 2016. 2015 forest health highlights: West Virginia. U.S. Forest Service, Newtown Square, Pennsylvania.

U.S. Geological Survey (USGS). 2011a. Bacteria in water. Avaialble at: http://water.usgs.gov/edu/bacteria.html. (accessed 2 February 2016).

U.S. Geological Survey (USGS). 2011b. National Land Cover Database 2011 (NLCD 2011). Avaialble at: http://www.mrlc.gov/nlcd2011.php. (accessed 11 February 2016).

U.S. Geological Survey (USGS). 2015a. Predicted surface water methylmercury concentrations in National Park Service Inventory and Monitoring Program Parks. Avaialble at: http://wi.water.usgs.gov/mercury/NPSHgMap.html. (accessed 6 February 2017).

U.S. Geological Survey (USGS). 2015b. Water properties and measurements. Avaialble at: http://water.usgs.gov/edu/characteristics.html. (accessed 2 February 2016).

U.S. Geological Survey (USGS). 2016a. National water information system: Mapper. Online database available at: http://maps.waterdata.usgs.gov/mapper/index.html. (accessed 31 March 2016).

U.S. Geological Survey (USGS). 2016b. Ranavirus. Avaialble at: http://www.nwhc.usgs.gov/disease_information/other_diseases/ranavirus.jsp. (accessed 31 March 2016).

U.S. Geological Survey (USGS). 2017a. Deadly fungus affecting hibernating bats could spread during summer. U.S. Geological Survey, Reston, Virginia.

U.S. Geological Survey (USGS). 2017b. Turbidity: Units of measurement. Avaialble at: https://or.water.usgs.gov/grapher/fnu.html. (accessed 2 October 2017).

Van Lear, D. H. and T. A. Waldrop. 1989. History, uses, and effects of fire in the Appalachians. General Technical Report SE-54. U.S. Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.

Vanderhorst, J. P., B. P. Streets, J. Jeuck, and S. C. Gawler. 2008. Vegetation classification and mapping of Bluestone National Scenic River, West Virginia. Technical Report NPS/NER/NRTR—2008/106. National Park Service, Philadelphia, Pennsylvania.

Waite, I. R., A. T. Herlihy, D. P. Larsen, and D. J. Klemm. 2000. Comparing strengths of geographic and nongeographic classifications of stream benthic macroinvertebrates in the Mid-Atlantic Highlands, USA. Journal of the North American Benthological Society 19(3):429-441.

Walsh, J. D., D. Wuebbles, K. Hayhoe, J. Kossin, K. Kunkel, G. Stephens, P. Thorne, R. Vose, M. Wehner, J. Willis, and others. 2014. Our changing climate. Chapter 2 *in* J. M. Melillo, T. C. Richmond, and G. W. Yohe, editors. Climate change impacts in the United States: The third national climate assessment. U.S. Global Change Research Program, Washington, D.C.

Weakland, C. A., and P. B. Wood. 2002. Cerulean warbler (*Dendroica cerulea*) microhabitat and landscape-level habitat characteristics in southern West Virginia in relation to mountaintop mining/valley fills. U.S. Geological Survey, Biological Resources Division, Reston, Virginia.

Webber, J. S. 2012. Water quality condition assessment of streams in national parks of the Mid-Atlantic USA integrating physical, chemical, and biological datasets. Pennsylvania State University, School of Forest Resources, State College, Pennsylvania.

Weese, J. A. 1992. AIPM gypsy moth monitoring program, 1992 trapping summary: New River Gorge National River, Gauley River National Recreation Area, Bluestone National Scenic River. National Park Service Unpublished Report, Glen Jean, West Virginia.

Welsh, H. H., and L. M. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: A case study from California's Redwoods. Ecological Applications 8(4):1118-1132.

Welsh, S. A., D. A. Cincotta, and J. F. Switzer. 2006. Fishes of Bluestone National Scenic River. Technical Report NPS/NER/NRTR – 2006/049. National Park Service, Philadelphia, Pennsylvania.

West Virginia Department of Environmental Protection (WVDEP). 2014. Requirements governing water quality standards (Title 47, Series 2). West Virginia Department of Environmental Protection, Charleston, West Virginia.

West Virginia Department of Environmental Protection (WVDEP). 2016a. Biological monitoring. Avaialble at: http://www.dep.wv.gov/wwe/watershed/bio_fish/pages/bio_fish.aspx. (accessed 1 November 2016).

West Virginia Department of Environmental Protection (WVDEP). 2016b. Oil & gas wells (OOG) shapefile. Distributed by West Virginia Department of Environmental Protection. Available at: http://tagis.dep.wv.gov/home/Downloads. (accessed 26 January 2017).

West Virginia Department of Environmental Protection (WVDEP). 2017. WVDEP acting mining program file geodatabase. Distributed by West Virginia Department of Environmental Protection. Available at: https://tagis.dep.wv.gov/home/Downloads. (accessed 7 February 2017).

West Virginia Division of Natural Resources (WVDNR). 2001. Mammals of West Virginia: A field checklist. West Virginia Division of Natural Resources, South Charleston, West Virginia.

West Virginia Division of Natural Resources (WVDNR). 2008. History of wildlife management in West Virginia. West Virginia Wildlife 8(2):2-18.

West Virginia Division of Natural Resources (WVDNR). 2011. Big game bulletin. West Virginia Division of Natural Resources, South Charleston, West Virginia.

West Virginia Division of Natural Resources (WVDNR). 2014. West Virginia invasive species strategic plan and voluntary guidelines. West Virginia Division of Natural Resources, Wildlife Resources Section, Charleston, West Virginia.

West Virginia Division of Natural Resources (WVDNR). 2015. 2015 West Virginia state wildlife action plan. West Virginia Department of Natural Resources, South Charleston, West Virginia.

West Virginia Division of Natural Resources (WVDNR). 2016a. Big game bulletin 2015. West Virginia Division of Natural Resources, South Charleston, West Virginia.

West Virginia Division of Natural Resources (WVDNR). 2016b. West Virginia migratory bird hunting: regulations summary Sept. 2016-Jan. 2017. Avaialble at: http://wvdnr.gov/hunting/Regs1617/2016_17migBirdRegs.pdf. (accessed 15 November 2016).

West Virginia Division of Natural Resources (WVDNR). 2017a. Rare, threatened and endangered species in West Virginia. Avaialble at: http://www.wvdnr.gov/Wildlife/RareSpecList.shtm. (accessed 16 May 2017).

West Virginia Division of Natural Resources (WVDNR). 2017b. West Virginia hunters harvest 3,012 black bears in 2016. West Virginia Division of Natural Resources, South Charleston, West Virginia.

West Virginia Division of Natural Resources (WVDNR). 2017c. West Virginia hunters harvest 112,384 deer in 2016. West Virginia Division of Natural Resources, South Charleston, West Virginia.

West Virginia Division of Natural Resources (WVDNR). 2018. West Virginia hunters harvest 3,160 black bears in 2017. West Virginia Division of Natural Resources, South Charleston, West Virginia.

West Virginia Invasive Species Working Group (WVISWG). 2011. Hydrilla. Avaialble at: https://sites.google.com/site/wviswg/species/plants/hydrilla. (accessed 18 September 2017).

West Virginia Natural Heritage Program (WVNHP). 2009. Invasive plant species of West Virginia. West Virginia Division of Natural Resources, Natural Heritage Program, South Charleston, West Virginia.

Wickham, J., P. B. Wood, M. C. Nicholson, W. Jenkins, D. Druckenbrod, G. W. Suter, M. P. Strager, C. Mazzarella, W. Galloway, and J. Amos. 2013. The overlooked terrestrial impacts of mountaintop mining. BioScience 63(5):335-348.

Wilson, L., and J. M. Purvis. 2000. Water quality monitoring program, 1994-1997: New River Gorge National River, Bluestone National Scenic River, Gauley River National Recreation Area. National Park Service, Glen Jean, West Virginia.

Wilson, L., and J. M. Purvis. 2003. Water quality monitoring program, 1998-2000: New River Gorge National River, Bluestone National Scenic River, Gauley River National Recreation Area. National Park Service, Glen Jean, West Virginia.

Wilson, L., K. Vandersall, and J. M. Purvis. 2006. Water quality monitoring program 2001-2003: New River Gorge National River, Bluestone National Scenic River, Gauley River National Recreation Area. National Park Service, Glen Jean, West Virginia.

Wood, J. M., P. B. Wood, and J. Perez. 2009. Hemlock ecosystem monitoring of New River Gorge National River and Gauley River National Recreation Area vegetation and bird communities: 1998–2008. Natural Resources Report NPS/NER/NRR—2009/019. National Park Service, Philadelphia, Pennsylvania.

Woodhams, D. C., R. A. Alford, and G. Marantelli. 2003. Emerging disease of amphibians cured by elevated body temperature. Diseases of Aquatic Organisms 55:65-67.

World Resources Institute (WRI) and International Institute for Environment and Development. 1989. World Resources 1988-89. Basic Books, New York, New York.

Wotawa, G., and M. Trainer. 2000. The influence of Canadian forest fires on pollutant concentrations in the United States. Science 288:324-328.

Yap, T. A., M. S. Koo, R. F. Ambrose, D. B. Wake, and V. T. Vredenburg. 2015. Averting a North American biodiversity crisis: A newly described pathogen poses a major threat to salamanders via trade. Science 349(6247):481-482.

Appendix A. Plant species observations in upland forests at Bluestone National Scenic River.

Table A-1. Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Acalypha gracilens	slender threeseed mercury	–	–	–	X	–
Acalypha rhomboidea	common threeseed mercury	–	–	–	–	X
Acer negundo var. negundo	boxelder	X	–	–	X	X
Acer nigrum	black maple	–	–	–	X	X
Acer pensylvanicum	striped maple	X	–	–	X	X
Acer rubrum var. rubrum	red maple	X	–	X	X	X
Acer saccharum var. saccharum	sugar maple	X	–	X	X	X
Achillea millefolium[b]	common yarrow	X	–	–	X	X
Actaea racemosa	black baneberry		–	–	–	X
Adiantum pedatum	maidenhair fern	X	–	–	X	X
Aesculus flava	yellow buckeye	X	–	X	X	X
Ageratina altissima var. altissima	white snakeroot	–	–	–	X	X
Agrimonia gryposepala	tall hairy agrimony	–	–	–	–	X
Agrimonia microcarpa	smallfruit agrimony	–	N	–	–	X
Agrimonia parviflora	harvestlice	–	–	–	X	X
Agrimonia pubescens	soft agrimony	–	–	–	X	X
Agrimonia rostellata	beaked agrimony	–	–	–	X	X
Agrostis capillaris[b]	colonial bentgrass	–	–	–	X	–

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Agrostis perennans	upland bentgrass	–	–	–	X	X
Ailanthus altissima[b]	tree–of–heaven	–	–	–	–	X
Albizia julibrissin[b]	silktree	–	–	–	X	–
Alliaria petiolata[b]	garlic mustard	X	–	–	X	X
Allium cernuum	nodding onion	X	G	X	X	X
Ambrosia artemisiifolia	annual ragweed	X	–	–	–	X
Amelanchier arborea	common serviceberry	X	–	X	X	–
Amelanchier spicata (stolonifera)	running serviceberry	–	–	–	–	X
Ampelopsis arborea[b]	peppervine	–	–	–	X	–
Amphicarpaea bracteata	American hogpeanut	–	–	–	X	X
Anemone acutiloba	sharplobe hepatica	X	–	–	X	X
Anemone americana	roundlobe hepatica	–	–	–	–	X
Anemone quinquefolia var. quinquefolia	nightcaps	X	–	–	X	X
Anemone virginiana	tall thimbleweed	–	–	–	–	X
Anomodon attenuatus[c]	anomodon moss	–	–	–	X	–
Antennaria plantaginifolia	plantainleaf pussytoes	X	–	X	X	X
Antennaria virginica	shale barren pussytoes	–	–	–	X	–
Apios americana	groundnut	–	–	X	–	X
Aplectrum hyemale	Adam and Eve	X	–	–	–	X
Apocynum cannabinum	Indianhemp	–	–	–	–	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Aralia nudicaulis	wild sarsaparilla	–	–	–	X	–
Aralia racemosa ssp. racemosa	American spikenard	–	–	–	X	–
Arisaema triphyllum	Jack–in–the–pulpit	X	–	–	X	X
Aristolochia macrophylla	pipevine	X	–	–	X	X
Aristolochia serpentaria	Virginia snakeroot	–	–	–	X	X
Arnoglossum reniforme	great Indian plaintain	–	–	–	X	–
Asarum canadense	Canadian wild ginger	–	–	–	X	X
Asclepias quadrifolia	fourleaf milkweed	X	–	–	X	X
Asclepias tuberosa	butterfly milkweed	X	–	–	X	–
Asclepias verticillata	whorled milkweed	–	–	–	X	–
Asimina triloba	pawpaw	–	–	–	X	X
Asplenium × ebenoides	Scott's spleenwort	–	–	–	X	–
Asplenium platyneuron	ebony spleenwort	X	–	–	X	X
Asplenium rhizophyllum	walking fern	X	–	–	X	X
Astragalus canadensis	Canadian milkvetch	–	–	–	–	X
Athyrium filix–femina	common ladyfern	–	–	–	–	X
Aulacomnium heterostichum[c]	aulacomnium moss	–	–	–	X	–
Aureolaria flava	smooth yellow false foxglove	–	–	–	X	X
Aureolaria laevigata	entireleaf yellow false foxglove	–	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Aureolaria pedicularia	fernleaf yellow false foxglove	–	–	–	–	X
Aureolaria virginica	downy yellow false foxglove	–	–	–	X	–
Bellis perennis[b]	lawndaisy	–	–	–	–	X
Berberis canadensis	American barberry	X	–	–	X	–
Berberis vulgaris[b]	common barberry	–	–	–	X	–
Betula lenta	sweet birch	X	–	–	X	X
Betula nigra	river birch	X	–	–	X	–
Bidens sp.	beggarticks	–	–	–	–	X
Bidens bipinnata	Spanish needles	X	–	–	X	–
Bidens tripartita	threelobe beggarticks	–	–	–	X	–
Boechera (Arabis) canadensis	sicklepod	–	–	X	–	X
Boechera laevigata	smooth rockcress	X	–	X	X	X
Boehmeria cylindrica	smallspike false nettle	X	–	–	X	–
Botrychium virginianum	rattlesnake fern	X	–	–	X	X
Brachyelytrum erectum	bearded shorthusk	–	–	X	X	X
Brachythecium oxycladon[c]	brachythecium moss	–	–	–	X	–
Brachythecium plumosum[c]	brachythecium moss	–	–	–	X	–
Bromus arvensis[b]	field brome	–	–	–	–	X
Bromus ciliatus	fringed brome	–	–	–	–	X
Bromus kalmii	arctic brome	–	–	–	–	X
Bromus pubescens	hairy woodland brome	–	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Brotherella recurvans[c]	recurved brotherella moss	–	–	–	X	–
Bryoandersonia illecebranv	bryoandersonia moss	–	–	–	X	–
Campanula americana	American bellflower	–	–	–	X	X
Campanula divaricata	small bonny bellflower	X	–	–	X	X
Campsis radicans	trumpet creeper	–	–	–	–	X
Cardamine angustata	slender toothwort	X	–	–	X	–
Cardamine concatenata	cutleaf toothwort	X	–	–	X	–
Cardamine diphylla	crinkleroot	–	–	X	–	X
Cardamine hirsuta	hairy bittercress	–	–	–	X	
Cardamine impatiens[b]	narrowleaf bittercress	–	–	–	X	X
Cardamine parviflora	sand bittercress	–	–	–	X	–
Carex albursina	white bear sedge	–	–	–	X	X
Carex amphibola	eastern narrowleaf sedge	–	–	–	X	X
Carex appalachica	Appalachian sedge	–	–	–	–	X
Carex atlantica ssp. atlantica	prickly bog sedge	–	–	–	–	X
Carex blanda	eastern woodland sedge	–	–	–	X	X
Carex bromoides	bromelike sedge	–	–	–	–	X
Carex caroliniana	Carolina sedge	–	–	–	X	–
Carex cephalophora	oval–leaf sedge	–	–	–	X	X
Carex communis var. communis	fibrousroot sedge	–	–	–	X	–
Carex debilis	white edge sedge	–	–	–	–	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Carex digitalis	slender woodland sedge	–	–	–	–	X
Carex folliculata	northern long sedge	–	–	–	–	X
Carex frankii	Frank's sedge	–	–	–	X	–
Carex gracillima	graceful sedge	–	–	–	X	X
Carex granularis	limestone meadow sedge	–	–	–	–	X
Carex hirsutella	fuzzy wuzzy sedge	–	–	–	X	X
Carex hitchcockiana	Hitchcock's sedge	–	–	–	X	X
Carex intumescens	greater bladder sedge	–	–	–	–	X
Carex jamesii	James' sedge	–	G	–	X	X
Carex laxiculmis var. laxiculmus	spreading sedge	–	–	–	X	X
Carex laxiflora	broad looseflower sedge	–	–	X	X	X
Carex leavenworthii	Leavenworth's sedge	–	–	–	–	X
Carex leptonervia	nerveless woodland sedge	–	–	–	–	X
Carex normalis	greater straw sedge	–	N	–	–	–
Carex oligocarpa	richwoods sedge	–	–	–	X	X
Carex pensylvanica	Pennsylvania sedge	–	G	–	X	–
Carex plantaginea	plantainleaf sedge	–	–	X	X	X
Carex platyphylla	broadleaf sedge	–	–	–	X	X
Carex prasina	drooping sedge	–	–	X	X	X
Carex radiata	eastern star sedge	–	–	–	X	X
Carex retroflexa	reflexed sedge	–	–	–	–	X
Carex rosea	rosy sedge	–	–	–	–	X
Carex swanii	Swan's sedge	–	–	–	X	X
Carex willdenowii	Willdenow's sedge	–	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Carex woodii	pretty sedge	–	N	–	X	–
Carpinus caroliniana ssp. virginiana	American hornbeam	X	–	–	X	X
Carya cordiformis	bitternut hickory	X	–	–	X	X
Carya glabra	pignut hickory	X	–	X	X	X
Carya ovata	shagbark hickory	X	–	X	X	X
Carya tomentosa (C. alba)	mockernut hickory	X	–	X	X	X
Castanea dentata	American chestnut	X	–	X	X	–
Caulophyllum thalictroides	blue cohosh	X	–	–	X	X
Ceanothus americanus	New Jersey tea	–	–	–	X	–
Celastrus orbiculatus[b]	Oriental bittersweet	–	–	–	–	X
Celastrus scandens	American bittersweet	X	–	–	–	X
Celtis occidentalis	common hackberry	–	–	–	X	X
Cerastium glomeratum[b]	sticky chickweed	–	–	–	X	–
Cerastium nutans	nodding chickweed	–	–	–	–	X
Cercis canadensis var. canadensis	eastern redbud	X	–	X	X	X
Cheilanthes lanosa	hairy lipfern	X	–	–	X	–
Chimaphila maculata	striped prince's pine	X	–	–	X	X
Chionanthus virginicus	white fringetree	X	–	–	X	X
Cinna arundinacea	sweet woodreed	–	–	–	–	X
Circaea alpine	Small enchanter's nightshade	–	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Circaea canadensis ssp. canadensis	broadleaf enchanter's nightshade	–	–	–	X	–
Circaea lutetiana	broadleaf enchanter's nightshade	–	–	–	–	X
Cirsium sp.	thistle	–	–	–	–	X
Clematis virginiana	devil's darning needles	X	–	–	X	X
Climacium americanum[c]	American climacium moss	–	–	–	X	–
Clinopodium vulgare	wild basil	X	–	–	–	X
Clintonia sp.	bluebead	–	–	–	–	X
Clintonia umbellulata	white clintonia	X	–	–	X	–
Collinsonia canadensis	richweed	X	–	X	X	X
Conopholis americana	American cancer–root	X	–	–	X	X
Convolvulus sp.	bindweed	–	–	–	–	X
Coreopsis auriculata	lobed tickseed	–	–	–	X	–
Coreopsis major	greater tickseed	X	–	–	X	X
Cornus alternifolia	alternateleaf dogwood	–	–	–	–	X
Cornus amomum	silky dogwood	–	–	–	X	–
Cornus florida	flowering dogwood	–	–	X	X	X
Cornus racemosa	gray dogwood	–	–	–	X	X
Corylus americana	American hazelnut	X	–	–	–	X
Crataegus sp.	hawthorn	X	–	–	X	X
Cryptotaenia canadensis	Canadian honewort	–	–	–	X	X
Cunila origanoides	common dittany	X	–	X	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Cynoglossum officinale[b]	gypsyflower; houndstongue	–	–	–	–	X
Cynoglossum virginianum var. virginianum	wild comfrey	–	–	–	X	X
Cypripedium acaule	moccasin flower	X	–	–	X	–
Dactylis glomerata[b]	orchardgrass	–	–	–	–	X
Danthonia compressa	flattened oatgrass	–	–	–	–	X
Danthonia spicata	poverty oatgrass	–	–	–	X	X
Dennstaedtia punctilobula	eastern hayscented fern	–	–	–	–	X
Desmodium glabellum	Dillenius' ticktrefoil	X	–	–	X	X
Desmodium glutinosum	pointedleaf ticktrefoil	–	–	–	X	X
Desmodium nudiflorum	nakedflower ticktrefoil	–	–	–	X	X
Desmodium rotundifolium	prostrate ticktrefoil	–	–	–	X	–
Desmodium viridiflorum	velvetleaf ticktrefoil	–	–	–	–	X
Diarrhena americana	American beakgrain	–	–	–	–	X
Dichanthelium boscii	Bosc's panicgrass	–	–	X	X	X
Dichanthelium clandestinum	deertongue	–	–	–	X	X
Dichanthelium commutatum	variable panicgrass	–	–	–	X	X
Dichanthelium depauperatum	starved panicgrass	–	–	–	X	–
Dichanthelium dichotomum	cypress panicgrass	–	–	X	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Dichanthelium dichotomum var. dichotomum	cypress panicgrass	–	–	–	X	X
Dichanthelium dichotomum ssp. yadkinense	cypress panicgrass	–	–	–	X	–
Dichanthelium latifolium	broadleaf rosette grass	–	–	–	–	X
Dichanthelium linearifolium	slimleaf panicgrass	–	–	–	–	X
Dicranodontium denudatum[c]	denuded dicranodontium moss	–	–	–	X	–
Dicranum fulvum[c]	dicranum moss	–	–	–	X	–
Dicranum scoparium[c]	dicranum moss	–	–	–	X	–
Dioscorea quaternata	fourleaf yam	X	–	X	X	X
Dioscorea villosa	wild yam	–	–	X	–	X
Dirca palustris	eastern leatherwood	–	–	–	X	X
Doellingeria infirma	cornel–leaf whitetop	–	–	X	–	X
Draba ramosissima	branched draba	X	–	–	X	–
Dryopteris carthusiana	spinulose wood fern	X	–	X	–	X
Dryopteris intermedia	intermediate woodfern	X	–	–	X	X
Dryopteris marginalis	marginal woodfern	X	–	X	X	X
Elaeagnus umbellata var. parvifolia[b]	autumn olive	–	–	–	X	X
Elymus hystrix var. hystrix	eastern bottlebrush grass	–	–	–	X	X
Elymus riparius	riverbank wildrye	–	–	–	–	X
Elymus virginicus var. virginicus	Virginia wildrye	–	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Epifagus virginiana	beechdrops	X	–	–	X	X
Epigaea repens	trailing arbutus	X	–	–	X	X
Erechtites hieraciifolius var. hieraciifolius	American burnweed	–	–	–	X	X
Erigeron sp.	fleabane	–	–	–	–	X
Erigeron annuus	eastern daisy fleabane	–	–	–	X	–
Erigeron strigosus var. strigosus	prairie fleabane	–	–	–	X	–
Erythronium americanum	dogtooth violet	X	–	X	–	–
Euonymus americana	strawberry bush; bursting–heart	–	–	–	X	X
Euonymus atropurpureus	burningbush	–	–	–	–	X
Eupatorium sp.	thoroughwort	–	–	–	–	X
Eupatorium fistulosum	trumpetweed	X	–	–	X	–
Eurybia divaricata	white wood aster	X	–	X	X	X
Eurybia macrophylla	bigleaf aster	–	–	–	X	X
Eurybia schreberi	Schreber's aster	–	–	–	X	X
Euthamia graminifolia	flat–top goldentop	–	–	–	–	X
Eutrochium purpureum	sweetscented joepyeweed	–	–	–	–	X
Fagus grandifolia	American beech	X	–	X	X	X
Fallopia scandens (Polygonum scandens)	climbing false buckwheat	X	–	–	X	X
Festuca subverticillata	nodding fescue	–	–	–	X	X
Fraxinus americana	white ash	X	–	–	X	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Fraxinus pennsylvanica	green ash	–	–	–	X	X
Galinsoga sp.	shaggy soldier	–	–	X	–	–
Galium aparine	stickywilly	X	–	–	X	X
Galium circaezans	licorice bedstraw	–	–	–	X	X
Galium circaezans var. hypomalacum	licorice bedstraw	–	–	–	X	–
Galium lanceolatum	lanceleaf wild licorice	–	–	–	X	X
Galium latifolium	purple bedstraw	–	–	–	X	X
Galium obtusum	bluntleaf bedstraw	–	–	–	–	X
Galium pilosum	hairy bedstraw	–	–	X	–	X
Galium triflorum	fragrant bedstraw	–	–	–	X	X
Gaultheria procumbens	eastern teaberry	X	–	–	X	X
Gaylussacia baccata	black huckleberry	–	–	–	X	X
Geranium maculatum	spotted geranium	X	–	X	X	X
Geum canadense	white avens	–	–	–	X	X
Geum vernum	spring avens	–	–	–	X	X
Geum virginianum	cream avens	–	–	–	–	X
Gillenia stipulata	Indian physic	–	–	–	–	X
Gillenia trifoliata	Bowman's root	X	–	–	–	X
Glechoma hederacea[b]	ground ivy	–	–	–	X	X
Gleditsia triacanthos	honeylocust	–	–	–	X	X
Glyceria melicaria	melic mannagrass	–	–	–	–	X
Glyceria striata	fowl mannagrass	–	–	–	–	X
Goodyera pubescens	downy rattlesnake–plantain	X	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Gymnadeniopsis (Platanthera) clavellata	small green wood orchid	–	–	–	–	X
Hackelia floribunda	manyflower stickseed	–	–	–	–	X
Hackelia virginiana	beggarslice	–	–	–	–	X
Halesia carolina	mountain silverbell	–	–	–	–	X
Hamamelis virginiana	American witchhazel	X	–	X	X	X
Hedwigia ciliata[c]	ciliate hedwigia moss	–	–	–	X	–
Helianthus divaricatus	woodland sunflower	X	–	–	X	X
Heliopsis helianthoides	smooth oxeye	–	–	–	–	X
Hesperis matronalis[b]	dame's rocket	–	–	–	X	–
Heuchera americana var. americana	American alumroot	X	–	–	X	X
Heuchera americana var. hispida	American alumroot	–	–	–	X	–
Heuchera villosa var. villosa	hairy alumroot	–	–	–	X	–
Hexastylis virginica	Virginia heartleaf	X	–	–	X	–
Hieracium paniculatum	Allegheny hawkweed	–	–	–	X	–
Hieracium venosum	rattlesnakeweed	X	–	–	X	X
Houstonia longifolia	longleaf summer bluet	X	–	X	X	X
Hybanthus concolor	eastern greenviolet	–	–	–	–	X
Hydrangea arborescens	wild hydrangea	X	–	–	X	–
Hydrastis canadensis	goldenseal	X	–	–	–	X
Hydrophyllum canadense	bluntleaf waterleaf	–	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Hydrophyllum virginianum	eastern waterleaf	X	–	–	X	X
Hypericum densiflorum	bushy St. Johnswort	–	–	–	–	X
Hypericum hypericoides	St. Andrew's cross	–	–	–	–	X
Hypericum mutilum	dwarf St. Johnswort	–	–	–	–	X
Hypericum perforatum[b]	common St. John's wort	–	–	–	X	X
Hypericum prolificum	shrubby St. Johnswort	–	–	–	X	X
Hypericum punctatum	spotted St. Johnswort	–	–	–	X	X
Hypnum imponens[c]	hypnum moss	–	–	–	X	–
Hypopitys monotropa	pinesap	–	–	–	X	X
Hypoxis hirsuta	common goldstar	–	–	–	X	–
Ilex montana	mountain holly	–	–	–	–	X
Ilex verticillata	common winterberry	–	–	–	–	X
Impatiens sp.	touch–me–not	–	–	–	–	X
Impatiens capensis	jewelweed	X	–	–	X	–
Ipomoea pandurata	man of the earth	–	–	–	X	–
Juglans nigra	black walnut	X	G	–	X	X
Juncus effusus	common rush	–	–	–	X	X
Juniperus virginiana var. virginiana	eastern redcedar	X	–	–	X	X
Kalmia latifolia	mountain laurel	X	–	–	X	–
Lactuca sp.	lettuce	–	–	–	–	X
Lactuca canadensis	Canada lettuce	–	–	–	X	–
Lamium purpureum[b]	purple deadnettle	–	–	–	–	X
Laportea canadensis	Canada woodnettle	–	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Lathyrus venosus	veiny pea	X	–	–	X	–
Lechea tenuifolia	narrowleaf pinweed	–	–	–	–	X
Leersia oryzoides	rice cutgrass	–	–	–	–	X
Leersia virginica	whitegrass	–	–	–	X	X
Lespedeza sp.	lespedeza	–	–	–	–	X
Lespedeza frutescens	shrubby lespedeza	–	–	–	X	–
Lespedeza procumbens	trailing lespedeza	–	–	–	X	–
Lespedeza violacea	violet lespedeza	X	–	–	X	–
Leucobryum glaucum[c]	leucobryum moss	–	–	–	X	–
Ligusticum canadense	Canadian licorice–root	–	–	–	X	–
Ligustrum sp. [b]	privet	–	–	–	–	X
Ligustrum vulgare[b]	European privet	–	–	–	X	–
Lilium superbum	turk's–cap lily	–	–	–	–	X
Lindera benzoin	northern spicebush	X	–	–	X	X
Liparis sp.	widelip orchid	–	–	–	X	–
Liriodendron tulipifera	tuliptree	X	–	X	X	X
Lithospermum latifolium	American stoneseed	–	–	–	X	X
Lobelia inflata	Indian–tobacco	X	–	–	X	X
Lobelia siphilitica	great blue lobelia	X	–	–	–	X
Lonicera canadensis	American fly honeysuckle	X	–	–	–	–
Lonicera japonica[b]	Japanese honeysuckle	X	–	–	X	X
Lonicera maackii[b]	Amur honeysuckle	–	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Lonicera morrowii[b]	Morrow's honeysuckle	–	–	–	–	X
Luzula multiflora ssp. multiflora	common woodrush	–	–	–	X	–
Lycopodium digitatum[c]	fan clubmoss	X	–	–	X	X
Lycopus uniflorus	northern bugleweed	–	–	–	–	X
Lycopus virginicus	Virginia water horehound	–	–	–	X	X
Lysimachia ciliata	fringed loosestrife	–	–	–	X	X
Lysimachia nummularia[b]	creeping jenny	–	–	–	X	X
Lysimachia quadrifolia	whorled yellow loosestrife	–	–	–	X	X
Lysimachia tonsa	southern yellow loosestrife	X	N	–	–	–
Magnolia acuminata	cucumber–tree	X	–	–	X	X
Maianthemum canadense	Canada mayflower	X	–	–	X	–
Maianthemum racemosum ssp. racemosum	feathery false lily of the valley	X	–	–	X	X
Malus sp.	apple	–	–	–	–	X
Meehania cordata	Meehan's mint	X	–	–	–	X
Menispermum canadense	common moonseed	–	–	–	–	X
Metzgeria conjugata[c]	liverwort	–	–	–	X	–
Metzgeria crassipilis[c]	liverwort	–	–	–	X	–
Microstegium vimineum[b]	Japanese stiltgrass	–	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Mitchella repens	partridgeberry	X	–	–	X	X
Mitella diphylla	twoleaf miterwort	X	–	–	X	X
Mnium sp.[c]	mnium calcareous moss	–	–	–	X	–
Monarda clinopodia	white bergamot	–	–	–	X	X
Monarda fistulosa var. brevis	wild bergamot	X	N	–	X	–
Monotropa uniflora	Indianpipe	X	–	–	X	X
Morus rubra	red mulberry	X	–	–	X	X
Muhlenbergia sobolifera	rock muhly	–	–	–	–	X
Muhlenbergia sylvatica	woodland muhly	–	–	–	–	X
Myosotis macrosperma	largeseed forget–me–not	–	–	–	X	–
Myosotis verna	spring forget–me–not	–	–	–	X	–
Nyssa sylvatica	blackgum	–	–	X	X	X
Oclemena acuminata	whorled wood aster	–	–	–	–	X
Onoclea sensibilis	sensitive fern	X	–	–	X	X
Ophioglossum vulgatum	southern adderstongue	–	–	–	–	X
Orthotrichum sp.[c]	orthotrichum moss	–	–	–	X	–
Osmorhiza claytonii	Clayton's sweetroot	–	–	–	X	X
Osmorhiza longistylis	longstyle sweetroot	–	–	–	X	X
Ostrya virginiana	hophornbeam	X	–	X	X	X
Oxalis corniculata[b]	creeping woodsorrel	–	–	–	X	–
Oxalis dillenii	slender yellow woodsorrel	–	–	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Oxalis grandis	great yellow woodsorrel	–	–	–	X	X
Oxalis stricta	common yellow oxalis	–	–	–	–	X
Oxalis violacea	violet woodsorrel	–	–	–	X	X
Oxydendrum arboreum	sourwood	X	–	–	X	X
Packera aurea	golden ragwort	X	–	–	X	X
Packera obovata	roundleaf ragwort	–	–	–	X	X
Panax quinquefolius	American ginseng	–	–	–	X	X
Paronychia canadensis	smooth forked nailwort	–	–	–	X	X
Paronychia fastigiata var. fastigiata	hairy forked nailwort	–	–	–	X	–
Parthenocissus quinquefolia	Virginia creeper	–	–	–	X	X
Passiflora lutea	yellow passionflower	–	–	–	X	X
Pellaea atropurpurea	purple cliffbrake	X	–	–	X	X
Penstemon hirsutus	hairy beardtongue	–	–	–	X	–
Penstemon pallidus	pale beardtongue	–	–	–	X	–
Persicaria longiseta[b]	oriental ladysthumb	–	–	–	X	–
Persicaria posumbu[b] *(Polygonum caespitosum)*	oriental ladysthumb	–	–	–	–	X
Persicaria (Polygonum) virginiana	jumpseed	X	–	–	X	X
Phegopteris hexagonoptera	broad beechfern	–	–	–	X	–
Phlox stolonifera	creeping phlox	X	–	–	–	X
Phlox subulata	moss phlox	X	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Phryma leptostachya	American lopseed	–	–	–	X	X
Phytolacca americana var. americana	American pokeweed	X	–	–	X	X
Pilea pumila	Canadian clearweed	–	–	–	X	X
Pinus strobus	eastern white pine	X	G	X	X	X
Pinus virginiana	Virginia pine	X	–	–	X	X
Plagiomnium ciliare[c]	plagiomnium moss	–	–	–	X	–
Plagiothecium denticulatum[c]	toothed plagiothecium moss	–	–	–	X	–
Plantago major[b]	common plantain	–	–	–	–	X
Platanthera orbiculata	lesser roundleaved orchid	–	–	–	X	–
Platanus occidentalis	American sycamore	X	–	–	X	X
Poa alsodes	grove bluegrass	–	–	–	X	–
Poa compressa[b]	Canada bluegrass	–	–	–	–	X
Poa cuspidata	early bluegrass	–	–	–	X	X
Poa sylvestris	woodland bluegrass	–	–	–	X	X
Poa trivialis[b]	rough bluegrass	–	–	–	X	–
Podophyllum peltatum	mayapple	X	–	–	X	X
Polygala paucifolia	gaywings	X	–	–	X	X
Polygonatum biflorum	smooth Solomon's seal	X	–	X	X	X
Polygonatum pubescens	hairy Solomon's seal	–	–	–	X	X
Polypodium appalachianum	Appalachian polypody	–	–	–	X	–
Polypodium virginianum	rock polypody	X	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Polystichum acrostichoides	Christmas fern	X	–	X	X	X
Polytrichum juniperinum[c]	juniper polytrichum moss	–	–	–	X	–
Polytrichum ohioense[c]	Ohio polytrichum moss	–	–	–	X	–
Populus grandidentata	bigtooth aspen	–	–	–	X	X
Potentilla canadensis	dwarf cinquefoil	–	–	X	X	X
Potentilla simplex	common cinquefoil	X	–		X	X
Prenanthes alba	white rattlesnakeroot	X	–	X	X	X
Prenanthes altissima	tall rattlesnakeroot	–	–	–	X	
Prenanthes trifoliolata	gall of the earth	–	–	–	–	X
Primula meadia	pride of Ohio	–	–	–	X	
Prosartes lanuginosa	yellow fairybells	–	–	X	–	X
Prunella vulgaris	common selfheal	X	–	–	–	X
Prunus avium[b]	sweet cherry	–	–	–	–	X
Prunus serotina var. serotina	black cherry	X	–	X	X	X
Pteridium aquilinum	western brackenfern	–	–	–	X	–
Pycnanthemum incanum var. incanum	hoary mountainmint	–	–	–	X	–
Pycnanthemum tenuifolium	narrowleaf mountainmint	–	–	–	–	X
Pylaisiadelpha tenuirostris[c]	pylaisiadelpha moss	–	–	–	X	–
Pyrularia pubera	buffalo nut	X	–	–	X	X
Pyrus pyrifolia[b]	Chinese pear	–	–	–	X	–
Quercus alba	white oak	X	–	X	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Quercus coccinea	scarlet oak	X	–	–	X	X
Quercus montana (Q. prinus)	chestnut oak	X	–	X	X	X
Quercus muehlenbergii	chinkapin oak	–	–	–	X	X
Quercus rubra	northern red oak	X	–	X	X	X
Quercus velutina	black oak	X	–	X	X	X
Ranunculus abortivus	littleleaf buttercup	–	–	–	X	X
Ranunculus fascicularis	early buttercup	–	–	–	X	–
Ranunculus recurvatus var. recurvatus	blisterwort	X	–	–	X	X
Rhododendron calendulaceum	flame azalea	X	–	–	–	X
Rhododendron maximum	great laurel	X	–	–	X	X
Rhus aromatica var. aromatica	fragrant sumac	–	–	–	X	X
Rhus glabra	smooth sumac	X	–	–	–	X
Rhus typhina	staghorn sumac	X	–	–	–	X
Robinia pseudoacacia	black locust	X	–	X	X	X
Rosa carolina var. carolina	Carolina rose	X	–	–	X	X
Rosa multiflora[b]	multiflora rose	X	–	–	X	X
Rubus flagellaris	northern dewberry	X	–	–	–	X
Rubus hispidus	bristly dewberry	–	–	–	–	X
Rubus occidentalis	black raspberry	X	–	–	X	X
Rubus odoratus var. odoratus	purpleflowering raspberry	X	–	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Rubus phoenicolasius[b]	wine raspberry, wineberry	X	–	–	X	X
Rudbeckia laciniata	cutleaf coneflower	X	–	–	–	X
Rumex acetosella[b]	common sheep sorrel	X	–	–	–	X
Salvia lyrata	lyreleaf sage	–	–	–	X	X
Sambucus sp.	elderberry	–	–	–	–	X
Sambucus nigra ssp. canadensis	common elderberry	X	–	–	X	–
Sanguinaria canadensis	bloodroot	X	–	–	X	X
Sanicula canadensis	Canadian blacksnakeroot	–	–	–	X	X
Sanicula canadensis var. canadensis	Canadian blacksnakeroot	–	–	–	X	–
Sanicula marilandica	Maryland sanicle	–	–	–	–	X
Sanicula odorata	clustered blacksnakeroot	–	–	–	X	X
Sanicula trifoliata	largefruit blacksnakeroot	–	–	–	X	X
Sassafras albidum	sassafras	X	–	X	X	X
Schizachyrium scoparium	little bluestem	–	–	–	X	–
Scirpus atrovirens	green bulrush	–	–	–	–	X
Scutellaria elliptica	hairy skullcap	–	–	–	X	X
Scutellaria nervosa	veiny skullcap	X	–	–	X	X
Scutellaria ovata ssp. rugosa	heartleaf skullcap	–	N	–	X	X
Scutellaria saxatilis	smooth rock skullcap	–	–	–	X	X
Securigera varia[b]	crownvetch	–	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Sedum ternatum	woodland stonecrop	X	–	X	X	X
Senecio sp.	ragwort	–	–	–	–	X
Setaria pumila[b]	yellow foxtail	–	–	–	–	X
Silene caroliniana ssp. pensylvanica	Pennsylvania catchfly	X	–	–	X	–
Silene stellata	widowsfrill, whorled catchfly	–	–	–	X	X
Sisyrinchium angustifolium	narrowleaf blue–eyed grass	–	–	–	X	–
Smallanthus uvedalia	hairy leafcup	–	–	–	X	–
Smilax ecirrhata	upright carrionflower	–	–	–	X	–
Smilax glauca	cat greenbrier	X	–	–	X	X
Smilax herbacea	smooth carrionflower	–	–	–	–	X
Smilax rotundifolia	roundleaf greenbrier	X	–	–	X	X
Smilax tamnoides	bristly greenbrier	–	–	–	X	X
Solanum sp.	nightshade	X	–	–	–	X
Solidago arguta var. caroliniana	Atlantic goldenrod	–	–	–	X	–
Solidago bicolor	white goldenrod	X	–	–	X	X
Solidago caesia	wreath goldenrod	X	–	X	X	X
Solidago curtisii	mountain decumbent goldenrod	–	–	–	X	–
Solidago erecta	showy goldenrod	–	–	–	–	X
Solidago flexicaulis	zigzag goldenrod	–	–	–	X	X
Solidago gigantea	giant goldenrod	X	–	–	X	–
Solidago hispida	hairy goldenrod	–	–	–	X	–
Solidago juncea	early goldenrod	–	–	–	X	–
Solidago nemoralis	gray goldenrod	X	–	–	–	X
Solidago rugosa	wrinkleleaf goldenrod	–	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Solidago sphacelata	autumn goldenrod	–	–	–	X	X
Solidago ulmifolia var. ulmifolia	elmleaf goldenrod	X	–	–	X	–
Sphenopholis nitida	shiny wedgescale	–	–	–	X	–
Stachys sp.	hedgenettle	–	–	–	–	X
Staphylea trifolia	American bladdernut	–	–	–	–	X
Steerecleus serrulatusnv	steerecleus moss	–	–	–	X	–
Stellaria media[b]	common chickweed	–	–	–	X	X
Stellaria pubera	star chickweed	X	–	X	X	X
Symphoricarpos orbiculatus	coralberry	–	–	–	–	X
Symphyotrichum cordifolium	common blue wood aster	–	–	–	X	X
Symphyotrichum laeve var. laeve	smooth blue aster	–	–	–	X	X
Symphyotrichum lanceolatum	white panicle aster	–	–	–	–	X
Symphyotrichum lateriflorum	calico aster	–	–	–	X	–
Symphyotrichum oblongifolium	aromatic aster	–	–	–	X	–
Symphyotrichum patens var. patens	late purple aster	–	–	–	X	–
Symphyotrichum praealtum	willowleaf aster	–	–	–	X	–
Symphyotrichum prenanthoides	crookedstem aster	X	–	–	X	X
Symphyotrichum shortii	Short's aster	–	–	–	–	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Symphyotrichum undulatum	wavyleaf aster	–	–	–	X	X
Taenidia integerrima	yellow pimpernel	–	–	X	X	X
Taraxacum officinale ssp. officinale[b]	common dandelion	X	–	–	X	X
Teucrium canadense	Canada germander	–	–	–	–	X
Thalictrum dioicum	early meadow–rue	–	–	X	X	–
Thalictrum pubescens	king of the meadow	X	–	–	–	X
Thalictrum thalictroides	rue anemone	X	–	–	X	X
Thaspium barbinode	hairyjoint meadowparsnip	–	–	–	–	X
Thelypteris noveboracensis	New York fern	–	–	–	X	–
Thuidium delicatulum[c]	delicate thuidium moss	–	–	–	X	–
Thuja occidentalis	arborvitae, eastern white cedar	–	G,N	–	X	–
Tiarella cordifolia	heartleaf foamflower	X	–	–	X	X
Tilia americana	American basswood	–	–	–	X	X
Toxicodendron radicans	eastern poison ivy	X	–	–	X	X
Trifolium repens[b]	white clover	X	–	–	–	X
Trillium erectum	red trillium	X	–	–	X	
Trillium grandiflorum	white trillium	X	–	–	–	X
Trillium undulatum	painted trillium	–	–	–	X	
Tsuga canadensis	eastern hemlock	X	–	X	X	X
Tussilago farfara[b]	coltsfoot	X	–	–	X	–
Ulmus americana	American elm	X	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Ulmus rubra	slippery elm	X	–	–	X	X
Urtica dioica ssp. dioica[b]	stinging nettle	X	–	–	X	X
Uvularia perfoliata	perfoliate bellwort	X	–	X	X	X
Uvularia puberula	mountain bellwort	–	–	–	–	X
Uvularia sessilifolia	sessileleaf bellwort	X	–	–	X	X
Vaccinium pallidum	Blue Ridge blueberry	X	–	–	X	X
Vaccinium stamineum	deerberry	X	–	–	X	X
Verbascum thapsus[b]	common mullein	X	–	–	X	X
Verbena urticifolia	white vervain	–	–	–	–	X
Verbesina alternifolia	wingstem	–	–	–	X	X
Verbesina occidentalis	yellow crownbeard	–	–	–	X	X
Veronica arvensis[b]	corn speedwell	–	–	–	X	–
Veronica officinalis var. officinalis[b]	common gypsyweed	X	–	–	X	X
Viburnum acerifolium	mapleleaf viburnum	X	–	–	X	X
Viburnum dentatum var. dentatum	southern arrowwood	X	–	–	X	X
Viburnum prunifolium	blackhaw	X	–	–	X	X
Viburnum rafinesquianum	downy arrowwood	–	G, N	–	X	X
Viburnum recognitum	northern arrowwood	–	–	–	–	X
Vicia americana	American vetch	–	–	–	–	X
Vicia caroliniana	Carolina vetch	X	–	–	X	X
Viola blanda	sweet white violet	–	–	–	–	X
Viola canadensis	Canadian white violet	–	–	–	X	–
Viola cucullata	marsh blue violet	–	–	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Table A-1 (continued). Plant species observations in upland forests at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in upland forests by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Fortney et al. (1995)	Vanderhorst et al. (2008)	ERMN 2007-2016
Viola hastata	halberdleaf yellow violet	–	–	–	X	X
Viola hirsutula	southern woodland violet	–	–	–	–	X
Viola palmata	early blue violet	–	–	–	–	X
Viola primulifolia	primrose leaf violet	–	–	–	–	X
Viola pubescens var. pubescens	downy yellow violet	–	–	–	X	X
Viola sororia	common blue violet	–	–	X	X	X
Viola striata	striped cream violet	–	–	–	X	X
Vitis aestivalis var. bicolor	summer grape	–	–	–	X	X
Vitis riparia	riverbank grape	–	–	–	X	–
Vitis vulpina	frost grape	–	–	–	X	X
Woodsia sp.	cliff fern	–	–	–	–	X
Zizia aptera	meadow zizia	–	–	–	–	X
Zizia aurea	golden alexanders	–	–	–	X	X
Zizia trifoliata	meadow alexanders	–	–	–	X	X
Total	**–**	**–**	**–**	**–**	**392**	**405**

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Non-native species

[c] Non-vascular (e.g., mosses, liverworts)

Appendix A. Plant species observations in Riparian Communities at Bluestone National Scenic River.

Table B-1. Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Acalypha gracilens	slender threeseed mercury	–	–	–	X
Acalypha rhomboidea	common threeseed mercury	–	–	X	–
Acalypha virginica	Virginia threeseed mercury	–	–	X	–
Acer negundo var. negundo	boxelder	X	–	X	X
Acer nigrum	black maple	–	–	X	–
Acer pensylvanicum	striped maple	X	–	X	–
Acer rubrum var. rubrum	red maple	X	–	X	X
Acer saccharinum	silver maple	–	–	–	X
Acer saccharum var. saccharum	sugar maple	X	–	X	X
Achillea millefolium[b]	common yarrow	X	–	X	–
Aesculus flava	yellow buckeye	X	–	X	X
Ageratina altissima var. altissima	white snakeroot	–	–	X	X
Agrimonia parviflora	harvestlice	–	–	X	X
Agrimonia pubescens	soft agrimony	–	–	X	X
Agrostis gigantea[b]	redtop	–	–	X	–
Agrostis perennans	upland bentgrass	–	–	X	X
Ailanthus altissima[b]	tree of heaven	–	–	–	X
Alliaria petiolata[b]	garlic mustard	X	–	X	X
Allium canadense var. canadense	meadow garlic	–	–	X	–
Allium vineale[b]	wild garlic	–	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Alnus serrulata	hazel alder	X	–	X	–
Amblystegium serpens[c]	amblystegium moss	–	–	X	–
Ambrosia artemisiifolia	annual ragweed	X	–	X	X
Ambrosia trifida	giant ragweed	X	–	–	X
Amelanchier arborea	common serviceberry	X	–	–	X
Ampelopsis arborea[b]	peppervine	–	–	X	–
Amphicarpaea bracteata	American hogpeanut	–	–	X	X
Andropogon gerardii	big bluestem	–	–	X	X
Anemone acutiloba	sharplobe hepatica	X	–	–	–
Anemone quinquefolia var. quinquefolia	nightcaps	X	–	X	–
Apios americana	groundnut	–	N	X	X
Apocynum cannabinum	Indian hemp	–	–	X	–
Arisaema dracontium	green dragon	–	–	X	X
Arisaema triphyllum	Jack–in–the–pulpit	X	–	X	X
Aristolochia macrophylla	pipevine	X	–	X	X
Arnoglossum atriplicifolium	pale Indian plaintain	–	–	X	X
Arnoglossum reniforme	great Indian plaintain	–	–	X	–
Artemisia vulgaris var. vulgaris	common wormwood	–	–	X	–
Asclepias syriaca	common milkweed	X	–	X	–
Asimina triloba	pawpaw	–	–	X	X
Asplenium platyneuron	ebony spleenwort	X	–	X	–
Atrichum sp. [c]	atrichum moss	–	–	X	–
Barbarea vulgaris[b]	garden yellowrocket	X	–	X	–
Berberis thunbergii[b]	Japanese barberry	–	–	–	X
Berberis vulgaris[b]	common barberry	–	–	X	–

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Betula lenta	sweet birch	X	–	X	X
Betula nigra	river birch	X	–	X	X
Bidens sp.	beggarticks	–	–	–	X
Bidens cernua	nodding beggartick	–	–	X	–
Bidens frondosa	devil's beggartick	X	–	X	–
Bidens tripartita	threelobe beggarticks	–	–	X	–
Bidens vulgata	big devils beggartick	–	–	X	–
Boehmeria cylindrica	smallspike false nettle	X	–	X	X
Botrychium virginianum	rattlesnake fern	X	–	X	X
Brachyelytrum erectum	bearded shorthusk	–	–	X	X
Brachythecium salebrosum[c]	brachythecium moss	–	–	X	–
Brassica nigra[b]	black mustard	–	–	X	–
Bromus sp.	brome	–	–	–	X
Bromus pubescens	hairy woodland brome	–	–	X	–
Bryhnia novae–angliae[c]	New England bryhnia moss	–	–	X	–
Calystegia sepium	hedge false bindweed	–	–	–	X
Campanula americana	American bellflower	–	–	X	–
Campsis radicans	trumpet creeper	–	–	–	X
Cardamine bulbosa	bulbous bittercress	X	–	X	–
Cardamine concatenata	cutleaf toothwort	X	–	X	–
Cardamine hirsuta	hairy bittercress	–	–	X	–
Cardamine impatiens[b]	narrowleaf bittercress	–	–	X	X
Cardamine pensylvanica	Pennsylvania bittercress	X	–	X	–
Carex albursina	white bear sedge	–	–	X	–
Carex amphibola	eastern narrowleaf sedge	–	–	X	X
Carex annectens	yellowfruit sedge	–	–	X	
Carex blanda	eastern woodland sedge	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Carex caroliniana	Carolina sedge	–	–	X	–
Carex communis var. communis	fibrousroot sedge	–	–	X	–
Carex crinita var. crinita	fringed sedge	–	–	X	–
Carex digitalis	slender woodland sedge	–	–	–	X
Carex emoryi	Emory's sedge	–	N	X	–
Carex frankii	Frank's sedge	–	–	–	X
Carex gracillima	graceful sedge	–	–	X	–
Carex laxiflora	broad looseflower sedge	–	–	X	X
Carex lupulina	hop sedge	–	–	X	–
Carex lurida	shallow sedge	–	–	X	X
Carex oligocarpa	richwoods sedge	–	–	–	X
Carex prasina	drooping sedge	–	–	X	–
Carex radiata	eastern star sedge	–	–	X	X
Carex retroflexa	reflexed sedge	–	–	–	X
Carex rosea	rosy sedge	–	–	–	X
Carex scoparia	broom sedge	–	–	–	X
Carex squarrosa	squarrose sedge	–	–	X	X
Carex stipata var. stipata	owlfruit sedge	–	–	X	X
Carex swanii	Swan's sedge	–	–	X	X
Carex tribuloides	blunt broom sedge	–	–	X	–
Carex vulpinoidea	fox sedge	–	–	X	X
Carpinus caroliniana ssp. virginiana	American hornbeam	X	–	X	X
Carya cordiformis	bitternut hickory	X	–	X	X
Carya glabra	pignut hickory	X	–	–	X
Carya ovata	shagbark hickory	X	–	X	–
Carya tomentosa (C. alba)	mockernut hickory	X	–	X	–

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Catalpa bignonioides	southern catalpa	–	–	X	–
Catalpa speciosa	northern catalpa	–	–	X	X
Celastrus orbiculatus[b]	Oriental bittersweet	–	–	–	X
Celtis occidentalis	common hackberry	–	–	X	–
Cephalanthus occidentalis	common buttonbush	–	–	X	X
Cercis canadensis var. canadensis	eastern redbud	X	–	X	X
Chaerophyllum procumbens	spreading chervil	–	–	–	X
Chamaecrista fasciculata	partridge pea	–	–	–	X
Chamaecrista nictitans	sensitive partridge pea	–	–	–	X
Chasmanthium latifolium	Indian woodoats	–	–	X	X
Chelone glabra	white turtlehead	X	–	X	X
Chenopodium ambrosioides	Mexican tea	–	–	X	–
Chimaphila maculata	striped prince's pine	X	–	X	–
Chionanthus virginicus	white fringetree	X	–	X	X
Cicuta maculata var. maculata	spotted water hemlock	–	–	X	–
Cinna arundinacea	sweet woodreed	–	–	X	X
Circaea canadensis ssp. canadensis	broadleaf enchanter's nightshade	–	–	X	–
Circaea lutetiana	broadleaf enchanter's nightshade	–	–	–	X
Claytonia virginica	Virginia springbeauty	–	–	X	–
Clematis virginiana	devil's darning needles	X	–	X	X
Climacium americanumnv	American climacium moss	–	–	X	–
Collinsonia canadensis	richweed	X	–	X	X
Commelina communis[b]	Asiatic dayflower	–	–	X	X
Conium maculatum[b]	poison hemlock	–	–	–	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Conopholis americana	American cancer–root	X	–	X	–
Convolvulus sp.	bindweed	–	–	–	X
Coreopsis sp.	tickseed	–	–	–	X
Coreopsis auriculata	lobed tickseed	–	–	X	–
Coreopsis pubescens	star tickseed	–	–	X	–
Coreopsis tinctoria	golden tickseed	–	–	X	–
Cornus amomum	silky dogwood	–	–	X	–
Cornus florida	flowering dogwood	–	–	X	X
Corylus americana	American hazelnut	X	–	–	X
Crataegus sp.	hawthorn	–	–	–	X
Crataegus crus–galli	cockspur hawthorn	–	–	X	–
Cryptotaenia canadensis	Canadian honewort	–	–	X	X
Cuscuta gronovii	scaldweed	–	–	–	X
Cyperus strigosus	stawcolored flatsedge	–	–	X	–
Dactylis glomerata ssp. glomerata[b]	orchardgrass	–	–	X	–
Daucus carota[b]	Queen Anne's lace	–	–	X	–
Desmodium glabellum	Dillenius' ticktrefoil	–	–	X	X
Desmodium glutinosum	pointedleaf ticktrefoil	–	–	X	–
Desmodium obtusum	stiff ticktrefoil	–	–	X	–
Desmodium paniculatum var. paniculatum	panicledleaf ticktrefoil	–	–	X	–
Desmodium rotundifolium	prostrate ticktrefoil	–	–	X	X
Diarrhena americana	American beakgrain	–	–	–	X
Dichanthelium boscii	Bosc's panicgrass	–	–	X	X
Dichanthelium clandestinum	deertongue	–	–	X	X
Dichanthelium depauperatum	starved panicgrass	–	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Dichanthelium dichotomum	cypress panicgrass	–	–	X	X
Dichanthelium dichotomum var. ramulosum	cypress panicgrass	–	–	X	–
Dichanthelium dichotomum ssp. yadkinense	cypress panicgrass	–	–	X	–
Dichanthelium latifolium	broadleaf rosette grass	–	–	–	X
Dioscorea quaternata	fourleaf yam	X	–	X	–
Diospyros virginiana	common persimmon	–	–	X	–
Dirca palustris	eastern leatherwood	–	G	X	X
Dryopteris intermedia	intermediate woodfern	X	–	X	–
Dryopteris marginalis	marginal woodfern	X	–	–	X
Echinochloa crus–galli[b]	barnyardgrass	–	–	X	–
Elaeagnus umbellata var. parvifolia[b]	autumn olive	–	–	X	X
Eleocharis palustris	common spikerush	–	N	–	–
Eleocharis tenuis var. tenuis	slender spikerush	–	–	X	–
Elephantopus carolinianus	Carolina elephantsfoot	–	–	X	X
Elymus canadensis	Canada wildrye	–	–	X	X
Elymus hystrix var. hystrix	eastern bottlebrush grass	–	–	X	X
Elymus riparius	riverbank wildrye	–	–	X	X
Elymus virginicus var. virginicus	Virginia wildrye	–	–	X	X
Equisetum hyemale ssp. affine	scouringrush horsetail	–	–	X	–
Eragrostis hypnoides	teal lovegrass	–	–	X	–
Erechtites hieraciifolius var. hieraciifolius	American burnweed	–	–	X	–
Erigeron annuus	eastern daisy fleabane	–	–	X	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Erigeron philadelphicus var. philadelphicus	Philadelphia fleabane	–	–	X	–
Erigeron pulchellus	robin's plantain	X	–	X	X
Euonymus americanus	bursting–heart	–	–	–	X
Euonymus atropurpureus	burningbush	–	–	–	X
Eupatorium fistulosum	trumpetweed	X	–	X	–
Eupatorium perfoliatum	common boneset	X	–	–	–
Euphorbia corollata	flowering spurge		–	X	–
Eurybia divaricata	white wood aster	X	–	X	X
Eutrochium purpureum var. purpureum	sweetscented joepyeweed	–	–	X	X
Fagus grandifolia	American beech	X	–	X	X
Fallopia convolvulus[b]	black bindweed	–	–	X	–
Fallopia japonica var. japonica[b] *(Polygonum cuspidatum)*	Japanese knotweed	–	–	X	–
Fallopia (Polygonum) scandens	climbing false buckwheat	X	–	X	X
Festuca subverticillata	nodding fescue	–	–	X	X
Fraxinus americana	white ash	X	–	X	X
Fraxinus pennsylvanica	green ash	–	–	X	X
Galinsoga sp.	gallant soldier	–	–	–	X
Galinsoga quadriradiata	shaggy soldier	–	–	X	
Galium aparine	stickywilly	X	–	X	X
Galium asprellum	rough bedstraw	–	–	X	–
Galium lanceolatum	lanceleaf wild licorice	–	–	X	–
Galium obtusum	bluntleaf bedstraw	–	–	–	X
Galium triflorum	fragrant bedstraw	–	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Geranium maculatum	spotted geranium	X	–	X	X
Geum canadense	white avens	–	–	X	X
Geum laciniatum	rough avens	–	–	–	X
Geum vernum	spring avens	–	–	X	X
Glechoma hederacea[b]	ground ivy	–	–	X	X
Gleditsia triacanthos	honeylocust	–	G	X	X
Glyceria striata	fowl mannagrass	–	–	X	X
Goodyera pubescens	downy rattlesnake–plantain	X	–	X	–
Hackelia virginiana	beggarslice	–	–	X	X
Hamamelis virginiana	American witchhazel	X	–	X	X
Helenium autumnale	common sneezeweed	X	–	X	–
Helianthus divaricatus	woodland sunflower	X	–	X	X
Helianthus strumosus	paleleaf woodland sunflower	–	–	X	–
Heliopsis helianthoides	smooth oxeye	–	–	X	X
Heliopsis helianthoides var. scabra	smooth oxeye	–	–	X	–
Hesperis matronalis[b]	dame's rocket	–	–	X	X
Houstonia caerulea	azure bluet	X	–	X	–
Humulus japonicus[b]	Japanese hop	–	–	X	X
Hybanthus concolor	eastern greenviolet	–	–	–	X
Hydrangea arborescens	wild hydrangea	X	–	X	–
Hydrophyllum virginianum	eastern waterleaf	X	–	X	–
Hygrohypnum ochraceum[c]	hygrohypnum moss	–	–	X	–
Hypericum ellipticum	pale St. Johnswort	–	–	X	–
Hypericum mutilum	dwarf St. Johnswort	–	–	X	–
Hypericum perforatum[b]	common St. John's wort	–	–	X	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Hypericum prolificum	shrubby St. Johnswort	–	–	X	X
Hypericum punctatum	spotted St. Johnswort	–	–	X	X
Ilex montana	mountain holly	–	–	–	X
Ilex verticillata	common winterberry	–	–	–	X
Impatiens capensis	jewelweed	X	–	X	X
Ipomoea sp.	morning–glory	–	–	–	X
Ipomoea pandurata	man of the earth	–	–	X	–
Iris sp.	iris	–	–	–	X
Iris pseudacorus[b]	paleyellow iris	–	–	X	–
Juglans cinerea	butternut	–	N	X	–
Juglans nigra	black walnut	X	G	X	X
Juncus dichotomus	forked rush	–	–	X	–
Juncus effusus	common rush	–	–	X	X
Juniperus virginiana	eastern redcedar	X	–	–	X
Lactuca sp.	lettuce	–	–	–	X
Laportea canadensis	Canada woodnettle	–	–	X	X
Leersia oryzoides	rice cutgrass	–	–	–	X
Leersia virginica	whitegrass	–	–	X	X
Lespedeza cuneata[b]	sericea lespedeza	–	–	X	X
Lespedeza frutescens	shrubby lespedeza	–	–	X	–
Lespedeza procumbens	trailing lespedeza	–	–	X	–
Lespedeza violacea	violet lespedeza	–	–	X	–
Leucanthemum vulgare[b]	oxeye daisy	–	–	X	–
Ligustrum vulgare[b]	European privet	–	–	X	X
Lilium sp.	lily	–	–	–	X
Lindera benzoin	northern spicebush	X	–	X	X
Lindernia dubia	yellowseed false pimpernel	–	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Liparis liliifolia	brown widelip orchid	–	–	X	–
Liriodendron tulipifera	tuliptree	X	–	X	X
Lobelia cardinalis	cardinalflower	X	–	X	–
Lobelia inflata	Indian–tobacco	X	–	X	X
Lobelia siphilitica var. siphilitica	great blue lobelia	X	–	X	–
Lonicera japonica[b]	Japanese honeysuckle	X	–	X	X
Lonicera morrowii[b]	Morrow's honeysuckle	–	–	–	X
Lophocolea heterophyllanv	liverwort	–	–	X	–
Luzula acuminata var. acuminata	hairy woodrush	–	–	X	–
Luzula multiflora ssp. multiflora	common woodrush	–	–	X	–
Lycopus virginicus	Virginia water horehound	–	–	X	–
Lysimachia ciliata	fringed loosestrife	–	–	X	X
Lysimachia japonica[b]	Japanese yellow loosestrife	–	–	X	–
Lysimachia nummularia[b]	creeping jenny	–	–	X	X
Lythrum salicaria[b]	purple loosestrife	–	–	X	–
Magnolia acuminata	cucumber–tree	X	–	X	–
Maianthemum canadense	Canada mayflower	X	–	X	–
Maianthemum racemosum ssp. racemosum	feathery false lily of the valley	X	–	X	X
Malus coronaria	sweet crabapple	–	–	X	–
Medeola virginiana	Indian cucumber	–	–	X	–
Medicago lupulina[b]	black medic	–	–	X	–
Meehania cordata	Meehan's mint	X	–	X	–
Melilotus officinalis[b]	sweetclover	–	–	X	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Menispermum canadense	common moonseed	–	–	X	X
Mentha arvensis	wild mint	–	–	X	–
Microstegium vimineum[b]	Japanese stiltgrass	–	–	–	X
Mimulus sp.	monkeyflower	–	–	–	X
Mimulus alatus	sharpwing monkeyflower	–	–	X	–
Mimulus ringens var. ringens	Allegheny monkeyflower	–	–	X	–
Mitchella repens	partridgeberry	X	–	X	X
Mnium sp. [c]	mnium calcareous moss	–	–	X	–
Monotropa uniflora	Indianpipe	X	–	X	–
Muhlenbergia sylvatica	woodland muhly	–	–	–	X
Myosotis macrosperma	largeseed forget–me–not	–	N	–	–
Myosoton aquaticum[b]	giant chickweed	–	–	X	–
Nasturtium officinale[b]	watercress	–	–	–	X
Nepeta cataria[b]	catnip	–	–	–	X
Nyssa sylvatica	blackgum	–	–	X	X
Oclemena acuminata	whorled wood aster	–	–	–	X
Oenothera parviflora	northern evening–primrose	–	–	X	–
Onoclea sensibilis	sensitive fern	X	–	X	X
Osmorhiza sp.	sweetroot	–	–	–	X
Osmorhiza claytonii	Clayton's sweetroot	–	–	X	–
Osmunda claytoniana	interrupted fern	–	–	X	–
Osmunda regalis var. spectabilis	royal fern	–	–	X	–
Ostrya virginiana	hophornbeam	X	–	–	X
Oxalis dillenii	slender yellow woodsorrel	–	–	X	X
Oxalis grandis	great yellow woodsorrel	–	–	X	–
Oxalis stricta	common yellow oxalis	–	–	X	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Oxalis violacea	violet woodsorrel	–	–	X	–
Oxydendrum arboreum	sourwood	X	–	–	X
Oxypolis sp.	cowbane	–	–	–	X
Packera anonyma	Small's ragwort	–	–	X	–
Packera aurea	golden ragwort	X	–	X	X
Packera obovata	roundleaf ragwort	–	–	–	X
Panicum virgatum	switchgrass	–	–	X	–
Parietaria pensylvanica	Pennsylvania pellitory	–	–	–	X
Parthenocissus quinquefolia	Virginia creeper	–	–	X	X
Passiflora lutea	yellow passionflower	–	–	X	–
Paulownia tomentosa[b]	princess tree	–	–	X	–
Pedicularis canadensis	Canadian lousewort	X	–	–	X
Pennisetum glaucum[b]	pearl millet	–	–	X	–
Persicaria (Polygonum) hydropiper	marshpepper knotweed	–	–	–	X
Persicaria hydropiperoides	swamp smartweed	–	–	X	X
Persicaria longiseta[b]	oriental ladysthumb	–	–	X	–
Persicaria pensylvanica	Pennsylvania knotweed	–	–	X	–
Persicaria posumbu[b] *(Polygonum caespitosum)*	Oriental ladysthumb	–	–	–	X
Persicaria punctata	dotted smartweed	–	–	X	–
Persicaria sagittata	arrowleaf tearthumb	X	–	X	–
Persicaria (Polygonum) virginiana	jumpseed	X	–	X	X
Phegopteris hexagonoptera	broad beechfern	–	–	X	–
Phlox maculata ssp. pyramidalis	wild sweetwilliam	–	–	X	X
Phlox stolonifera	creeping phlox	X	–	X	–

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Physalis longifolia var. subglabrata	longleaf groundcherry	–	–	X	–
Physocarpus opulifolius	common ninebark	X	–	X	–
Phytolacca americana	American pokeweed	X	–	–	X
Pilea pumila	Canadian clearweed	–	–	X	X
Pinus strobus	eastern white pine	X	G	X	X
Plagiomnium ciliare[c]	plagiomnium moss	–	–	X	–
Plantago major[b]	common plantain	–	–	–	X
Plantago rugelii var. rugelii	blackseed plantain	–	–	X	–
Platanus occidentalis	American sycamore	X	–	X	X
Poa alsodes	grove bluegrass	–	–	X	–
Poa compressa[b]	Canada bluegrass	–	–	–	X
Poa pratensis ssp. pratensis[b]	Kentucky bluegrass	–	–	X	–
Poa sylvestris	woodland bluegrass	–	–	–	X
Podophyllum peltatum	mayapple	X	–	X	–
Polygonatum biflorum	smooth Solomon's seal	X	–	–	X
Polygonatum pubescens	hairy Solomon's seal	–	–	X	–
Polystichum acrostichoides	Christmas fern	X	–	X	X
Potentilla canadensis	dwarf cinquefoil	–	–	X	–
Potentilla simplex	common cinquefoil	X	–	X	X
Prenanthes sp.	rattlesnakeroot	–	–	–	X
Prenanthes altissima	tall rattlesnakeroot	–	–	X	–
Prunella vulgaris	common selfheal	X	–	X	X
Prunus serotina var. serotina	black cherry	X	–	X	X
Pyrularia pubera	buffalo nut	X	–	–	X
Quercus alba	white oak	X	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Quercus montana (Q. prinus)	chestnut oak	X	–	X	–
Quercus muehlenbergii	chinkapin oak		–	X	X
Quercus rubra	northern red oak	X	–	X	X
Quercus velutina	black oak	X	–	X	X
Ranunculus abortivus	littleleaf buttercup		–	X	X
Ranunculus hispidus var. nitidus	bristly buttercup	X	–	X	–
Ranunculus recurvatus var. recurvatus	blisterwort	X	–	X	X
Rhizomnium sp. [c]	rhizomnium moss	–	–	X	–
Rhododendron arborescens	smooth azalea	–	–	X	–
Rhododendron maximum	great laurel	X	–	X	X
Rhus sp.	sumac	X	–	–	X
Robinia pseudoacacia	black locust	–	–	X	X
Rorippa sylvestris[b]	creeping yellowcress	–	–	X	X
Rosa carolina var. carolina	Carolina rose	X	–	X	X
Rosa multiflora[b]	multiflora rose	X	–	X	X
Rubus sp.	raspberry	X	–	X	–
Rubus flagellaris	northern dewberry	X	–	–	X
Rubus odoratus	purpleflowering raspberry	X	–	–	X
Rubus phoenicolasius[b]	wine raspberry, wineberry	X	–	X	X
Rudbeckia laciniata var. laciniata	cutleaf coneflower	X	–	X	X
Rudbeckia triloba	browneyed Susan	–	–	–	X
Rumex acetosella[b]	common sheep sorrel	X	–	X	–
Rumex crispus[b]	curly dock	X	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Rumex obtusifolius[b]	bitter dock	X	–	X	X
Salix caroliniana	coastal plain willow	–	–	X	–
Salix nigra	black willow	X	–	X	–
Salix sericea	silky willow	–	–	X	–
Salvia lyrata	lyreleaf sage	–	–	X	X
Sanguinaria canadensis	bloodroot	X	–	X	X
Sanicula canadensis	Canadian blacksnakeroot	–	–	X	X
Sanicula odorata	clustered blacksnakeroot	–	–	X	X
Saponaria officinalis[b]	bouncingbet	–	–	X	X
Sassafras albidum	sassafras	X	–	X	X
Schedonorus (Lolium) arundinaceus[b]	tall fescue	–	–	X	X
Schedonorus pratensis[b]	meadow fescue	–	–	X	–
Schoenoplectus heterochaetus	slender bulrush	X	–	–	–
Scrophularia marilandica	carpenter's square	–	–	–	X
Scutellaria sp.	skullcap	X	–	X	–
Scutellaria lateriflora	blue skullcap	–	–	–	X
Scutellaria saxatilis	smooth rock skullcap	–	N	–	–
Securigera varia[b]	crownvetch	–	–	X	X
Sedum ternatum	woodland stonecrop	X	–	X	X
Senecio suaveolens	false Indian plantain	X	–	–	X
Senna hebecarpa	American senna	–	–	X	–
Sicyos angulatus	oneseed burr cucumber	–	–	X	X
Silene stellata	widowsfrill, whorled catchfly	–	–	X	–
Silphium asteriscus var. trifoliatum	whorled rosinweed	–	–	X	–

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Sisyrinchium angustifolium	narrowleaf blue–eyed grass	–	–	X	X
Smilax ecirrhata	upright carrionflower	–	–	X	–
Smilax glauca	cat greenbrier	X	–	X	X
Smilax herbacea	smooth carrionflower	–	–	X	X
Smilax rotundifolia	roundleaf greenbrier	X	–	X	X
Smilax tamnoides	bristly greenbrier	–	–	X	X
Solanum carolinense	Carolina horsenettle	X	–	X	X
Solidago bicolor	white goldenrod	X	–	X	–
Solidago caesia	wreath goldenrod	X	–	X	X
Solidago canadensis	Canada goldenrod	–	–	X	–
Solidago curtisii	mountain decumbent goldenrod	–	–	X	–
Solidago flexicaulis	zigzag goldenrod	–	–	X	–
Solidago gigantea	giant goldenrod	X	–	X	X
Solidago puberula	downy goldenrod	–	–	–	X
Solidago rugosa	wrinkleleaf goldenrod	–	–	X	X
Solidago ulmifolia var. ulmifolia	elmleaf goldenrod	X	–	X	–
Spiraea virginiana	Virginia spiraea	–	N, G	–	–
Stachys cordata	heartleaf hedgenettle	–	–	–	X
Stachys latidens	broadtooth hedgenettle	–	–	–	X
Stachys tenuifolia	smooth hedgenettle	–	–	–	X
Steerecleus serrulatus[c]	steerecleus moss	–	–	X	–
Stellaria longifolia	longleaf starwort	–	–	X	–
Stellaria media[b]	common chickweed	–	–	–	X
Stellaria pallida[b]	common chickweed	–	–	X	–
Stellaria pubera	star chickweed	X	–	X	X

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Symphyotrichum laeve	smooth blue aster	–	–	–	X
Symphyotrichum lateriflorum	calico aster	–	–	X	–
Symphyotrichum praealtum	willowleaf aster	–	–	X	–
Symphyotrichum prenanthoides	crookedstem aster	X	–	X	X
Symphyotrichum puniceum var. puniceum	purplestem aster	–	–	X	–
Taraxacum officinale[b]	common dandelion	X	–	–	X
Taxus canadensis	Canada yew	X	–	–	–
Teucrium canadense var. canadense	Canada germander	–	–	X	X
Thalictrum dioicum	early meadow–rue	–	–	–	X
Thalictrum pubescens	king of the meadow	X	–	–	X
Thalictrum thalictroides	rue anemone	X	–	X	–
Thaspium barbinode	hairyjoint meadowparsnip	–	–	X	–
Thelypteris noveboracensis	New York fern	–	–	X	–
Thuidium delicatulum[c]	delicate thuidium moss	–	–	X	–
Tiarella cordifolia	heartleaf foamflower	X	–	X	–
Tilia americana	American basswood	–	–	X	X
Toxicodendron radicans	eastern poison ivy	X	–	X	X
Tradescantia sp.	spiderwort	–	–	–	X
Tradescantia ohiensis	Virginia spiderwort	–	–	X	–
Tradescantia virginiana	bluejacket	–	–	X	–
Trautvetteria caroliniensis	Carolina bugbane	–	–	X	–
Trifolium hybridum[b]	Alsike clover	–	–	X	X
Trifolium pratense[b]	red clover	X	–	X	X
Trifolium repens[b]	white clover	X	–	X	–

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Trillium undulatum	painted trillium	–	–	X	–
Tsuga canadensis	eastern hemlock	X	–	X	X
Tussilago farfara[b]	coltsfoot	X	–	X	X
Typha latifolia	broadleaf cattail	X	–	–	–
Ulmus americana	American elm	X	–	X	X
Ulmus rubra	slippery elm	X	–	X	X
Urtica dioica ssp. dioica[b]	stinging nettle	X	–	X	X
Uvularia perfoliata	perfoliate bellwort	X	–	X	X
Verbena urticifolia	white vervain	–	–	X	X
Verbesina alternifolia	wingstem	–	–	X	X
Verbesina occidentalis	yellow crownbeard	–	–	X	X
Vernonia gigantea	giant ironweed	–	–	X	–
Vernonia noveboracensis	New York ironweed	X	–	X	X
Veronica americana	American speedwell	X	–	X	–
Veronica officinalis var. officinalis[b]	common gypsyweed	X	–	X	X
Veronicastrum virginicum	Culver's root	–	–	X	–
Viburnum acerifolium	mapleleaf viburnum	X	–	–	X
Viburnum dentatum var. dentatum	southern arrowwood	X	–	X	X
Viburnum lentago	nannyberry	–	–	–	X
Viburnum prunifolium	blackhaw	X	–	X	X
Vicia caroliniana	Carolina vetch	X	–	–	X
Viola cucullata	marsh blue violet	–	–	X	–
Viola sororia	common blue violet	–	–	X	X
Viola striata	striped cream violet	–	–	X	X
Vitis aestivalis var. bicolor	summer grape	–	–	X	–
Vitis riparia	riverbank grape	–	–	X	X

[a] In this column, an “N” represents species documented by Norris in a study focusing strictly on rare species, while a “G” indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Table B-1 (continued). Plant species observations in riparian communities at Bluestone National Scenic River. Note that the Oxley (1975) column is not a full species list, as the source did not identify which species were found in upland vs. riparian areas, but is just a record of which species found in uplands by Vanderhorst et al. (2008) and/or Eastern Rivers and Mountains Network 2007-2016 were also documented by Oxley. Also, some Oxley specimen identifications were corrected by Streets et al. (2008) – these changes are incorporated into the Oxley (1975) column.

Scientific Name	Common Name	Oxley (1975)	Norris (1992)/Grafton (1993)[a]	Vanderhorst et al. (2008)	ERMN (2007–2016
Vitis rupestris	sand grape	–	–	X	–
Vitis vulpina	frost grape	–	–	X	X
Xanthium strumarium	rough cocklebur	–	–	X	X
Zizia aptera	meadow zizia	–	–	–	X
Zizia aurea	golden alexanders	–	–	X	X
Zizia trifoliata	meadow alexanders	–	–	X	X
Total	**–**	**–**	**–**	**377**	**265**

[a] In this column, an "N" represents species documented by Norris in a study focusing strictly on rare species, while a "G" indicates species listed in the Grafton (1993) text as present at BLUE. Neither source provided a comprehensive species list for the park.

[b] Exotic species

[c] Non-vascular (e.g., mosses, liverworts)

Appendix B. Bird species observed in Bluestone National Scenic River during the various avian inventory and monitoring efforts.

Table C-1. Bird species observed in Bluestone National Scenic River during the various avian inventory and monitoring efforts. X indicates a confirmed species, P indicates a probable species, and U indicates an unconfirmed species.

Scientific Name	Common Name	NPS (2017)	Point Counts	Pauley et al. (2003)	Marshall et al. (2013)	CBC
Accipiter cooperii	Cooper's hawk	X	–	X	–	X
Accipiter striatus	sharp–shinned hawk	X	–	X	–	X
Actitis macularius	spotted sandpiper	–	X	–	–	–
Aegolius acadicus	northern saw–whet owl	–	–	–	–	X
Agelaius phoeniceus	red–winged blackbird	X	–	X	–	X
Aix sponsa	wood duck	X	–	X	–	X
Anas acuta	northern pintail	X	–	X	–	X
Anas americana	American wigeon	–	–	–	–	X
Anas clypeata	northern shoveler	–	–	–	–	X
Anas crecca	green–winged teal	X	–	X	–	X
Anas discors	blue–winged teal	–	–	–	–	X
Anas platyrhynchos	mallard	X	X	X	–	X
Anas rubripes	American black duck	X	–	X	–	X
Anas strepera	gadwall	X	–	X	–	X
Anthus rubescens	American pipit	–	–	–	–	X
Aquila chrysaetos	golden eagle	–	–	–	–	X
Archilochus colubris	ruby–throated hummingbird	X	X	X	X	–
Ardea alba	great egret	–	–	–	–	X
Ardea herodias	great blue heron	X	–	X	–	X
Asio otus	long–eared owl	–	–	–	–	X
Aythya affinis	lesser scaup	X	–	X	–	X
Aythya americana	redhead	X	–	X	–	X
Aythya collaris	ring–necked duck	–	–	–	–	X
Baeolophus bicolor	tufted titmouse	X	X	X	X	X
Bombycilla cedrorum	cedar waxwing	X	X	X	–	X
Bonasa umbellus	ruffed grouse	X	X	X	X	X
Branta canadensis	Canada goose	X	–	X	–	X
Bubo virginianus	great horned owl	X	–	X	–	X
Bucephala albeola	bufflehead	X	–	X	–	X

Scientific Name	Common Name	NPS (2017)	Point Counts	Pauley et al. (2003)	Marshall et al. (2013)	CBC
Bucephala clangula	common goldeneye	–	–	–	–	X
Buteo jamaicensis	red–tailed hawk	X	X	X	–	X
Buteo lagopus	rough–legged hawk	–	–	–	–	X
Buteo lineatus	red–shouldered hawk	X	–	X	–	X
Buteo platypterus	broad–winged hawk	X	X	X	–	–
Butorides virescens	green heron	X	–	X	–	–
Cardinalis cardinalis	northern cardinal	X	X	X	X	X
Cathartes aura	turkey vulture	X	X	X	–	X
Catharus guttatus	hermit thrush	–	–	–	–	X
Catharus minimus	gray–cheeked thrush	–	–	–	–	X
Catharus ustulatus	Swainson's thrush	–	–	–	–	X
Certhia americana	brown creeper	X	–	–	X	X
Chaetura pelagica	chimney swift	X	X	X	–	–
Charadrius vociferus	killdeer	X	–	X	–	X
Chordeiles minor	common nighthawk	X	–	X	–	–
Circus cyaneus	northern harrier	–	–	–	–	X
Cistothorus palustris	marsh wren	–	–	–	–	X
Cistothorus platensis	sedge wren	–	–	–	–	X
Clangula hyemalis	long–tailed duck	–	–	–	–	X
Coccyzus americanus	yellow–billed cuckoo	X	X	X	X	–
Coccyzus erythropthalmus	black–billed cuckoo	X	–	X	–	–
Colaptes auratus	northern flicker	X	X	X	X	X
Colinus virginianus	northern bobwhite	–	–	–	–	X
Columba livia	rock pigeon	–	–	–	–	X
Contopus virens	eastern wood pewee	X	X	X	X	–
Coragyps atratus	black vulture	X	–	X	–	X
Corvus brachyrhynchos	American crow	X	X	X	X	X
Corvus corax	common raven	X	X	X	–	X
Cyanocitta cristata	blue jay	X	X	X	X	X
Cygnus columbianus	tundra swan	–	–	–	–	X
Dryocopus pileatus	pileated woodpecker	X	X	X	X	X
Dumetella carolinensis	gray catbird	X	–	–	–	X
Empidonax minimus	least flycatcher	X	–	X	–	–
Empidonax traillii	willow flycatcher	X	–	X	–	–
Empidonax virescens	Acadian flycatcher	X	X	X	X	–
Eremophila alpestris	horned lark	–	–	–	–	X

Scientific Name	Common Name	NPS (2017)	Point Counts	Pauley et al. (2003)	Marshall et al. (2013)	CBC
Euphagus carolinus	rusty blackbird	–	–	–	–	X
Falco sparverius	American kestrel	–	–	–	–	X
Fulica americana	American coot	X	–	X	–	X
Gavia immer	common loon	–	–	–	–	X
Geothlypis formosa	Kentucky warbler	X	X	X	–	–
Geothlypis philadelphia	mourning warbler	X	–	X	–	–
Geothlypis trichas	common yellowthroat	X	–	–	–	X
Haemorhous mexicanus	house finch	–	–	–	–	X
Haemorhous purpureus	purple finch	–	–	–	–	X
Haliaeetus leucocephalus	bald eagle	–	–	–	–	X
Helmitheros vermivorum	worm–eating warbler	X	X	X	X	–
Hesperiphona vespertina	evening grosbeak	–	–	–	–	X
Hylocichla mustelina	wood thrush	X	X	X	X	–
Icterus galbula	Baltimore oriole	X	X	X	X	–
Junco hyemalis	dark–eyed junco	X	–	–	–	X
Lanius ludovicianus	loggerhead shrike	–	–	–	–	X
Larus argentatus	herring gull	–	–	–	–	X
Larus delawarensis	ring–billed gull	X	–	–	–	X
Lophodytes cucullatus	hooded merganser	X	–	X	–	X
Loxia curvirostra	red crossbill	–	–	–	–	X
Megaceryle alcyon	belted kingfisher	X	X	X	X	X
Megascops asio	eastern screech–owl	X	–	X	–	X
Melanerpes carolinus	red–bellied woodpecker	X	X	X	X	X
Melanerpes erythrocephalus	red–headed woodpecker	–	–	–	–	X
Meleagris gallopavo	wild turkey	X	X	X	–	X
Melospiza georgiana	swamp sparrow	–	–	–	–	X
Melospiza lincolnii	Lincoln's sparrow	–	–	–	–	X
Melospiza melodia	song sparrow	X	X	X	–	X
Mergus merganser	common merganser	X	–	X	–	X
Mergus serrator	red–breasted merganser	–	–	–	–	X
Mimus polyglottos	northern mockingbird	–	–	–	–	X
Mniotilta varia	black–and–white warbler	X	X	X	X	–
Molothrus ater	brown–headed cowbird	X	X	–	–	X
Myiarchus crinitus	great–crested flycatcher	X	X	X	–	–
Oxyura jamaicensis	ruddy duck	X	–	X	–	X
Pandion haliaetus	osprey	X	X	X	–	X

Scientific Name	Common Name	NPS (2017)	Point Counts	Pauley et al. (2003)	Marshall et al. (2013)	CBC
Parkesia motacilla	Louisiana waterthrush	X	X	X	X	–
Parkesia noveboracensis	northern waterthrush	U	–	–	–	–
Passer domesticus	house sparrow	–	–	–	–	X
Passerculus sandwichensis	savannah sparrow	–	–	–	–	X
Passerella iliaca	fox sparrow	–	–	–	–	X
Passerina cyanea	Indigo bunting	X	X	X	X	–
Phalacrocorax auritus	double–crested cormorant	X	–	X	–	X
Phasianus colchicus	ring–necked pheasant	–	–	–	–	X
Pheucticus ludovicianus	rose–breasted grosbeak	X	X	X	–	–
Picoides pubescens	downy woodpecker	X	X	X	X	X
Picoides villosus	hairy woodpecker	X	X	X	X	X
Pipilo erythrophthalmus	eastern towhee	X	X	X	X	X
Piranga olivacea	scarlet tanager	X	X	X	X	–
Plectrophenax nivalis	snow bunting	–	–	–	–	X
Podiceps auritus	horned grebe	–	–	–	–	X
Podilymbus podiceps	pied–billed grebe	X	–	X	–	X
Poecile atricapillus	black–capped chickadee	P	X	–	–	X
Poecile carolinensis	Carolina chickadee	X	X	X	X	X
Polioptila caerulea	blue–gray gnatcatcher	X	X	X	X	X
Pooecetes gramineus	vesper sparrow	–	–	–	–	X
Quiscalus quiscula	common grackle	–	–	–	–	X
Regulus calendula	ruby–crowned kinglet	–	–	–	–	X
Regulus satrapa	golden–crowned kinglet	–	X	–	–	X
Sayornis phoebe	eastern phoebe	X	X	X	X	X
Scolopax minor	American woodcock	–	–	–	–	X
Seiurus aurocapilla	ovenbird	X	X	X	X	–
Setophaga americana	northern parula	X	X	X	X	–
Setophaga caerulescens	black–throated blue warbler	X	X	X	X	–
Setophaga cerulea	cerulean warbler	X	X	X	X	–
Setophaga citrina	hooded warbler	X	X	X	X	–
Setophaga coronata	yellow–rumped warbler	X	–	–	–	X
Setophaga dominica	yellow–throated warbler	X	X	X	X	–
Setophaga palmarum	palm warbler	–	–	–	–	X
Setophaga pensylvanica	chestnut–sided warbler	X	–	X	–	–
Setophaga pinus	pine warbler	–	–	–	–	X
Setophaga ruticilla	American redstart	X	X	X	X	–

Scientific Name	Common Name	NPS (2017)	Point Counts	Pauley et al. (2003)	Marshall et al. (2013)	CBC
Setophaga striata	blackpoll warbler	X	X	X	–	–
Setophaga virens	black–throated green warbler	X	X	X	X	–
Sialia sialis	eastern bluebird	–	–	–	–	X
Sitta canadensis	red–breasted nuthatch	–	–	–	–	X
Sitta carolinensis	white–breasted nuthatch	X	X	X	X	X
Sphyrapicus varius	yellow–bellied sapsucker	–	–	–	–	X
Spinus pinus	pine siskin	–	–	–	–	X
Spinus tristis	American goldfinch	X	X	X	–	X
Spizella passerina	chipping sparrow	X	X	X	–	X
Spizella pusilla	field sparrow	X	–	–	X	X
Spizelloides arborea	American tree sparrow	–	–	–	–	X
Stelgidopteryx serripennis	northern rough–winged swallow	X	–	X	–	–
Strix varia	barred owl	X	–	X	–	X
Sturnella magna	eastern meadowlark	–	–	–	–	X
Sturnus vulgaris	European starling	–	–	–	–	X
Tachycineta bicolor	tree swallow	X	X	X	–	–
Thryothorus ludovicianus	Carolina wren	X	X	X	X	X
Toxostoma rufum	brown thrasher	X	–	–	X	X
Tringa melanoleuca	greater yellowlegs	–	–	–	–	X
Troglodytes aedon	house wren	X	–	–	–	X
Troglodytes hiemalis	winter wren	P	X	–	–	X
Turdus migratorius	American robin	X	X	X	X	X
Vermivora chrysoptera	golden–winged warbler	–	X	–	–	–
Vermivora cyanoptera	blue–winged warbler	X	X	X	–	–
Vireo flavifrons	yellow–throated vireo	X	X	X	X	–
Vireo griseus	white–eyed vireo	X	–	X	–	–
Vireo olivaceus	red–eyed vireo	X	X	X	X	–
Vireo solitarius	blue–headed vireo	X	X	X	X	X
Zenaida macroura	mourning dove	X	–	X	X	X
Zonotrichia albicollis	white–throated sparrow	X	–	–	–	X
Zonotrichia leucophrys	white–crowned sparrow	–	–	–	–	X
Number of Species Observed	**–**	**104**	**64**	**93**	**44**	**127**
Number of Possibly Occurring Species Noted	**–**	**2**	**0**	**0**	**0**	**0**
Number of Unconfirmed Species Noted	**–**	**1**	**0**	**0**	**0**	**0**

Appendix C. Bird species abundance estimates during general surveys in Bluestone National Scenic River.

Table D-1. Species abundance estimates during general surveys in Bluestone National Scenic River (Pauley et al. 2003).

Scientific Name	Common Name	Little Bluestone River	Indian Creek
Accipiter cooperii	Cooper's hawk	2	–
Accipiter striatus	sharp-shinned hawk	1	–
Agelaius phoeniceus	red-winged blackbird	3	–
Aix sponsa	wood duck	8	–
Anas platyrhynchos	Louisiana waterthrush	3	1
Archilochus colubris	ruby-throated hummingbird	4	–
Ardea herodias	great blue heron	5	1
Baeolophus bicolor	tufted titmouse	15	20
Bombycilla cedrorum	cedar waxwing	15	–
Bonasa umbellus	ruffed grouse	3	2
Branta canadensis	Canada goose	36	–
Buteo lineatus	red-shouldered hawk	2	1
Buteo platypterus	broad-winged hawk	1	2
Butorides virescens	green heron	4	–
Cardinalis cardinalis	northern cardinal	10	1
Cathartes aura	turkey vulture	10	–
Chaetura pelagica	chimney swift	9	2
Charadrius vociferus	killdeer	3	–
Chordeiles minor	common nighthawk	1	–
Cistothorus palustris	mallard	20	3
Coccyzus americanus	yellow-billed cuckoo	2	2
Colaptes auratus	northern (yellow-shafted) flicker	3	5
Contopus virens	eastern wood-pewee	9	9
Coragyps atratus	black vulture	3	–
Corvus brachyrhynchos	American crow	22	14
Corvus corax	common raven	3	2
Cyanocitta cristata	blue jay	15	10
Dryocopus pileatus	pileated woodpecker	5	5
Empidonax minimus	least flycatcher	2	1
Empidonax traillii	willow flycatcher	–	1

Scientific Name	Common Name	Little Bluestone River	Indian Creek
Empidonax virescens	Acadian flycatcher	8	12
Geothlypis formosa	Kentucky warbler	5	4
Helmitheros vermivorum	worm-eating warbler	12	9
Hylocichla mustelina	wood thrush	10	19
Icterus galbula	Baltimore oriole	5	–
Megaceryle alcyon	belted kingfisher	5	2
Megascops asio	eastern screech-owl	2	–
Melanerpes carolinus	red-bellied woodpecker	3	3
Meleagris gallopavo	wild turkey	8	9
Melospiza melodia	song sparrow	6	–
Mniotilta varia	black-and-white warbler	11	19
Myiarchus crinitus	great crested flycatcher	5	7
Passerina cyanea	indigo bunting	15	7
Pheucticus ludovicianus	rose-breasted grosbeak	4	7
Picoides pubescens	downy woodpecker	10	7
Picoides villosus	hairy woodpecker	2	1
Pipilo erythrophthalmus	eastern towhee	11	9
Piranga olivacea	scarlet tanager	6	10
Poecile atricapillus	black-billed cuckoo	4	1
Poecile carolinensis	Carolina chickadee	10	17
Polioptila caerulea	blue-gray gnatcatcher	13	8
Sayornis phoebe	eastern phoebe	5	3
Seiurus aurocapilla	ovenbird	8	25
Setophaga americana	northern parula	10	9
Setophaga caerulescens	black-throated blue warbler	2	–
Setophaga cerulea	cerulean warbler	10	4
Setophaga citrina	hooded warbler	8	12
Setophaga dominica	yellow-throated warbler	7	5
Setophaga pensylvanica	chestnut-sided warbler	10	5
Setophaga ruticilla	American redstart	9	2
Setophaga virens	black-throated green warbler	3	10
Sitta carolinensis	white-breasted nuthatch	7	8
Spinus tristis	American goldfinch	20	27
Spizella passerina	chipping sparrow	1	2

Scientific Name	Common Name	Little Bluestone River	Indian Creek
Stelgidopteryx serripennis	northern rough-winged swallow	3	–
Strix varia	barred owl	2	1
Tachycineta bicolor	tree swallow	4	–
Thryothorus ludovicianus	Carolina wren	12	7
Turdus migratorius	American robin	8	10
Vermivora cyanoptera	blue-winged warbler	2	–
Vireo flavifrons	yellow-throated vireo	3	6
Vireo griseus	white-eyed vireo	2	–
Vireo olivaceus	red-eyed vireo	17	25
Vireo solitarius	blue-headed vireo	2	5
Zenaida macroura	mourning dove	6	3
Species Richness	–	**75**	**55**
Total Individuals	–	**535**	**402**

Appendix D. Species abundance observed in Bluestone National Scenic River during PCS efforts along the Little Bluestone River, Mountain Creek, Jarrell Branch from 2009-2012

Table E-1. Species abundance observed in Bluestone National Scenic River during point count survey efforts along the Little Bluestone River, Mountain Creek, Jarrell Branch from 2009-2012 (Marshall et al. 2013).

Scientific Name	Common Name	Number of Individuals
Archilochus colubris	ruby-throated hummingbird	2
Baeolophus bicolor	tufted titmouse	20
Bonasa umbellus	ruffed grouse	4
Cardinalis cardinalis	northern cardinal	9
Certhia americana	brown creeper	1
Coccyzus americanus	yellow-billed cuckoo	1
Colaptes auratus	northern flicker	1
Contopus virens	eastern wood-pewee	9
Corvus brachyrhynchos	American crow	13
Cyanocitta cristata	blue jay	23
Dryocopus pileatus	pileated woodpecker	14
Empidonax virescens	Acadian flycatcher	175
Helmitheros vermivorum	worm-eating warbler	29
Hylocichla mustelina	wood thrush	100
Icterus galbula	Baltimore oriole	2
Megaceryle alcyon	belted kingfisher	2
Melanerpes carolinus	red-bellied woodpecker	3
Mniotilta varia	black-and-white warbler	21
Parkesia motacilla	Louisiana waterthrush	72
Passerina cyanea	indigo bunting	9
Picoides pubescens	downy woodpecker	5
Picoides villosus	hairy woodpecker	7
Pipilo erythrophthalmus	eastern towhee	6
Piranga olivacea	scarlet tanager	72
Poecile carolinensis	Carolina chickadee	51
Polioptila caerulea	blue-gray gnatcatcher	14
Sayornis phoebe	eastern phoebe	17
Seiurus aurocapilla	ovenbird	89
Setophaga americana	northern parula	25
Setophaga caerulescens	black-throated blue warbler	1
Setophaga cerulea	cerulean warbler	2
Setophaga citrina	hooded warbler	2

Scientific Name	Common Name	Number of Individuals
Setophaga coronata	yellow-throated warbler	13
Setophaga ruticilla	American redstart	37
Setophaga virens	black-throated green warbler	13
Sitta carolinensis	white-breasted nuthatch	9
Spizella pusilla	field sparrow	2
Thryothorus ludovicianus	Carolina wren	16
Toxostoma rufum	brown thrasher	1
Turdus migratorius	American robin	2
Vireo flavifrons	yellow-throated vireo	6
Vireo olivaceus	red-eyed vireo	168
Vireo solitarius	blue-headed vireo	36
Zenaida macroura	mourning dove	3
Species Richness	**–**	**44**
Species Abundance (Total)	**–**	**1107**

Appendix E. Mammal species occurring at Bluestone National Scenic River.

Table F-1. Mammal species occurring at Bluestone National Scenic River according to NPSpecies (2016b) and species observed by Pauley et al. (2003), 1997-1999.

Scientific Name	Common Name	Pauley et al. (2003)
Blarina brevicauda	northern short-tailed shrew	X
Castor canadensis	American beaver	X
Cryptotis parva	North American least shrew	X
Didelphis virginiana	Virginia opossum	X
Eptesicus fuscus	big brown bat	X
Glaucomys volans[a]	southern flying squirrel	–
Lasionycteris noctivagans	silver-haired bat	–
Lasiurus borealis	eastern red bat	X
Lasiurus cinereus	hoary bat	–
Lynx rufus	bobcat	X
Marmota monax	woodchuck, groundhog	X
Mephitis mephitis	striped skunk	X
Microtus pennsylvanicus	meadow vole	X
Mus musculus[b]	house mouse	X
Mustela frenata	long-tailed weasel	X
Myodes gapperi	southern red-backed vole	X
Myotis leibii	eastern small-footed myotis	X
Myotis lucifugus	little brown myotis/bat	X
Myotis septentrionalis	northern myotis/long-eared bat	X
Myotis sodalis	Indiana myotis/bat	X
Napaeozapus insignis	woodland jumping mouse	X
Neotoma magister	Allegheny woodrat	X
Odocoileus virginianus	white-tailed deer	X
Ondatra zibethicus	common muskrat	X
Parascalops breweri	hairy-tailed mole	X
Perimyotis subflavus	tricolored bat (eastern pipistrelle)	–
Peromyscus leucopus	white-footed deermouse	X
Peromyscus maniculatus	North American deermouse	X
Procyon lotor	raccoon	X
Sciurus carolinensis	eastern gray squirrel	X
Sciurus niger	eastern fox squirrel	X

[a] Not confirmed, but probably present

[b] Non-native

Table F-1 (continued). Mammal species occurring at Bluestone National Scenic River according to NPSpecies (2016b) and species observed by Pauley et al. (2003), 1997-1999.

Scientific Name	Common Name	Pauley et al. (2003)
Sorex cinereus	cinereus (masked) shrew	X
Sorex dispar	long-tailed shrew	X
Sorex fumeus	smoky shrew	X
Sorex hoyi	American pygmy shrew	X
Sylvilagus floridanus	eastern cottontail	X
Synaptomys cooperi	southern bog lemming	X
Tamias striatus	eastern chipmunk	X
Tamiasciurus hudsonicus	red squirrel	X
Urocyon cinereoargenteus[a]	gray fox	X
Ursus americanus	American black bear	–
Vulpes vulpes	red fox	X
Zapus hudsonius	meadow jumping mouse	X

[a] Not confirmed, but probably present

[b] Non-native

Appendix F. Herpetofauna species occurring at Bluestone National Scenic River.

Table G-1. Herpetofauna species of Bluestone National Scenic River (NPS Pauley et al. 2003, 2016b). Abundances are from NPSpecies (NPS 2016b) and state ranks are from the WV DNR (2015).

Group	Scientific Name	Common Name	Abundance	State Rank[a]
Reptiles	*Agkistrodon contortrix mokasen*	*northern copperhead*	Uncommon	–
	Chelydra serpentina	*common snapping turtle*	Common	–
	Coluber constrictor constrictor	*northern black racer*	Rare	–
	Diadophis punctatus edwardsii	*northern ringneck snake*	Uncommon	–
	Eumeces fasciatus	*five-lined skink*	–	–
	Nerodia sipedon sipedon	*common water snake*	Common	–
	Opheodrys aestivus	*rough greensnake*	Rare	S2
	Pantherophis (Elaphe) alleghaniensis	*eastern ratsnake*	Uncommon	–
	Regina septemvittata	*queen snake*	Rare	–
	Sceloporus undulatus	*eastern fence lizard*	Uncommon	–
	Terrapene carolina carolina	*eastern box turtle*	Common	–
	Thamnophis sirtalis sirtalis	*common garter snake*	Common	–
Amphibians	*Ambystoma jeffersonianum*	Jefferson salamander	Rare	S2
	Ambystoma maculatum	spotted salamander	Uncommon	–
	Ambystoma opacum	marbled salamander	Uncommon	–
	Anaxyrus americanus americanus	eastern American toad	Common	–
	Aneides aeneus	green salamander	Uncommon	S3
	Desmognathus fuscus	northern dusky salamander	Common	–
	Desmognathus monticola	seal salamander	Common	–
	Desmognathus ochrophaeus	Allegheny Mountain dusky salamander	Rare	–
	Desmognathus quadramaculatus	black-bellied salamander	Rare	S3
	Eurycea cirrigera	southern two-lined salamander	Common	–
	Eurycea longicauda	long-tailed salamander	Uncommon	–
	Eurycea lucifuga	cave salamander	Rare	S3
	Gyrinophilus porphyriticus porphyriticus	northern spring salamander	Uncommon	–
	Hemidactylium scutatum	four-toed salamander	Rare	–
	Hyla chrysoscelis	Cope's gray treefrog	Common	–
	Hyla versicolor	gray treefrog	Rare	–
	Lithobates catesbeianus	American bullfrog	Common	–
	Lithobates clamitans melanota	northern green frog	Common	–

Group	Scientific Name	Common Name	Abundance	State Rank[a]
Amphibians (continued)	*Lithobates palustris*	pickerel frog	Uncommon	–
	Lithobates sylvaticus	wood frog	Common	–
	Notophthalmus viridescens viridescens	red-spotted newt	Common	–
	Plethodon cinereus	eastern red-backed salamander	Common	–
	Plethodon kentucki	Cumberland Plateau salamander	Common	–
	Plethodon richmondi	southern ravine salamander	Uncommon	–
	Plethodon wehrlei	Wehrle's salamander	Uncommon	–
	Pseudacris brachyphona	mountain chorus frog	Uncommon	–
	Pseudacris crucifer	northern spring peeper	Common	–
	Pseudotriton ruber ruber	northern red salamander	Rare	S3

[a] Ranks are only given for species with a rank of S3 or higher.

Appendix G. Abundance of herpetofauna species occurring at Bluestone National Scenic River by terrestrial habitat type.

Table H-1. Abundance of herpetofauna species at Bluestone National Scenic River by terrestrial habitat type, as observed from 1996-2000 by Pauley et al. (2003). Column headings/habitat types are: For – Forest, OF – Old field, F/RW – Field/Rights-of-way, TRB – Trails/Roads and banks, RO – Rock outcrops, ER/BF – Emergent rocks/Boulder Fields. Amphibian results include VES and pitfall trap results. Species detection during chorus surveys is noted with a “C”.

Group	Scientific Name	Common Name	For	OF	F/RW	TRB	RO	ER/BF	Total
Reptiles	*Agkistrodon contortrix mokasen*	northern copperhead	3	–	–	1	–	–	**4**
	Coluber constrictor constrictor	northern black racer	–	–	1	1	–	–	**2**
	Diadophis punctatus edwardsii	northern ringneck snake	3	1	1	8	–	–	**13**
	Eumeces fasciatus	five-lined skink	2	–	1	–	–	–	**3**
	Nerodia sipedon sipedon	common water snake	–	–	–	1	–	–	**1**
	Opheodrys aestivus	rough greensnake	–	–	–	1	–	–	**1**
	Pantherophis (Elaphe) alleghaniensis	eastern ratsnake	6	–	–	5	–	–	**11**
	Regina septemvittata	queen snake	–	–	1	–	–	–	**1**
	Sceloporus undulatus	eastern fence lizard	1	–	1	1	3	–	**6**
	Terrapene carolina carolina	eastern box turtle	12	–	–	9	–	1	**22**
	Thamnophis sirtalis sirtalis	common garter snake	2	–	–	3	–	–	**5**
Amphibians	*Ambystoma maculatum*	spotted salamander	–	–	–	–	1	–	**1**
	Plethodon wehrlei	Wehrle's salamander	1	–	–	–	1	2	**4**
	Anaxyrus americanus americanus	eastern American toad	27	–	2	6	7	1	**43**
	Aneides aeneus	green salamander	1	–	–	–	3	3	**7**
	Desmognathus fuscus	northern dusky salamander	–	–	–	–	6	–	**6**
	Desmognathus monticola	seal salamander	4	–	–	–	10	–	**14**

Group	Scientific Name	Common Name	For	OF	F/RW	TRB	RO	ER/BF	Total
Amphibians (continued)	*Desmognathus ochrophaeus*	Allegheny Mountain dusky salamander	1	–	–	–	–	–	**1**
	Eurycea cirrigera	southern two-lined salamander	25	–	–	5	22	–	**52**
	Eurycea longicauda	long-tailed salamander	7	–	–	–	17	1	**25**
	Eurycea lucifuga	cave salamander	–	–	–	–	2	–	**2**
	Hemidactylium scutatum	four-toed salamander	–	–	–	–	1	–	**1**
	Hyla versicolor	gray tree frog	–	–	C	–	–	–	**C**
	Lithobates clamitans melanota	northern green frog	2	–	1	C	2	–	**5**
	Lithobates palustris	pickerel frog	30	1	2	5	24	1	**63**
	Lithobates sylvaticus	wood frog	2	–	–	–	–	5	**7**
	Notophthalmus viridescens viridescens	red-spotted newt	14	–	–	3	26	1	**44**
	Plethodon cinereus	eastern red-backed salamander	102	–	–	3	43	26	**174**
	Plethodon kentucki	Cumberland Plateau salamander	11	–	–	1	11	–	**23**
	Plethodon richmondi	southern ravine salamander	33	–	–	–	2	–	**35**
	Pseudacris brachyphona	mountain chorus frog	–	–	–	C	–	–	**C**
	Pseudacris crucifer	northern spring peeper	1	–	–	–	2	–	**3**
	Pseudotriton ruber ruber	northern red salamander	1	–	–	–	1	2	**4**
Totals	**–**	**–**	**291**	**2**	**10**	**53**	**184**	**43**	**583**

Appendix H. Abundance of herpetofauna species occurring at Bluestone National Scenic River by aquatic habitat type.

Table I-1. Abundance of herpetofauna species at Bluestone National Scenic River by aquatic habitat type, as observed from 1996-2000 by Pauley et al. (2003). Column headings/habitat types are: EP – Ephemeral pools, PP – permanent pools, RP – Road-rut pools, WM – Wet meadow, S/S – Springs/Seeps, FOS – 1st order streams, SOS – 2nd order streams, TOS – 3rd order streams, RIV – Bluestone River, RZ – Riparian zone. Amphibian results include VES and pitfall trap results. Species detection during chorus surveys is noted with a "C", and detection of egg masses is indicated with an "E".

Group	Scientific Name	Common Name	EP	PP	RP	WM	S/S	FOS	SOS	TOS	RIV	RZ	Totals
Reptiles	Chelydra serpentina	common snapping turtle	–	–	2	–	–	–	–	–	3	–	5
	Nerodia sipedon sipedon	common water snake	1	–	–	–	1	–	1	–	–	2	5
	Regina septemvittata	queen snake	–	–	–	–	–	–	–	–	1	–	1
	Terrapene carolina carolina	eastern box turtle	2	–	2	1	3	–	–	–	1	9	18
Amphibians	Ambystoma jeffersonianum	Jefferson salamander	16, E	–	–	–	–	–	–	–	–	–	16
	Ambystoma maculatum	spotted salamander	30, E	1	40	–	–	–	–	–	–	–	71
	Ambystoma opacum	marbled salamander	58, E	4	–	–	–	–	–	–	–	–	62
	Anaxyrus americanus americanus	eastern American toad	C	–	21, C	–	–	–	–	–	C	5, C	26
	Aneides aeneus	green salamander	–	–	–	–	–	–	–	–	–	2	2
	Desmognathus fuscus	northern dusky salamander	–	–	–	–	1	62	42	1	–	1	107
	Desmognathus monticola	seal salamander	–	–	–	–	1	24	16	–	–	2	43

Group	Scientific Name	Common Name	EP	PP	RP	WM	S/S	FOS	SOS	TOS	RIV	RZ	Totals
Amphibians (continued)	Desmognathus ochrophaeus	Allegheny Mountain dusky salamander	–	–	–	–	1	1	–	–	–	–	2
	Desmognathus quadramaculatus	black-bellied salamander	–	–	–	–	–	10	–	–	–	–	10
	Eurycea cirrigera	southern two-lined salamander	–	1	–	–	–	48	37	3	–	15	104
	Gyrinophilus porphyriticus porphyriticus	northern spring salamander	–	–	–	–	1	1	1	–	–	–	3
	Hemidactylium scutatum	four-toed salamander	–	–	2, E	–	–	–	–	–	–	–	2
	Hyla chrysoscelis	Cope's gray treefrog	C	–	50, C	C	–	–	–	–	–	1, C	51
	Lithobates catesbeianus	American bullfrog	4, C	3, C	4, C	–	–	C	1	–	–	–	12
	Lithobates clamitans melanota	northern green frog	41	8	6	C	–	1	6	–	–	4, C	66
	Lithobates palustris	pickerel frog	3, C	–	3	–	1	3	4	–	C	71, C	85
	Lithobates sylvaticus	wood frog	26, C, E	C, E	E	–	–	1	–	–	–	1	28
	Notophthalmus viridescens viridescens	red-spotted newt	52	59	11	–	–	2	–	–	–	15	139
	Plethodon cinereus	eastern red-backed salamander	–	–	–	–	–	1	–	–	–	5	6
	Plethodon kentucki	Cumberland Plateau salamander	–	–	–	–	–	1	–	–	–	8	9
	Plethodon richmondi	southern ravine salamander	–	–	–	–	–	–	–	–	–	1	1

Group	Scientific Name	Common Name	EP	PP	RP	WM	S/S	FOS	SOS	TOS	RIV	RZ	Totals
Amphibians (continued)	Pseudacris brachyphona	mountain chorus frog	C	–	95, C, E	–	–	–	–	–	–	–	95
	Pseudacris crucifer	northern spring peeper	2, C	–	–	–	–	–	–	–	–	8	10
	Pseudotriton ruber ruber	northern red salamander	–	–	–	–	–	2	–	–	–	–	2
Totals	**–**	**–**	**235**	**76**	**236**	**1**	**9**	**157**	**108**	**4**	**5**	**150**	**981**

Appendix I. Number of habitat types where each herpetofauna species was observed within Bluestone National Scenic River.

Table J-1. Number of habitat types where each herpetofauna species was observed within Bluestone National Scenic River by Pauley et al. (2003).

Group	Scientific Name	Common Name	Total Habitat Types	Terrestrial Types	Aquatic Types
Reptiles	*Terrapene carolina carolina*	eastern box turtle	9	3	6
	Sceloporus undulatus	eastern fence lizard	4	4	–
	Diadophis punctatus edwardsii	northern ringneck snake	4	4	–
	Nerodia sipedon sipedon	common water snake	4	–	4
	Eumeces fasciatus	five-lined skink	2	2	–
	Regina septemvittata	queen snake	2	1	1
	Agkistrodon contortrix mokasen	northern copperhead	2	2	–
	Coluber constrictor constrictor	northern black racer	2	2	–
	Pantherophis (Elaphe) alleghaniensis	eastern ratsnake	2	2	–
	Thamnophis sirtalis sirtalis	common garter snake	2	2	–
	Chelydra serpentina	common snapping turtle	2	–	2
	Opheodrys aestivus	rough greensnake	1	1	–
Amphibians	*Lithobates palustris*	pickerel frog	13	6	7
	Lithobates clamitans melanota	northern green frog	11	4	7
	Anaxyrus americanus americanus	eastern American toad	9	5	4
	Notophthalmus viridescens viridescens	red-spotted newt	9	4	5
	Eurycea cirrigera	southern two-lined salamander	8	3	5
	Lithobates sylvaticus	wood frog	7	2	5
	Plethodon cinereus	eastern red-backed salamander	6	4	2
	Desmognathus monticola	seal salamander	6	2	4
	Desmognathus fuscus	northern dusky salamander	6	1	5
	Plethodon kentucki	Cumberland Plateau salamander	5	3	2
	Lithobates catesbeianus	American bullfrog	5	–	5
	Pseudacris crucifer	northern spring peeper	4	2	2

Group	Scientific Name	Common Name	Total Habitat Types	Terrestrial Types	Aquatic Types
Amphibians (continued)	*Pseudotriton ruber ruber*	northern red salamander	4	3	1
	Ambystoma maculatum	spotted salamander	4	1	3
	Hyla chrysoscelis	Cope's gray treefrog	4	–	4
	Plethodon richmondi	southern ravine salamander	3	2	1
	Pseudacris brachyphona	mountain chorus frog	3	1	2
	Desmognathus ochrophaeus	Allegheny Mountain dusky salamander	3	1	2
	Eurycea longicauda	long-tailed salamander	3	3	–
	Plethodon wehrlei	Wehrle's salamander	3	3	–
	Gyrinophilus porphyriticus porphyriticus	northern spring salamander	3	–	3
	Hemidactylium scutatum	four-toed salamander	2	1	1
	Ambystoma opacum	marbled salamander	2	–	2
	Hyla versicolor	gray treefrog	1	1	–
	Eurycea lucifuga	cave salamander	1	1	–
	Desmognathus quadramaculatus	black-bellied salamander	1	–	1
	Aneides aeneus	green salamander	1	–	1
	Ambystoma jeffersonianum	Jefferson salamander	1	–	1

Appendix J. Observation locations for herpetofauna species at Bluestone National Scenic River.

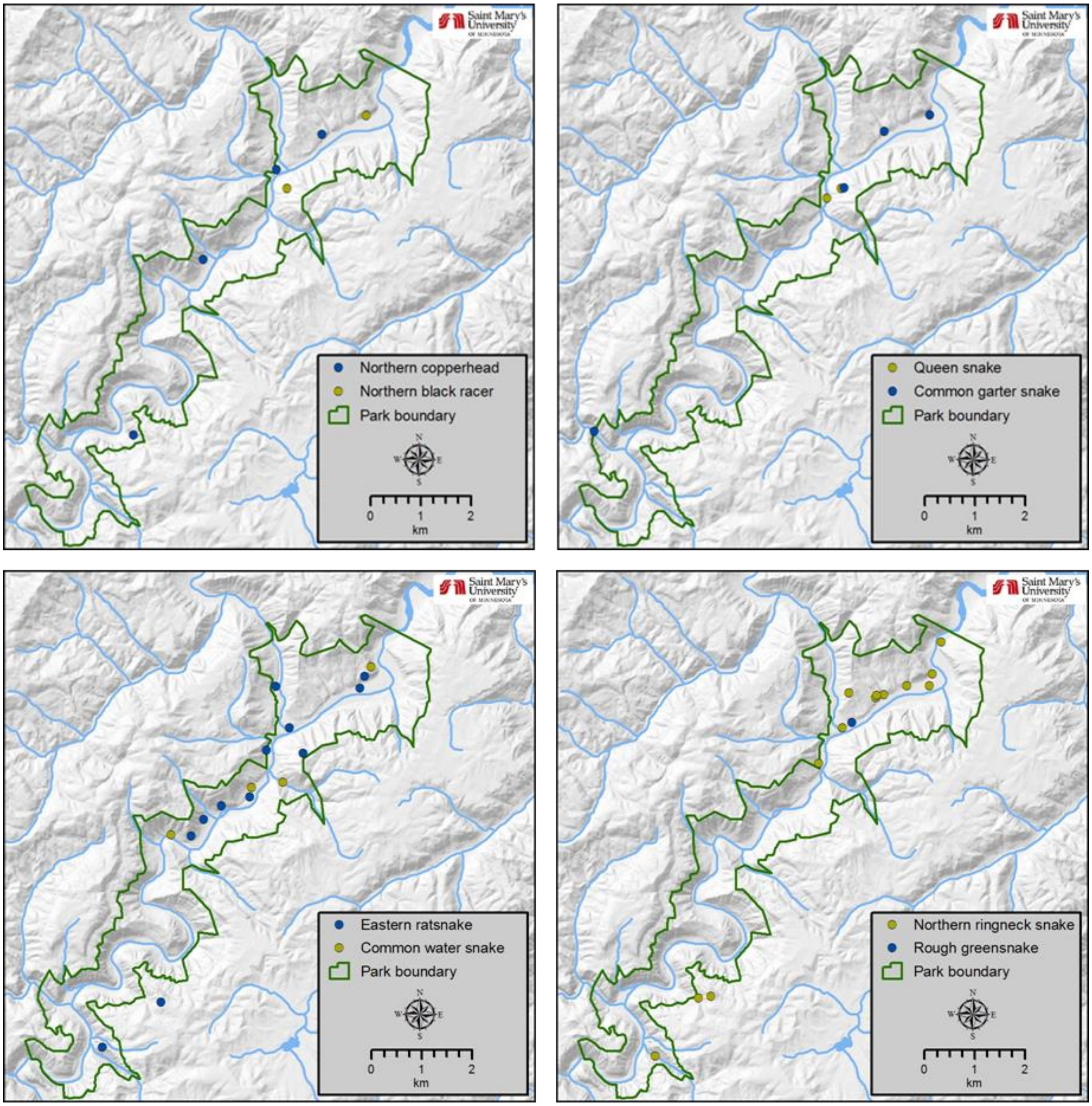


Figure K-1. Sampling locations where eight different snake species were observed within Bluestone National Scenic River (Pauley et al. 2003).

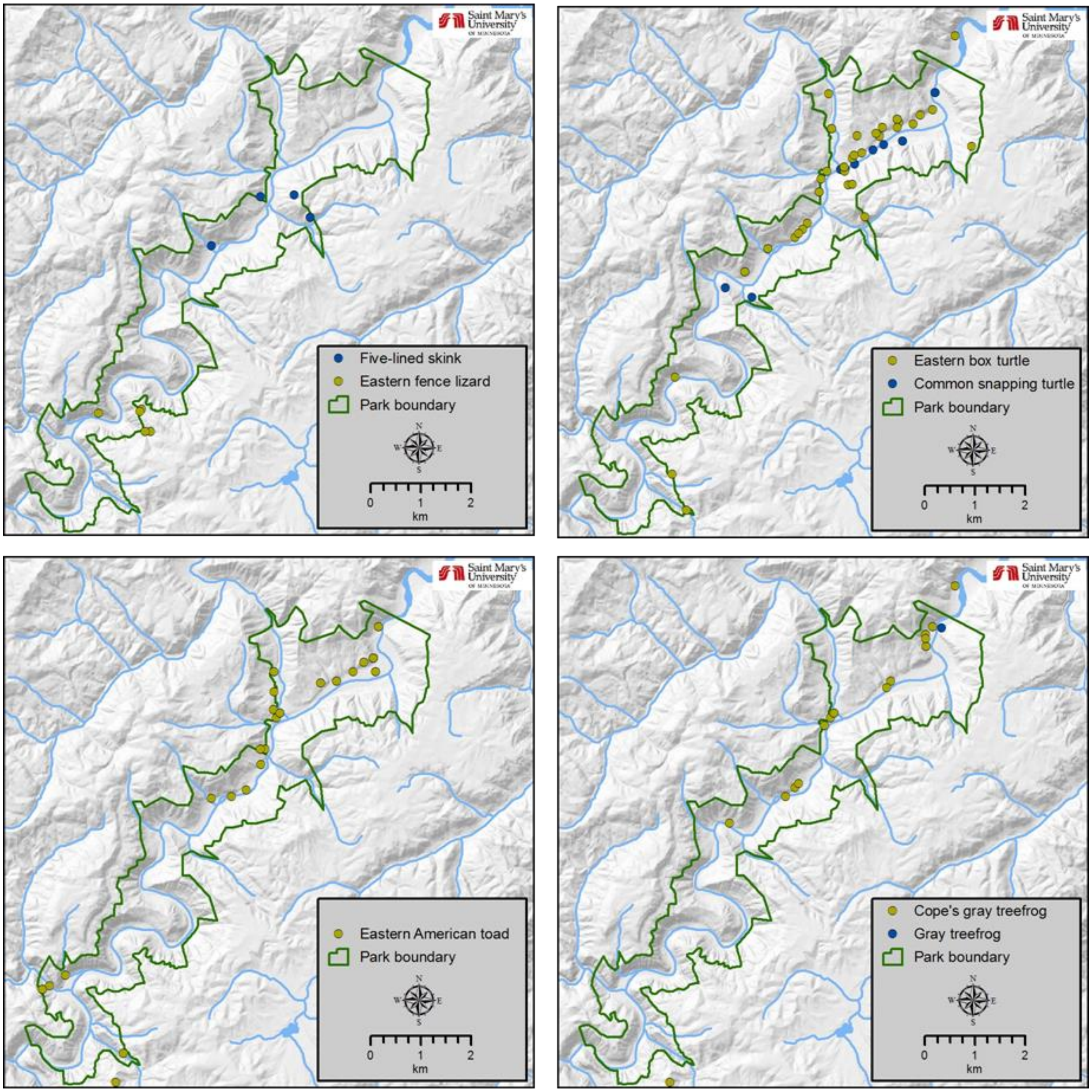


Figure K-2. Sampling locations where lizard (upper left), turtle (upper right), toad (lower left), and treefrog (lower right) species were observed within Bluestone National Scenic River (Pauley et al. 2003).

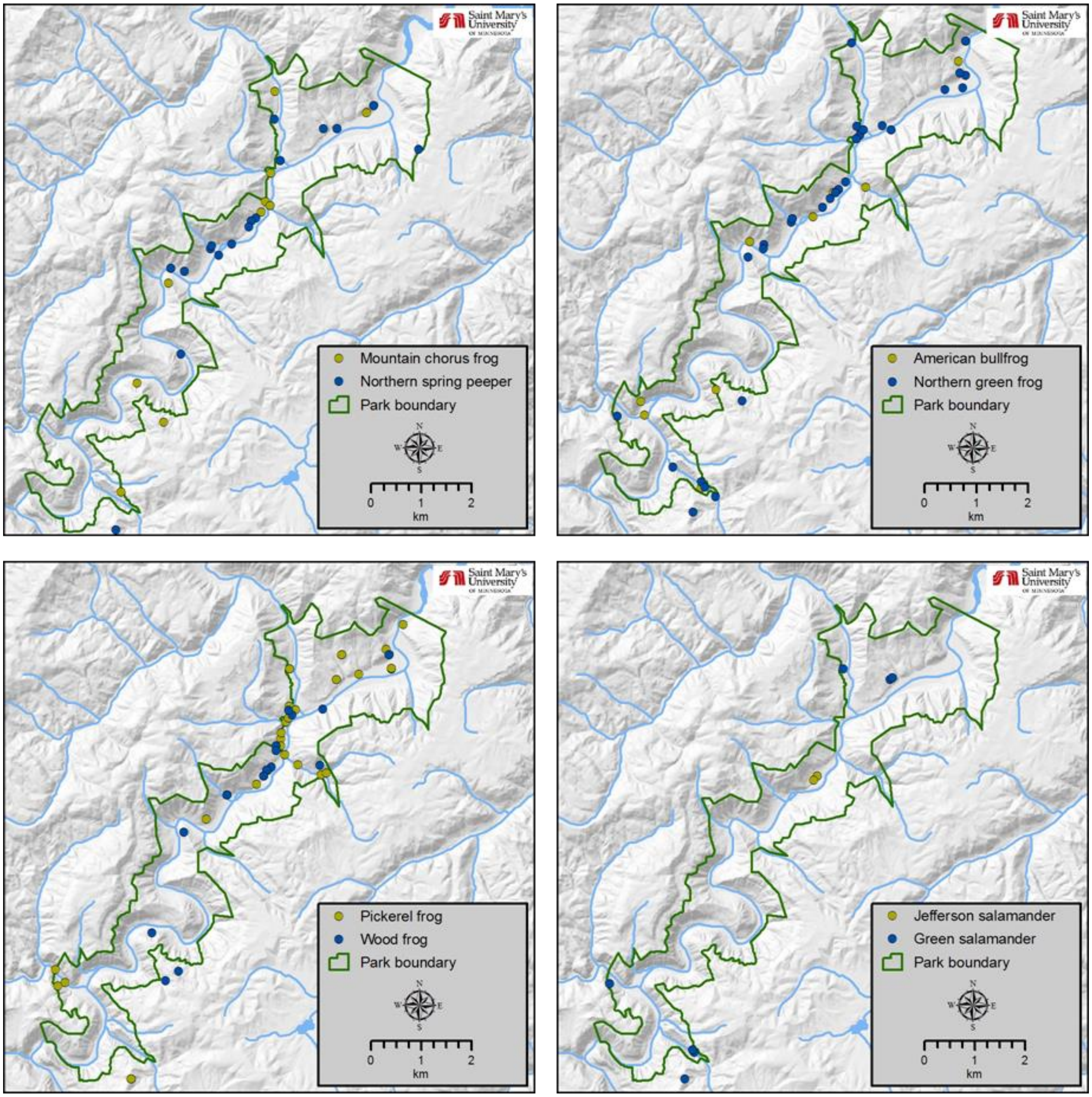


Figure K-3. Sampling locations where several frog and two salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003).

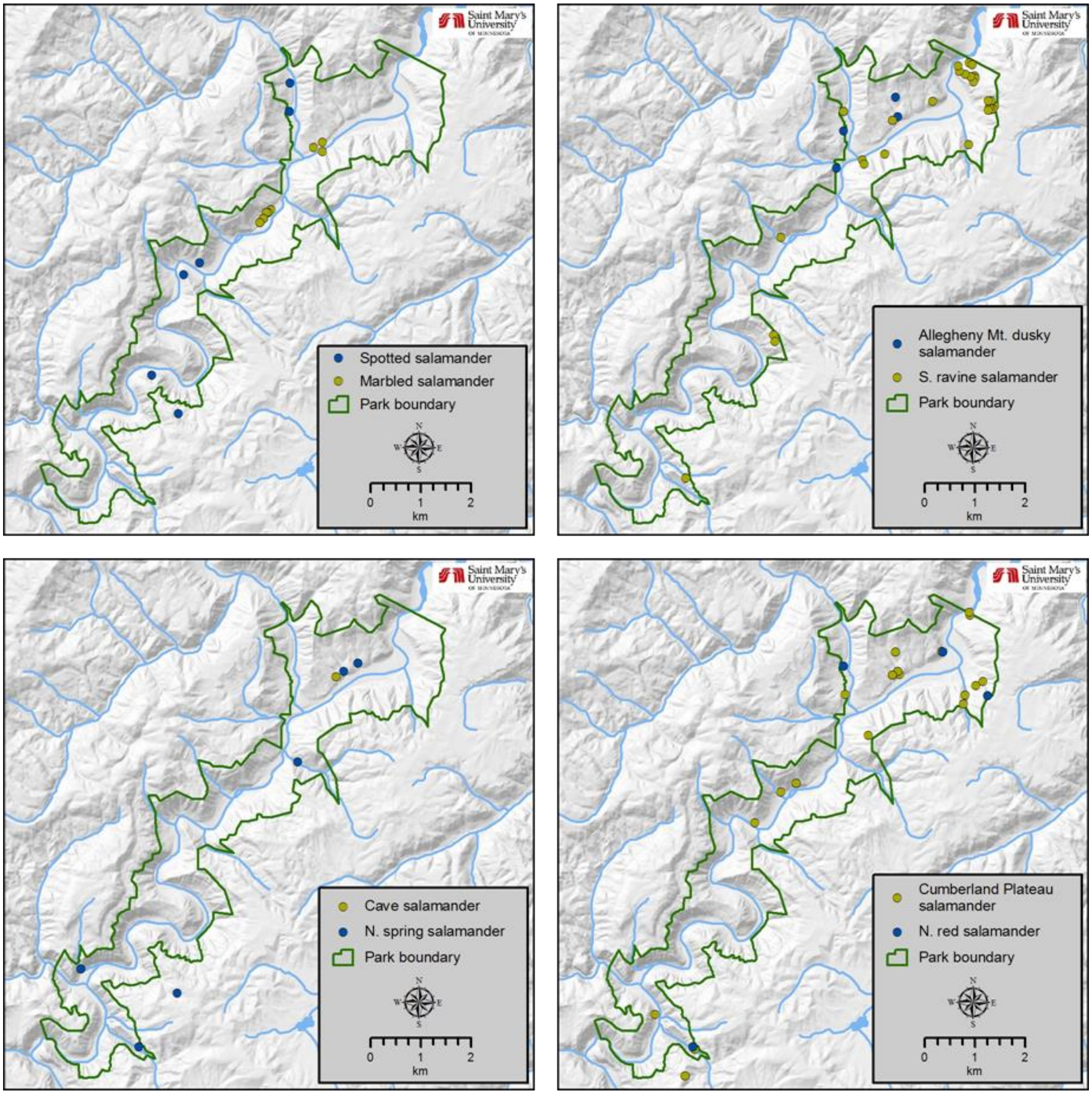


Figure K-4. Sampling locations where several salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003).

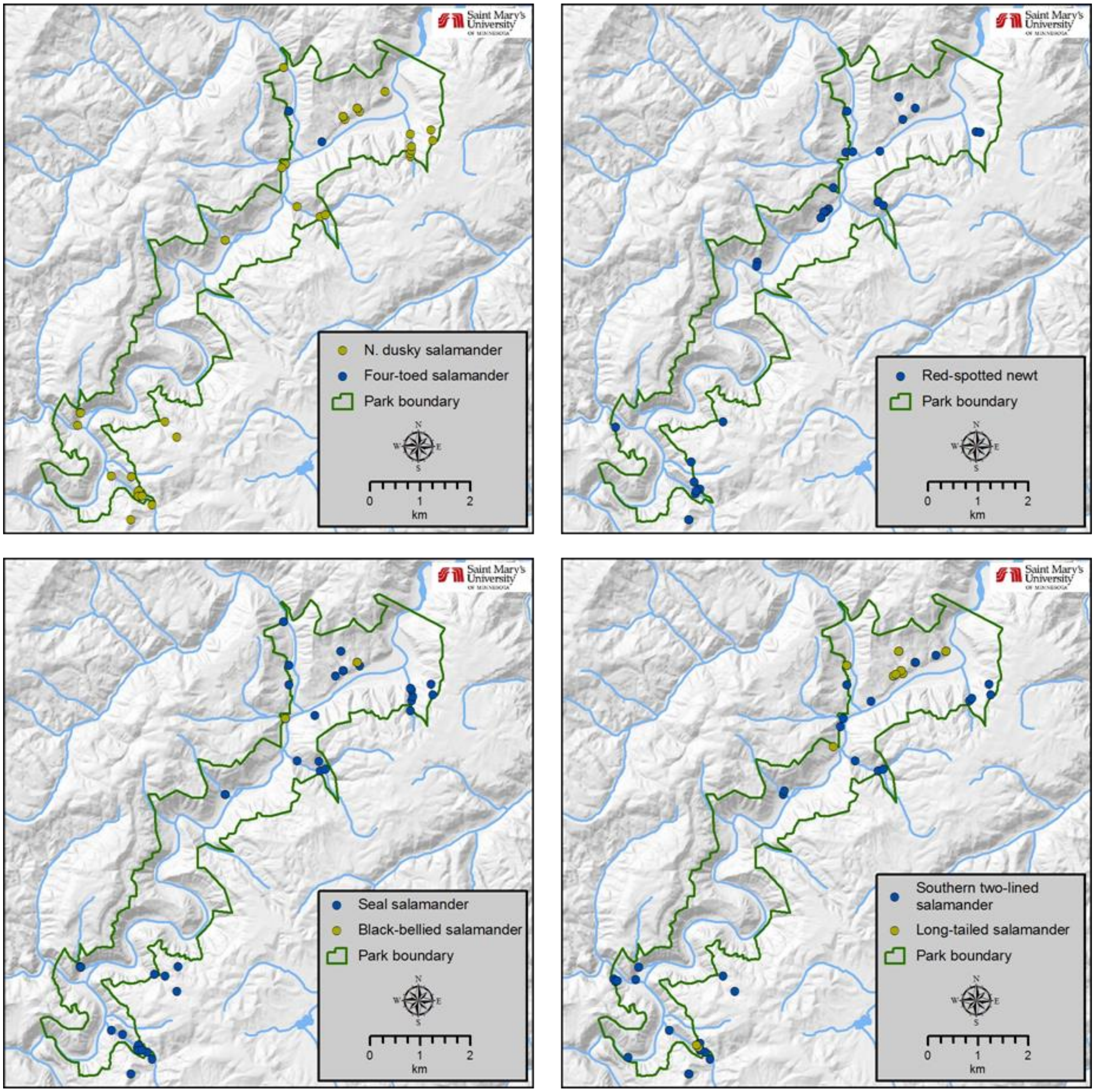


Figure K-5. Sampling locations where several salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003).

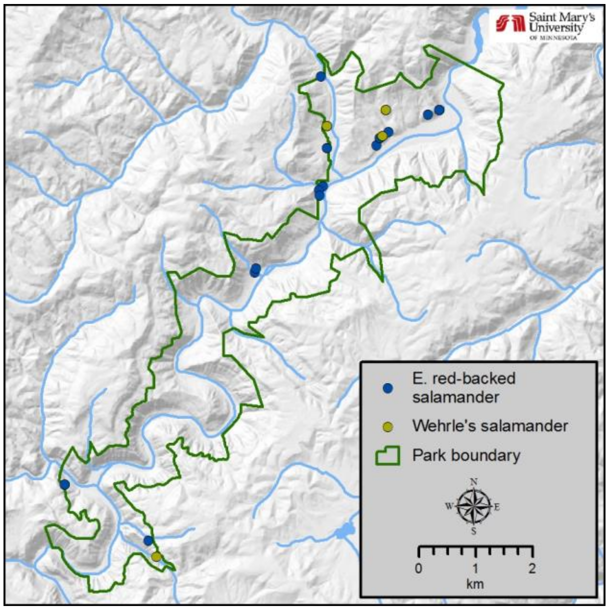


Figure K-6. Sampling locations where two salamander species were observed within Bluestone National Scenic River (Pauley et al. 2003).

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

NPS 619/149441, November 2018

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

EXPERIENCE YOUR AMERICA ™