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The Ephemeroptera, Megaloptera, Odonata, Plecoptera, and Trichoptera Of the Blue Ridge Parkway, North Carolina and Virginia

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Introduction

Aquatic insects are ubiquitous inhabitants of freshwater lotic and lentic systems throughout the world, outside of Antarctica. Among those orders of insects whose immature stages are primarily aquatic, the EMOPT taxa (Ephemeroptera [mayflies], Megaloptera [alderflies, dobsonflies, fishflies], Odonata [damselflies, dragonflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]), more than 25,000 species have been documented (Balian et al. 2008). In North America approximately 3,250 species are known, representing 12% of the world fauna (Merritt et al. 2008). Morse et al. (1997) indicated that nearly half of the North American species of the above orders occur in the southeastern United States, with many species endemic to the region, especially the southern Appalachians. McCafferty et al. (2010) documented 300 species of mayflies from the southeast, nearly half of all mayfly species recorded from North America. Hamilton and Morse (1990) state that about 40% of the caddisfly species known from North America occur in the Southeast, and about 12% are endemic taxa. Master et al. (1998) considered the United States a global center of freshwater biodiversity, and claimed that the “extraordinary diversity” of the Southeast was the result of its “diverse physical geography, favorable climate, and a long dynamic history.”

In addition to having great ecological significance to healthy aquatic ecosystem functioning, aquatic insects are valuable indicators of ecosystem health. Most species have annual life cycles, while some have multiple generations per year, and others have two or three year life cycles. Insects, therefore, can show a rapid response to perturbations and environmental stress. Different species have different abilities to tolerate ecological disturbance, from habitat alteration or pollution to global climate change. The large number of aquatic insect species responding to a wide range of disturbances makes them excellent indicators of water quality. Many federal and state agencies, as well as a variety of citizen groups, use these characteristics to monitor the health of aquatic resources (e.g., Carter and Resh 2001, Resh and Jackson 1993, Resh and McElravy 1993, Rosenberg et al. 2008). At least 86 National Parks conduct aquatic macroinvertebrate monitoring as a part of the National Park Service’s Inventory and Monitoring Program (Fancy and Bennetts 2012). Thus, the importance of aquatic resources and the significance of aquatic insects as indicators of the health of those resources are widely recognized, and are widely utilized in monitoring programs.

The U.S. Geological Survey conducted an inventory of the aquatic insect fauna in 17 national parks from 2005 to 2007. In 2010 and 2011, an additional park was surveyed. Thus, all 18 parks in the Appalachian Highlands Monitoring Network (Big South Fork National River and Recreation Area, Blue Ridge Parkway, Great Smoky Mountains National Park, Obed Wild and Scenic River) and the Cumberland Piedmont Monitoring Network (Abraham Lincoln Birthplace National Historic Site, Carl Sandburg Home National Historic Site, Chickamauga and Chattanooga National Military Park, Cowpens National Battlefield, Cumberland Gap National Historical Park, Fort Donelson National Battlefield, Guilford Courthouse National Military Park, Kings Mountain National Military Park, Little River Canyon National Preserve, Mammoth Cave National Park, Ninety Six National Historic Site, Russell Cave National Monument, Shiloh National Military Park, Stones River National Battlefield) were included.

The goals of the surveys were to provide each park with a comprehensive assessment of the

aquatic insect fauna including: species lists with distributions and relative abundances of each species; curated specimens having Park Service Catalog Numbers assigned, and deposited either at the parks, or at Mammoth Cave National Park; a database of findings to be incorporated into the National Park Service's Interior Collections Management System (ICMS); and an assessment of the quality of the aquatic resources of the parks based on the known environmental requirements of the species found.

Separate reports are available for most of the 18 parks included in this survey. This document reports the findings for the Blue Ridge Parkway (BLRI), and relates the findings from BLRI to the other parks.

Blue Ridge Parkway

The BLRI is a narrow ribbon of land 755 km (469 mi) long, averaging approximately 500 m (0.3 mi) in width. It extends from Rockfish Gap, Virginia, at the southern terminus of the Skyline Drive and Shenandoah National Park, to Cherokee, North Carolina, at the Great Smoky Mountains National Park. It occupies 32,944 ha (127 mi²) of Appalachian ridge line. BLRI ranges in elevation from 183 to 1944 m (600 to 6378 ft.), although the roadway itself ranges from 198 to 1843 m (649 to 6047 ft.).

Aquatic Resources

The BLRI extends approximately 305 km (190 miles) north to south. The upper elevations receive high levels of precipitation, and as such are a primary source of headwaters for hundreds of streams. Countless numbers of these sources are small seeps, some of them ephemeral, although many are permanent, and are easily accessed along the roadway. The BLRI is said to include 400 streams and to cross five major rivers (Emmott et al. 2005). In addition, half of North Carolina's remaining bogs and fens are within the BLRI. Most BLRI watersheds have very low acid neutralizing capacity, and therefore are very susceptible to acidic deposition, and there are at least four state-listed 303(d) streams (Emmott et al. 2005). [‘The term "303(d) list" is short for the list of impaired and threatened waters (stream/river segments, lakes) that the Clean Water Act requires all states to submit for EPA approval every two years on even-numbered years.’ From the Environmental Protection Agency website < water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/overview.cfm >.]

Methods

The methods used in all parks are detailed in Appendix 1, Methods. Comments specific to BLRI are included here.

The BLRI is marked along its length with mile markers from 0 at Rockfish Gap to 469 at the southern terminus. The markers are on the right side of the road when travelling south, and serve as extremely convenient tools for identifying sampling locations, such as “BLRI 083.3 right,” which is interpreted as stopping at the location 0.3 miles south of mile marker 83 and sampling on the right (southbound) side of the road. Some sampling locations can also be identified by a landmark, such as a named overlook, stream crossing, or significant natural feature. In those instances, the named feature is incorporated into the locality identifier, as in “BLRI 067.0 left Falling Rock Creek”. Because the BLRI is very narrow in places, some sample localities were

found to lie outside the park boundary when plotted in the GIS. In those cases, the data and specimens were retained as park data, under the assumption that they represent conditions and fauna typical of the park, normally just a few meters away.

The BLRI is divided into four management districts that have assigned Resource Specialists. During sampling from 2005 to 2007, these individuals assisted by making collections of aquatic organisms during the course of their regular field duties, or on their own time. These collections greatly enhanced the sampling for this study, for which the authors are grateful.

Simultaneously with this study, an independent survey of park streams was conducted by David R. Lenat (DRL) on behalf of the Appalachian Highlands Monitoring Network, targeting known and suspected rare species of all aquatic invertebrate groups and habitats, especially in the higher elevations of the BLRI. Lenat recorded species abundances as “rare,” “common,” and “abundant,” representing specimen counts of 1-2, 3-9, and 10 or more, respectively. The EMOPT data from that survey are included here, although the specimens are not included among those delivered to the park and are not assigned NPS Catalog Numbers by this project. A significant tool used by DRL in his survey is a standard aquarium net, which has a very fine mesh and captures small invertebrates often missed by the larger meshes of seines and D-frame nets typically used in aquatic insect surveys. DRL worked with Steven V. Fend, U.S. Geological Survey, CA, to identify and describe the aquatic worms (Oligochaeta) from these samples.

Finally, the first author conducted a limited survey of aquatic invertebrates along the Parkway from 1991 to 1992. Results from that survey are also included, where appropriate.

Results

Locations and Events

Aquatic invertebrates were sampled at 324 locations along the BLRI from mile post 1 to mile post 459.5 (see Appendix 2 Maps, and Appendix 3, Locations and Events). Of those sites, 254 yielded specimens, and 251 had target specimens. Each location was sampled from 1-10 times, representing 533 collecting events. Elevations sampled ranged from 183 m at the James River Visitor Center, Milepost 63, to 1857 m at Rt. 128 exit to Mt. Mitchell, at Milepost 355.3. Dividing the range of elevations into equal thirds, we coded each site as Low, Mid, or High elevation. Of the 250 locations having EMOPT species and elevation data, Low elevations (183-

Table 1. Comparison of the distribution of the elevation of sample locations with park area of the elevation classes.

	Range	Park	Samples
Low	183-832 m	34%	19% (47 sites)
Mid	832-1265 m	51%	50% (124 sites)
High	1265-1948 m	15%	32% (79 sites)

832 m) were sampled at 47 sites, Mid elevations (832-1265 m) were sampled at 124 sites, and High elevations (1265-1948 m) were sampled at 79 sites. These numbers are compared with the elevation classes of the park based on area in Table 1. The low elevations were underrepresented in our sampling, the mid elevations were represented equally with the park area at mid elevations, and the high elevations were overrepresented. However, this simple comparison does not account for the distribution of aquatic resources, which are more abundant at higher elevations due to orographic effects. We conclude that our sampling effort was adequate to well represent the park's water resources.

Target Species

We collected 35,692 specimens, including 32,802 target taxa (EMOPT species, Table 2 and Appendix 4, Target Species Data). By far, the Trichoptera were the most well represented group with 14,858 individuals and 218 species. The far greater abundance of caddisflies compared to the other orders is due to the fact the caddisflies are a larger group of insects in terms of the number of species, and also is partially due to our use of light traps as the principal means of collection. Most caddisflies are very strongly attracted to lights, often occur in large numbers, and occur in a very wide range of habitats. Many Ephemeroptera also are strongly attracted to lights, but seldom occur in very large numbers except along productive lakes and large rivers. These habitats are not common along the BLRI. Additionally, female subimagos (not sexually mature and often not identifiable) predominate in light trap collections of mayflies. Certain groups of Plecoptera are attracted to lights, but the majority of species are not. Odonata rarely come to lights, and only *Corydalus cornutus*, the Eastern Dobsonfly or hellgrammite (larva), is a regular visitor to lights among the Megaloptera. Therefore, insects in these groups are best collected by active sampling methods, normally involving the use of nets and sieves. These more labor intensive techniques, which we also used, resulted in fewer specimens per site than the passive method of light-trapping.

Species distribution along the length of the BLRI was uneven (Fig. 1), showing no correlation between elevation and the total number of target species collected (Pearson correlation = 0.067, $P > 0.76$). Gaps in the numbers of species along the BLRI, such as from mile marker 240 to mile marker 260, seem primarily to be due to the lack of suitable habitat for aquatic insects, and also, in some instances, to the absence of suitable locations for researchers to stop and collect.

The lack of correlation between elevation and numbers of target species is surprising, since the Parkway is significantly lower in the northern sections (Virginia) than in the southern sections (North Carolina), as shown in Table 3. Further-more, 175 species were found only in the sections of the BLRI north of mile marker 295, which corresponds with the New River drainage, while 77 species were limited to the southern section of the BLRI south of mile marker 295. This is discussed in more detail below.

Table 2. Numbers of taxa and specimens of the target EMOPT species collected from the Blue Ridge Parkway. This includes only specimens that were identified to species, and unique genera for which species identification was not possible. Refer to Appendix 4 for a complete listing of all EMOPT specimens.

	Families	Genera	Species	Specimens
Ephemeroptera	10	34	67	1,996
Megaloptera	1	5	5	48
Odonata	9	29	53	339
Plecoptera	9	34	70	1,780
Trichoptera	22	69	218	14,858
totals	51	171	413	19,021

Table 3. Results of t-tests of the mean elevations in meters of the northern (Virginia) and southern (North Carolina) extent of the Blue Ridge Parkway based on elevations of mile markers, and elevations of sample sites from Appendix 3.

Elevation Source	VA mean elevation	NC mean elevation	t score	df	p-value
Mile Markers	739.23	1,160.70	-18.2341	457.996	<0.0001
Sample Sites	654.81	1,279.42	6.5017	439.926	<0.0001

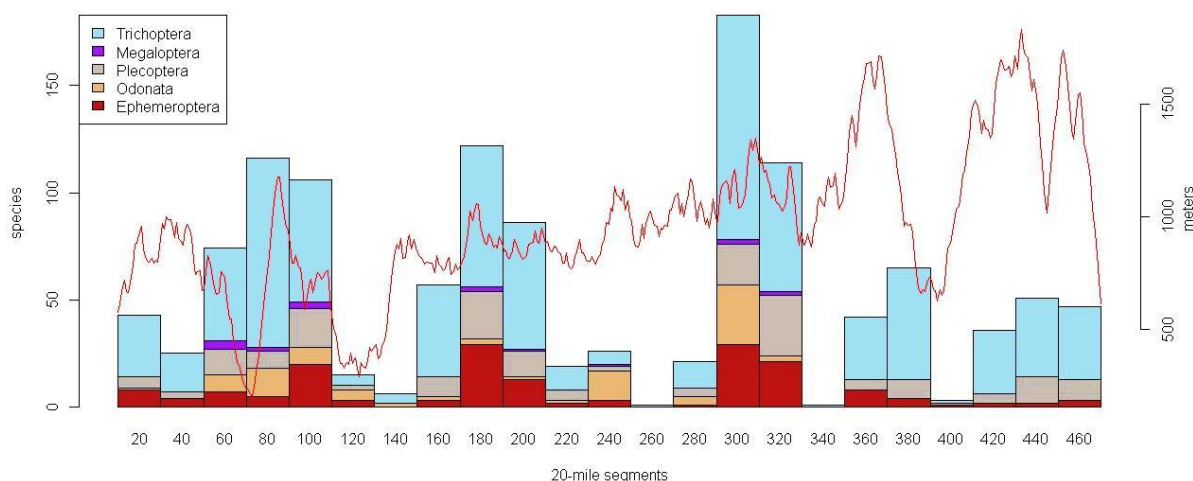


Figure 1. Distribution of species counts by 20-mile segments of the Blue Ridge Parkway, with the Parkway elevation profile in meters overlain in red.

Species of Interest

Three-hundred seven species (74%) of the 413 EMOPT species found in the BLRI were considered species of interest and are detailed in Appendix 6. The tables in Appendix 6 contain a great deal of information about the species and the higher taxa in which they are included. Readers are encouraged to refer to the species accounts for details concerning those species that could be of importance when considering an action that potentially may impact the species or their habitat. Below we provide a brief example of the nature of the considerations that led to our selection of them as possible species of interest.

Rare species – We recognize rare species as those that occur in just three or fewer (<17%) of the 18 parks included in the broader survey. Twenty-seven species were found only in BLRI, 95 were found in BLRI and one other park, and 62 were found in BLRI and two other parks. These 184 species may merit close attention from managers since the species have limited distributions in the networks. The 27 that are known from BLRI only (Table 4) are not just sparsely distributed within the networks, but have limited distributions within BLRI itself. Eight of the species were collected at only one location each on a single occasion, and none was represented by more than three individuals. None of the species in Table 4 was found at more than 8 locations or was represented by as many as 20 specimens. Some of these species have special habitat requirements that limit their potential distribution within the BLRI. *Manophylax altus*, for example, is restricted to damp, vertical rock faces in sheltered locations. The type locality for this species is just off the BLRI on the entrance road to Mt. Mitchell State Park. The habitat at this location is a rock face on the upstream side of a culvert under the road. The other known locations for *M. altus* are the rock faces along the road to the Craggy Gardens Picnic Area, which are sheltered by growths of *Rhododendron*. More details about *M. altus* are included in Appendix 6. *Homoplectra monticola* is found in seeps and very small spring runs where the larvae are found under rocks, habitats which often look to many observers as barely aquatic at all.

Examination of Appendix 4 reveals that some sites or clusters of sites within a mile or two of each other have more than one species of interest. Seven species in Table 4 (*Epithea princeps regina*, *Hydropsyche brunneipennis*, *H. hoffmani*, *H. leonardi*, *H. opthalmica*, *Hydroptila metoeca*, *Neoperla catharae*) occur within a stretch of BLRI of less than a mile from Otter Lake to James River Visitor Center. The largest numbers occur at Mabry Mill, where eight species are found (*Acroneuria kirchneri*, *Agapetus baueri*, *Culoptila plummerensis*, *Hydroptila ampoda*, *Litobrancha recurvata*, *Remenus kirchneri*, *Sweltsa voshelli*, *Yugus kondratieffi*). Eight other locations have 2-3 species each. Locations that have multiple species of interest should receive special attention when activities that could impact the hydrologic resources are planned for the area.

Table 4. Species found only along the Blue Ridge Parkway and not in any of the other parks included in this survey. The number of different localities (#Loc), different collections (#Col), and number of specimens (#Spm) are given for each species.

Order	Family	Species	#Loc	#Col	#Spm
Ephemeroptera	Ameletidae	<i>Ameletus tarteri</i>	1	1	3
	Ephemeridae	<i>Litobrancha recurvata</i>	5	5	6
Odonata	Coenagrionidae	<i>Enallagma doubledayi</i>	1	1	7
		<i>Enallagma hageni</i>	1	1	1
	Corduliidae	<i>Epithea princeps regina</i>	2	2	2
Plecoptera	Chloroperlidae	<i>Sweltsa voshelli</i>	4	4	7
	Perlidae	<i>Acroneuria kirchneri</i>	4	4	11
		<i>Neoperla catharae</i>	2	3	5
	Perlodidae	<i>Isoperla slossonae</i>	3	3	12
		<i>Remenus kirchneri</i>	3	3	12
		<i>Yugus kondratieffi</i>	1	1	1
Trichoptera	Apataniidae	<i>Manophylax altus</i>	2	4	17
	Brachycentridae	<i>Adicropheps hitchcocki</i>	1	1	2
	Glossosomatidae	<i>Agapetus baueri</i>	3	4	5
		<i>Culoptila plummerensis</i>	2	2	5
	Hydropsychidae	<i>Homoplectra monticola</i>	5	7	11
		<i>Hydropsyche brunneipennis</i>	2	2	14
		<i>Hydropsyche hoffmani</i>	2	3	7
		<i>Hydropsyche leonardi</i>	2	2	2
		<i>Hydropsyche opthalmica</i>	1	1	2
	Hydroptilidae	<i>Hydroptila ampoda</i>	3	3	4
		<i>Hydroptila metoeca</i>	2	2	9
	Lepidostomatidae	<i>Lepidostoma sommermanae</i>	3	3	4
	Limnephilidae	<i>Anabolia consocia</i>	1	1	1
		<i>Pycnopsyche pani</i>	8	9	12
	Polycentropodidae	<i>Plectrocnemia clinei</i>	1	1	1
	Rhyacophilidae	<i>Rhyacophila shenandoahensis</i>	2	2	2

Ranked species – The treatment of species as rare based on their restricted occurrence within the 18 parks of this study does not take into account the rarity of the species over the wider known ranges of the species. No species of EMOPT is confined to the BLRI, although some are known only from the BLRI and its immediate vicinity (i.e., *Manophylax altus*). Taking a broader perspective on the distribution of species, and thus of their potential vulnerability to extirpation, adds insights to the consideration of the status of a species within the larger landscape of the Parkway. NatureServe (<http://www.natureserve.org/>), a private not-for-profit conservation organization, considers the status of species at much broader scales, from regional to national to global. They have established criteria for ranking the vulnerability of species across these scales based on the number of known occurrences, geographic extent, and population status of each species. This system is explained in the introduction to Appendix 6, but ultimately it leads to a status rank for each species that ranges from G5 to G1, meaning, respectively, that populations of any given species are secure globally (G5) or are less secure (G4 – G2) to critically imperiled

globally (G1), and thus at risk of extirpation from its native habitat. In a similar manner, most states have adopted a version of this system and applied it to their own flora and fauna. At state levels, the ranks range from S5 to S1, with corresponding meanings attached. Only two EMOPT species encountered on the Parkway did not have a global or state rank, both of them having been described since this survey began (the caddisflies *Agapetus baueri* and *Pycnopsyche pani*). Every species which has a global or state ranking of G1-G3 or S1-S3 is considered a species of special interest for the purposes of this inventory, and is included in the species of interest table in Appendix 6.

One-hundred seventy-three of the EMOPT taxa found in this survey are ranked G1 – G3, and 123 have a state rank of S1 – S3. The state ranks often result in more species being considered critically imperiled, imperiled, or vulnerable than the global ranks. Approximately 90 species have state ranks of S1 – S3 that have global ranks of G4 – G5. This is what should be expected, as the potential for harm to or even extirpation of local populations is higher overall than for combined regional or global populations of a species.

Tolerance values – Aquatic invertebrates are short-lived — most species have one-year life cycles, some have multiple generations per year, while smaller numbers may require two or more years to complete their life cycles. Because of this, invertebrates are exposed to threats over multiple generations in very short time spans, and demonstrate a response, negative, positive, or neutral, in correspondingly short periods of time. This makes them very useful as indicators of environmental trends. Much study has enabled biologists to establish measures of the response of aquatic invertebrates to different types of pollution and environmental changes and to rank aquatic insect species' sensitivity, or their ability to “tolerate” these disturbances (Lenat 1988, Resh et al. 1996). These values typically range from 0 (least tolerant) to 10 (most tolerant). We recorded the established tolerance values for all species included in this survey which we could obtain from various published sources. These values are reported in the tables in Appendix 6. If a species has a tolerance value in the most sensitive range (0-3), it is included in the tables on that basis alone. These species are the most sensitive to disturbance, and therefore, knowing where they occur helps managers to understand the relative health of different locations in the park. This is summarized in Figures 2 and 3, and in Appendix 7, Site Tolerance Values.

Elevation effects

Elevation varies along the latitudinal gradient of the Parkway, being significantly lower in the northern than in the southern section (Table 3). The biodiversity of mountain stream systems such as those that originate along the BLRI are strongly influenced by elevation. The distribution of species was found to be affected by the approximately 1700 m elevation gradient in this survey. For every species found at a minimum of 15 different locations, we performed Chi-square tests for their occurrence in the three elevation classes given in Table 1. Of the 49 species that met this criterion, 38 showed significant deviations from expected (Table 5). Some species having a significant Chi-square, such as the caddisfly *Rhyacophila nigrita*, the stonefly *Acroneuria abnormis*, and the mayfly *Eurylophella funeralis* are strongly over-represented in the lower elevations, suggesting that they might be favored by environmental conditions that prevail at the lower elevations (i.e., warmer water temperatures, larger stream sizes). Other species, including the caddisfly *Neophylax mitchelli* and the mayfly *Ephemerella catawba*, appear at high elevations with greater than expected frequency, and therefore may not be limited by environmental conditions associated with higher elevations, or perhaps may do better under

those conditions. Species not having a significant Chi-square apparently are unaffected by environmental conditions associated with the elevation gradient along the BLRI, or perhaps the type of sampling used simply failed to find any relationship.

Table 5. Chi-square tests of elevation distribution of those target species that were found at 15 or more locations along the Blue Ridge Parkway. The Low, Mid, and High elevation categories are those given in Table 1, and the expected proportions of occurrences in each category was calculated from the percentage of samples taken in each elevation category also provided in Table 1. The 38 species that had elevation distributions that differed significantly from expected are indicated by asterisks: * ≤ 0.05 ; ** ≤ 0.01 ; *** ≤ 0.001 ; **** ≤ 0.0001 .

Order	Family	Species	Low	Med	High	Chi2
Ephemeroptera	Ameletidae	<i>Ameletus cryptostimulus</i>	2	12	6	6.5*
	Baetidae	<i>Baetis tricaudatus</i>	2	14	3	9.1**
	Ephemerellidae	<i>Ephemerella catawba</i>	11	21	10	9.5***
		<i>Eurylophella funeralis</i>	2	18	4	18.7****
	Heptageniidae	<i>Epeorus dispar</i>	6	12	10	1.7
		<i>Maccaffertium merivulvum</i>	11	24	11	7.2*
		<i>Stenacron carolina</i>	8	32	10	6.1*
Plecoptera	Chloroperlidae	<i>Haploperla brevis</i>	5	13	2	7.8**
	Leuctridae	<i>Leuctra ferruginea</i>	9	16	5	13.0****
	Nemouridae	<i>Amphinemura wui</i>	4	10	6	0.7
	Peltoperlidae	<i>Peltoperla tarteri</i>	2	15	1	12.4****
	Perlidae	<i>Acroneuria abnormis</i>	9	11	0	27.7****
		<i>Eccopectura xanthenes</i>	9	11	3	20.1****
		<i>Isoperla holochlora</i>	2	17	5	16.7****
	Perlodidae	<i>Isoperla pseudosimilis</i>	7	10	11	5.2
		<i>Malirekus hastatus</i>	3	14	8	3.5
		<i>Remenus bilobatus</i>	4	14	3	4.4
	Dipseudopsidae	<i>Phylocentropus lucidus</i>	6	10	0	16.8****
Trichoptera	Glossosomatidae	<i>Glossosoma nigrilor</i>	7	19	3	10.5***
	Goeridae	<i>Goera calcarata</i>	7	20	4	8.6**
	Hydropsychidae	<i>Cheumatopsyche analis</i>	3	14	2	6.0
		<i>Diplectrona modesta</i>	11	29	15	2.7
		<i>Hydropsyche betteni</i>	4	16	2	7.1*
		<i>Hydropsyche morosa</i>	2	10	4	2.7
		<i>Hydropsyche sparna</i>	9	24	9	5.2
		<i>Parapsyche apicalis</i>	21	22	20	32.1****
		<i>Parapsyche cardis</i>	8	16	3	13.7****
		<i>Oecetis inconspicua</i>	3	19	3	10.9****
	Limnephilidae	<i>Pseudostenophylax uniformis</i>	14	14	9	27.0****
		<i>Pycnopsyche flavata</i>	12	15	5	24.5****
		<i>Pycnopsyche gentilis</i>	13	42	14	7.4*
	Molannidae	<i>Molanna blenda</i>	13	29	5	21.2****
	Odontoceridae	<i>Psilotreta frontalis</i>	6	28	6	9.2***
	Philopotamidae	<i>Dolophilodes distincta</i>	17	30	12	20.5****
		<i>Wormaldia moesta</i>	23	18	7	63.1****
	Polycentropodidae	<i>Nyctiophylax nephophilus</i>	3	8	5	0.2
		<i>Plectrocnemia cinerea</i>	4	11	1	7.6**
	Psychomyiidae	<i>Lype diversa</i>	11	22	3	21.3****
	Rhyacophilidae	<i>Rhyacophila appalachia</i>	2	15	2	11.5****
		<i>Rhyacophila carolina</i>	17	20	7	36****
		<i>Rhyacophila celadon</i>	8	6	1	25.5****
		<i>Rhyacophila fuscula</i>	5	10	8	1.5
		<i>Rhyacophila glaberrima</i>	13	14	15	17.4****
		<i>Rhyacophila nigrita</i>	25	11	6	84.4****
		<i>Rhyacophila teddyi</i>	9	5	4	25.4****
		<i>Rhyacophila torva</i>	11	9	10	20.7****
	Sericostomatidae	<i>Fattigia pele</i>	12	15	8	19.6****
	Thremmatidae	<i>Neophylax aniqua</i>	9	20	2	18.1****
		<i>Neophylax mitchelli</i>	23	39	27	16.7****

Species Distribution North and South

The more than 300 km latitudinal extent of the Parkway raises the question of whether or not species respond to this gradient as revealed by their distributions. To examine this, we set the New River as the dividing line between the northern and southern extents of the parkway. The New River flows in the channel of the ancient pre-glacial Teays River and is significant in understanding the distributions of many fish and amphibian species (Berendzen et al. 2003, Hocutt et al. 1978, Janssen 1953, Lemmon et al. 2007, Ross 1969). Mile marker 295 was chosen as the dividing line, and the locations of all EMOPT species were determined relative to that location. Many species were found to occur both north and south of mile marker 295. But, 175 species were found to occur only north of the New River, and 77 were found to occur only south of the New River. Most of these species are widespread, and may be expected eventually to be found more widely distributed along the Parkway. However, a few species do seem to have restricted distributions that may well indicate the influence of historical factors (Table 6).

Table 6. Species that occur only to the north or only to the south of the New River are presented below. Just those species found at 5 or more locations are shown.

Species found north of the New River			
Order	Family	Species	North
Megaloptera	Corydalidae	<i>Nigronia fasciatus</i>	7
Odonata	Calopterygidae	<i>Calopteryx maculata</i>	9
	Coenagrionidae	<i>Argia fumipennis violacea</i>	5
		<i>Cordulegaster erronea</i>	5
Trichoptera	Libellulidae	<i>Libellula luctuosa</i>	5
	Glossosomatidae	<i>Protophila</i> species	5
	Hydroptilidae	<i>Orthotrichia aegerfasciella</i>	7
	Leptoceridae	<i>Oecetis avara</i>	5
		<i>Oecetis cinerascens</i>	5
		<i>Triaenodes injustus</i>	9
	Odontoceridae	<i>Psilotreta rufa</i>	5
	Phryganeidae	<i>Phryganea sayi</i>	13
	Psychomyiidae	<i>Psychomyia nomada</i>	5
Species found south of the New River			
Order	Family	Species	South
Trichoptera	Goeridae	<i>Goerita semata</i>	14
	Limnephilidae	<i>Pycnopsycha conspersa</i>	6

Taxa Represented Only as Genus

Not all specimens could be identified to species. In some cases, specimens were damaged, or were in the wrong life stage to permit species identification. But since those specimens represent genera that were not otherwise found during the survey, we list them here (Table 7) and include them in the total numbers of species known from the park in their respective groups. For most of these genera several species are known in the study area. The mayflies *Acentrella* and *Proclleon*, for example, were represented in other parks in the broader study by four and two species, respectively. But we cannot determine which species of these two genera are actually present in BLRI from the specimens we collected. In the case of the stonefly *Zapada* we know that the specimens collected represent an undescribed species, or perhaps two undescribed species, known to occur in the Southern Appalachian Mountains. Further study will be necessary to determine which species are present in these genera in the BLRI.

Table 7. Taxa represented only by specimens that could be determined to genus but not to species. Records account for the only record of these genera in the park.

Order	Family	Genus
Ephemeroptera	Baetidae	<i>Acentrella</i>
		<i>Proclleon</i>
Megaloptera	Leptohyphidae	<i>Tricorythodes</i>
	Corydalidae	<i>Neohermes</i>
	Sialidae	<i>Sialis</i>
Odonata	Gomphidae	<i>Ophiogomphus</i>
Plecoptera	Nemouridae	<i>Ostrocerca</i>
		<i>Zapada</i>
Trichoptera	Taeniopterygidae	<i>Taeniopteryx</i>
	Limnephilidae	<i>Limnephilus</i>

Non-target Taxa

The non-target taxa that are always captured as a result of bulk sampling (i.e., light traps), included 2,890 tallied specimens (Table 8 and Appendix 5, Non-Target Species Data) of aquatic and terrestrial snails, worms, beetles, flies, etc., and many unsorted, unidentified, and uncounted additional specimens still in jars. These unsorted lots are not included in the database or the appendices. In addition, hand and net sampling also leads to the collection of non-target specimens, as interesting finds are deliberately retained. More than 160 of the non-target species we collected are aquatic, and include such species as gnats, horse and deer flies, mosquitoes, predaceous diving beetles, riffle beetles, water scavenger beetles, worms, amphipods, isopods, and others. The smaller number of the non-target terrestrial taxa are highlighted in Appendix 5. Some of these non-target species are interesting because they are rare or uncommon in inventories. These include, for example, the Pleasing Lacewing, *Nallachius americanus* (Dilaridae). The larvae of these small moth-like insects live under the bark of recently dead trees, or occasionally under the bark of longer dead trees. The larvae feed on a variety of soft-bodied insects also encountered under the bark. Females have a long ovipositor which is used to deposit eggs into small cavities in the wood of dead trees. We collected a single female of this species.

Among the material collected by DRL are a number of aquatic worms (Oligochaeta: Lumbriculidae), including several new species and new genera. *Martinidrilus carolinensis* Fend and Lenat 2007 and *Pseudorhynchelmis murdocki* Fend and Lenat 2010 represent newly described genera and species from BRLI. Other new species have been described, and more are awaiting description.

Two other aquatic non-target species that were found, the spongillaflies *Climacia areolaris* and *Sisyra vicaria*, have larvae that live in and feed on freshwater sponges. The presence of these two geographically widespread species (Bowles 2006) of sponge parasites indicates that freshwater sponges also occur in or near the locality where these adults were collected, although we did not see or collect any sponges.

A complete list of all species collected, both EMOPTs and non-target species, is included in Appendix 9.

Table 8. Numbers of taxa and specimens of the non-target species collected from the Blue Ridge Parkway. The entry Oligochaeta_order refers to specimens of worms not identified to Order. See Appendix 5 for a complete listing of non-target specimens.

Order	Families	Genera	Specimens
Amphipoda	1	1	40
Basommatophora	3	3	12
Branchiobdellida	2	2	11
Coleoptera	12	30	305
Decapoda	1	2	7
Diptera	20	102	1963
Enchytraeida	1	1	2
Neotaenioglossa	1	1	1
Hemiptera	6	7	23
Hymenoptera	2	2	2
Isopoda	2	3	35
Lepidoptera	1	1	1
Lumbriculida	1	4	85
Mecoptera	2	3	23
Sorbeoconcha	2	2	99
Neuroptera	6	7	35
Oligochaeta_order	1	1	24
Orthoptera	4	5	13
Rhynchobdellida	1	1	2
Tricladida	3	3	119
Tubificida	2	6	54
Veneroida	2	3	34
totals	76	190	2890

Discussion

The Blue Ridge Parkway is a corridor of significant aquatic insect habitats, especially seeps, springs and first order streams that are protected from much of the habitat degradation that

Table 9. Parks of the Appalachian Highland and Cumberland Piedmont monitoring networks with each park's area (in hectares, calculated from NPS GIS data), number of EMOPT species, and number of collection events.

Park	Area (ha)	EMOPT species	Collection Events
ABLI	138	34	9
BISO	49,545	280	157
BLRI	32,944	413	533
CARL	108	139	95
CHCH	3,326	116	42
COWP	340	58	34
CUGA	8,118	205	47
FODO	210	53	23
GRSM	209,988	575	1754
GUCO	82	33	11
KIMO	1,583	94	34
LIRI	5,586	163	106
MACA	20,791	133	60
NISI	384	91	39
OBRI	3,769	221	58
RUCA	130	15	8
SHIL	1,605	120	71
STRI	261	50	8

occurs just outside the BLRI boundary. The species of EMOPT are exceptionally diverse (Table 2), include a number of rare species (Table 5), and are excellent indicators of the overall health of the aquatic habitat (Figs. 2 and 3, Appendix 7). The total number of EMOPT taxa from BLRI (407) far exceeds that of all other parks in the Appalachian Highlands Monitoring Network with the exception of GRSM (575); and also exceeds that of every park in the Cumberland Piedmont Monitoring Network. Two factors help account for the great diversity of BLRI, and for its lower diversity compared with GRSM. One is total land area and the other is sampling effort (Table 9).

There is a highly significant correlation between park area and the number of EMOPT species for all parks in the two monitoring networks (Pearson correlation = 0.8435, $P < 0.0001$). Similarly, using the number of sampling events as a measure of sampling effort, we obtain an equally significant correlation between park area and the number of sampling events (Pearson correlation = 0.9722, $P < 0.0001$). These results imply that 1) larger areas have more species, and 2) greater sampling leads to the discovery of more species, which are well-known and frequently studied issues in ecology (Cao et al. 2002, Chong and Stohlgren 2007, Collins et al. 2002, Hill et al. 1994, Lewis 2006,

Thomas et al. 2004). There are more aquatic species to be found in BLRI, and since the land area of the Park will not increase significantly, they can be found only through additional sampling effort.

It is often thought that size of an area is a principal factor controlling species diversity because of greater potential habitat heterogeneity as compared to smaller areas (i.e., Báldi 2008). The habitat heterogeneity of BLRI has been alluded to above, and is very likely a principal factor to consider in the EMOPT faunal diversity. The habitat diversity should be a primary consideration in the maintenance of the faunal diversity into the future. Stressors that might reduce the habitat heterogeneity of the BLRI have the potential to similarly reduce the EMOPT diversity.

The EMOPT fauna of the BLRI is a substantial reservoir of biodiversity in the Appalachian Highlands Monitoring Network, as well as in the Southeast. Further study will be necessary to fill the many gaps that remain in our knowledge, but BLRI also needs immediate and continuing protection from the numerous stressors that threaten it (Emmott et al. 2005). This study has established a baseline of information about the park's aquatic fauna that will serve as the building block for continuing efforts to understand and protect the BLRI aquatic resources. Below we discuss some approaches that may help managers use the information in this report to better manage the aquatic resources of the Parkway.

Significance of Aquatic Resources

The aquatic fauna of the Blue Ridge Parkway is remarkable. We now consider how to evaluate the fauna at each sampling location, and along continuous sections of the Parkway. We develop below two measures of the significance of locations along the Parkway based on the fauna.

Sensitivity Index -- Aquatic insects are considered to be excellent indicators of environmental conditions and for this reason are widely used in biomonitoring. Many but not all species of aquatic macroinvertebrates, therefore, have been assigned tolerance values by various monitoring agencies, including the Environmental Protection Agency (Barbour et al. 1999), the Tennessee Department of Environment and Conservation Division of Water Pollution Control (Arnwine 2006), and the North Carolina Department of Environment and Natural Resources (Biological Assessment Unit 2006). Tolerance values are empirically derived from hundreds or thousands of observations of species occurrences in habitats subjected to different degrees of degradation. Therefore, tolerance values are objective, and are calibrated to the habitats and regions in which the species are found. These values are provided in Appendix 6 and constitute one of the criteria for our recognition of a species as one of potential interest.

This study was not designed to monitor communities and develop biotic indices and, in fact, many of our samples were taken in springs, seeps, and other minimal water habitats that are not treated in biomonitoring protocols. Nor is light-trapping for adults a standard method for aquatic macroinvertebrate monitoring. However, by using the cumulative assigned tolerance values as a measure of relative health, we still can make a prescribed assessment of the condition of BLRI streams. For this purpose, in addition to the target species we included those non-target species that have established tolerance values. Restricting sites to those having at least 5 species with assigned tolerance values results in 166 sites at which an analysis of overall species sensitivity can be examined. For each of these sites, we produced boxplots of the proportions of the tolerance values of species as a measure of overall site sensitivity (Figure 2). The horizontal grey line represents the median tolerance value over all sites (2.1) indicating that BLRI springs, seeps, and streams support aquatic faunas that are generally unimpaired by the effects of pollutants and other disturbances. In fact, 134 of the 166 sites (81%) have median tolerance values of 3.0 or less, and only one site has a tolerance value greater than 7 (site 91 in Figure 2, BLRI 297.7 left Cold Prong, median tolerance value = 7.9). This site is a beaver pond and 10 of the 16 species recorded are Odonata, all of which have high tolerance values. Site tolerance values are better (lower) at higher elevations (Pearson correlation = -0.3871, $P < 0.0001$), but $r^2 = 0.1498$.

These results are compared with those of the 17 other parks in this inventory in Figure 3. This graph shows the overall tolerance values for all parks based on all species having assigned tolerance values that were sampled in each park. Only BLRI (2.1), GRSM (2.0), and RUCA (2.6) have overall median tolerance values less than three. A statistical comparison of the values for the parks with each other is not provided, as the differences in sampling effort, aquatic resources, and faunas are likely to render such analyses invalid.

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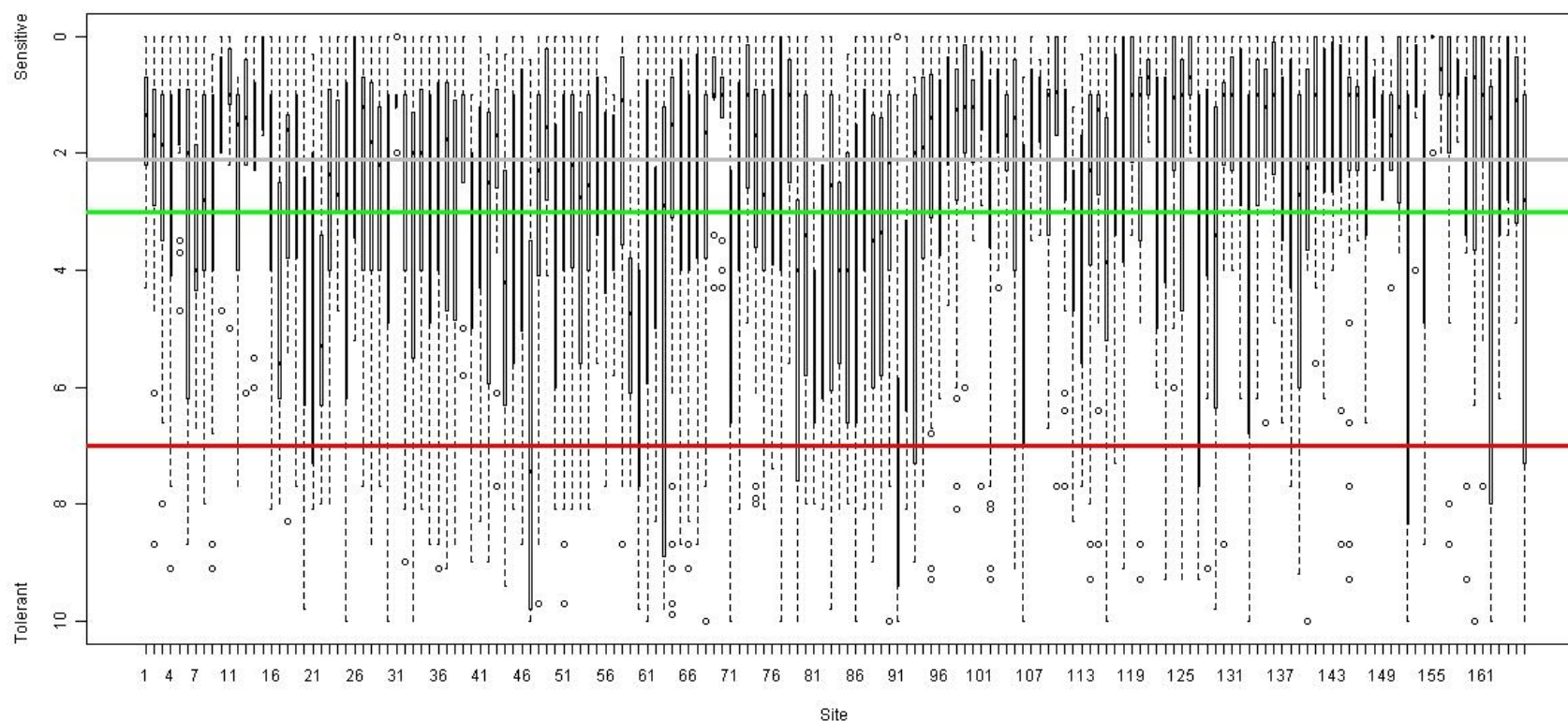


Figure 2. Site tolerance values based on both target (Ephemeroptera, Odonata, Plecoptera, Megaloptera, and Trichoptera) and non-target species. Each sample location having five or more species with an established tolerance value is shown with a boxplot. The horizontal green line indicates a tolerance value of 3. The horizontal red line indicates a tolerance value of 7. The horizontal grey line indicates the median tolerance value (2.1) of all 166 sites. The y-axis is inverted in order to highlight sites having greater overall sensitivities (greater number of species having lower tolerance values). An explanation of the parts of a boxplot in this orientation is provided below.

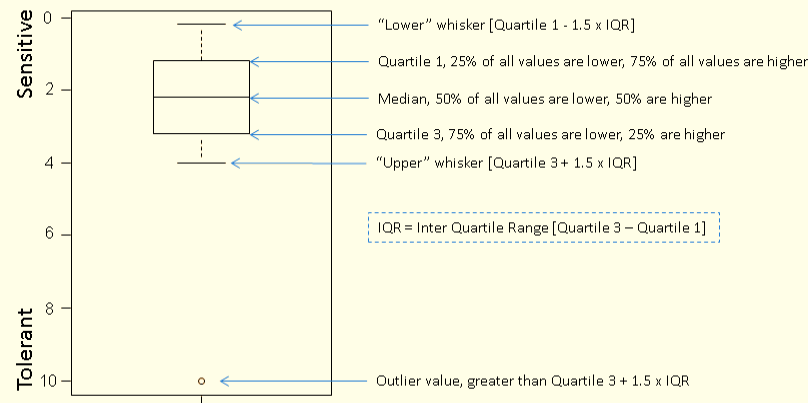
Legend: 1 - BLRI 001.0 right; 2 - BLRI 001.1 right; 3 - BLRI 005.2 left; 4 - BLRI 006.0 right; 5 - BLRI 009.7 Dripping Rock spring; 6 - BLRI 015.4 BS38504; 7 - BLRI 015.6 left; 8 - BLRI 020.0 right; 9 - BLRI 029.3; 10 - BLRI 032.7; 11 - BLRI 033.2 left; 12 - BLRI 052.1; 13 - BLRI 052.6 left; 14 - BLRI 055.3 right; 15 - BLRI 056.6 left; 16 - BLRI 056.7 right; 17 - BLRI 058.7 left; 18 - BLRI 060.8 Otter Creek Campground; 19 - BLRI 061.0 SS39203; 20 - BLRI 063.0 Otter Lake; 21 - BLRI 063.0 Outflow Otter Lake; 22 - BLRI 063.6 James River Visitor Center; 23 - BLRI 067.0 left Falling Rock Creek; 24 - BLRI 080.9; 25 - BLRI 082.3 right; 26 - BLRI 084.4 Sp38504; 27 - BLRI 085.0 Sp38504; 28 - BLRI 085.5 SS39203; 29 - BLRI 085.6 Peaks of Otter Lodge stream; 30 - BLRI 086.0 Abbott Lake; 31 - BLRI 086.0 Big Spring Peaks of Otter Picnic Area; 32 - BLRI 086.0 Elk Run Peaks of Otter; 33 - BLRI 086.0 Little Stoney Creek; 34 - BLRI 086.0 outflow Abbott Lake; 35 - BLRI 087.9 left; 36 - BLRI 088.1 Sp39203; 37 - BLRI 090.2 Sp38504; 38 - BLRI 103.0 SS38504; 39 - BLRI 114.3 right; 40 - BLRI 124.8 left; 41 - BLRI 146 right; 42 - BLRI 146.4 right; 43 - BLRI 159.1; 44 - BLRI 159.5 right; 45 - BLRI 160.2 left; 46 - BLRI 162 Sp38504; 47 - BLRI 162.3 Rakes Mill Pond; 48 - BLRI 165.3 Little Rock Castle Creek; 49 - BLRI 165.3 Rock Castle Creek, primitive campground; 50 - BLRI 175.8 left; 51 - BLRI 176.2 left Mabry Mill; 52 - BLRI 176.2

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right Mabry Mill; 53 - BLRI 180.6 Mayberry Creek; 54 - BLRI 187.6 Big Laurel Creek; 55 - BLRI 208.9 left; 56 - BLRI 210.1 left; 57 - BLRI 213.3; 58 - BLRI 217.5 Sp39203; 59 - BLRI 222.8 right Big Pine Creek; 60 - BLRI 223.5 Sp38504; 61 - BLRI 228.5 MSp38504; 62 - BLRI 228.9 left Little Glade Branch; 63 - BLRI 230.3 Little Glade Mill Pond and trib.; 64 - BLRI 241.5 AMSp39203; 65 - BLRI 242 CSp38504; 66 - BLRI 243 AStream39203; 67 - BLRI 248.4 MSp38504; 68 - BLRI 272 Spring39203; 69 - BLRI 272.5 left; 70 - BLRI 273.7 right; 71 - BLRI 286.0 R beaver pond; 72 - BLRI 286.5 L Goshen Creek; 73 - BLRI 292.2 Big Spring at Parkway; 74 - BLRI 293.2 right; 75 - BLRI 293.5 Moses Cone, Apple Barn Rd 2; 76 - BLRI 293.5 Moses Cone, Apple Barn Road; 77 - BLRI 293.5 Moses Cone, spring seep #1; 78 - BLRI 293.5 Moses Cone, spring seep #2; 79 - BLRI 294.0 Bass Lake; 80 - BLRI 294.6 Trout Lake; 81 - BLRI 295.9 R Beaver Pond; 82 - BLRI 295.9 Sims Pond; 83 - BLRI 296 ABog39203; 84 - BLRI 296.4 Boone Fork in Julian Price Park; 85 - BLRI 296.4 right beaver pond in bog, JPrice Park; 86 - BLRI 296.4 right bog Julian Price Park; 87 - BLRI 296.4 right Boone Fk Julian Price Park; 88 - BLRI 296.4 right Sims Creek Julian Price Park; 89 - BLRI 297.4 left Price Lake; 90 - BLRI 297.5 Seep38504; 91 - BLRI 297.7 left Cold Prong; 92 - BLRI 298.1 right Cold Prong; 93 - BLRI 299.0 right Cold Prong; 94 - BLRI 299.8 Seep39203; 95 - BLRI 299.9 Boone Fork above Kanawha; 96 - BLRI 300.1 Seep38504; 97 - BLRI 301.0 right; 98 - BLRI 301.1 right; 99 - BLRI 302.6; 100 - BLRI 302.8 right; 101 - BLRI 303.3 right; 102 - BLRI 303.4 Wilson Creek; 103 - BLRI 303.7 Wilson Creek; 104 - BLRI 304.0; 105 - BLRI 304.5; 106 - BLRI 304.6 CSp39203; 107 - BLRI 304.75 left; 108 - BLRI 304.75 right; 109 - BLRI 304.9 right; 110 - BLRI 305.5 right; 111 - BLRI 313.3 Left; 112 - BLRI 315.6 right Camp Creek; 113 - BLRI 316.4 Linville Falls Riverbend Picnic Area; 114 - BLRI 316.4 Linville Falls Visitor Center; 115 - BLRI 319 Spring39203; 116 - BLRI 333.4 CSp38504; 117 - BLRI 355.3; 118 - BLRI 356.1 Sp39203; 119 - BLRI 356.2 right; 120 - BLRI 357.6 right; 121 - BLRI 358.3; 122 - BLRI 358.8 right; 123 - BLRI 359.2; 124 - BLRI 360.3 left; 125 - BLRI 360.3 right; 126 - BLRI 365.0 right; 127 - BLRI 366.6 Sp38504; 128 - BLRI 366.7 CSp38504; 129 - BLRI 367 Sp38504; 130 - BLRI 367.2 right; 131 - BLRI 367.6 Craggy Gardens Picnic Area; 132 - BLRI 367.6 Craggy Picnic Area entrance seep; 133 - BLRI 367.6 Craggy Picnic Area Road Mid-Length; 134 - BLRI 371.5 right; 135 - BLRI 371.6; 136 - BLRI 374.6 Bull Creek; 137 - BLRI 376.2; 138 - BLRI 376.7 right; 139 - BLRI 407 ABS52007; 140 - BLRI 408.0 stream in Pisgah Campground; 141 - BLRI 418.8 Graveyard Fields; 142 - BLRI 420.2 right Forest Service Road 816; 143 - BLRI 420.6 Dark Prong; 144 - BLRI 420.6 Sp39203; 145 - BLRI 422.4 left; 146 - BLRI 422.5 left; 147 - BLRI 422.5 right; 148 - BLRI 422.5 right lower creek; 149 - BLRI 422.5 right upper; 150 - BLRI 423.2 right; 151 - BLRI 424.1 Sp38504; 152 - BLRI 424.8 right Wolf Mountain Overlook; 153 - BLRI 426.6 R; 154 - BLRI 427.5 Sp40488; 155 - BLRI 431.7 right; 156 - BLRI 439.9 Right; 157 - BLRI 446.7 right Woodfin Cascades; 158 - BLRI 446.7 right Woodfin Cascades at top; 159 - BLRI 449.8 Sp38504; 160 - BLRI 450.6; 161 - BLRI 452.3 right; 162 - BLRI 453.4 Hornbuckle Valley; 163 - BLRI 454.2 Soco Gap; 164 - BLRI 455.3; 165 - BLRI 455.7 BS38504; 166 - BLRI 459.5 Bunches Bald Overlook.

Since the y axis is reversed, the following explanation may help understanding.



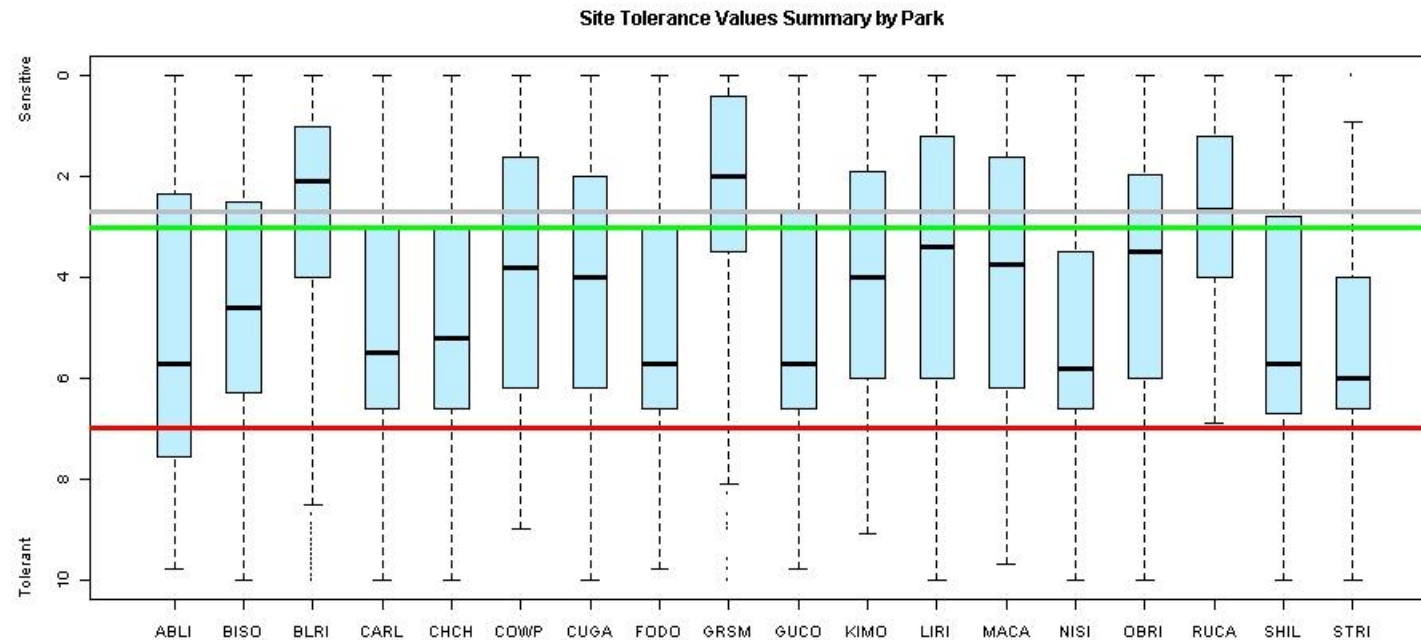


Figure 3. Overall tolerance values of species for each park in the Appalachian Highlands and Cumberland Piedmont monitoring networks. Park tolerance values are based on all species sampled in each park. The horizontal green line indicates a tolerance value of 3. The horizontal red line indicates a tolerance value of 7. The horizontal grey line indicates the median tolerance value (2.7) of all parks. The y-axis is inverted in order to highlight sites having greater overall sensitivities (greater number of species having lower tolerance values). An explanation of the parts of a boxplot in this orientation is provided on the previous page.

The site tolerance values above use all taxa that have an established a tolerance value. To convert the raw site tolerance values above into sensitivity indices, we recalculated the site tolerance values using only those species which have a tolerance value of ≤ 3 . These are the species that have the highest sensitivity to disturbance. We then weighted the scores by the number of species found at the site. We subtracted the average site tolerance values from 10, the maximum possible value for any site. This has the effect of inverting the sensitivity scale so that the most sensitive sites have higher values than the least sensitive sites. We then added the number of sensitive species to the result. We refer to this as the site **sensitivity index** (SI). The weighting of the site tolerance values by the number of species present resolves the issue that arises when two sites have the same site tolerance values but have different numbers of sensitive species. From a practical standpoint it seems desirable to be able to assign a higher weight to the site that has more sensitive species when, as is always the case, resources are limited and choices must be made. Thus, a site having more sensitive species would receive greater consideration in making management decisions than a site of equal sensitivity but having fewer species. The SI is very highly correlated with the number of species, and the species count could be used as a surrogate for SI. However, in practice the SI does change the ranking of sites in some cases compared with the number of species alone, and because it involves the use of the tolerance values in its derivation, we believe it is preferable to using just the species count.

Conservation Scores -- The standard macroinvertebrate measures used in monitoring programs and summarized in the rankings and tolerance values used to identify species of interest and to develop the site sensitivity index above, generally ignore the myriad uncommon species that inhabit the very small headwater systems that form the majority of the habitats sampled along the BLRI. Therefore, one of us (DRL) devised a scoring system to rank species and sites according to a different set of criteria that specifically allows for the consideration of these headwater species. Initially, the rarity of each species is assessed, and then the following standards are used to develop the **conservation scores** (CS):

CS

1. Fairly widespread species, but limited to cold-water springs and rarely seen in routine water quality monitoring.
2. Rare in NC/VA, but may be more common farther north or west, or its presence in BLRI represents a significant range extension or disjunction. Also included are species that may be widespread, but are very uncommon throughout their range.
3. Species with limited distribution, usually just 2-3 states, and limited to springs and seeps in the Appalachians. Rare, although this rarity may be a function of limited sampling of spring and seep habitats.
4. Extremely rare species, proposed endangered species, or possible new species.

We applied this procedure to all of the species determined to be species of interest as listed in Appendix 6, assigning a CS to each. Conservation scores also were assigned to the non-target species. One-hundred sixty-three species have CS > 0 (Table 10). Conservation scores are additive when multiple species are considered by site, providing a direct measure of the relative ranking of sites in terms of their potential significance for conservation. We summed the conservation scores for all species found at each site. One-hundred eighty-seven sites had conservation scores of greater than 0, and 73 had scores of 10 or higher.

Table 10. Conservation scores assigned to target and non-target taxa from the Blue Ridge Parkway. Only species that have a score greater than 0 are shown.

Phylum	Class	Order	Family	Taxon	CS
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae	<i>Oligobdella biannulata</i>	3
				nr. <i>Bichaeta</i> n. species	4
	Oligochaeta	Lumbriculida	Lumbriculidae	<i>Eclipidrilus</i> n. species	4
				<i>Martiniidrilus carolinensis</i>	4
				<i>Pararhynchelmis murdocki</i>	4
				<i>Rhyacodrilus</i> n. species	4
				<i>Alotanypus aris</i>	1
				<i>Hudsonimyia karelena</i>	2
				<i>Hudsonimyia parrishi</i>	1
				<i>Hudsonimyia parrishi/karelena</i>	1
				<i>Macropelopia decedens</i>	1
Arthropoda	Insecta	Diptera	Chironomidae	<i>Orthocladus</i> n. species	1
				<i>Paracricotopus mozleyi</i>	1
				<i>Psectrotanypus</i> species A (Epler)	1
				<i>Rheocricotopus</i> n. species	1
				<i>Skutzia epleri</i>	4
				<i>Tokunagaia</i> species	1
				<i>Thaumalea</i> species	1
				<i>Ameletus</i> n. species	4
				<i>Ameletus tarteri</i>	3
				<i>Callibaetis pretiosus</i>	1
				<i>Diphetor hageni</i>	1
				<i>Baetisca</i> species	1
				<i>Ephemerella hispida</i>	1
				<i>Ephemera blanda</i>	1
				<i>Ephemera guttulata</i>	1
				<i>Epeorus dispar</i>	1
				<i>Heptagenia julia</i>	1
				<i>Heptagenia marginalis</i>	1
				<i>Rhithrogena amica</i>	1
				<i>Rhithrogena exilis</i>	1
				<i>Rhithrogena</i> n. species	3
				<i>Isonychia serrata</i>	1
				<i>Leptophlebia johnsoni</i>	1
				<i>Paraleptophlebia assimilis</i>	1
				<i>Paraleptophlebia moerens</i>	1
				<i>Neohermes</i> species	1
				<i>Allocapnia stannardi</i>	4
				<i>Alloperla</i> species	1
				<i>Sweltsa mediana</i>	1
				<i>Sweltsa urticae</i>	4
				<i>Sweltsa voshelli</i>	2
				<i>Leuctra alexanderi</i>	1
				<i>Leuctra carolinensis</i>	1
				<i>Leuctra nephophila</i>	4
				<i>Leuctra</i> species	1
				<i>Megaleuctra williamsae</i>	4
				<i>Amphinemura appalachia</i>	1
				<i>Ostrocerca</i> species	2
				<i>Soyedina</i> species	1
				<i>Zapada</i> species	4
				<i>Peltoperla</i> species	3
				<i>Peltoperla tarteri</i>	4

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Phylum	Class	Order	Family	Taxon	CS
				<i>Tallaperla anna</i>	1
				<i>Tallaperla elisa</i>	3
			Perlidae	<i>Acroneuria kirchneri</i>	1
				<i>Beloneuria stewarti</i>	1
				<i>Perlesta frisoni</i>	1
				<i>Perlesta n. species</i>	3
			Perlodidae	<i>Clioperla clio</i>	1
				<i>Isoperla bellona</i>	3
				<i>Isoperla n. species</i>	4
				<i>Isoperla namata</i> group	1
				<i>Remenus kirchneri</i>	4
				<i>Yugus arinus</i>	2
				<i>Yugus bulbosus</i>	3
				<i>Yugus kondratieffi</i>	4
			Taeniopterygidae	<i>Strophopteryx limata</i>	1
				<i>Taeniopteryx</i> species	1
		Trichoptera	Apataniidae	<i>Manophylax altus</i>	4
			Brachycentridae	<i>Adicrophleps hitchcocki</i>	3
				<i>Micrasema burksi</i>	1
			Dipseudopsidae	<i>Phylocentropus auriceps</i>	1
				<i>Phylocentropus placidus</i>	1
			Glossosomatidae	<i>Agapetus baueri</i>	3
				<i>Culoptila plummerensis</i>	2
			Goeridae	<i>Goerita semata</i>	3
			Hydropsychidae	<i>Arctopsyche irrorata</i>	2
				<i>Diplectronea metaqui</i>	3
				<i>Homoplectra doringa</i>	1
				<i>Homoplectra monticola</i>	4
				<i>Homoplectra</i> species	1
				<i>Hydropsyche brunneipennis</i>	1
				Hydropsychidae_genus species	4
				<i>Parapsyche cardis</i>	1
			Hydroptilidae	<i>Hydroptila coweetensis</i>	2
				<i>Hydroptila delineata</i>	1
				<i>Hydroptila gunda</i>	1
				<i>Hydroptila hamata</i>	1
				<i>Hydroptila new species</i>	1
				<i>Hydroptila oneili</i>	1
				<i>Hydroptila paramoena</i>	3
				<i>Hydroptila perdita</i>	1
				<i>Hydroptila quinola</i>	1
				<i>Hydroptila remita</i>	1
				<i>Hydroptila talladega</i>	1
				<i>Ochrotrichia graysoni</i>	1
				<i>Ochrotrichia riesi</i>	1
				<i>Ochrotrichia tarsalis</i>	1
				<i>Orthotrichia</i> species	1
				<i>Oxyethira pallida</i>	1
				<i>Stactobiella martynovi</i>	1
			Lepidostomatidae	<i>Lepidostoma excavatum</i>	3
				<i>Lepidostoma flinti</i>	3
				<i>Lepidostoma lobatum</i>	1
				<i>Lepidostoma mitchelli</i>	3
				<i>Lepidostoma n. species</i>	4
				<i>Theliopsyche corona</i>	3

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Phylum	Class	Order	Family	Taxon	CS
				<i>Theliopsyche epilonis</i>	3
				<i>Theliopsyche grisea</i>	2
				<i>Theliopsyche</i> species	2
			Leptoceridae	<i>Mystacides sepulchralis</i>	1
				<i>Nectopsyche candida</i>	1
				<i>Triaenodes ignitus</i>	1
				<i>Triaenodes perna</i>	1
				<i>Triaenodes taenia</i>	2
			Limnephilidae	<i>Anabolia</i> species	2
				<i>Frenesia difficilis</i>	1
				<i>Frenesia missa</i>	1
				<i>Limnephilus</i> species	2
				<i>Pseudostenophylax</i> species	1
				<i>Pseudostenophylax uniformis</i>	1
				<i>Pycnopsyche pani</i>	3
				<i>Pycnopsyche sonso</i>	1
				<i>Pycnopsyche</i> species	4
			Molannidae	<i>Molanna ulmerina</i>	1
			Odontoceridae	<i>Pseudogoera singularis</i>	3
				<i>Psilotreta amera</i>	3
				<i>Psilotreta rossi</i>	1
				<i>Psilotreta rufa</i>	1
			Philopotamidae	<i>Fumonta major</i>	1
				<i>Wormaldia</i> species	1
				<i>Wormaldia thyria</i>	1
			Phryganeidae	<i>Banksiola dossuaria</i>	2
			Polycentropodidae	<i>Cyrnellus fraternus</i>	1
				<i>Plectrocnemia clinei</i>	1
				<i>Polycentropus blicklei</i>	1
				<i>Polycentropus carlsoni</i>	2
				<i>Polycentropus centralis</i>	1
				<i>Polycentropus colei</i>	4
				<i>Polycentropus elarus</i>	2
				<i>Polycentropus rickeri</i>	2
			Ptilocolepidae	<i>Palaeagapetus celsus</i>	2
			Rhyacophilidae	<i>Rhyacophila accola</i>	4
				<i>Rhyacophila appalachia</i>	1
				<i>Rhyacophila banksi</i>	1
				<i>Rhyacophila celadon</i>	3
				<i>Rhyacophila kondratieffi</i>	4
				<i>Rhyacophila minora</i>	1
				<i>Rhyacophila montana</i>	4
				<i>Rhyacophila mycta</i>	4
				<i>Rhyacophila</i> n. species	1
				<i>Rhyacophila shenandoahensis</i>	3
				<i>Rhyacophila teddyi</i>	2
			Sericostomatidae	<i>Agarodes</i> species	2
				<i>Agarodes tetron</i>	2
				<i>Fattigia pele</i>	2
			Thremmatidae	<i>Neophylax mitchelli</i>	1
	Malacostraca	Amphipoda	Crangonyctidae	<i>Stygobromus carolinensis</i>	4
				<i>Stygobromus</i> n. species 1	4
				<i>Stygobromus</i> n. species 2	4
Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae	<i>Fontigens orolibas</i>	3
Platyhelminthes	Turbellaria	Tricladida	Planariidae	<i>Phagocata bursaperforata</i>	1

Using Site Sensitivity Indices and Conservation Scores – We used both the site sensitivity indices and the conservation scores to rank sites according to their potential significance for conservation (Appendix 7, Table A7-1). We then combined samples in different ways to evaluate multiple sites simultaneously. First, we grouped all data from a single mile marker into a single “sample,” instead of using site codes. This has the effect, for example, of combining all collections at Mabry Mill, mile marker 176.2, into a single collection, rather than treating “BLRI 176.2 left Mabry Mill” and “BLRI 176.2 right Mabry Mill” as separate sites for analysis. We then were able to analyze these locations as one site, “BLRI 176.2” (Appendix 7, Table A7-2). Second, we combined all locations between subsequent mile markers into a single lot for analysis. This, in addition to combining the Mabry Mill sites as before, also grouped the two nearby sites “BLRI 176.1 ASS39203” and “BLRI 176.1 BSp39203” with the Mabry Mill sites as a single site labeled “BLRI 176” (Appendix 7, Table A7-3). Finally, we grouped all samples within each 10-mile stretch of the Parkway into a single lot. This resulted, for example, in the group “DM 010,” representing all samples taken in the stretch from mile marker 0 to mile marker 10 (Appendix 7, Table A7-4).

The ranking of sites by the two scoring systems differed among all groupings of the sites, although the similarity between the sites increased with the level of grouping. Of the ungrouped sites, 224 have SI scores and 187 have CS values. Thirty-nine sites have SI values but do not have CS values; conversely, two sites have CS values but do not have SI values. The highest ranked site by SI was ranked second by CS, and the highest ranked site by CS was ranked fourth by SI. Among the 20 highest ranked sites, both SI and CS include eight of the same sites. When grouped by milepost, the first and second ranked sites by SI were the same as the second and first ranked sites by CS. The SI and CS each ranked “DM 300” highest among the 10-mile groupings of sites.

Detecting patterns among sites by direct examination of the tables in Appendix 7 is challenging. Therefore we prepared maps of the distribution of the rankings along the length of the Parkway. The scores in each table in Appendix 7 can be plotted in the same manner, but we present here the results for the sites grouped by mile (Figure 4, and Appendix 8) and grouped by 10-mile segments (Figure 5). In these plots, the circles are scaled by CS and SI such that the largest circles represent the highest values. The yellow circles represent the conservation scores, and the purple circles represent the sensitivity index. The brown color represents the overlap between the CS and SI. Examination of the overview map of the scores grouped by mile (Fig. 4) reveals sections of the BLRI that have clusters of highly ranked sites that indicate significant stretches of Parkway that potentially should be considered of special interest for conservation. Evaluating these groups in the more detailed maps in Appendix 8, and examining the SI and CS values, and list of species from each site, provide a ready way to assign conservation priorities for the aquatic fauna of the BLRI. The plot of sites grouped by 10-mile segments (Fig. 5) reveals a very similar pattern and results in a nearly identical assessment. Table 11 presents our assessment using the data in Appendix 7, the overview maps in Figures 4 and 5, and the plots in Appendix 8.

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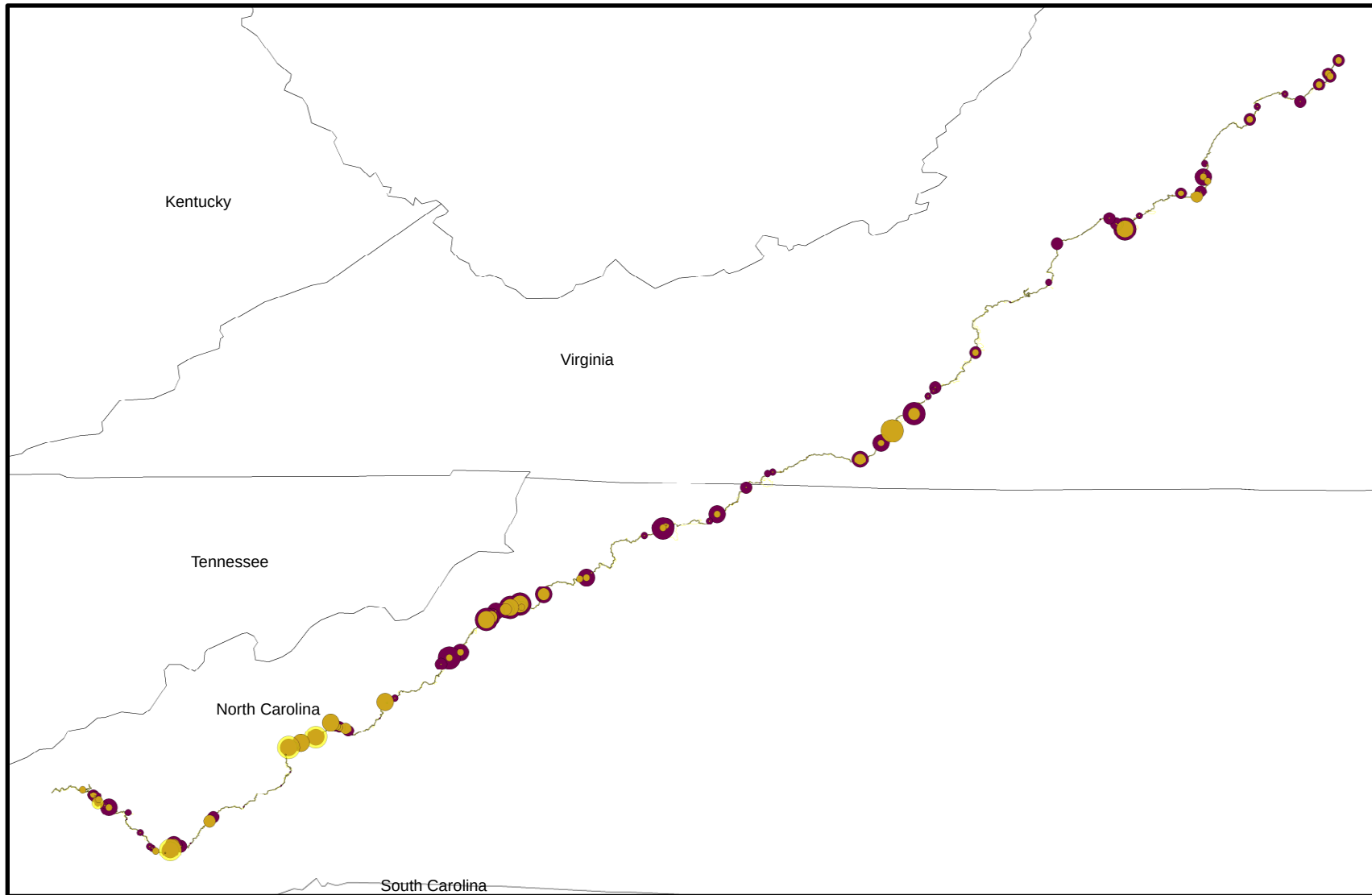


Figure 4. Sensitivity index and conservation score along the Blue Ridge Parkway grouped by mile. The size of the circles represents the relative values of the SI or CS. SI circles are purple, CS circles are yellow. Where the two overlap, the color is brown. For greater detail, see the maps in Appendix 8.

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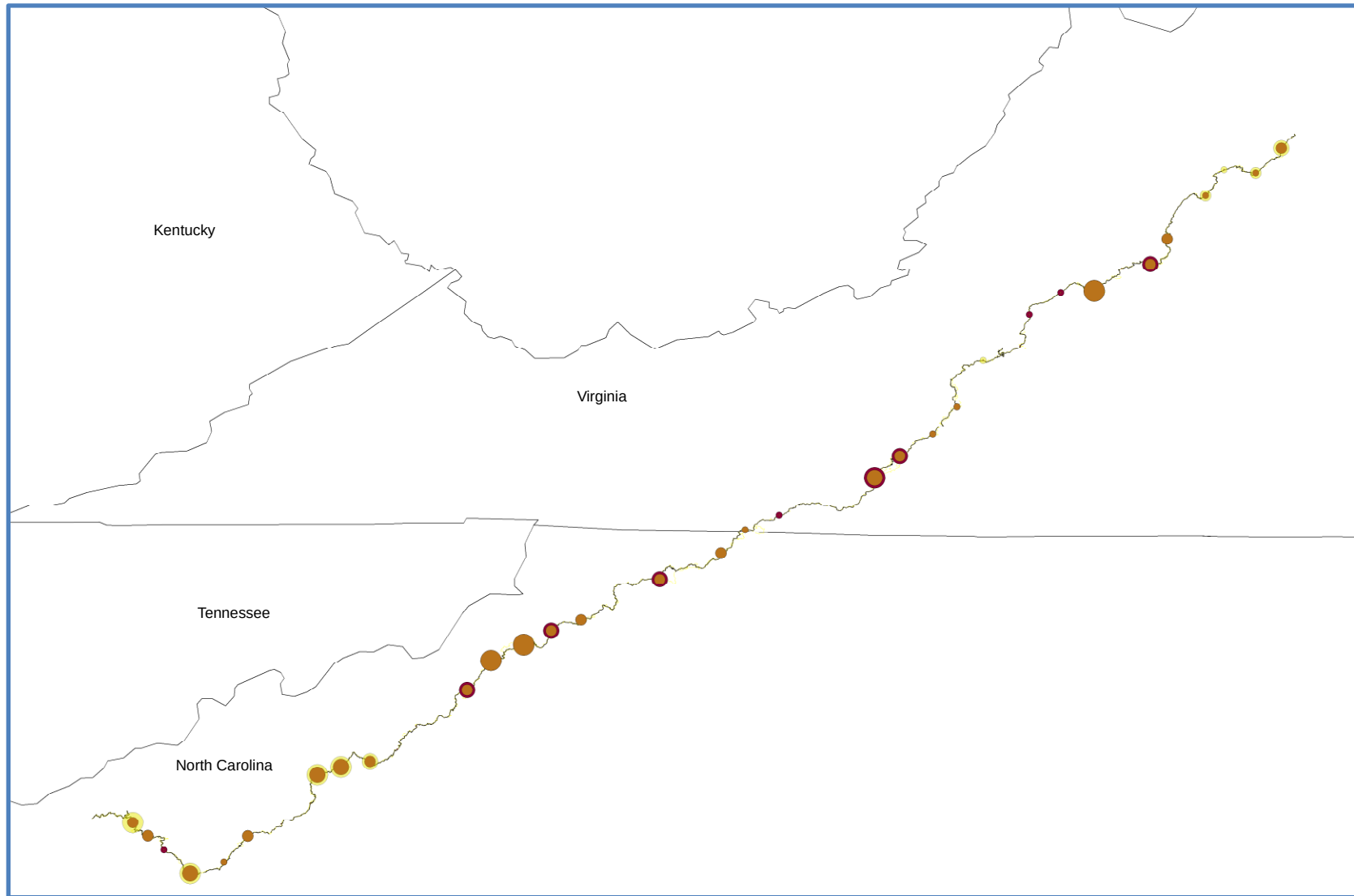


Figure 5. Sensitivity index and conservation score along the Blue Ridge Parkway grouped by 10-mile segments. The size of the circles represents the relative values of the SI or CS. SI circles are purple, CS circles are yellow. Where the two overlap, the color is brown.

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Table 11. Areas of potential high conservation interest selected on the basis of high sensitivity index (SI) and/or high conservation score. The areas selected are provided a short identifier. The Notes field provides a brief description of what the area entails. Specific sites, identified by the SiteCode used in the database are listed with SI and CS values, the number of species of interest found at the sites (S), and a partial list of significant species found at each site. Sites identified by DM represent the cumulative data from the 10-mile stretch of Parkway from, for example, for DM 010, milepost 0 to milepost 10.

Area	Notes	Sites	SI	CS	S	Species
Humpback Rocks to Dripping Rock Spring	The creek and wetlands at Humpback Rocks, and the spring off the Appalachian Trail a short hike from the spring at Dripping Rock	BLRI 001.1 right	29.68	8	16	Peltoperla tarteri
		BLRI 005.2 left	23.79	12	17	Paraleptophlebia moerens, Peltoperla tarteri, Rhyacophila kondratieffi
		BLRI 006.0 right	29.89	34	18	Eclipidrilus n. species, Peltoperla tarteri, Stygobromus n. species 1
		BLRI 009.7 Dripping Rock spring	24.87	27	14	Eclipidrilus n. species, Peltoperla tarteri, Stygobromus n. species 1
		DM 010	55.82	39	42	Eclipidrilus n. species, Paraleptophlebia moerens, Peltoperla tarteri, Rhyacophila kondratieffi, Stygobromus n. species 1
Dancing Ck & Otter Ck, Otter Lake, to James River	The Otter Creek drainage, from Dancing Creek to Otter Lake and downstream to the James River has numerous species of interest.	BLRI 056.7	36.74	11	45	Acroneuria kirchneri, Alloperla chloris, Hydroptila n. sp., Peltoperla tarteri
		BLRI 063.0 Otter Lake	32.42	10	73	Acroneuria arenosa, Acroneuria filicis
		BLRI 063.6 James River Visitor Center	22.07	13	53	Oecetis n. sp.
		BLRI 063	37.39	11	95	Acroneuria arenosa, Acroneuria filicis, Oecetis n. sp.
		BLRI 067.0 left Falling Rock Creek	31.93	10	32	Adicropheps hitchcocki, Ochrotrichia riesi
		DM 060	53.64	19	74	Acroneuria kirchneri, Hydroptila n.sp., Peltoperla tarteri, Pycnopsyche pani
		BLRI 085.5				Bichaeta n. sp., Isoperla pseudosimilis, Martinidrilus
Peaks of Otter	The entire Peaks of Otter area from Mile Marker 85.5 to 88.1 harbors a large number of species of interest including 8 new or newly described species and genera.	SS39203	33.85	25	20	carolinensis
		BLRI 085.6	22.74	10	12	Peltoperla tarteri
		BLRI 086.0	100.77	47	107	Isoperla n. sp., Isoperla pseudosimilis, Pararhynchelmis murdocki, Peltoperla tarteri, Pycnopsyche pani, Rhyacophila kondratieffi
		BLRI 086.0 Abbott Lake	65.72	58	63	Isoperla n. species, Isoperla pseudosimilis, Peltoperla tarteri, Pycnopsyche pani
		BLRI 086.0 Elk Run Peaks of Otter	41.77	15	38	Peltoperla tarteri, Pycnopsyche pani
		BLRI 086.0 Little Stoney Creek	22.86	12	20	Peltoperla tarteri

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Area	Notes	Sites	SI	CS	S	Species
		BLRI 086.0 outflow Abbott Lake	43.94	17	45	<i>Isoperla n. sp.</i> , <i>Peltoperla tarteri</i> , <i>Rhyacophila kondratieffi</i>
		BLRI 087.9 left	24.75	22	10	<i>Isoperla n. sp.</i>
		BLRI 088.1 Sp39203	24.63	11	12	<i>Isoperla n. sp.</i>
						<i>Bichaeta n. species</i> , <i>Homoplectra monticola</i> , <i>Isoperla n. species</i> , <i>Isoperla pseudosimilis</i> , <i>Peltoperla tarteri</i> , <i>Pycnopsyche pani</i> , <i>Rhyacophila kondratieffi</i>
Little Rock Castle Creek	Little Rock Castle Creek is likely to harbor many more species of interest than we know of presently. It is a heterogeneous area that has only been partially explored	DM 090	111.8	59	125	
		BLRI 165.3 Little Rock Castle Creek	69.76	28	68	<i>Acroneuria kirchneri</i> , <i>Peltoperla tarteri</i>
Mabry Mill	Mabry Mill is a BLRI treasure on the basis of its aquatic fauna alone. The many seeps along with the streams and mill pond contribute to its rich fauna.	BLRI 165	72.76	23	73	<i>Acroneuria kirchneri</i> , <i>Peltoperla tarteri</i>
		BLRI 176.2 left Mabry Mill	79.68	48	84	<i>Acroneuria kirchneri</i> , <i>Bichaeta n. species</i> , <i>Culoptila plummerensis</i> , <i>Peltoperla tarteri</i> , <i>Phagodrilus n. species</i> , <i>Yugus kondratieffi</i>
		BLRI 176.2 right Mabry Mill	55.63	18	55	<i>Sweltsa voshelli</i>
						<i>Acroneuria kirchneri</i> , <i>Bichaeta n. species</i> , <i>Culoptila plummerensis</i> , <i>Hydroptila n. sp.</i> , <i>Peltoperla tarteri</i> , <i>Phagodrilus n. species</i> , <i>Sweltsa voshelli</i> , <i>Yugus kondratieffi</i>
Julian Price Park and near vicinity	Julian Price Park and its vicinity has nearly 200 species of interest, including several undescribed or rare species. The combination of the bog, creeks, and many seeps contribute to this richness.	DM 180	97.66	52	131	
						<i>Ameletus n. sp.</i> , <i>Cricotopus n. sp.</i> , <i>Lepidostoma n. sp.</i> , <i>Hydroptila n. sp.</i> , <i>Rhyacophila kondratieffi</i> , <i>Rhyacophila mycta</i> , <i>Psilotreta amera</i>
Boone Fork and Wilson Creek	The combination of Boone Fork and Wilson Creek faunas. Both areas have many species of interest. The stretch along the Tanawa Trail has many seeps that eventually flow into Wilson Creek and are home to dozens of species of interest as well as new and recently described species.	DM 300	140.7	84	198	
						<i>Ameletus n. sp.</i> , <i>Cricotopus n. sp.</i> , <i>Isoperla pseudosimilis</i> , <i>Lepidostoma n. species</i> , <i>Hydroptila n. sp.</i> , <i>Orthocladus n. species</i> , <i>Psilotreta amera</i> , <i>Pycnopsyche pani</i> , <i>Rhyacophila kondratieffi</i> , <i>Rhyacophila mycta</i> , <i>Rhyacophila n. species</i> , <i>Theliopsyche grisea</i>
Linville River at Visitor Center	This is another area that needs further study, as indications are that many more species are liable to be found here. This also includes the stretch of habitats from Mile Marker 313 to 319.	DM 310	102.8	63	86	
		BLRI 316.4 Linville Falls Visitor Center	65.57	15	65	<i>Ameletus n. sp.</i>
Craggy Gardens area	This area, particularly in the immediate vicinity of the picnic	DM 320	85.54	23	77	<i>Acroneuria filicis</i> , <i>Ameletus n. species</i> , <i>Isoperla pseudosimilis</i>
		BLRI 367	46.12	55	40	<i>Manophylax altus</i> , <i>Pseudogoera singularis</i> , <i>Psilotreta amera</i> , <i>Rheocricotopus n. sp.</i> , <i>Rhyacophila accola</i>

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Area	Notes	Sites	SI	CS	S	Species
	area, contains the known habitat of <i>Manophylax altus</i> in the BLRI. It also has many other species of interest and several new or recently described species.	BLRI 367.2 right	25.97	23		
		BLRI 367.6 Craggy Gardens Picnic Area	18.95	10		
		BLRI 367.6 Craggy Picnic Area entrance seep	22.15	9		
		BLRI 367.6 Craggy Picnic Area Road Mid-Length	22.29	31		
						<i>Homoplectra monticola</i> , <i>Isoperla</i> n. sp., <i>Isoperla pseudosimilis</i> , <i>Manophylax altus</i> , <i>Orthocladus</i> n. species, <i>Pseudogoera singularis</i> , <i>Psilotreta amera</i> , <i>Rheocricotopus</i> n. species, <i>Rhyacophila accola</i> , <i>Rhyacophila kondratieffi</i> , <i>Rhyacophila</i> n. sp., <i>Stygobromus</i> n. species 2
Devils Courthouse	Several unique species occur in the many high elevation seeps in this area either along the roadway ditches or just down the crest on either side.	DM 370	67.03	82	64	
		BLRI 422	59.85	57	43	<i>Isoperla pseudosimilis</i> , <i>Megaleuctra williamsae</i> , <i>Rhyacophila mycta</i> , <i>Theliopsyche corona</i> , <i>Theliopsyche epilonis</i>
High Elevation seeps and springs	Most of the high elevation reaches of the BLRI, exemplified by those in the stretch from mile marker 440-460 are rich in species of interest. These high elevation seeps, as well as those in the rest of the Parkway, deserve special attention for the conservation of their faunas.	DM 450	48.12	24	30	<i>Isoperla pseudosimilis</i> , <i>Lepidostoma flinti</i> , <i>Rhyacodrilus</i> n. species, <i>Rhyacophila mycta</i> , <i>Rhyacophila</i> n. species
		DM 460	51.95	60	43	<i>Palaeagapetus celsus</i> , <i>Rhyacophila montana</i> , <i>Rhyacophila mycta</i> , <i>Stygobromus</i> n. species 1, <i>Theliopsyche corona</i> , <i>Theliopsyche epilonis</i>

Both the sensitivity index and the conservation score are potentially useful in making decisions regarding the selection of priority areas for conservation. The sensitivity index is limited in that it applies to aquatic species only, and specifically to those species which are normally encountered in monitoring activities and have been assigned a tolerance value. The concept of tolerance values in biomonitoring is well established and many studies have documented their usefulness in monitoring programs. Aquatic biomonitoring, however, is designed to evaluate flowing water systems larger than the majority of springs, seeps, and runs found in BLRI. In addition, the criteria used to assign tolerance values to species are weighted by the responses species show to pollution that may be very extreme. Monitoring is not designed to evaluate pristine sites relative to other pristine sites, which is the situation found in BLRI. Therefore, the usefulness of the concept in BLRI may be limited. The conservation scores, on the other hand, are designed to evaluate all aquatic species, whether they are used in biomonitoring programs or not. The concept is similar to the NatureServe global rankings and state-modified rankings of rare species. Conservation scores may be applied to all species, terrestrial or aquatic, and may be thought of as local rankings of species tailored to a landscape of interest. Both the selection of rare taxa and the assignment of conservation scores can be very subjective. Other biologists might select rare taxa differently or might assign somewhat different conservation scores. But we believe it is likely that the overall trends and the conclusion would be very similar regardless of who assigns the scores, provided the experts doing the scoring have similar experience and familiarity with the biota. We have found that using the sensitivity index and the conservation score in concert has provide us a useful means of prioritizing reaches of BLRI for management consideration in the event of proposed actions that might affect the hydrological resources of the Park.

Further Research

The BLRI possesses a truly remarkable aquatic invertebrate fauna. In addition to being very rich in terms the numbers of species, the fauna also contains many species and genera new to science, and many others that are rare locally, regionally, and globally. This study also has served to point out the need for further study to improve our knowledge and understanding of the biotic resources of BLRI. Additional work is required before several of the new species and genera already discovered can be described and named, as well as to refine our awareness of their distribution and habitat requirements. Many of the named species along the BLRI are unassociated in all life history stages, a serious impediment to conserving the species over the long term. This is particularly so when the aquatic stages are unknown, as it is in the aquatic stage that insects are at most risk to habitat alterations of various types. Association is achieved by collecting in the vicinity of the known adult locations in order to find the larvae and rear them to the adult stage. Conversely, the highly unusual hydropsychid larva which was collected at MP 360.3 in 1992 (by a BLRI temporary employee, Martina Hape) and has never been collected since despite many efforts by trained entomologists, is one that needs to be rediscovered so that it can be associated with the unknown adult stage. Much additional collecting needs to occur in winter, when the BLRI often is closed because of weather, in order to expand our understanding of the winter stonefly fauna. Further studies on the habitats and distributions of virtually all species are required to provide managers with the knowledge necessary to properly assess and manage the BLRI aquatic resources.

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