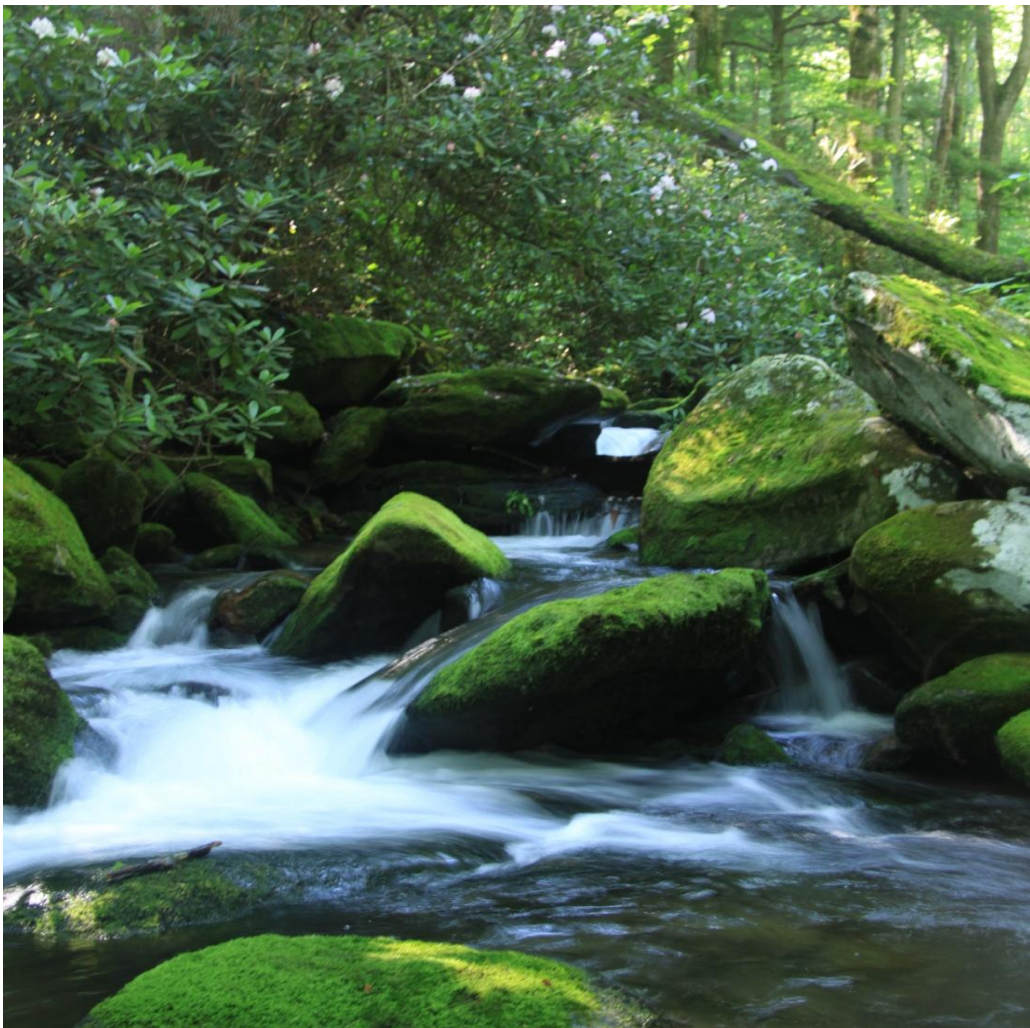




Benthic Macroinvertebrate Monitoring in Great Smoky Mountains National Park

A Summary of Methods and Results 1994-2005

Natural Resource Technical Report NPS/GRSM/NRTR—2012/631



ON THE COVER

Cosby Creek in Great Smoky Mountains National Park
Photo by Steve E. Moore

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Becky J. Nichols

National Park Service
Great Smoky Mountains National Park
1316 Cherokee Orchard Road
Gatlinburg, TN 37738

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Contents

	Page
Figures.....	v
Tables.....	v
Abstract.....	vii
1. Introduction.....	1
2. Methods.....	3
2.1 Site Selection	3
2.2 Sampling Plan.....	3
2.3. Documenting Habitat Variables.....	5
2.4 Sampling Procedure	6
2.4.1 Kick-net.....	6
2.4.2 D-net	6
2.4.3 Fine-mesh Sampler	6
2.4.4 Sand Sampler	6
2.4.5 Leaf-pack Sampler	7
2.4.6 Visual Search	7
2.5 Specimen Identification/Quality Assurance	7
2.6 Data Analysis.....	7
2.6.1 Taxa Richness	7
2.6.2 North Carolina Biotic Index.....	8
2.6.3 Final Bioclassification	8
2.6.4 Trend Analysis	9
3. Results.....	11
4. Summary	15

Contents (continued)

	Page
5. Literature Cited	17

Figures

	Page
Figure 1. Aquatic macroinvertebrate monitoring sites in GRSM.	5
Figure 2. Species richness at the 27 permanent long-term aquatic macroinvertebrate monitoring sites.....	11
Figure 3. Species accumulation curve for the aquatic macroinvertebrate long-term monitoring program in GRSM.....	12
Figure 4. Final bioclassification values for Abrams Creek site 1 from 1994-2005, with linear regression trendline.....	12
Figure 5. Final bioclassification values for Abrams Creek site 2 from 1994-2005, with linear regression trendline.....	13
Figure 6. Taxonomic richness for Abrams Creek site 1 (blue) and Abrams Creek site 2 (red) over time, with linear regression trendline.....	14
Figure 7. Power Analysis results for all permanent aquatic macroinvertebrate monitoring sites in GRSM.	14

Tables

	Page
Table 1. GRSM macroinvertebrate monitoring site locations in North Carolina and Tennessee.....	4
Table 2. Scores for EPT taxa richness and NCBI values.	8

Abstract

Great Smoky Mountains National Park (GRSM) began an Inventory and Monitoring program in 1993, and benthic macroinvertebrates were selected as a component primarily because of their utility in assessing water quality, and because of their abundance in park streams. The overall goal of the benthic macroinvertebrate monitoring program in GRSM is to maintain a park-wide system of monitoring sites to track the environmental health of park streams, and to detect and quantify changes in conditions using various analysis tools such as biotic indices. This program is designed to collect data through repeated sampling over time to answer the question of whether or not a particular benthic macroinvertebrate community displays trends indicative of ecosystem stress.

Presented here is a summary of data collected from 1994 through 2003. Results indicate excellent water quality in most areas of the park over the span of this sampling. The cumulative number of taxa encountered is 536, and the species accumulation curve is leveling off, indicating that we have documented a high percentage of the species occurring in the lotic habitats sampled. When examining trends over time, two streams showed a decline in the biotic index values. Further investigation and sampling in these streams currently is being conducted to ascertain the source of perturbation.

GRSM currently is undergoing a revision of its monitoring program to align with the NPS Vital Signs program. Aquatic macroinvertebrates will again be a component of this program and sampling will resume as plans are finalized.

1. Introduction

Great Smoky Mountains National Park (GRSM) is one of the largest fully protected natural areas in the eastern US, encompassing over 2000 km² in east Tennessee and western North Carolina. It is believed to be one of the most species-rich national parks in the national park system, with over 17,000 documented species. Factors that contribute to this diversity include the age and general north-south orientation of the mountains, elevations that range from about 300 m to over 2000 m, including several of the highest peaks in eastern North America, complex geochemistry, abundant moisture, and the mountains' apparent role as refugia for species during major climatic shifts over time. The Southern Appalachians in general are one of six "hot spots" for biodiversity recognized nationally by NatureServe (Stein et al. 2000).

All of the streams in GRSM (~3400 km total length) are part of the Tennessee River system, which is recognized as one of the most diverse aquatic systems in the world (Stein et al. 2000). Within these streams, and other aquatic habitats in the park, 965 species of aquatic macroinvertebrates have been documented, and 76 species of fish currently are present. The majority of park streams are high-gradient first and second order, but there also are third through sixth order streams within park boundaries.

Streams are hierarchical systems and aquatic biota are affected by factors on both regional and local scales (Mykrä et al. 2004). Within-region variation in geology, land use, and water chemistry may override the influence of regional factors. Some studies have shown that local-scale (catchment) characteristics are more useful than regional factors in predicting stream macroinvertebrate and fish assemblage structure (Mykrä et al. 2004). Indices have been developed to represent how aquatic communities respond to catchment characteristics and natural and anthropogenic stressors. One of the earliest of these was a multimetric index of biotic integrity (IBI) for fish assemblages (Karr 1981). Following the development of the fish IBI, similar indices were developed for benthic macroinvertebrates (Hilsenhoff 1988), periphyton, and riparian birds (Klemm et al. 2003). The rationale behind all such indices is that a set of variables or metrics representing community structure, pollution tolerance, etc., offers robust and sensitive insights into how an assemblage responds to stressors (Klemm et al. 2003).

Aquatic insects and other benthic invertebrates are the most widely used organisms in freshwater biomonitoring (Bonada et al. 2006); they are subjected directly to changes in the physical and chemical conditions of the water, and are therefore good indicators of ecosystem health. Aquatic biota exhibit responses to a wide array of stressors, including those having synergistic or antagonistic effects. In the Smokies, these stressors include primarily acid deposition, forest changes due to exotic pest infestations, and climate change.

The National Park Service (NPS) initiated a long-term monitoring program in 1992 and GRSM was selected as one of the first four units to be established as a prototype park. A comprehensive plan was developed in 1993 that established goals, monitoring questions, components, and funding amounts (NPS 1993). Aquatic macroinvertebrates were selected as a component of the long-term monitoring program primarily because of their utility in assessing water quality, and because of their abundance in park streams. Sampling protocols were developed in 1992 (Parker and Salansky 1992).

The overall goal of the benthic macroinvertebrate monitoring program in GRSM is to maintain a park-wide system of monitoring sites to track the environmental health of park streams, and to detect and quantify changes in conditions using various analysis tools such as biotic indices. The specific objectives are:

- to acquire a baseline inventory of the aquatic macroinvertebrates in park streams
- to develop long-term baseline data for aquatic communities in park streams
- to determine correlations among macroinvertebrates, fish, habitat, and water quality monitoring data
- to develop long-term trend information for the park's aquatic macroinvertebrate fauna.

This program is designed to collect data through repeated sampling over time to answer the question of whether or not a particular benthic macroinvertebrate community displays trends indicative of ecosystem stress. These data relate directly to many other Inventory and Monitoring components in the park, particularly the fisheries and water quality programs. Additionally, the data provide a baseline dataset for many areas outside of the park which may be experiencing greater impacts to their aquatic resources.

Presented here is a summary of data collected from 1994 through 2003. During the first year of the program (1993), protocols were refined and the most appropriate sample season was determined; therefore, data from that year is not included due to inconsistencies with other years. From 2004 until present, only occasional sampling was done when funds were available to do so. GRSM is currently undergoing a revision of its monitoring program to align with the NPS Vital Signs program. Aquatic macroinvertebrates will again be a component of this program and sampling will resume as plans are finalized.

2. Methods

The rapid bioassessment protocols presented here have been adapted from the Standard Operating Procedures developed and used by the North Carolina Department of Environment and Natural Resources, Division of Water Quality, Environmental Sciences Section, Bioassessment Unit (NCDENR 2011). These protocols (hereafter referred to as the NC protocols) have been designed for use in this region, including sites within GRSM.

2.1 Site Selection

A site is defined as a section of river or stream approximately 100 to 200 m long. Some of the macroinvertebrate monitoring sites have been chosen to coincide with fish monitoring sites; therefore, site length is dependent on stream size and the location of suitable natural impediments to fish movements at the lower and upper ends. Sections 200 m long are established on streams greater than 9 m in width. Characteristics considered in determining the number of sites sampled on a particular stream include changes in stream order and width, gradient, structural characteristics (waterfalls, cascades, etc.), topography, accessibility, stream length, and number of tributaries. Also, it is preferable to select sites at least 100 m downstream of any confluence so as to allow the two (or more) streams to sufficiently mix. Water chemistry can be highly variable at the point of confluence, depending upon the geology of each stream's drainage area. Most streams include two or more macroinvertebrate sampling sites, except small first order streams less than 2 km long or less than 4 m wide at the confluence.

2.2 Sampling Plan

Twenty streams including a total of 27 sites are slated to be sampled on a yearly basis. These sites are referred to as permanent sites, and they were subjectively selected across as many different watersheds in the park as possible, including varying forest types, elevations, substrates, etc. Each site is sampled once per season, with the season extending from June through September. This time frame ensures that all samples can be analyzed without the need to compensate for seasonal population fluctuations.

To accomplish the goal of a park-wide monitoring system and the objective of a baseline inventory of the macroinvertebrates of the park, other sites are sampled each year in addition to the permanent sampling sites. There are 45 principal watersheds in GRSM (Parker and Pipes 1990). This is too many to be sampled in one year; therefore, a long-term rotational schedule has been adopted. Each summer, one or more watersheds are selected for sampling across elevational gradients in streams of different order and basin characteristics. The number of watersheds and sampling sites depend on the size of the watersheds selected; selection is made in consultation with other park program managers in order to coordinate sampling whenever possible. To-date, 106 sites (Table 1) throughout the park (Fig. 1) have been sampled; some numerous times.

Streams are sampled roughly in the same order, and at approximately the same time of year as in the previous year. This allows for a more accurate comparison of species data between years. The timing of sampling is highly dependent upon weather conditions and water level, so this schedule must be flexible. Starting in early June, sampling begins on the smaller streams. As the season progresses, the larger streams are sampled, finally ending with the largest order streams

Table 1. GRSM macroinvertebrate monitoring site locations in North Carolina and Tennessee. Numbers following a stream name indicate the number of sites on that stream greater than one.

North Carolina: Haywood County	Tennessee: Sevier County
Baxter Creek	Alum Cave Creek
¹ Beech Creek	Ash Camp Creek
Bettis Branch	¹ Baskins Creek (2)
¹ Cataloochee Creek	Cannon Creek
Chestnut Branch	Churn Hollow
¹ Lost Bottom (3)	Copeland Creek
Mouse Creek	Dudley Creek
¹ Palmer Creek	Dunn Creek
	Fighting Creek
	¹ LeConte Creek
North Carolina: Swain County	Little Pigeon River
Bee Gum Branch	¹ Little River (2)
Beech Flats Prong (2)	Ramsay Branch
Bradley Fork	Ramsey Creek
Bulldie Creek	Rhododendron Creek
¹ Bunches Creek (2)	¹ Road Prong
Chasteen Creek	Roaring Fork
Chokeberry Branch	Rough Creek
Collins Creek	¹ Sams Creek (2)
Deep Creek (3)	¹ Shutts Prong
¹ Defeat Creek	¹ Silers Creek
Enloe Creek	Soak Ash Creek
¹ Flat Creek	¹ Starkey Creek (2)
Forney Creek (6)	Walker Camp Prong
Hammer Branch	West Prong Little Pigeon River
¹ Hazel Creek (3)	
Indian Creek (2)	
Kephart Prong	Tennessee: Blount County
Mingus Creek	¹ Abrams Creek (2)
Moore Springs Branch	Beard Cane Creek
Oconaluftee River (2)	Cane Creek
Peachtree Creek	Flint Branch
Pole Road Creek	Hesse Creek (2)
Raven Fork (7)	Kingfisher Creek
Straight Fork (2)	Panther Creek
¹ Taywa Creek	Pinkroot Branch
¹ Twentymile Creek	Shop Creek
White Oak Branch	Tabcat Creek
	Thunderhead Prong
Tennessee: Cocke County	Whiteoak Sink
Camel Hump Creek	
Greenbrier Creek	
Indian Camp Creek (2)	
¹ Rock Creek (2)	

¹annual sites

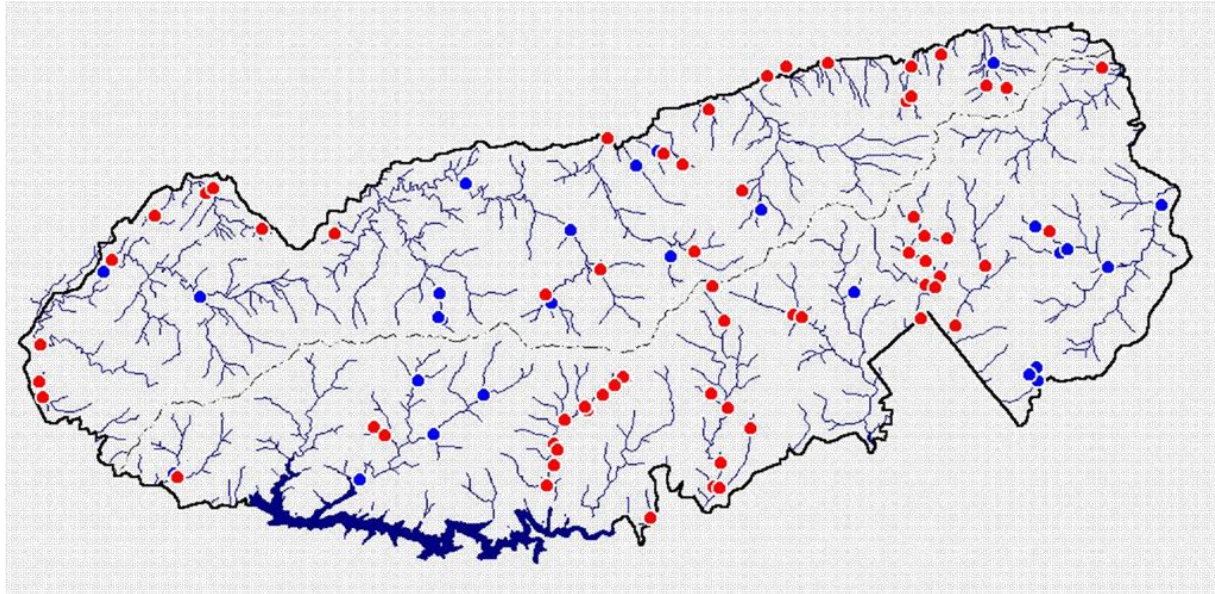


Figure 1. Aquatic macroinvertebrate monitoring sites in GRSM. Blue dots indicate permanent, annually-collected sites; red dots indicate rotating sites. The hatched line represents the state line between Tennessee to the north, and North Carolina to the south.

near the end of August or early September. Sampling in some years has been sporadic, primarily due to a lack of funding to obtain species-level identifications and to hire field personnel.

2.3. Documenting Habitat Variables

Before sampling for macroinvertebrates begins, various site characteristics are recorded, including the following:

- Stream width, measured from one wetted shore to the opposite wetted shore perpendicular to the thalweg (the deepest part of the channel), is a primary factor in determining expected taxa richness, especially in unimpacted headwater streams. A tape measure is used to measure stream width at 10 m intervals throughout the length of the 100 m stream section to be sampled. At 200 m large-stream sampling sites, 20 m intervals are used.
- Stream gradient is an important factor influencing current flow, channel structure, and habitat availability. A clinometer is used to measure the gradient within each 10 to 20 m section.
- Depth is measured at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ stream width across each transect as the stream width is measured.
- At each point where depth is measured on each transect, the dominant substrate class within a radius of 0.5 m is determined. Substrate size measurements are used to categorize it into one of eight classes (i.e., silt, sand, small gravel, large gravel, cobble, small boulder, large boulder, and bedrock; modified from Platts et al. 1983).
- As stream width and gradient are being measured, estimates are made of the percentage of invertebrate habitat classes in each transect interval. These classes include snags, undercut banks, root mats, backwater, detritus, vegetation, and other.

2.4 Sampling Procedure

The standard qualitative method followed at each collection site consists of three kick-net samples, one composite D-net sample (composite samples are comprised of several collections in each distinct habitat type throughout the site; the quantity varies considerably among streams), one composite leaf-pack sample, one composite fine-mesh rock and/or log wash sample, one composite sand sample, and one composite visual search. Each technique is described below. Invertebrates are separated from the rest of the sample in the field, and are picked roughly in proportion to their abundance; no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field (i.e., *Tallaperla* sp.), no more than 10 individuals are collected. Specimens are preserved in plastic vials containing 95% ethanol.

2.4.1 Kick-net

A kick-net is used to sample in riffle areas; however, in streams lacking enough riffles, samples are taken from root mats, snags, or bank areas. This method typically results in the highest number and diversity of organisms, and careful attention must be paid when picking representative species off of the net.

2.4.2 D-net

D-net samples are usually taken from bank areas, including mud banks, root mats, and macrophyte beds. Bank samples are particularly important for the collection of edge species that prefer low current environments. Chironomids, oligochaetes, odonates, caddisflies, alderflies, crayfish, and certain mayflies often are collected with this technique. A D-net also is used to sample gravel riffle areas where stone-cased caddisflies may be abundant.

2.4.3 Fine-mesh Sampler

A fine-mesh sampler is used to collect smaller invertebrates missed by the kick and D-nets. This sampler is made out of a cylinder cut from 10-cm PVC pipe, with fine-mesh (200 μm) netting placed between PVC pipe fittings that fit snugly together. This device can be used in a variety of ways. The simplest technique is to wash rocks or logs into a large plastic tub. Rocks are selected which have visible growths of periphyton, bryophytes, or a coating of silt. The material remaining in the tub is poured through the fine-mesh sampler into a sorting tray and rinsed. Specimens are picked from the tray and preserved in 95% ethanol. Small chironomids, oligochaetes, baetid mayflies, hydroptilid caddisflies, and other grazers are collected with this technique.

2.4.4 Sand Sampler

Sandy habitats often contain a distinctive fauna, but sampling this habitat can be difficult. Sandy substrates (in areas with definite flow, if possible) are sampled with a large bag constructed of fine-mesh (200 μm) netting. The net is constructed from a 1 m² piece of netting folded in half and sewn together on the opposite side and the bottom. This bag is employed like a Surber sampler, but the lack of a rigid frame allows for easy storage when folded. The bag is held open near the substrate, and the sand is vigorously disturbed by the collector's hands or feet. The material collected (a lot of sand and a few organisms) is then emptied into a plastic tub half-filled with water. The sample is stirred and poured into a fine-mesh sampler, after which the filtrate is picked through. Chironomids, oligochaetes, gomphid dragonflies, and certain mayflies are commonly found with this technique. This process is repeated until no additional organisms are

found or until no different organisms are encountered. The sand remaining in the tub is picked for large or heavy organisms that have not been washed free by stirring.

2.4.5 Leaf-pack Sampler

Leaf packs, sticks, and small logs are hand collected and placed into a sieve bucket where the material is rinsed and then discarded; the remaining debris is then sorted for organisms. Generally, leaf packs are collected from rocks or snags in fast current areas. These samples are especially useful for collecting shredders, particularly crane flies, stoneflies, and caddisflies.

2.4.6 Visual Search

Conducting a visual inspection of various microhabitats not included with other sampling techniques often adds to the species list. Large rocks and logs, for example, are a preferred microhabitat for some species because of their stability during high water levels. Decaying logs are picked apart to look for chironomids, and many taxa can be found under loose bark. Rocks near the shore in negligible current will harbor certain mayflies, and leaves near the shore may be the primary habitat for some snails. Mussel species, although generally uncommon in the park, may be found by careful visual inspection of the stream bottom. If empty shells are found during sampling, further searching is conducted to find live specimens.

2.5 Specimen Identification/Quality Assurance

After field work is completed, samples are sent to a consulting firm for taxonomic identification, to the species level when possible. Taxonomic quality control is maintained in several ways. First, the contractor chosen for sample processing must be qualified and experienced working with the fauna of the park. Specimens must be identified using current regional identification manuals and more specialized taxonomic literature where appropriate. If questions occur, park authorities are asked for assistance. Specimens of unusual or rare taxa are compared with specimens in the park collections when possible. If no park authority is available and questions cannot be resolved by reference to previously identified material, taxonomic assistance is obtained from outside specialists.

2.6 Data Analysis

The following values are calculated each year from species data collected during the summers. Indices and scores over all years to-date are then combined to examine long-term trends in the data.

2.6.1 Taxa Richness

Species richness, or number of species, is the simplest measure of diversity. The association of good water quality with high species richness has been thoroughly documented (see Rosenberg et al. 2008). Increasing levels of ecosystem stress gradually eliminate the more sensitive species, leading to progressively lower species richness. Total taxa richness and taxa richness for Ephemeroptera, Plecoptera, and Trichoptera (EPT) combined are calculated for each site sampled in GRSM. Scores for EPT taxa richness values for several major ecoregions have been developed for the standard qualitative sampling method (NCDENR 2011; Table 2), which are used for the final bioclassification determination. The EPT score primarily reflects the influence of chemical pollutants; the effects of sediment are poorly assessed by taxa richness analysis.

Table 2. Scores for EPT taxa richness and NCBI values.

Score	EPT Richness	NCBI
5.0	>43	<4.00
4.6	42-43	4.00-4.04
4.4	40-41	4.05-4.09
4.0	34-39	4.10-4.83
3.6	32-33	4.84-4.88
3.4	30-31	4.89-4.93
3.0	24-29	4.94-5.69
2.6	22-23	5.70-5.74
2.4	20-21	5.75-5.79
2.0	14-19	5.80-6.95
1.6	12-13	6.96-7.00
1.4	10-11	7.01-7.05
1.0	0-9	>7.05

2.6.2 North Carolina Biotic Index

The North Carolina Biotic Index (NCBI; Lenat 1993) is another tool for assessing water quality that takes into account tolerance and abundance values of each taxon in a sample. Tolerance values indicate the ability of a taxon to withstand pollution and ecosystem stress, with 0 denoting complete intolerance, and 10 denoting extreme tolerance. In North Carolina, tolerance values have been derived from hundreds of samples taken in diverse water quality conditions across the state (Lenat 1993). These values represent the best available assessments of tolerances for the taxa found in the park; they are listed at http://portal.ncdenr.org/c/document_library/get_file?uuid=c2fdf380-aa8a-481e-8388-a6e6596c6a96&groupId=38364 and were last updated in April, 2010. As this list is updated, with tolerance value changes and/or new species additions, analyses are recalculated. The abundance codes, n (1, 3, or 10), for each taxon are derived from the number of specimens collected. One to two specimens are coded as 1; 3 to 9 specimens are coded as 3; and 10 or more specimens are coded as 10. The NCBI is then calculated as follows:

$$NCBI = \frac{\sum TV_i (n_i)}{N}$$

TV_i = tolerance value of the i^{th} taxon

n_i = abundance code (1, 3, or 10) of i^{th} taxon

N = sum of all abundance codes

2.6.3 Final Bioclassification

For most mountain streams in the southeast US, equal weight is given to both the EPT taxa richness and the NCBI when assigning final bioclassifications. For each site, both values receive a score (Table 2), and the two scores are then averaged and rounded to produce the final bioclassification. Scores have been derived by examining average biotic index values over many years in many ecoregions (NCDENR 2011). The final bioclassification number corresponds with the following stream quality ratings:

Excellent: 5

Good: 4

Good-Fair: 3

Fair: 2

Poor: 1

During this process, if the two scores to be averaged differ by exactly one, resulting in a final score that is midway between two scores, the total number of EPT individuals (EPT N) is used to determine whether to round up or round down. If EPT N is greater than the criteria listed below, the final score is rounded up; if it is less, the final score is rounded down.

Excellent (5) vs. Good (4)	191
Good (4) vs. Good-Fair (3)	125
Good-Fair (3) vs. Fair (2)	85
Fair (2) vs. Poor (1)	45

2.6.4 Trend Analysis

After calculating the above indices and bioclassifications each year for each site, they are combined with the full dataset from previous years and examined for trends, using the null hypothesis that the sites do not differ significantly over time. Analysis of variance is used to determine if a significant trend can be detected at one or more sites. If a trend is detected, data from other elements of the program are examined to determine if similar trends exist in other components of the ecosystem, and what the possible causes for the trend may be. If the trend is noted in several sites, in other components of the ecosystem, and if no causes can be immediately identified, an investigation of the situation will be undertaken.

To be certain that the data accurately reflect trends in environmental conditions, power analysis is used to determine how reliable the data are, considering a number of variables. The software program MONITOR, developed by the U.S. Geological Survey, uses linear regression to estimate the statistical power of population monitoring programs relative to: number of sites monitored, magnitude of counts per site, count variation, duration and interval of monitoring, strength and nature of ongoing population trends, and significance level associated with trend determination (Toft and Shea 1983).

3. Results

Species richness values varied over time (Fig. 2), most likely as a direct result of the varying sampling effort each year with different personnel, and perhaps some climatological factors. For example, only seven samples were collected in 2005, and the richness values were quite low; however, in years where a large number of samples was collected, the richness values are correspondingly high. There is a strong correlation between the number of samples in a given year, and the number of taxa collected in that same year ($r=0.52$).

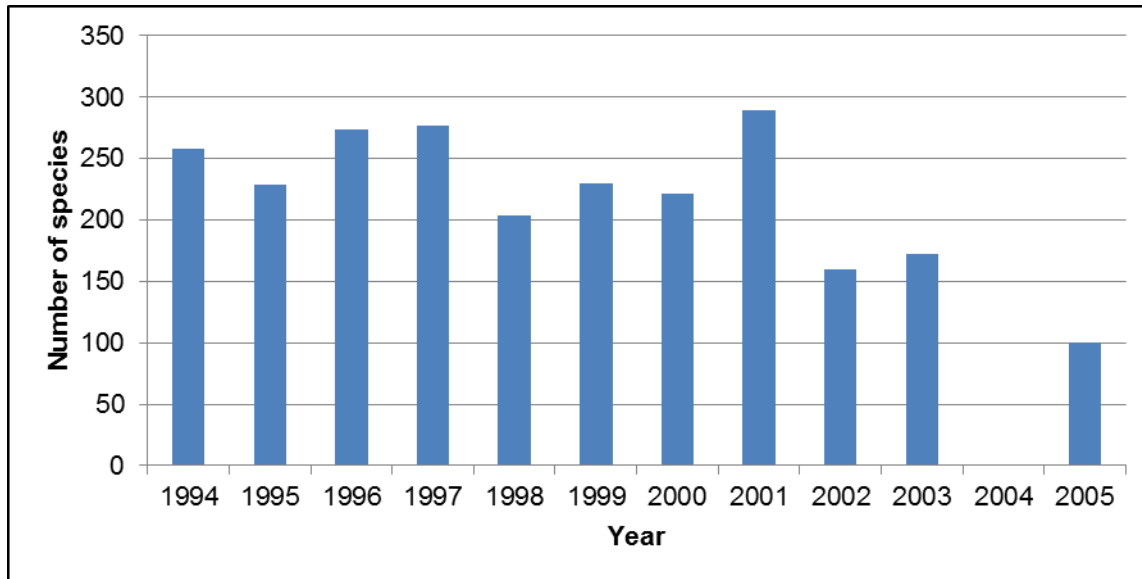


Figure 2. Species richness at the 27 permanent long-term aquatic macroinvertebrate monitoring sites (pooled per year).

Since this monitoring program began, 536 aquatic macroinvertebrate species have been documented from stream sites. Additional aquatic species have been documented through other programs, such as the All Taxa Biodiversity Inventory, and various outside research studies. The species accumulation curve (Fig. 3) shows some leveling off from 2003-2005, perhaps indicating that we have discovered most of the aquatic species in the lotic systems that have been sampled in the park.

Final bioclassification ratings were calculated for all sites, and of all the 27 annual monitoring sites, only two showed a notable decline over time; Abrams Creek site 1, and Abrams Creek site 2 (Figs. 4, 5). Site 1 had a rating of Fair (3) in the years 2000, 2001, 2003, and 2005. This is the only stream in the park to have a rating this low. Site 2 had ratings in the Excellent (5) and Good (4) categories, but the overall trend was downward. All other streams, although varying from year to year, stayed within the Excellent and Good categories and did not have a declining trendline.

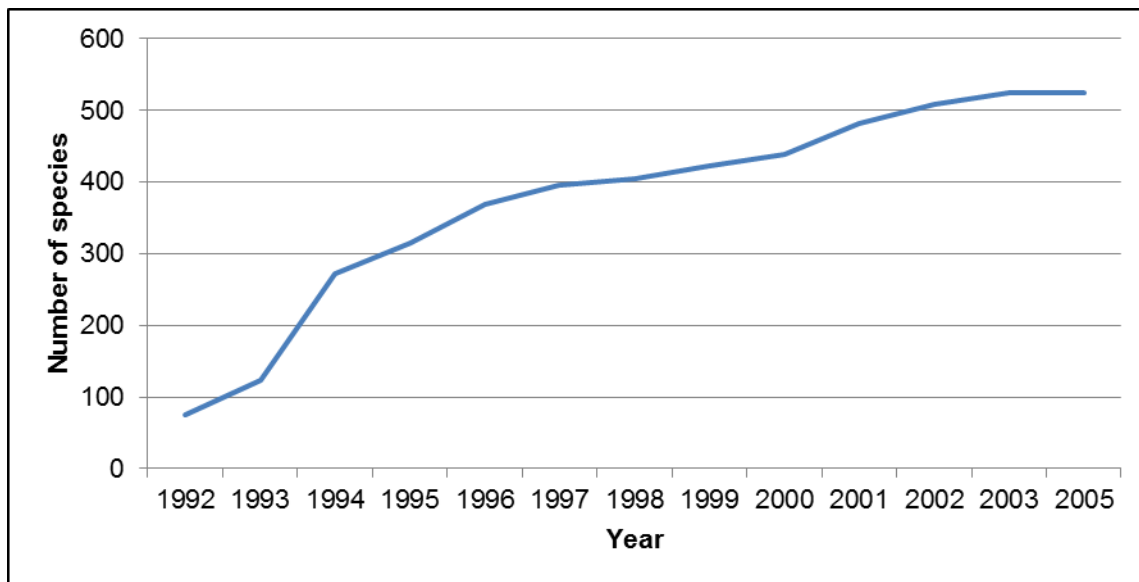


Figure 3. Species accumulation curve for the aquatic macroinvertebrate long-term monitoring program in GRSM.

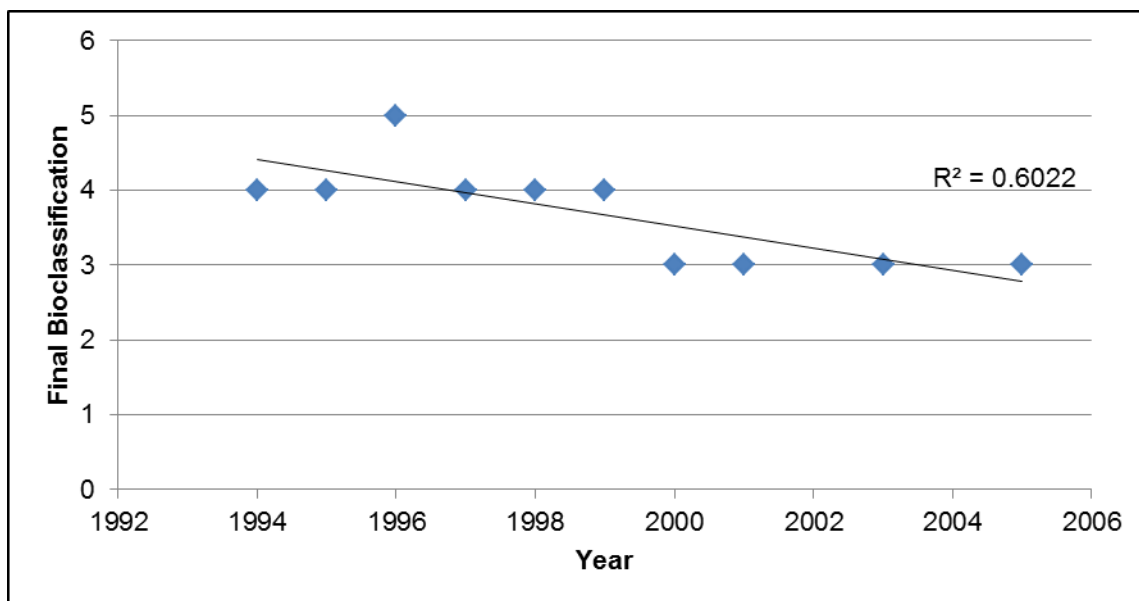


Figure 4. Final bioclassification values for Abrams Creek site 1 from 1994-2005, with linear regression trendline.

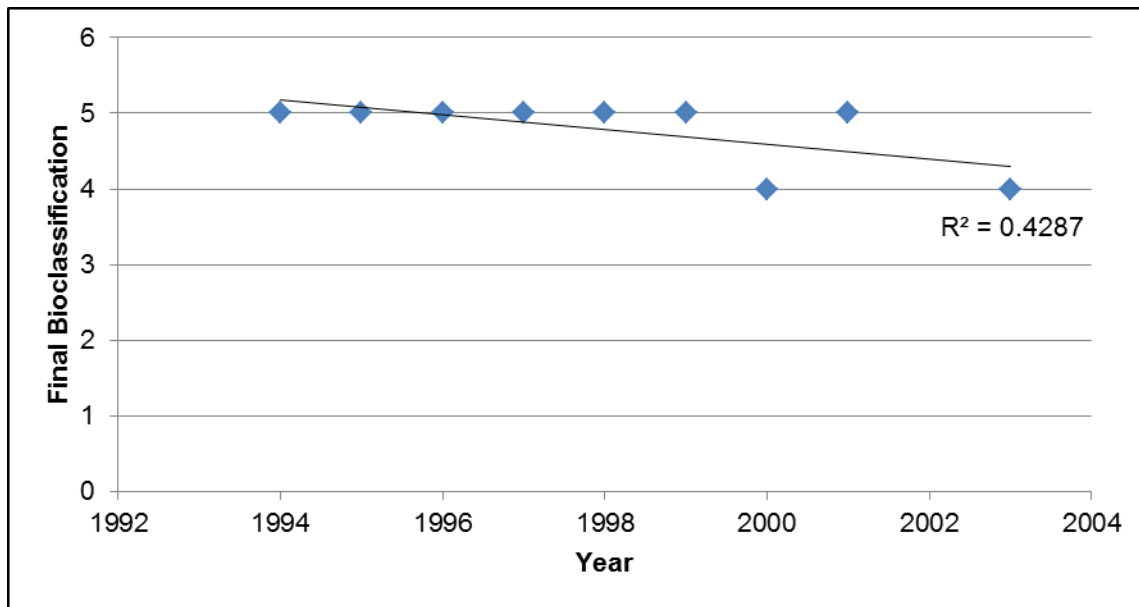


Figure 5. Final bioclassification values for Abrams Creek site 2 from 1994-2005, with linear regression trendline.

Site 1 on Abrams Creek is near the lower end of the watershed within a primarily mixed pine/oak vegetation community type. Being a fifth order stream at this point, water levels can be quite high after rain events, along with visually significant levels of suspended solids. Site 2 on Abrams Creek is at the west end of Cades Cove, downstream of the confluence with Mill Creek. Water chemistry at this site, and at site 1, often is quite different than many of the other monitoring sites due to the limestone influences from Cades Cove (see Robinson et al. 2001). For example, the mean pH at sites 1 and 2 are 7.4 and 7.2, respectively, and mean conductivity is 98 μS and 49 μS , respectively. All other sites have a pH below 7, and conductivity values averaging 15 μS .

Taxonomic richness generally decreases with decreasing water quality, and although it is not a strong relationship, there is indeed a decline in total taxonomic richness at both Abrams Creek sites (Fig. 6). The taxonomic groups that declined the most, at both sites, were the Trichoptera, Odonata, and Diptera (family Chironomidae). Further examination of water quality in these areas currently is being pursued, with emphasis on nutrient levels and sediment load.

Power analysis was used to evaluate how reliable this data set is for determining trends in aquatic communities over time. For nearly all sites, the analysis resulted in a power of 1 (i.e., 100% of the time, we are able to detect a trend as small as $\pm 4\%$ with an $\alpha = 0.2$; Fig. 7). Only a couple of sites had power values significantly lower than one, which indicates that the data set is not sufficient to provide accurate trend information. Defeat Creek (DF), for example, which has a power level of approximately 0.4, is a site that is very difficult to reach, logistically, and has only been sampled five times, as opposed to 10-12 times for many of the other streams. As a result, the data set is not long enough for this particular site to accurately examine trends.

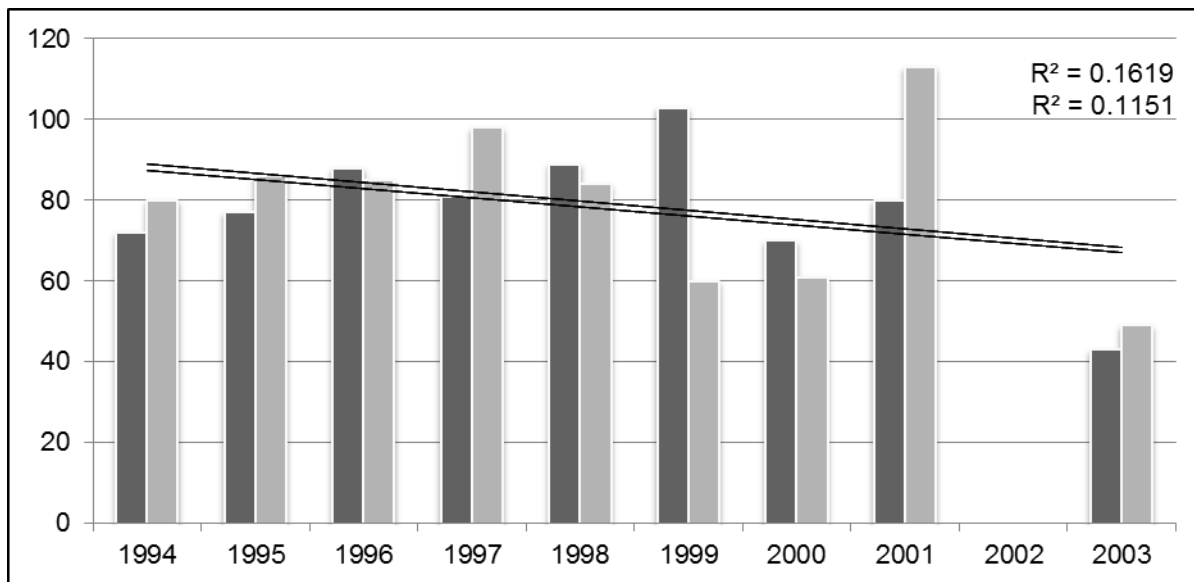


Figure 6. Taxonomic richness for Abrams Creek site 1 (dark gray) and Abrams Creek site 2 (light gray) over time, with linear regression trendline.

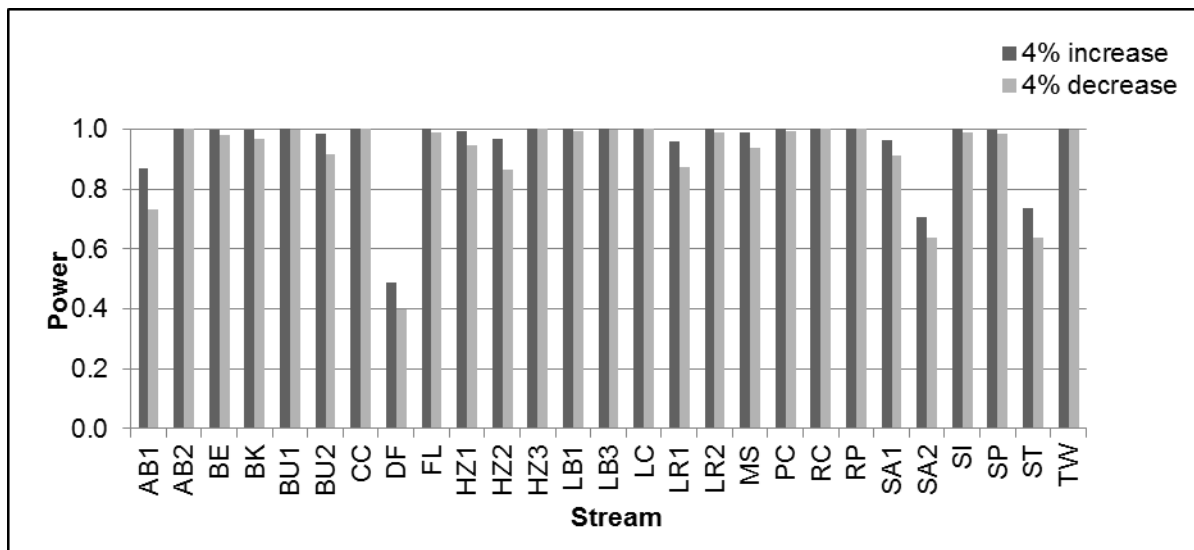


Figure 7. Power Analysis results for all permanent aquatic macroinvertebrate monitoring sites in GRSM.

4. Summary

Biotic indices for the 27 long-term monitoring sites over a 10-year span generally indicate excellent water quality in GRSM with regard to the aquatic macroinvertebrate community. Because the Abrams Creek sites both indicate a decline in water quality, there may be some impacts occurring within this watershed that need further examination. Directed sampling in these two sites is currently being conducted in order to determine if a downward trend is still occurring, and if so, why. Potential water quality issues have also been indicated by an overgrowth of a native green alga, *Cladophora* sp., in Abrams Creek. This genus apparently is an indicator of high phosphorus levels; the source of this is being investigated as well.

Continuing analyses of these data will be conducted, especially with regard to other components of the Inventory and Monitoring program, and with regard to Abrams Creek sites specifically (e.g., community structure changes, presence/absence of algal indicator species, water chemistry analyses, etc.). Also, as the park moves toward a fully integrated Vital Signs monitoring program, long-term data will be used to inform the new sampling design and protocol, including sampling frequency, sample locations, and taxonomic resolution required. Historic sites will be used when possible; however, new sites also will be chosen within a statistically valid framework, and will provide information on environmental impacts such as climate change, acid deposition, and vegetation changes due to forest insects and diseases.

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