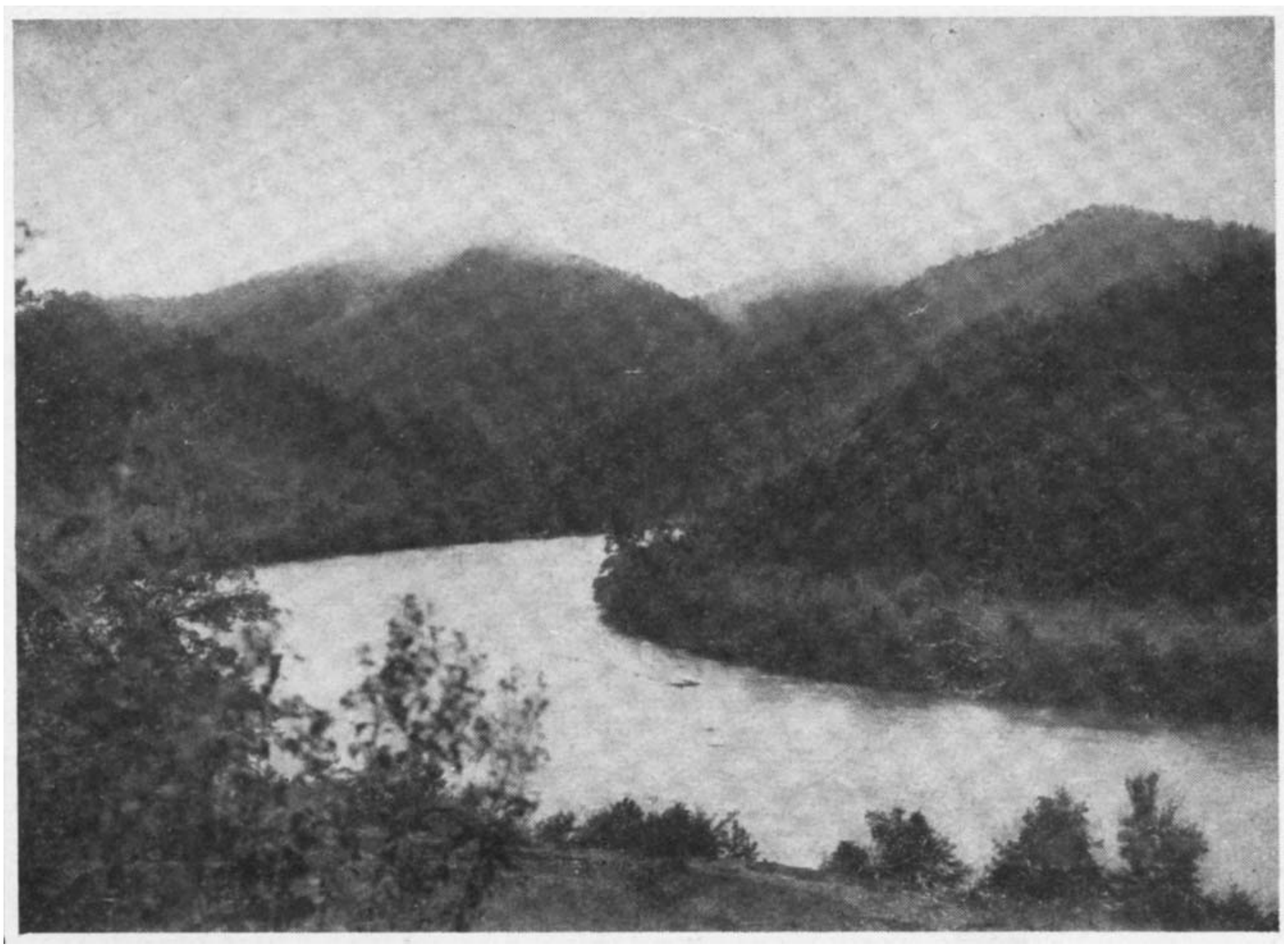
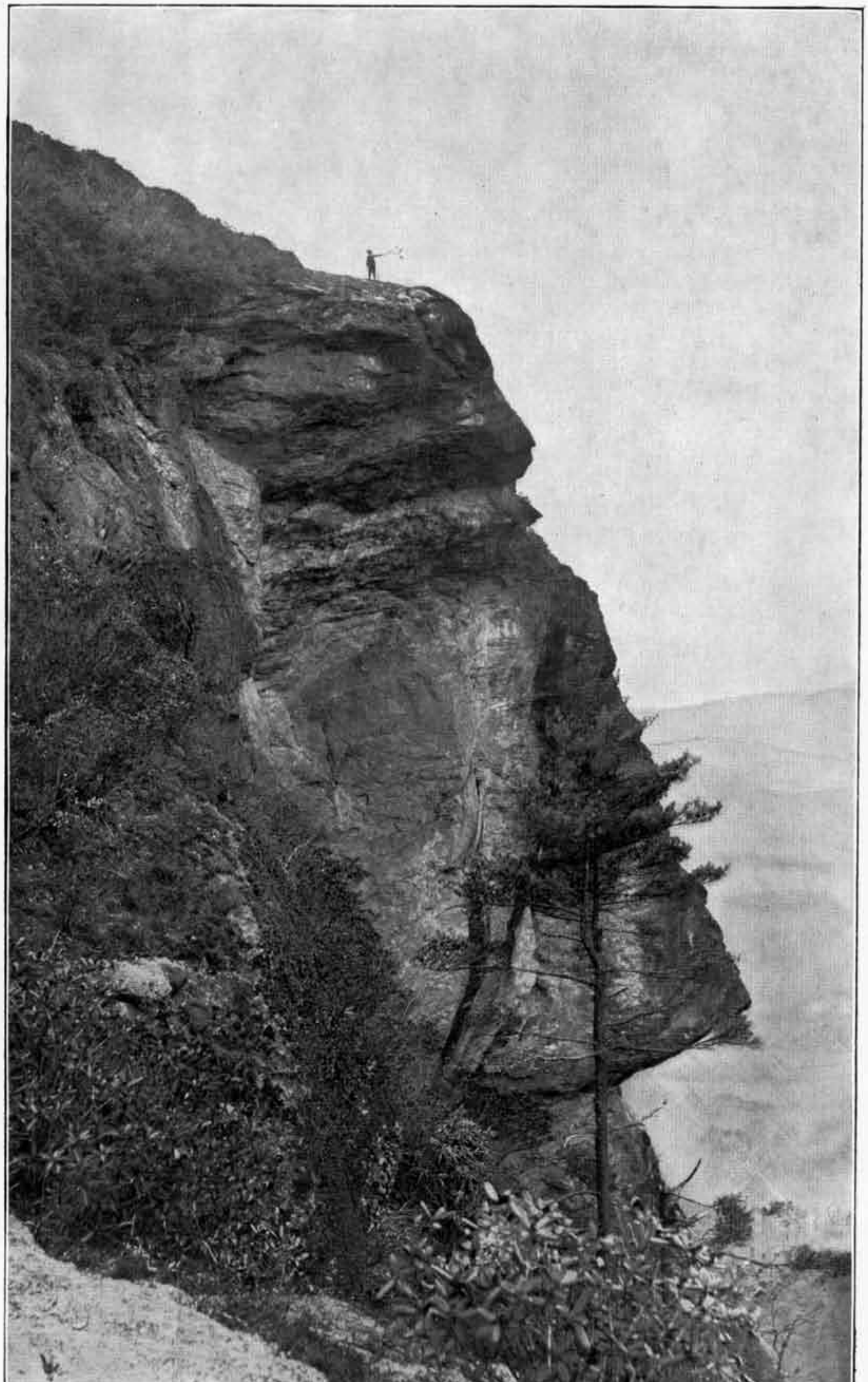
Institute for the Environment
Highlands Field Site
2009 Internship Research Reports



Highlands Biological Station
Highlands, North Carolina

Cover Images

Front cover—"Beautiful View Along Little Tennessee River" from *Hardwood Record*, October 10, 1906, p. 39, from Horace Kephart album, p. 18 (MSS 80-24); *back cover*—Plate XI ("Whiteside Mountain, Southeast Profile, North Carolina") from *Message from the President of the United States transmitting a Report of the Secretary of Agriculture in Relation to the Forests, Rivers and Mountains of the Southern Appalachian Region* (Washington: Government Printing Office, 1902). Used with permission from Hunter Library, Western Carolina University.



(Photographed by Scadin.)

WHITESIDE MOUNTAIN, SOUTHEAST PROFILE, NORTH CAROLINA. (See p. 21.)

Introduction

2009 marks a number of significant anniversaries — among them the bicentennial of the births of Charles Darwin, Abraham Lincoln, and Edgar Allen Poe, the 20th anniversary of the fall of the Berlin Wall, and, closer to home, the 75th anniversary of the founding of Great Smoky Mountains National Park. The Smokies have served as a sort of touchstone for us in the IE program this year, as they did long ago for Horace Kephart, woodsman, author, and tireless advocate for the establishment of the Park.

Kephart came to the Smokies 105 years ago, in 1904, seeking, in his words, a "back of beyond." It was the balm of wildland, rugged terrain, and people with a sense of place that Kephart sought, and his passion and labors, together with the labors of many others, came to fruition 75 years ago this year with the Park's establishment. Local naturalist and Kephart scholar George Ellison calls the Smokies a "place of refuge," and it has indeed been such a place for many others besides Kephart — in a very literal sense for the Cherokee historically, and in a figurative, emotional sense for many people today.

The Smokies changed radically in the period between the first publication of Kephart's book *Our Southern Highlanders* in 1913 and the revised edition in 1922. "*Nine years have passed since this book first came from the press*," Kephart wrote, continuing:

> *My log cabin on the Little Fork of Sugar Fork has fallen in ruin. The great forest wherein it nestled is falling too, before the loggers' steel. A railroad has pierced the wilderness. A graded highway crosses the country. There are mill towns where newcomers dwell. An aeroplane has passed over the county seat. Mountain boys are listening, through instruments of their own construction, to concerts played a thousand miles away..."*

Those changes have continued at an ever-accelerating pace since then, and the greater southern Appalachian landscape today is a mosaic of public and private land; wild, farmed, and built land; land supporting astounding biodiversity and land that has been compromised. It is a land with a unique history that reflects the interplay of geology, biology, and human culture. It is no longer "back of beyond," but it is still alluring, and as instructive as it is beautiful. It is our hope that our students will take what they have learned this fall about how a rich confluence of circumstances creates "place," and apply this knowledge to achieve a deeper appreciation of the "places" they will call home in the future.

The work presented in this book represents the culmination of each student's semester-long effort at tackling a particular problem pertaining to *this* place, situated in western North Carolina, near the southern terminus of the Blue Ridge Physiographic Province.

ACKNOWLEDGEMENTS

On behalf of the IE-HFS class of 2009, we would like to thank the many individuals who took the time out of their already busy professional lives to help develop and guide the students' courses and projects this year. Thanks to internship mentors Jenny Sanders (Little Tennessee Watershed Association), Brent Martin (The Wilderness Society), Curtis Smalling (North Carolina Audubon Society), Hillrie Quin (The Highlands Plateau Greenway), and Jason and Jennifer Love (Coweeta Hydrologic Laboratory). Other individuals that assisted with the internships included Ed Schwartzman (NC Department of Environment and Natural Resources), Patrick Brannon (Highlands Biological Station), Doug Landwehr (Highlands Plateau Audubon Society), Bill Alexander (Biltmore), Robert Tucker (Inside-Outside), and Jeff Zahner (Chattooga Gardens). We also thank Brennan Bouma and Lindsay Leonard of the IE for their assistance organizing and overseeing the internships, and Larry Band for facilitating this year's capstone project.

We thank Gary Wein for generously assisting with the GIS component of several projects in addition to teaching Landscape Analysis. We also thank John Chamblee of the University of Georgia and Coweeta Hydrologic Lab for working with students to complete this year's capstone project using data collected by Bill McLarney of the Little Tennessee Watershed Association. We appreciate Dr. McLarney's willingness to take the students in the field for a day of data collection as well. Thanks to the many guest instructors and speakers that contributed to this year's program and to the staff at the Highlands Biological Station for facilitating the students' work and living experience in Highlands. The program has also benefitted from private donations from numerous individuals through scholarships and contributions, enhancing the experience for our students each year. Brian O'Shea of *The Highlander* newspaper and Katie Brugger, producer of *Heart of the High Country* cable program, have been wonderful supporters, sharing with the Highlands community our many activities and excursions from classroom and lab to river and trail. We are grateful, finally, for the hospitality shown by residents of the Town who continue to welcome our students into the community each semester.

Jim Costa and Anya Hinkle
IE-Highlands Field Site Directors
December 2009

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INFORMING THE PUBLIC ON THE WATER QUALITY WITHIN THE LITTLE TENNESSEE RIVER WATERSHED

MARIANE F. BLALOCK

Abstract. The Little Tennessee Watershed Association published a State of the Streams report in 2002 in order to inform the public about the quality of the Upper Little Tennessee River watershed. The goal of the present project is to create a new report that updates the water quality information and provides the public with resources to understand and protect their local streams. Experts in a variety of fields were contacted to write short segments on different topics relating to water quality issues and maps were constructed to illustrate main points. In January of 2010, a revised State of the Streams Report that includes all of the compiled text and maps will be available in the Macon County Public Library and online at the Little Tennessee Watershed Association's website. The new report will be used as an informational and motivational resource on watershed issues that will hopefully encourage more citizen involvement, whether financially or through volunteer hours with local projects.

Key words: biomonitoring; Little Tennessee River; Little Tennessee Watershed Association (LTWA); water quality; watershed.

INTRODUCTION

The U.S. Environmental Protection Agency defines a watershed as "the area of land where all of the water that is under it or drains off of it goes into the same place." There are over 2,000 watersheds in the United States (US EPA). Divided by geographic barriers such as mountain ridgelines, watersheds include water that is underground, on the surface of the land and in the atmosphere above the land that will contribute to the water cycle within that watershed's boundaries. Aquatic systems of these watersheds support a variety of fish, amphibian, insect and plant species and are often impacted by the many human-caused changes to the environment. Humans have long settled beside rivers and lakes for agricultural, aesthetic, recreational and other reasons. Naturally, this raises water quality issues.

Watershed systems can be divided into zones, from headwaters to low-gradient rivers. Smaller headwater streams are usually narrow, steep and shaded by a dense canopy, keeping the water cool and generally low in sediment. Headwater streams provide feeding habitat for many aquatic species, including insects, fish and salamanders. They also serve as safe spawning habitat for many downstream fish species due to cooler temperatures, lower sediment, fewer predatory fish and generally lower pollution levels. The trophic structure in smaller streams is dominated by decomposers that break down dead organic matter to be used by organisms downstream. As the water progresses downstream, the smaller streams merge until eventually the river flows in a wider, flatter and more open channel with much more sediment and sunlight. This environment supports plants and different species of fish and aquatic insects that include more herbivores and predators.

Reducing or eliminating vegetation on the banks of headwater streams increases the amount of sunlight and sediment that can cause upstream portions to function like downstream rivers, affecting the entire river ecosystem. When upstream habitats lose their canopy, decomposers suffer from loss of a food source, therefore decreasing the available food resources for downstream communities. Also, the increased sunlight encourages plant growth and becomes more comparable to a downstream community structure. Lastly, increased sediment and numbers of predators makes the environment less hospitable for insect larvae and fish eggs.

Vegetative buffer zones along streams are essential for several reasons in addition to changing the aquatic community structures. In large rainstorm events, the vegetation absorbs some of the runoff and slows down water that actually reaches the stream itself, recharging the groundwater and preventing a large volume of fast-moving water to enter the stream all at once. Stormwater runoff erodes banks and brings sediment into the stream, increasing the turbidity of water; turbidity can decrease the oxygen content in the stream, decrease stream velocity or clog microhabitats in the channel that many species use to feed or breed (Jackson et al. 2005). This effect is magnified with development because impervious surfaces, such as buildings and roads, decrease the amount of available soil and vegetation to absorb the runoff. In the case of agriculture close to the stream, riparian vegetation filters out excess nutrients which will negatively impact some fish populations (Fenn et al. 1998, Peterjohn and Correll 1984) or harmful pollutants that can directly kill some fish species (Anderson et al. 2002). Riparian vegetation also discourages livestock from directly accessing streams. Livestock are known to erode banks by consuming riparian vegetation, increase turbidity by trampling banks and streambeds and to increase nutrient concentrations by defecating directly into the stream (Lowrance et al. 1984, Peterjohn and Correll 1984).

Another major threat to watershed systems is the introduction of exotic species into a stream. These may be fish species stocked for recreational purposes, or they may accidentally arrive and escape into the waters. Introduced species often disrupt the natural structure of aquatic communities. In some cases, exotics out-compete native species because they do not have any natural predators or diseases to control their populations. Their impacts are even more drastic when the ecosystem is already compromised or unstable (Mills et al. 1993). Natural communities have niches for a diversity of organisms to occupy, and healthy ecosystems have some overlap in which one species can take over the role of a niche if another species were to disappear. This allows the environment to quickly bounce back to an equilibrium state after disturbance. In a highly disturbed habitat, however, a niche may be left open for an exotic species to occupy, because all other species that are capable of filling that niche are gone and no natural competition remains.

Municipalities seek to develop management plans that allow for human activities to continue while improving water quality. Effective management plans will encourage streambank stabilization and stream restoration to rebuild a natural riparian buffer (Schultz et al. 1995). Farmers can improve water quality by reducing the amount of pesticides and fertilizers used and by fencing out their livestock from streambanks. Local county Soil and Water Conservation District offices offer programs to share the costs or give tax incentives for developing alternative water sources for livestock. Floodplain ordinances provide guidelines that mandate minimum distances from the stream for development to occur, which also protects homes by avoiding damage to property in the case of flooding. Repairing septic leaks prevents excess nutrients from flowing into streams, and keeping bare ground covered with vegetation or gravel will prevent erosion and reduce the amount of sediment entering streams. Planting rain gardens with hydro- to mesophytic plants between houses will absorb the extra runoff from impervious surfaces and recharge the groundwater. Finally, conservation-focused groups can serve as resources for information about financial assistance in fixing problems, and learning about or getting involved with a particular issue. These groups include governmental agencies, non-profits or community organizations.

The upper portion of the Little Tennessee River watershed covers 450 square miles, from the headwaters to Fontana Lake. The Little Tennessee River begins in Rabun County, Georgia and flows north through Macon and Swain counties in North Carolina before eventually entering Tennessee. The area has a long history of human settlement, yet has escaped much of the industrial pollution that has devastated many other Southern Appalachian rivers. The Little Tennessee River is "one of few rivers in the southeast to retain its full complement of native fish species" (LTWA 2002: 10). Despite comprising only two percent of the entire drainage area in the Tennessee River Valley system, the Upper Little Tennessee River watershed contains 60 species of freshwater fish, or one quarter of the total freshwater fish species found in the valley. Because the main problem faced by this particular watershed is sediment from many non-point sources on both public and private land, educating the public is key if water quality is to improve. Large scale control of riparian zone development and widespread establishment of riparian buffers are the best ways to prevent erosion problems, but the many individuals responsible for the discharge of excess sediment must be educated as well as restricted in their treatment of the streambanks (LTWA 2002).

The Little Tennessee Watershed Association (LTWA) is a non-profit organization that has been active since 1993 to "protect and restore water quality and habitat in the upper Little Tennessee River and its tributaries upstream of the Fontana Lake" (LTWA 2002: 47). The organization relies on members and grants for funding, which they use to sponsor volunteers, educational outreach and cost-sharing of restoration projects in riparian areas. LTWA works with a variety of groups including landowners, concerned citizens, partner organizations and policymakers to promote watershed health in the Little Tennessee River Valley.

The LTWA Biomonitoring Program, the scientific portion of the organization, is an ongoing effort to monitor water quality using fish as indicators of stream health. Stream health is assessed using an Index of Biotic Integrity (IBI), based on twelve criteria that encompass diversity, age class, trophic structure, percentage of tolerant and intolerant fish and the presence of fish diseases or parasites. This score range is then divided into five ratings, from excellent to very poor. Dr. Bill McLarney is the scientist leading the Biomonitoring Program, sampling in the Little Tennessee River watershed. For over 20 years, Dr. McLarney has evaluated over 200 sites, 15 of which are fixed and monitored every year, using community volunteers to help catch fish at each site. Sites are chosen to represent a diversity of stream sizes, natural and impacted communities, and cases of specific interest (such as recovery after a development). Each year, Dr.

McLarney produces reports on individual streams or sites, and in 2002 the LTWA printed a State of the Streams Report which incorporated 13 years of data collection. In these reports, the watershed was divided into five main subwatersheds, with an accompanying description of local conditions, the IBI ratings, and maps to show broader trends (LTWA 2002).

The purpose of my project was to update the 2002 State of the Streams report to include Dr. McLarney's most recent findings, as well as revise text and update the maps. The updated report will help inform the public on the current condition of their local streams, and give them the background and resources necessary to better manage their watershed. The new report will also feature a condensed version of the educational and history sections from the previous report, a more comprehensive biomonitoring section and updated maps. Broadening the scope of information, the new report will highlight local conservation efforts with descriptions of their projects, a map of conservation lands and projects, and contact information for all partner organizations. The new report will also explain alternative water quality monitoring methods, species of interest and a more coherent index of watershed problems and resources for the public.

MATERIALS AND METHODS

Once the focus of the new report was determined, new sections were organized and contributors were recruited. The first two sections found at the beginning of the 2002 report, "An Introduction to Watersheds" and "The Upper Little Tennessee Watershed," were reviewed and condensed by LTWA staff to be reprinted in the new report. A copy of the new outline detailing sections and authors is summarized in Table 1. Not all of the titles are final, but they will be very similar to the descriptions provided in the table.

Using ArcGIS® (ESRI 2008), maps were constructed to integrate spatial information about the study watershed. ArcGIS shapefiles, with information about land use, topography, and the location of Dr. McLarney's sites were compiled to produce the maps for the new report. The LTWA had archived layers that included stream coverage and the Little Tennessee River watershed and subwatershed boundaries. Josh Pope from the Macon County Mapping Department provided Macon County layers, such as city limits, roads, and floodplains. Andrea Leslie from the Department of Environment and Natural Resources provided the locations of Dr. McLarney's fish sites in GIS layer format and a Microsoft Office Excel spreadsheet of the ratings, which were later joined in ArcMap® (ESRI 2008). Dr. Ted Gragson from the University of Georgia and Dr. Ryan Kirk from Elon University supplied the most recent landuse layers from 2006. Foundation layers such as North Carolina county lines, US state lines, and North Carolina river basins were downloaded from the University of North Carolina at Chapel Hill's library website (http://www.lib.unc.edu/reference/gis/datafinder). Conservation properties were sent as shapefiles or downloaded from the website of the organizations that own or manage each property. Figs. 1 and 2 are examples of the sampling sites and landcover maps used in the report.

After receiving all of the text from project contributors, the text, pictures and maps were laid out in print format using Adobe InDesign® CS4 (Adobe 2008). In January 2010, the new report will be available to the public as a hardcopy in the Macon

County Public Library, located in Franklin, NC, and electronically through the LTWA website (www.ltwa.org).

RESULTS

For the text portion of the report, main contributors numbered nearly 25. Table 1 outlines the writing segments and their authors for the new report.

TABLE 1. 2010 State of the Streams Report Topics and Authors

Section Title	Topic	Author	Affiliation
Section 1: Introduction to the Little Tennessee (LT)	• What is a Watershed? • The Upper LT Watershed	Mariane Blalock Mariane Blalock Jenny Sanders	UNC Inst. for the Environment (IE) UNC-IE LTWA Exec Dir
Section 2: Unique features of the LT Watershed	• Aquatic Biodiversity • Recreation in the LT • The Economic Value of Maintaining a Healthy Watershed	Dr. Bill McLarney Jenny Sanders Stacie Guffie	LTWA Biomonitoring Prog. Dir (BP) LTWA Exec Dir LTWA Chair
Section 3: Cultural History	• Pre-Contact Cherokee History in the LT	Tyler Howe	Eastern Band of Cherokee Indians Tribal Historic Preservation Office
	• Sidebar: Weirs	Lamar Marshall	Wildsouth
	• Sidebar: River Cane	David Cozzo	Revitalization of Traditional Cherokee Artisan Resources
	• The Little Tennessee Through Two Centuries of Use, Abuse and Restoration	Barbara McRae	Franklin Press
Section 4: Threats to Stream Health	• Common Problems Faced by Watersheds- Sediment, Agriculture, Development, Urban/Impervious Surfaces, Point Source Pollution	Jenny Sanders Dr. Bill McLarney Angie Rogers	LTWA Exec Dir LTWA BP Dir NC Natural Heritage Program
	• Sidebar: Endangered Mussels in Trouble in the LT	Steve Fraley	NC Wildlife Resources Commission
Section 5: Biomonitoring	• Biomonitoring Data • Sidebar: Macroinvertebrates as Indicators of Stream Health	Dr. Bill McLarney Dave Penrose	LTWA BP Dir Watershed Science Incorporated
Section 6: Progress and Current Conservation Efforts	• The Needmore Tract • A Summary of Ordinance Changes in Macon County • LTWA	Paul Carlson Jenny Sanders Stacie Guffie Jenny Sanders	Little Tennessee Land Trust LTWA Exec Dir LTWA Chair LTWA Exec Dir
	• Little Tennessee Land Trust	Sharon Taylor Kate Patterson	Little Tennessee Land Trust
	• Macon County Soil and Water Conservation District	Doug Johnson	Macon County Soil and Water Conservation District
	• Natural Heritage Program	Angie Rogers	NC Natural Heritage Program
	• US Fish and Wildlife Service	Anita Goetz	US Fish and Wildlife Service
	• Wildlife Resources Commission	Steve Fraley	NC Wildlife Resources Commission
	• Ecosystem Enhancement Program	Andrea Leslie	Ecosystem Enhancement Program
	• World Wildlife Fund	Andrea Leslie	Ecosystem Enhancement Program
	• Division of Water Quality	Kathy Tyndall	NC Division of Water Quality
Section 7: Resources and Actions	• Lessons and Resources for Landowners	Jill Wiggins	LTWA
	• Establishing buffers- how, why and who can help	Jason Love	Coweeta Hydrologic Lab

The new report contains 15 maps across all sections, including a map of the North Carolina river basins, showing the Little Tennessee River valley with respect to all of the other watersheds in the region and a topographic map indicating the elevation of the area. A map of all of the conservation efforts relevant to the study area displays public lands and smaller restoration projects that are very narrowly focused. The biomonitoring maps make up the rest of the map collection. These include a general map of the entire watershed with all of Dr. McLarney's sites, which are then are subdivided according to the five main watersheds with an accompanying landcover map for each. Fig. 1 gives an example of one of the sub-watershed biomonitoring sampling site maps and Fig. 2 gives an example of a landcover map.

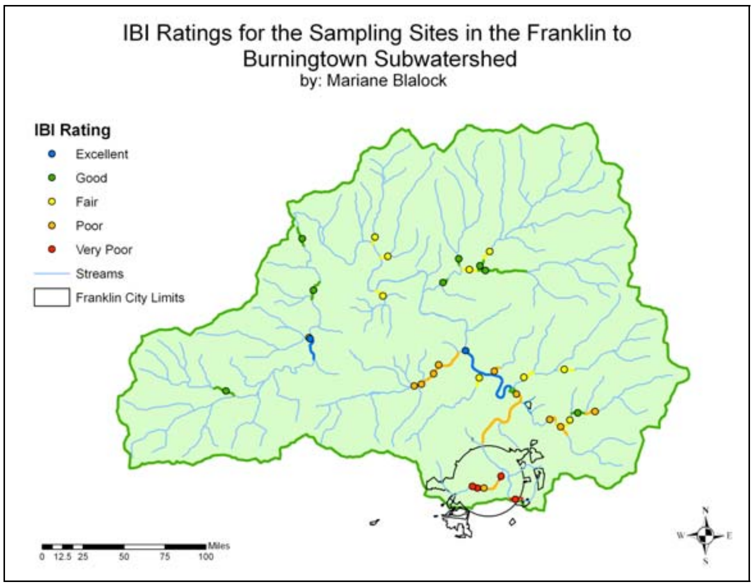

FIG. 1. Sample watershed map: IBI sites in the Franklin to Burningtown sub-watershed with corresponding color-coded IBI ratings.

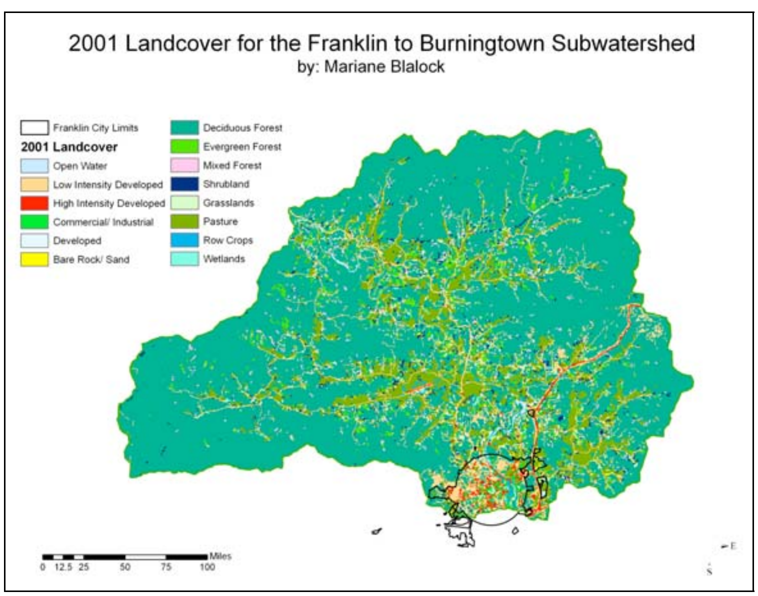

FIG. 2. Sample landcover map for the Franklin to Burningtown sub-watershed, using 2001 landcover data.

DISCUSSION

The new report achieves the goals that the LTWA set out for it to accomplish, including updating the biomonitoring results section and giving the public resources that relate to local watershed issues. The current conditions of individual sub-watersheds and streams are conveyed clearly to the public, both visually and textually. A more comprehensive list of resources has been subdivided by common problems faced by watersheds and proposes solutions with a directory for further personal research or resources to repair problems and get involved. The 2002 report was unorganized in this area, but the new report makes it easier for the public to look up their specific issue and find resources related to that problem together in one list. Another improvement upon the 2002 report is the new section dedicated to conservation efforts that were realized since the 2002 report was published, as well as projects that are currently still in progress. Learning about locally successful conservation projects of various sorts may inspire citizens to get involved in a variety of ways, including signing conservation easements for their lands, volunteering for restoration projects or urging the county legislature to pass certain conservation measures.

Within the last decade, attention given to water quality issues has been expanding across the board. Policymakers have been more willing to pass water quality legislation and the public has been more concerned about the conditions of their local streams. Although the 2002 report may not specifically be credited for this change in attitude, it provided a bridge for the public to better understand water quality issues, including the science behind water quality and what decisions policymakers are facing. Since 2002, floodplain ordinances have been passed (Krutulis 2008) and sediment and erosion control ordinances are slowly strengthening, which will positively impact the water quality in coming decades. The public may also be interested in seeing the effects of the recent boom in development in Macon County, which peaked just after the first report was published. Unlike a policy change for ordinances, effects of development near streams are more immediate and will be evident in the data presented in the report. These development projects are localized to certain streams, but their effect can be drastic because of such rapid clear-cutting of riparian buffers, erosion during construction and the increased number of impervious surfaces.

A significant point source polluter of concern is the former Fruit of the Loom plant in Rabun County, Georgia. In the past when the plant changed owners and was shut down for two years, downstream IBI scores improved considerably, but stream health decreased again as soon as the plant returned to operation. This biological proof of the plant's harmful effects helped the county to pass stricter permit requirements as well as change the wastewater treatment to an alternative and safer chemical. The plant has been out of operation since 2006, so many people will be interested in seeing the difference in water quality since then. The plant is in the process of changing owners again, and will soon be converted to a municipal sewage treatment plant. The biomonitoring results presented in the new report may help the county to define wastewater treatment policies that will be more environmentally friendly.

Overall the project was an improvement and a success. The 2002 report was so well received that all copies have been distributed, and the copy in the library is checked out frequently. The new report will be an even better resource for the public, in terms of educating them more thoroughly on a wider spectrum of watershed issues and giving them resources for action. In the future, updated editions with more current information would benefit the public even more.

ACKNOWLEDGMENTS

First of all I would like to thank my mentor, Jenny Sanders, the Executive Director of the LTWA, for being such a great resource and teaching me about non-profits. I would also like to thank Josh Pope from the Macon Co. Mapping Department, who so patiently helped me with ArcMap's quirks. I thank Dr. Bill McLarney for being a pleasure to work with and a knowledgeable aquatic conservationist. Lastly, I'd like to thank Drs. Jim Costa and Anya Hinkle with the Highlands Biological Station for reviewing this paper and encouraging my scientific writing techniques.

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CHANGES IN BIRD SPECIES IN HIGHLANDS, NORTH CAROLINA, 1884-2009

ANDREW T. CHIN

Abstract. The Highlands Plateau, located in southwestern Northern Carolina, provides important habitat for many birds including several subspecies endemic to the Southern Appalachians. Historically the area has been subjected to many changes in land use that have altered available habitat for avifauna. Birding records have been collected in this region since the 1800s by Charles L. Boynton, Eugene Odum, Jane Holt, Thelma Howell, and many others. I have compiled records from 1884 to 2009 in a Microsoft Access database. After breaking the data down by decade, I found 15 species that were not seen on the Plateau until the 1910s or later. Analysis also showed 12 species that historically used the Plateau but have not been recorded in the past three or more decades. The results are likely due to changes in available niches based on the land use and stand age of forests at any given time. Further research should look at the relationship of bird populations to land use changes and forest age.

Key words: avifauna; birds; forest age; Highlands Plateau; Highlands, NC; land use change; Southern Appalachians.

INTRODUCTION

The Highlands Plateau has undergone many land use changes since the 1880s. A combination of logging, agriculture and commercial and residential development has led to continual changes in forest age and plant assemblages. Commercial logging occurred in Macon County, which includes the town of Highlands, starting in the late 1800s and peaking in the 1910s (Kirk 2009). The effects of clear cutting hardwood forests have been shown to increase bird diversity in the short-term (Horn 1984). Horn's data, collected on the Highlands Plateau, showed that despite an increase in the number of species in clear-cut land, the composition and structure of bird communities were altered. For example, virgin forests are suitable habitat for bird species that nest in forest interiors, but not species that need edge or open space. Logging forces birds that were nesting in the forest interior to leave and find alternate nesting sites; disturbed habitat created by logging is ideal for species that breed in open areas. Since the mid-1900s commercial logging has decreased on the Plateau and many cut over plots have been allowed to regenerate. Over time as shrubs and small trees begin to grow, intermediate habitat is created for bird species that nest in shrub thickets. The process of logging and post-logging recovery creates a diverse patchwork of habitats from open fields to shrublands and finally, woodlands; as a result avian diversity changes with the changing availability of niches during forest succession.

Many studies have been conducted to determine how avifauna respond to disturbance and utilize different successional stages of forest habitat. One of the first such studies, conducted by C. C. Adams (1908), found that diversity of bird species was not highest in mature habitats but in habitats in the middle stages of succession. A corollary study done in Highlands, NC looked at the relationship between successional stages and bird density instead of bird diversity (Odum 1950). Odum (1950) censused bird populations in three different successional stages (early, middle, mature) of two plant communities, an oak-chestnut community and a hemlock community. The results of the study showed that while density does appear to vary with successional stage, the pattern differs depending upon the forest community studied. In oak-chestnut stands mid-successional shrublands had higher bird densities than mature plots, while in hemlock stands bird density increased with successional stage. Odum (1950) concluded that bird densities were highest in the middle stages of succession in oak-chestnut stands, but in hemlock stands, bird densities were highest in mature stands.

In the 1970s and 1990s Holt (2000) repeated bird surveys of the oak-chestnut and hemlock stands originally conducted by Odum (1950) in the 1940s (as described above). The comparison of the two studies showed that neotropical migrants declined as forests (both deciduous and hemlock) matured between 1945 and 1995, while short-distance migrants and permanent residents increased during the same time period (Holt 2000). Holt hypothesized that permanent residents and short-distant migrants are more tolerant of changing habitat conditions than neotropical migrants. Therefore, Holt (2000) believed that recent changes in bird populations are a result of increasing habitat fragmentation, while Odum (1950) believed his conclusions were based on birds' preferences for different successional stages. Although the Highlands Plateau has been studied for relationships between forest dynamics and bird populations, scientists do not completely understand how changes in stand age and degree of fragmentation of forests affect bird diversity and abundance.

Currently, the Highlands Plateau is designated as an Important Bird Area (IBA) by Audubon North Carolina (Lee 2004). Highlands, due to its relatively high elevation of approximately 3800 feet, is often at the southern limit of the ranges of species more commonly found in northern areas, such as the Canada Warbler, Veery, and Chestnut-sided Warbler. The Plateau is also home to many Southern Appalachian endemic subspecies such as the Black-throated Blue Warbler, Dark-eyed Junco, and Blue-headed Vireo (Lee 2004). The habitat of all birds that use the Highlands Plateau is being threatened by residential and golf course development, which can degrade and fragment forests. Therefore, the Audubon Society and other organizations are working to conserve critical birding habitat. Further research on the effects of land use change on bird populations could prove a useful resource for conservation groups.

Although birding records in Highlands continued after Holt's censuses in the 1990s, the studies that Odum and Holt conducted have not been duplicated. As a result, the patterns that Holt (2000) found have not been updated. In order to analyze the trends initially discovered by Odum and Holt, I have compiled birding records dating back to the 1880s and continuing through 2009. With over a century of observations, I looked for indications of species change on the Highlands Plateau, as changes in bird species present on the Plateau may indicate changes in habitat types and quality.

METHODS

Study Area

The Highlands Plateau is located near the southern terminus of the Blue Ridge Province. The Plateau is characterized by high elevation with altitudes ranging from about 3000-5000+ feet with the average being approximately 4000 feet. The region receives high amounts of rainfall, usually averaging over 80 inches of precipitation a year. Odum (1950) describes the Highlands Plateau as having two main plant communities. The first is the deciduous sere usually found at higher elevations and dominated by oaks and formerly chestnuts. The second is the hemlock sere found in moist, low elevation conditions and characterized by hemlocks and birches.

A majority of observations analyzed were collected within a radius of 4 miles centered at Sunset Rock in the Town of Highlands (Fig. 1). The focal study area includes many developed areas, such as the municipality of Highlands and sections of highway US 64. However, the area consists primarily of deciduous and evergreen forests. Some notable geographic features of the study area are: Whiteside Mountain, Satulah Mountain, Horse Cove, Sequoyah Lake, and Mirror Lake.

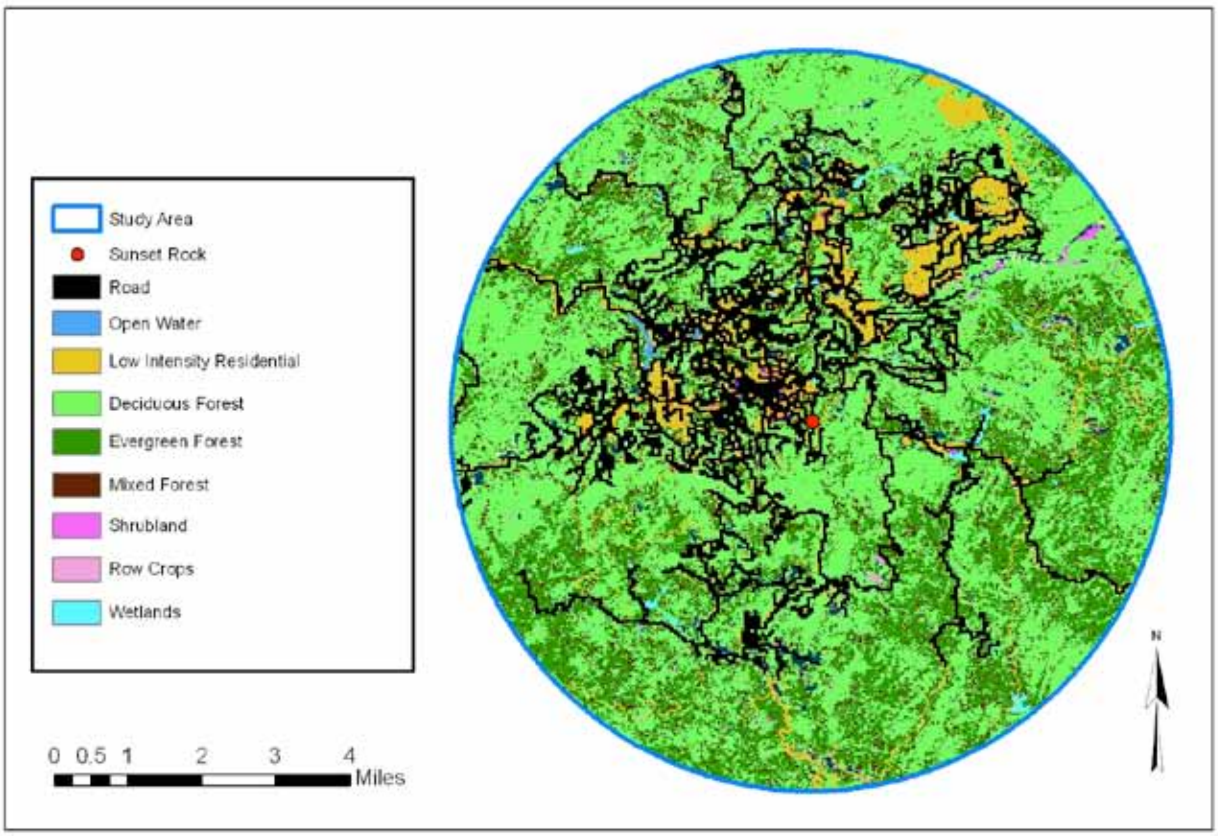

FIG. 1. The study area within a 4 mile radius centered at Sunset Rock, Highlands, NC. Map is based on 1996 land use data and road center lines for the Town of Highlands.

Database

The original database of birding records of Highlands, North Carolina was created by Dr. Doug Landwehr, a member of the Highlands Plateau Audubon Society, using Microsoft Access. The database includes fields for bird species, observer, location, and date. Additional fields include habitat, climate conditions, distance between observer and bird, and numbers of individuals or pairs. Ideally, each record would contain all of the above information, but a record was considered valid if at least the first four fields mentioned above were complete.

A second table in the database was created to detail information on the bird species themselves. Initially this table contained fields for the bird's common name, scientific name, alpha code, group (e.g. diurnal raptors), abundance, and seasonal status. The abundance and seasonal status data were acquired from the Birds of the Highlands Plateau checklist published by the Highlands Plateau Audubon Society. To this table I added fields for nesting site, feeding status, foraging method, migratory status, and breeding status. The information required to fill these latter fields was taken from *The Land Manager's Guide to the Birds of the South* (Hamel 1992) and *The Birder's Handbook* (Ehrlich et al. 1988). Quality assurance for the information I added on bird species was done by Curtis Smalling, Important Bird Areas Coordinator and Mountain Program Manager for Audubon North Carolina.

The records found in the database come from numerous sources ranging from research data to recent Audubon point counts. Much of the earliest recorded data (1884-1886) came from the personal birding journal of C. L. Boynton. The Boynton journal was acquired from the Biltmore archives and had not been seen or analyzed by anyone outside of family and employees of the Biltmore Estate. I transcribed the records from this journal into the database. Due to the detailed nature of the journal, some entries were excluded: for common birds, such as the Dark-eyed Junco, only one record was entered per season per year. Other important data were taken from birding censuses conducted by Eugene Odum (1950) and Jane Holt (2000). Checklists of bird species created by Thelma Howell (1945) and David Johnston (1964) provided comprehensive lists of expected species. Recent data were obtained from the local chapter of Audubon Society, members of which conduct point counts and Christmas counts annually. Finally, a number of other observers are credited with records in the database as well (see Appendix A).

Assumptions and Analysis of Trends

In order to more easily identify changes in species occurrences since 1884, data were grouped by decade based on the year each record was made. This provided a simple way to view distinct increments of time. Although separating records by decade was an arbitrary choice that created unequal numbers of records in each group, it did enable trend analysis and creation of a species accumulation curve.

All bird species recorded over the study period were included in a species accumulation curve, a graphical representation of the total number of birds recorded from the beginning of the database up through any given decade. I manually created the curve using Microsoft Excel. The first data point represents how many bird species were seen in the 1880s and the second point represents the first data point plus any new species recorded during the 1890s. Once the last decade (2000s) is plotted, the number of species should give a prediction of how many different bird species have used the Highlands Plateau over the study period.

The focus of trend analysis was on bird species that are known to historically breed on the Plateau. Breeding birds were more of a concern because they are the most likely to indicate changes in habitat and landscape availability. Birds that migrate through the region are less likely to indicate such changes. Therefore, before analysis was done on individual species I discarded birds that only use the Plateau during migration. To be able to easily visualize trends I created a spreadsheet that contained breeding bird species as rows and decades as columns. The number in each cell represented how many records of that bird were found in that particular decade. Because there were limited records for many decades, I used a set of assumptions to fill in gaps in data: (1) for decades that had no records in them, I looked to see if the decade before and after had any records of the bird. If both the decades preceding and succeeding contained records, I assumed that the bird was present during the decade in question even if no official records were made of the bird. I marked the cell with an “x” which represents an assumption that the bird was indeed present. (2) I used the same assumption for up to two blank decades in a row. (3) If there were three blank decades in a row I assumed this was an indication that the species was not present and therefore an “x” was not added to the cells in question.

Once the spreadsheet was updated with assumptions to represent missing data, I divided birds into six categories (Table 1):

TABLE 1. Categories of bird species based on presence and absence throughout study.

Category	Description
1	Species present through all decades or species likely present through the entire study (according to C. Smalling, pers. comm.)
2	Species not seen in the first 3 decades (1880s-1910s)
3	Species not seen in last 3 decades (1980s-2000s)
4	Species not seen in the first 3 decades or last 3 decades, but present in middle decades (1920s-1970s)
5	Any remaining species that were missing in 3 or more decades
6	Species that do not have enough data to generate analysis

From this spreadsheet I could visually identify species that were not initially present on the Plateau but over time have started using the Plateau as habitat. The trend of species historically using the Plateau but that no longer do so could also be identified from the spreadsheet.

RESULTS

Database

The Microsoft Access database contains 3515 birding records from the Highlands Plateau and surrounding areas. The dates range from 5/25/1884 to 6/15/2009, with records made by 106 observers. There are 198 unique bird species represented; approximately 124 of them breed on the Plateau either presently or historically. The most commonly recorded birds were the Ovenbird, Red-eyed Vireo, Eastern Towhee, American Crow, and Wood Thrush. Decades that had the most records (over 350) were the 1940s, 1950s, 1960s, 1990s, and the 2000s. Decades that had the fewest records (under 40) were the 1890s, 1910s, 1920s, and the 1980s (Table 2). The database will be digitally archived at the Highlands Biological Station and with Audubon North Carolina’s Curtis Smalling.

Species Change

The species accumulation curve shows that throughout the time of the study, 1884-2009, 198 different species have been recorded on the Highlands Plateau (Fig. 2). However, by the 1950s 185 species had already been recorded, meaning only 13 new species were witnessed in the past five decades. As a point of clarification, the 2000s did not record all 198 species. In fact, in the 2000s, only 94 species were recorded (Table 2, Fig. 3), which indicates that 104 species seen in previous decades were not recorded in the past 10 years.

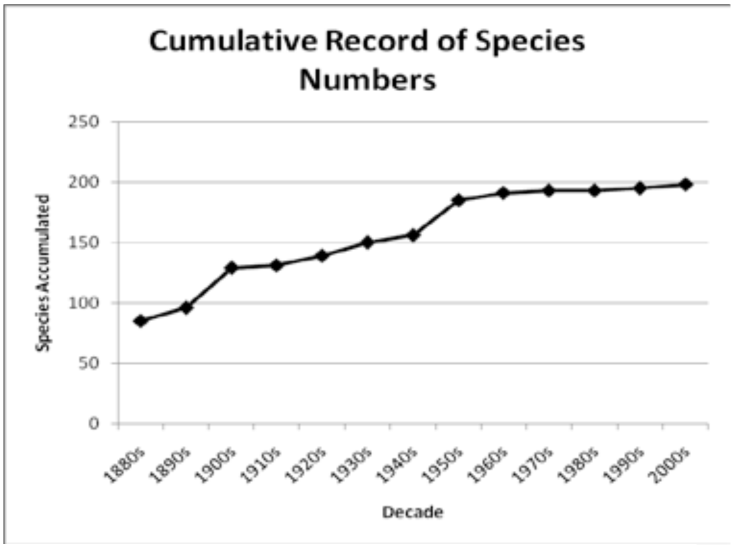

FIG. 2. Species accumulation curve showing total number of species accumulated by decade.

TABLE 2. Number of records and species recorded during each decade.

Decade	Species Recorded	Number of Records
1880s	85	176
1890s	22	23
1900s	72	191
1910s	15	21
1920s	30	39
1930s	102	178
1940s	107	423
1950s	156	468
1960s	108	416
1970s	99	263
1980s	12	12
1990s	94	363
2000s	94	2319

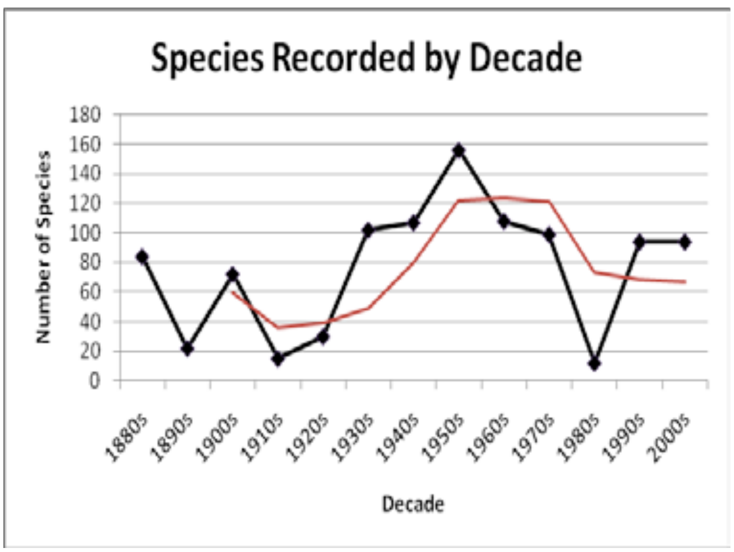

FIG. 3. Graph showing how many species were recorded in each decade in black and a three period moving average in red.

One trend identified was those species that were not present in the first few decades, but began using the Plateau as habitat during the 1910s or later (Table 3). These species are the Brown-headed Cowbird, Canada Goose, Cooper's Hawk, Eastern Screech Owl, European Starling, House Sparrow, Northern Bobwhite, Northern Mockingbird, Northern Parula, Pine Warbler, Ruffed Grouse, White-breasted Nuthatch, Wood Duck, Worm-eating Warbler, and Yellow Warbler.

Another trend reflected in the data is those species that used the Plateau early in the study but have not been recorded since the 1970s (Table 3). These species are the Eastern Kingbird, Bewick's Wren, Common Nighthawk, Common Yellowthroat, Kentucky Warbler, Olive-sided Flycatcher, Red-headed Woodpecker, Red-winged Blackbird, Sharp-shinned Hawk, Yellow-breasted Chat, Yellow-throated Vireo, and Whip-poor-will. There were also three species that were not recorded in the first 3 decades or last 3 decades (Table 3). These species are the American Kestrel, Green-backed Heron, and White-eyed Vireo.

TABLE 3. Breeding bird species broken into groups. List also contains migratory status, conservation status, and notes provided by C. Smalling. S = short distant migrants and permanent residents that generally winter in the US. L = long distant migrants that generally winter south of the US.

Common Name	Migratory Status	Conservation Status	Notes
GROUP 1: Species present in all decades (* indicates species that were not recorded in every decade but assumed to be present through the entire study)			
ACADIAN FLYCATCHER*	L		
AMERICAN CROW	S		
AMERICAN GOLDFINCH	S		
AMERICAN REDSTART*	L		
AMERICAN WOODCOCK*	S		
BELTED KINGFISHER	S		
BLACK-THROATED BLUE WARBLER	L	Endemic sub-species	
BLACK-THROATED GREEN WARBLER*	L	Endemic sub-species	
BLUE JAY	S		
BLUE-HEADED VIREO	L	Endemic sub-species	same as Solitary Vireo
CEDAR WAXWING	S		
CHIMNEY SWIFT	L		
CHIPPING SPARROW	L		
COMMON RAVEN*	S		
DARK-EYED JUNCO	S	Endemic sub-species	
DOWNY WOODPECKER	S		
EASTERN BLUEBIRD*	S		
EASTERN WOOD-PEWEE	L		
FIELD SPARROW	L		
GOLDEN-WINGED WARBLER*	L	Federal Species of Conservation Concern, Audubon Red List, NC Special Concern	
GREAT CRESTED FLYCATCHER*	L		
HAIRY WOODPECKER	S		
HOODED WARBLER*	L		
INDIGO BUNTING	L		
LEAST FLYCATCHER	L		
NORTHERN CARDINAL	S		
NORTHERN FLICKER	S		
NORTHERN ROUGH-WINGED SWALLOW*	L		
PILEATED WOODPECKER	S		
RED-BREASTED NUTHATCH	S		
RED-TAILED HAWK	S		
ROSE-BREASTED GROSBEAK	L		
RUBY-THROATED HUMMINGBIRD	L		
SCARLET TANAGER	L		
SONG SPARROW	S		
WINTER WREN	S	Endemic sub-species	
YELLOW-BELLIED SAPSUCKER	S	Endemic sub-species, NC Special Concern	

Common Name	Migratory Status	Conservation Status	Notes
BLUE-GRAY GNATCATCHER*	L		
LOUISIANA WATERTHRUSH*	L		
SWAINSON'S WARBLER*	L	Audubon Yellow List	
YELLOW-BILLED CUCKOO*	L		
GROUP 2: Species not seen in the first 3 decades (1880s-1910s)			
BROWN-HEADED COWBIRD	S		
CANADA GOOSE	S		non-migratory population increasing dramatically across the southeast
COOPER'S HAWK	S		
EASTERN SCREECH OWL	S		
EUROPEAN STARLING	S		exotic
HOUSE SPARROW	S		exotic
NORTHERN BOBWHITE	S		huge declines statewide in past forty years
NORTHERN MOCKINGBIRD	S		recently expanding in NC as a breeder
NORTHERN PARULA	L		
PINE WARBLER	L		lower elevation
RUFFED GROUSE	S	Endemic sub-species	
WHITE-BREASTED NUTHATCH	S		
WOOD DUCK	S		
WORM-EATING WARBLER	L		
YELLOW WARBLER	L		
GROUP 3: Species not seen in last 3 decades (1980s-2000s)			
BEWICK'S WREN	S	Endemic sub-species	probably extirpated in NC
COMMON NIGHTHAWK	L		
COMMON YELLOWTHROAT	L		probably here but not reported
EASTERN KINGBIRD	L		
KENTUCKY WARBLER	L	Audubon Yellow List	
OLIVE-SIDED FLYCATCHER	L	Audubon Yellow List, NC Special Concern	probably extirpated in NC
RED-HEADED WOODPECKER	S	Audubon Yellow list	
RED-WINGED BLACKBIRD	S		probably here but not reported
SHARP-SHINNED HAWK	S		
YELLOW-BREASTED CHAT	L		
YELLOW-THROATED VIREO	L		
WHIP-POOR-WILL	L		declining statewide
GROUP 4: Species not seen in the first 3 decades or last 3 decades, but present in middle decades (1920s-1970s)			
AMERICAN KESTREL	S		
GREEN-BACKED HERON	L		
WHITE-EYED VIREO	L		
GROUP 5: Any remaining species that were missing in 3 or more decades			
AMERICAN ROBIN	S		
BALTIMORE ORIOLE	L		
BARN SWALLOW	L		
BARRED OWL	S		

Common Name	Migratory Status	Conservation Status	Notes
BLACK AND WHITE WARBLER	L		
BLACKBURNIAN WARBLER	L		
BROAD-WINGED HAWK	L		
BROWN CREEPER	S	Endemic sub-species, NC Special Concern	
BROWN THRASHER	S		
CANADA WARBLER	L	Audubon Yellow list	
CAROLINA CHICKADEE	S		
CAROLINA WREN	S		
CHESTNUT-SIDED WARBLER	L		
COMMON GRACKLE	S		
EASTERN MEADOWLARK	S		
EASTERN TOWHEE	S		
GOLDEN-CROWNED KINGLET	S	Endemic sub-species	
GRAY CATBIRD	L		
HOUSE WREN	S-L		
MALLARD	S		
MOURNING DOVE	S		
OVENBIRD	L		
PEREGRINE FALCON	L		reintroduced in NC in the 1970s
PINE SISKIN	S		
PRAIRIE WARBLER	L	Audubon Yellow List	
RED CROSSBILL	S	Endemic sub-species, NC Special Concern	
RED-BELLIED WOODPECKER	S		
RED-EYED VIREO	L		
RED-SHOULDERED HAWK	S		lower elevations
TUFTED TITMOUSE	S		
TURKEY VULTURE	L		
VEERY	L		
WILD TURKEY	S		
WOOD THRUSH	L	Audubon Yellow lIst	
YELLOW-THROATED WARBLER	L		
GROUP 6: Species that do not have enough data to generate analysis			
BARN OWL	S		huge declines in NC in past forty years
BLACK VULTURE	L		
BLACK-BILLED CUCKOO	L		
BLUE GROSBEAK	L		lower elevations
BLUE-WINGED WARBLER	L		lower elevations
CERULEAN WARBLER	L	Federal Species of Conservation Concern, Audubon Yellow List, NC Special Concern	
GRASSHOPPER SPARROW	L		very little suitable habitat in Highlands
GREAT HORNED OWL	S		
HOUSE FINCH	S		western invasive
KILLDEER	L		
ORCHARD ORIOLE	L		

Common Name	Migratory Status	Conservation Status	Notes
PURPLE MARTIN	L		lower elevations
RING-NECKED PHEASANT	S		exotic
ROCK DOVE	S		exotic
SUMMER TANAGER	L		lower elevations
VESPER SPARROW	S	NC Special Concern	very little habitat for this species on the Plateau
WARBLING VIREO	L		

DISCUSSION

The species accumulation curve (Fig. 2) shows a plateau in the addition of new bird species recorded during the sampling period, beginning in the 1950s. Although a few new species have been recorded since the 1950s the majority of bird species had been recorded by the middle decades of the 1900s. This represents a sampling saturation on the Plateau, meaning that for the extra input of effort to record birds the chances of revealing a new species in recent decades has been very low. However, this does not mean that avifauna have reached an equilibrium composition. If the species accumulation curve (Fig. 1) is compared to the number of species recorded in each decade (Fig.2), it is evident that only about half of the species ever recorded in the study are still using the Plateau in the 2000s. The maximum diversity of bird species was seen between the 1930s-1970s with the peak coming in the 1950s, which shows that bird diversity is dynamic and changes from decade to decade.

The trends identified in this study likely reflect a combination of many factors, including land use change, forest succession, habitat fragmentation, and missing data. The Highlands Plateau, like much of the Southern Appalachians, has undergone many changes in land use in the recent past. Models of land use in Macon County show that agriculture peaked from the 1890s to the 1920s and then slowly declined (Kirk 2009). The same model also shows that logging peaked during the 1910s and 1920s, but that regrowth caused total forest area to peak during the 1960s-1980s. Since the 1980s, development has been increasing steadily, causing an overall decline of forested land.

Prior to the late 19th century logging phase, the Highlands Plateau consisted of mostly virgin forests, which created ideal habitat for bird species that need extensive old-growth stands. Because almost all stands were the same age, there were not many available niches for species that need open land or dense shrub thickets. The lack of diverse habitats may help explain why only 96 species were accumulated during the 1880s and 1890s, although missing data may also explain the relatively low numbers of species recorded during the first two decades of the study.

Logging during the early decades of the 1900s opened up new niches on the Plateau. Many species that were not recorded until the 1910s or after, such as the Yellow Warbler, Northern Bobwhite, and Brown-headed Cowbird, favor either open spaces or shrubs. It is possible that before lands were cut over there were no suitable habitats for species with such habitat needs. However, the barren lands that timber companies left after cutting made suitable niches for species dependent on disturbed or open areas and may have allowed for species not seen in the 1800s to colonize during this era.

The regrowth of cut lands and fallow agricultural fields created a patchwork matrix of many forested stands of different ages during the middle decades of the 1900s. Differing stand ages allows for an increased diversity of niches that may account for the 156 species recorded in the 1950s, which was the most of any decade. In fact, the 1930s-1970s recorded the five highest species totals in the study (Fig. 3). The relatively high diversity of species during this period may explain why the species accumulation curve plateaus starting in the 1950s (Fig. 2).

By the 1990s and 2000s succession of young forest stands containing mostly shrubs and saplings to more mature stands with larger canopy trees is evident (Kirk 2009). The loss of disturbed edge habitats and thickets could explain why some disturbance-dependent species (e.g. Bewick's Wren and Eastern Kingbird) that prefer shrublands or open land for breeding have not been seen in the last three decades. As forest stands continue to mature, it is possible that the Plateau will lose additional species that require open space or dense thickets to breed. The model that Kirk (2009) created to predict forest stand age showed that by 2030 over 50% of the forests in Macon County will be over 120 years old. If this projection is accurate, many bird species adapted to disturbance may find it difficult to find suitable breeding habitat.

My results reflect the conclusions of Adams (1908) almost 100 years ago, that mature forests create homogenous habitat that only certain bird species can utilize. However, in the middle stages of succession there is a wider variety of niches that allow for a greater diversity of guilds of birds to colonize. Although mature stands do not support the level of avian diversity of middle-aged stands, bird diversity appears maximized when different forest stand ages are available within the same landscape.

Although forests are becoming more mature, development pressures cause them to be highly fragmented. New roads and subdivisions not only destroy forested areas but also create fragments of remaining forest stands. Many forest interior breeders require a large patch size, which means these birds only breed when there is a continuous stand of suitable habitat even if their nesting and foraging does not require the entire stand. Small fragments create higher edge-to-area ratios and leave nests more susceptible to predation and parasitism. It is likely that fragmentation will decrease population densities of certain species and possibly lead to their loss from the region. Development has been increasing since the 1980s and is projected to increase with each subsequent future decade (Kirk 2009). Therefore, fragmentation may already be affecting species abundance and diversity in the records found in the database, and will certainly be a major influence on future bird populations.

Although the modern conditions on the Plateau may be more fragmented than ever before, the amount of forest cover is greater now than it was 80 years ago (Kirk 2009). Many stands are currently reaching maturity or will reach maturity within the next few decades. For many land managers, mature forests are a goal of conservation. However, the results I found in this study suggest that mature stands may not provide maximally diverse habitats for avifauna. Therefore, a question that land managers need to address is the goal of conservation efforts. In respect to the conservation of birds, is it more important to manage for maximum diversity of bird species or to preserve species of concern? If diversity of avifauna is ideal then returning land cover conditions to the 1950s may be one useful technique. However, if managing for species of concern, such as the species noted in the conservation status column of Table 3, is the goal then maintaining specific habitats may be a better option.

The trends that I have identified are limited by the amount and quality of records available in the database. As noted earlier, there are many gaps in the data simply because birding records were not consistent across the decades. Therefore, my analysis is based on existing records and the assumptions I used to fill in gaps in the data. Future studies might try a different set of assumptions or could use the records in the database to run other statistical analyses. That said, the analysis did reveal some interesting trends with conservation implications. For example, one species of interest that has not been witnessed in the last three decades is the Olive-sided Flycatcher. This species is a conifer specialist and is usually found in spruce-fir forests, but has been known to use the hemlock forests on the Plateau. The decline of hemlocks due to the hemlock woolly adelgid may be force the Olive-sided Flycatcher further north or higher in elevation where spruce-fir forests are more common, making it even less likely for them to occur on the Highlands Plateau.

Future studies of birds on the Highlands Plateau could expand on the wealth of records and trends already witnessed. One potential study would be a replication of the analysis originally done by Odum (1950) and repeated by Holt (2000), which would allow for analysis of birds in a defined study area for 60+ years and could show long-term trends correlating bird populations and habitat type. Another interesting study could test the relation of bird species to the stand age that those species occupy. The effects of fragmentation on population composition (e.g. species/guild abundance) would also be an area of interest for future ornithologists.

In conclusion, both current and historical land use affect niche diversity and influence which bird species breed on the Highlands Plateau. Records compiled from 1884-2009 have shown that a number of species were not recorded until the 1910s or later, coinciding with the era of logging, which might indicate the requirement of open areas or shrubs for some species. Similarly, some species have not been recorded in recent decades, which may indicate the influence of habitat fragmentation and forest succession on bird species. Finally, the high number of species recorded in the middle decades of the 1900s (1930s-1970s) may reveal that maximal habitat diversity was achieved on the Plateau during this period.

ACKNOWLEDGEMENTS

I would like to thank Curtis Smalling, my mentor, for his support throughout the entirety of this project. I also thank Doug Landwehr for starting the database and sharing it with me. Thanks to the Boynton Family, Biltmore Estate, and Bill Alexander, Forest Historian at Biltmore Estate, for presenting me with the opportunity to transcribe the journal of C. L. Boynton. Finally, I would like to acknowledge anybody who has made birding records on the Plateau both past and present. Without observers this project never would have been possible.

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APPENDIX A

List of observers credited in the database.

First Name	Last Name
	ANDERSON
LINDA	BAILEY
R	BECKHAM
A	BICKNELL
C	BOYNTON
WILLIAM	BREWSTER
C	BRIMLEY
ROY	BROWN
T	BURLEIGH
KAREN	CARLSON
N	CATHCART
D	CEE
J	CHAMBERLAIN
HELEN	CHAMBERS
OVERTON	CHAMBERS
JOHN	CHEEK
M	CROSBY
TOLIVER	CRUNKLETON
JOHN	DE LAPP
LAURA	DECKER
	DENDY
J	DENTON
MARY	DUPREE
ROBERT	DUPREE
C	EKDAHL
MARY	ENLOE
R	GORDON
MARTINA	HAGGARD
D	HARBISON
G	HARBISON
D	HEDDON
J	HEDDON
M	HEDDON
DALE	HEIN
JANE	HOLT
JOHN	HORN

First Name	Last Name
A	HOWELL
THELMA	HOWELL
MARIE	HUGER
M	INGERSOLL
	JELKS
D	JOHNSTON
JOE	KEENER
R	KEENER
RICK	KNEISEL
BARBARA	LEE
DAVID	LEE
R	LOVELACE
LAURA	MANSBERG
LEONCE	MANY
M	MANY
ALICE	MCCOLLOUGH
TOLLIVER	MOUNTAIN
NORA	MURDOCK
GUY	NESOM
EUGENE	ODUM
CHARLTON	OGBURN
J	PARNELL
J	PATTEN
STEVE	PIERSON
J	POTTS
	QUAY
E	REINKE
L	RICE
H	ROBERTSON
T	ROGERS
DIA	SARGENT
HUGH	SARGENT
LYDIA	SARGENT
RALPH	SARGENT
	SHERMAN
MARCUS	SIMPSON

First Name	Last Name
HENRY	STEVENSON
R	STEVENSON
J	STEWART
LAURIE	STEWART
ARTHUR	STRUPKA
BRADFORD	TORREY
J	VALENTINE
DAVID	VAN VORHEES
LEONCE	WALL
WALLACE	WALLACE
PRICE	WEBB
F	WESTON
A	WETMORE
F	WHITMAN
GEORGE	WOOD
W	WOOLCOTT
HENRY	WRIGHT
BOB	ZAHNER
	UNKOWN
J	BARNHARDT
HARRY	WASHINGTON
BETTY	WASHINGTON
	BROWN
DAVID	ADAMS
ALAN	WALLACE
BROCK	HUTCHINS
AVERY	DOUBLEDAY
JACK	BORNEMAN
ROMNEY	BATHURST
EDWIN	POOLE
	AUDUBON GROUP
PAT	DAVIS
DOUG	LANDWEHR
R	WILEY

CHANGES IN BIRD SPECIES IN HIGHLANDS, NORTH CAROLINA, 1884-2009

ANDREW T. CHIN

Abstract. The Highlands Plateau, located in southwestern Northern Carolina, provides important habitat for many birds including several subspecies endemic to the Southern Appalachians. Historically the area has been subjected to many changes in land use that have altered available habitat for avifauna. Birding records have been collected in this region since the 1800s by Charles L. Boynton, Eugene Odum, Jane Holt, Thelma Howell, and many others. I have compiled records from 1884 to 2009 in a Microsoft Access database. After breaking the data down by decade, I found 15 species that were not seen on the Plateau until the 1910s or later. Analysis also showed 12 species that historically used the Plateau but have not been recorded in the past three or more decades. The results are likely due to changes in available niches based on the land use and stand age of forests at any given time. Further research should look at the relationship of bird populations to land use changes and forest age.

Key words: avifauna; birds; forest age; Highlands Plateau; Highlands, NC; land use change; Southern Appalachians.

INTRODUCTION

The Highlands Plateau has undergone many land use changes since the 1880s. A combination of logging, agriculture and commercial and residential development has led to continual changes in forest age and plant assemblages. Commercial logging occurred in Macon County, which includes the town of Highlands, starting in the late 1800s and peaking in the 1910s (Kirk 2009). The effects of clear cutting hardwood forests have been shown to increase bird diversity in the short-term (Horn 1984). Horn's data, collected on the Highlands Plateau, showed that despite an increase in the number of species in clear-cut land, the composition and structure of bird communities were altered. For example, virgin forests are suitable habitat for bird species that nest in forest interiors, but not species that need edge or open space. Logging forces birds that were nesting in the forest interior to leave and find alternate nesting sites; disturbed habitat created by logging is ideal for species that breed in open areas. Since the mid-1900s commercial logging has decreased on the Plateau and many cut over plots have been allowed to regenerate. Over time as shrubs and small trees begin to grow, intermediate habitat is created for bird species that nest in shrub thickets. The process of logging and post-logging recovery creates a diverse patchwork of habitats from open fields to shrublands and finally, woodlands; as a result avian diversity changes with the changing availability of niches during forest succession.

Many studies have been conducted to determine how avifauna respond to disturbance and utilize different successional stages of forest habitat. One of the first such studies, conducted by C. C. Adams (1908), found that diversity of bird species was not highest in mature habitats but in habitats in the middle stages of succession. A corollary study done in Highlands, NC looked at

SURVEY OF *EURYCEA LONGICAUDA LONGICAUDA* HABITAT IN THE LITTLE TENNESSEE AND NANTAHALA RIVER DRAINAGES

ANNA G. DECKER AND BRITTANY R. ROBINSON

Abstract. An accurate understanding of the factors that affect habitat availability is necessary for the conservation of any species. In North Carolina the plethedontid salamander *Eurycea longicauda longicauda* is listed as a species of Special Concern. We conducted a survey of the habitat of *E. l. longicauda* in Western North Carolina along the Nantahala and Little Tennessee Rivers. We sampled thirteen sites in half-hour, hour, and two hour long surveys. A total of four *Eurycea longicauda longicauda* individuals were found at three sites. The populations of *E. l. longicauda* are limited in its range and were found to show no preference in their cover object or soil type, but seemed to prefer less acidic environments.

Keywords: distribution; Eurycea longicauda*; Fontana; habitat survey; Little Tennessee River drainage; Nantahala Lake; Nantahala River drainage; salamander.*

INTRODUCTION

There currently exist two subspecies within the species *Eurycea longicauda*: *E. l. melanopleura*, the dark-sided salamander and *E. l. longicauda*, the long-tailed salamander. *E. l. melanopleura* is considered the western ranging subspecies and is typically associated with the Ozarks, being distributed through parts of Oklahoma, Nebraska, and Missouri. *E. l. longicauda* is distributed to the east through many mid-western, southeastern, and mid-Atlantic states, ranging from Missouri and southern Illinois to the Appalachian highlands from southern New York to north Georgia (Ryan and Conner 2009). However, local distributions of the species are extremely dependent upon the availability of suitable habitats and the local abundance of invertebrate prey upon which they feed.

E. l. longicauda is characterized by a yellow to orange-red dorsal coloration, a clear yellowish underside region, and vertical herringbone marks on the tail. While long thought to be associated with cave habitats, *E. l. longicauda* is also known to inhabit creeks and seeps that have a shale or limestone substrate, as well as vernal ponds which are thought to be used mainly for breeding purposes and are occupied only during the spring and early summer months (Anderson and Martino 1966). It is generally believed that this species prefers basic soils to those that are more acidic. However, Mushinsky (1975) suggested that when individuals of *E. l. longicauda* were presented with soils of different pH levels, they showed no preference. The wild individuals used by Muchinsky were collected from limestone caves where there was alkaline soil. This suggests that *E. l. longicauda* prefers limestone not because of the pH level of the soil, but because of some other organismal or vegetative factor that may be associated with alkaline, limestone substrates.

Reproductive habits affect the seasonal distribution of *E. longicauda*, and are dependent on factors such as altitude and the availability of the aquatic habitats that are used for breeding. Though eggs have been observed from early autumn to late winter, it is believed that during optimal conditions they are usually deposited in the late autumn. Clutches usually include between 61-106 eggs (Hutchison 1956, Minton 2001) and are laid in aquatic habitats such as on the underside of rocks in fast moving water, in ponds or other standing water, in seeps or intermittent streams, and in subsurface waters (Anderson and Martino 1966). They have also been found in extremely humid environments such as on cave walls (Franz 1964). Individuals of this species undergo a larval stage of about six months before metamorphosing into adult. After metamorphosis, juveniles spend time near their hatching site and gradually migrate away from the edges of the water (Franz and Harris 1965). Adult members of this species are mainly terrestrial and can be found underneath rotten logs and flat rocks, but still exist fairly close to some body of water. As autumn progresses *E. l. longicauda*, like most other Plethodontidae, retreat below the surface of the soil where they spend the colder winter months (Taylor and Mays 2006). Taylor and Mays (2006) noted that this species becomes inactive during these months even in environments such as caves that do not experience a decrease in temperature.

The three-lined salamander (*Eurycea guttolineata*) is closely related to *E. longicauda* and the two are referred to as sister-species. *E. guttolineata* was actually considered to be a third subspecies of *E. longicauda* until fairly recently when Carlin (1997) used genetic and morphological characters to show that the two exhibit species-level divergence. Their close connection is relevant because of the wide distribution and abundance of *E. guttolineata* within western North Carolina. What determinants exist to limit the distribution of *E. l. longicauda* while allowing for large populations of *E. guttolineata* are poorly understood. Therefore, knowledge of the factors that define the presence or absence of *E. l. longicauda* in North Carolina is crucial for managing their populations as they are considered a Special Concern Species by the North Carolina Wildlife Resources Commission (NCWRC 2008).

The distribution of the species within North Carolina remains poorly understood. Martoff et al. (1980) report that *E. l. longicauda* is found in the Watauga, Nantahala and Little Tennessee River watersheds. Unpublished records from 1981 confirmed the presence of *E. l. longicauda* populations at three sites in southwestern North Carolina: two within the Nantahala River watershed, and one along the Little Tennessee River near Fontana Lake (Bruce and Holland 1981). Dr. Richard Bruce (Western Carolina University, emeritus, pers. comm.) reported that the species was abundant along the Nantahala River both above and below Nantahala Lake in the early 1980s. Additionally, three specimens were recorded below Nantahala Lake in June 2009 (NCNHP EO 9). Other than this, there have been no recent published records to indicate the status of *E. l. longicauda* populations in the state. Therefore, the purpose of the present study is to assess the current status of the species in the Little Tennessee and Nantahala watersheds.

MATERIALS AND METHODS

In order to understand how much available habitat occurred in our study area, we conducted a survey to locate sites that would provide what appears to be suitable habitat for *E. l. longicauda*. The habitat assessment was based on prior knowledge of the species' distribution and habitat specifications (Bartlett 2006, Bruce and Holland 1981). For survey site selection we evaluated the entire length of both the Little Tennessee and the Nantahala Rivers from the beginning of Fontana Lake to the town of Franklin, along with some other creeks and areas of the Nantahala drainage basin for the following parameters: land cover and shade, hydrology (velocity and stream width), and soil moisture. We assumed that *E. l. longicauda* would prefer habitats that were moist and alkaline, close to a permanent water source, in partial to full sunlight, with land cover consisting of deciduous hardwoods. We also considered what other salamander species we would expect to find in each area in order to uncover possible ecological relationships such as competition or predation. Access to the rivers was restricted somewhat by terrain, and limited to areas where access was granted. We sampled sites representative of many different micro and macro habitats that can serve as models for the entire stretch of the two rivers within our study area.

Fifteen sites were chosen that fit our requirements, and each site was surveyed for salamander populations in half-hour, hour, or two hour long increments depending on the amount of habitat available to search. At each site, we separated the available search area into sections and designated who would survey each section in order to make sure that the whole area was examined. All possible cover objects were flipped and leaf litter, if present, was searched. All individuals were collected in bags and kept next to the cover object under which they were found until the end of the survey to avoid re-sampling. We documented the GPS coordinates and elevation using a Garmin GPS72. A visual assessment of land features and weather conditions was also recorded to provide a general description of the area at the time of the survey. At each site, we described the hydrology of the closest body of water using a measuring tape to measure the width and categorized the velocity of the water as standing, slow moving, moderately fast moving, or fast moving water. We also recorded the type of forest and vegetation at the site using Schafale and Weakley's (1990) forest community classification system.

All salamander species found at each site were identified and recorded, with special attention paid to *E. l. longicauda*. For specimens of other species, we recorded at which site they were found, what type of cover object they were found under, and how far from the water they were found. For the study species, the microhabitat was further documented. We classified the type of cover object, identifying it as a rock, log, or other type of object. For cover objects that were rocks, we recorded type of rock, and measured the length, width, and thickness in centimeters; for logs we used a tape measure to record the length and thickness and also determined the stage of decay; all other objects were described in detail. We also documented the characteristics of the soil or substrate under the cover object, and visually categorized the moisture level of this substrate as either very dry, dry, moist, or very moist. We used a tape measure to measure the distance from the cover object to the closest body of water, and also described the general terrain features between the object and water to show any barriers that needed to be crossed by the *E. l. longicauda* individual in order to reach the water. Finally, we classified the amount of shade over the cover object, categorizing the point as in complete shade, partial shade, or no shade.

RESULTS

Of the fifteen areas that were selected for survey, *E. l. longicauda* occurred at three of these locations: site A, site C, and site H (Table 1, Fig. 1). These sites are described in detail below and a summary of all sites is presented in Table 2. Two *E. l. longicauda* individuals were discovered at site A on 09/04/09, one at site C on 09/11/09, and one at site H on 10/09/09. We were unable to relocate these populations on the later dates listed in Table 1. A description of all species found at each site can be viewed in Table 3.

Site A can be characterized as a riparian sub-pool where the Nantahala River begins to form the Nantahala Lake. The river here was moderately fast moving and about ten meters wide. The water level is regulated by a dam which is located at the opposite end of the lake. The area surveyed extended from the water's edge to about three meters up the bank. There was little vegetation cover near the edge of the lake with rich cove forest above the bank and the survey area was in full to partial sunlight. The actual lakebed where *E. l. longicauda* was found had a

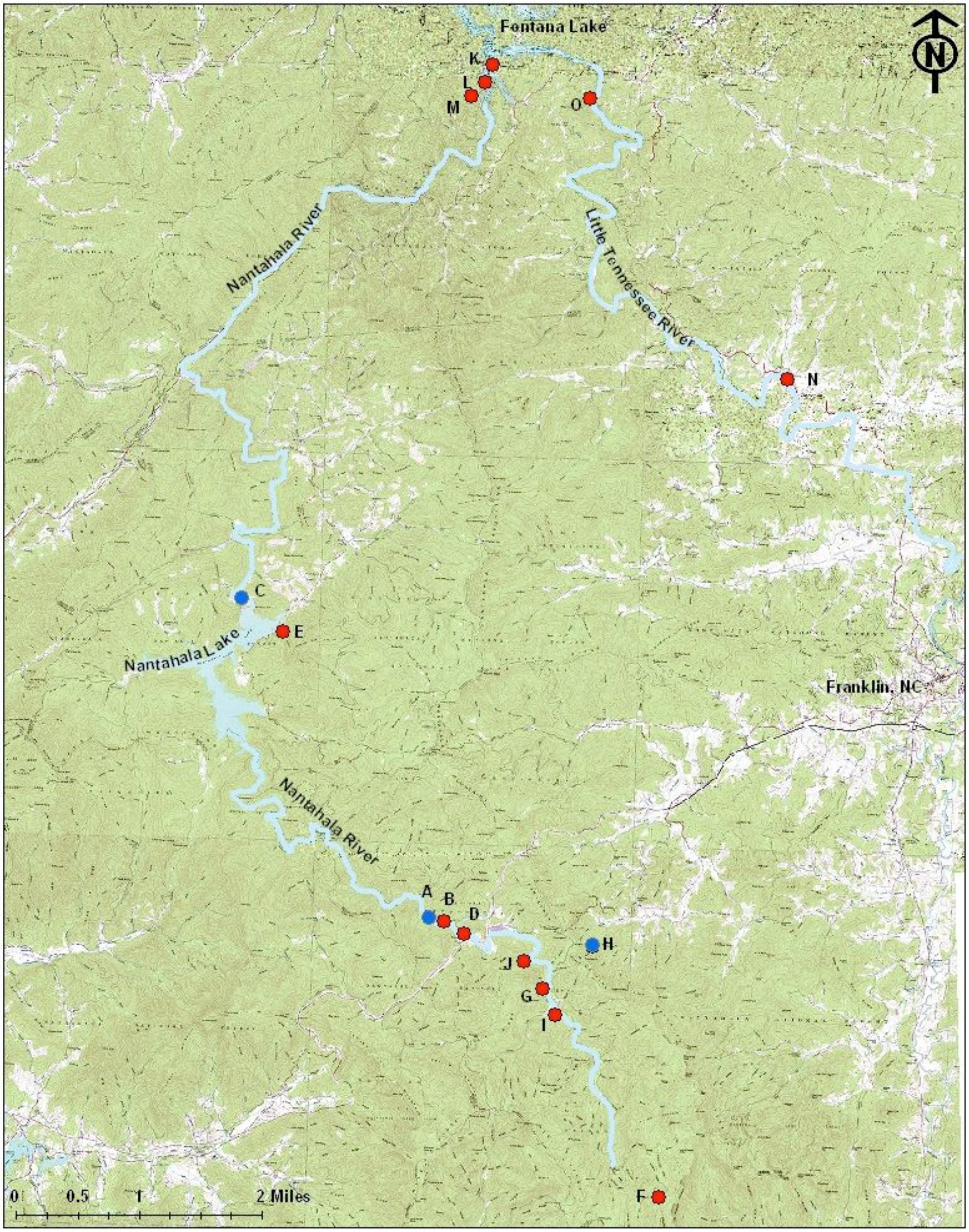

FIG. 1. Map showing locations surveyed. Blue indicates sites where populations of *E. l. longicauda* were found. See Table 1 for a key of the locations and their GPS coordinates.

TABLE 1. Names, locations, and dates of sites surveyed. Asterisks (*) represent *E. l. longicauda* occurrence.

Site	Description	GPS Coordinates	Date(s) Surveyed
A	Carol Miley's Lake Bed	N 35° 08.243 W 83° 38.429	09/04/09*; 11/19/09
B	Carol Miley's Vernal Pool	N 35° 07.524 W 83° 37.187	09/04/09; 09/25/09; 11/19/09
C	Nantahala Dam Road	N 35° 12.162 W 83° 39.448	09/04/09*; 09/11/09; 10/02/09; 10/30/09; 11/19/09
D	Jeff Sutherland's Farm	N 35° 05.775 W 83° 34.033	09/06/09
E	Wine Spring	N 35° 11.535 W 83° 38.355	09/11/09; 10/30/09
F	Laurel Branch	N 35° 01.555 W 83° 30.360 (location of trail head)	09/14/09
G	Park Ridge Trail	N 35° 04.585 W 83° 32.395	9/28/09; 10/16/09
H	Wasilik Poplar	N 35° 05.654 W 83° 31.347 (location of trail head)	10/09/09*; 10/16/09
I	Standing Indian	N 35° 02.518 W 83° 32.884	10/23/09
J	Park Creek	N 35° 05.334 W 83° 32.417	10/26/09; 11/06/09
K	Fontana Lake Boat Site	N 35° 22.787 W 83° 33.669	11/12/09
L	Fontana Lake Bed	N 35° 22.911 W 83° 33.463	11/13/09
M	Creek near Fontana Lake	N 35° 21.818 W 83° 34.307	11/13/09
N	Little Tennessee River site 1	N 35° 16.685 W 83° 26.701	09/18/09
O	Little Tennessee River site 2	N 35° 21.395 W 83° 30.746	09/18/09

sandy substrate with flat shale-type rocks, which implies that it was at one time underwater and is periodically submerged.

Site C is a riparian flood plain positioned just north of the Nantahala Dam and just downstream of the lake. On 09/11/09 the river was narrow, only two to three meters wide, slow moving, and the banks of the river were sandy and dry with many rocks of variegated size, ranging from small to large. The site was in full to partial sunlight and the area surveyed was about ten meters wide, more than twenty meters long, and ended where the rocks became less frequent and the density of the vegetation increased. The area surveyed was flooded when dam maintenance was required. A survey was conducted on 11/19/09 that extended into the forest of hemlock and mixed hardwood, and yielded no salamanders.

Lastly, site H contained a seep that was geographically isolated from the Nantahala River or any creek draining into it. The area was deep in a mixed deciduous hardwood forest and available cover objects consisted of both heavily decayed logs and large, flat rocks on the north facing slope of a mountain. This survey site was located in partial to full shade and was very moist, as it was raining the day the *E. l. longicauda* individual was discovered.

The *E. l. longicauda* occurrences we observed varied over a wide range of microhabitats, showing no distinguishable overall trend. The individuals at site A were found underneath large, flat rocks (on average 20 cm long x 10 cm wide x 3 cm thick) in a sandy substrate that had a moderate to high level of moisture. The individuals were found about one to two meters from the water's edge. They were found among considerable amounts of leaf litter that effectively serve as camouflage for their orange bodies. The individual found at site C was found under a medium sized rock (15 cm long x 7 cm wide x 2.5 cm thick) with a sandy, dry substrate underneath. The rock was under partial shade and was about five meters from the river where the soil became increasingly moist. At site H, the specimen discovered at this location was found under a medium size decayed log with no bark remaining. The log was surrounded by wet leaves and moist soil but was not close to a water source.

TABLE 2. Description of all sites.

Site	Description
A	Nantahala River where Nantahala Lake begins to back up. River is moderately fast moving and about ten meters wide. Bank is covered in moist sand and large rocks. Surrounded by rich cove forest dominated by Eastern Hemlock (*Tsuga canadensis*) and Rosebay Rhododendron (*Rhododendron maximum*). Surveyed area in partial to no shade.
B	Vernal pool located adjacent to the Nantahala River. Standing water. Cover objects included rocks and decaying logs. In a rich cove forest with complete shade and moist soil. We attempted to relocate a site in the floodplain of the Nantahala near Rainbow Springs based on Braswell et al. in May 1976 (NCNHP EO 10).
C	Nantahala River downstream of the dam. River is about two to three meters wide and slow moving. Surveyed flood plain is sandy and dry with many rocks of all sizes. Shrubs in the surveyed area and rich cove forest and mixed hardwood forest above the floodplain. Area is in partial to no shade.
D	Along the bank of the Nantahala River in moist soil with medium sized flat rocks and decaying logs. Rosebay Rhododendron close to the river and Hemlocks farther from the bank. Area is in partial to full shade.
E	Nantahala Lake bed moving up the small Wine Spring creek. Creek is about a meter wide and moderately fast moving. Dry to moist soil of coarse rock. Lots of debris including medium sized rocks and logs. Rich cove forest above the creek. Area is in partial to no shade.
F	Along the bank of the Laurel Creek before it drains into the Nantahala River. Creek is fast moving and about 5 meters wide. Very moist wetland type area, and cover objects are large rocks and bedrock on the banks and in the creek. Forest can be classified as an Acidic Cove forest dominated by Rosebay Rhododendron (*Rhododendron maximum*). Area is in full shade. We attempted to relocate a site in the Standing Indian Management Area based on Bailey and Bruce (1974).
G	Along the bank of the Nantahala River. River is fast moving and about 8 meters wide. Bank covered in very moist rich and sandy soil with many standing pools. Vegetation near the river is dominated by Rosebay Rhododendron, Mountain Laurel (*Kalmia latifolia*), and Doghobble (*Leucothoe fontanesiana*) and further away begins to form a rich cove forest. Area is in partial to full shade.
H	Along a seep isolated from the Nantahala River. Seep is slow moving and less than a meter wide. Soil is extremely moist and cover objects include leaf litter, rocks, and decaying logs. Forest classified as rich cove including Tulip Polar (*Liriodendron tulipifera*), Eastern Hemlock, Rosebay Rhododendron, and Doghobble. Area is in full shade.
I	Upriver from site G. See site G description. Survey included rock piles that extended into the river.
J	Downriver from site G. On Park Creek where water is moderately fast moving and about 3 meters wide. Moist soil with rock and logs as available cover objects. Rich cove forest with notable decline in Rosebay Rhododendron and increase in Sweet Birch (*Betula lenta*), Yellow Birch (*Betula alleghaniensis*), Red Oak (*Quercus rubra*), and Red Maple (*Acer rubrum*). Area is in mostly partial shade.
K	On the bank of Fontana Lake. Water is standing and survey location was up the 20 meter wide steep bank and into the forest above. Bank covered in large rocks and fallen trees. Soil was very moist and consisted of clay and rock. Bank in full, direct sunlight. Forest above was rich cove consisting of mainly Rosebay Rhododendron and Doghobble near the edge.
L	Near site K. In a wide floodplain of a meter wide, slow moving creek that flows into nearby Fontana Lake. Floodplain consisted of moist pasty clay that became very moist near the creek. There were many rocks closer to the creek which was in direct sunlight. The area surveyed was along the creek and on the bank above the floodplain. The bank was covered in Blackberry (*Rubus alleghanensis*) and rich cove forest species and was in partial sunlight.
M	Small creek (less than a meter wide and slow moving) draining into the Little Tennessee River. Cover objects included small rocks and decaying logs. Soil was sandy and moist. Located in a rich cove forest dominated by Rosebay Rhododendron and Eastern Hemlock. Area in full shade.
N	Along the bank of the Little Tennessee River. Survey area included many small rocks that extended into the river. Soil beneath was rocky and very moist. Survey area was in full, direct sunlight. Area beyond the bank not surveyed was grassy with few trees.
O	On a steep bank of the Little Tennessee River. Bank was about 15 meters wide and covered in large, flat rocks. Soil beneath was sandy and very dry. Survey area was in full, direct sunlight. Above the bank was a rich cove forest.

TABLE 3. Description of species found at each site.

Site	Date	Length of Survey	Species	Number Found	Type of Cover	Proximity to Water
A	09/04/09	half-hour	*E. l. longicauda*	2	1. rock 2. rock	1. ~ 2m 2. ~ 1m
			Notophthalmus viridescens	1	1. rock	1. ~ 2m
			Desmognathus fuscus	2	1. rock 2. rock	1. ~ 3m 2. ~ 3m
	11/18/09	one hour	(no salamanders found)			
B	09/04/09	half-hour	*Notophthalmus viridescens*	1	1. none	1. in wáter
	09/25/09	half-hour	*Desmognathus aeneus*	1	1. log	1. ~ 6m
C	09/06/09	one hour	*E. l. longicauda*	1	1. rock	1. ~ 5m
			Desmognathus fuscus	2	1. rock 2. rock	1. ~ 2m 2. ~ 4m
	09/11/09	one hour	*Eurycea bislineata*	1	1. rock	1. ~ 5m
	10/02/09	one hour	*Eurycea bislineata*	2	1. rock 2. none	1. ~ 5m 2. ~ 5m
	10/30/09	one hour	(no salamanders found)			
D	09/06/09	half-hour	*Desmognathus fuscus*	2	1. rock 2. rock	1. > 1m 2. > 1m
			Desmognathus quadramaculatus	1	1. rock	1. > 1m
E	09/11/09	one hour	*Eurycea guttolineata*	2	1. rock 2. rock	1. ~ 4m 2. ~ 5m
			Notophthalmus viridescens	2	1. rock 2. log	1. ~ 4m 2. ~ 4m
	11/06/09	one hour	(no salamanders found)			
F	09/14/09	two hours	*Desmognathus quadramaculatus*	20	all under rock	> 1m
			Pseudotriton ruber	1	1. moss	1. ~ 3m
			Gyrinophilus porphyriticus	4	1. rock 2. rock 3. rock 4. rock	1. ~ 5m 2. ~ 4m 3. ~ 4m 4. ~ 4m
			Desmognathus monticola	1	1. rock	1. > 1m
G	09/28/09	two hours	*Desmognathus fuscus*	3	all under rock	> 3m
			Desmognathus quadramaculatus	4	all under rock	> 2m
			Desmognathus ocoee	2	1. rock 2. log	1. > 1m 2. ~ 2m
			Plethodon shermani	1	1. rock	1. ~ 2m
			Gyrinophilus porphyriticus	1	1. rock	1. > 1m
			Eurycea bislineata	2	1. rock 2. rock	1. ~ 3m 2. ~ 2m
	10/16/09	one hour	*Desmognathus quadramaculatus*	3	1. rock 2. rock 3. rock	1. ~ 2m 2. ~ 2m 3. > 1m
			Desmognathus fuscus	2	1. rock 2. rock	1. ~ 2m 2. ~ 1m
H	10/09/09	one hour	*E. l. longicauda*	1	1. log	1. ~ 5m
			Plethodon shermani X *Plethodon teyahalee* hybrid	3	all under logs	< 6m
I	10/23/09	one hour	*Eurycea bislineata*	2	all under rock	> 1m

			Desmognathus fuscus	1	1. log	1. ~ 2m
			Desmognathus quadramaculatus	3	1. rock 2. rock 3. rock	1. > 1m 2. ~ 2m 3. ~ 1m
J	10/26/09	one and a half hours	*Eurycea bislineata*	3	1. log 2. log 3. none	1. ~ 6m 2. ~ 3m 3. ~ 3m
			Desmognathus ocoee	2	1. log 2. rock	1. ~ 15m 2. ~ 4m
K	11/12/09	one hour	*Plethodon cinereus*	1	1. rock	1. ~ 20m
L	11/13/09	half hour	(no salamanders found)			
M	11/13/09	half hour	(no salamanders found)			
N	09/18/09	half hour	(no salamanders found)			
O	09/18/09	one hour	(no salamanders found)			

DISCUSSION

Our results show that *E. l. longicauda* is rare in the Little Tennessee and Nantahala drainage systems. During the 17:30 hours that were spent surveying, we had a very low occurrence of the species, with only four collected. Their rarity is also indicated by the fact that the species was absent from the majority of our sampling sites, which represent almost all available habitat in the two drainages. Of our fifteen sampling sites, *E. l. longicauda* populations were present at three. The published literature and communications with salamander researchers suggested that this species prefers habitat that is in close proximity to water and requires cover objects consisting of medium to large size flat rocks. Given that we found long-tailed salamanders less than three meters from water as well in an area with no body of water in close proximity, our study neither confirmed nor denied what the suitable habitat requirements are for the species. We found individuals that were under the large, flat rocks that we believed would be favored habitat, but they were also found underneath a log in an area where rocks were not even present. In sum, our results showed no trends to indicate what preferred habitat might look like.

All locations where *E. l. longicauda* occurred were sampled multiple times and individuals were only found at each of these sites on one occasion. This indicates that there may be some other fluctuating variable such as seasonal temperature affecting the presence of *E. l. longicauda* within the study area. Our data show that we typically found more salamanders of every species in early autumn, with fewer occurrences in the late autumn season. We believe that this can be attributed to a decrease in temperature, as salamanders are known to move underground as weather gets colder (Taylor and Mays 2006). This could have affected our surveys, which leads us to suggest that future studies be conducted from early spring to late autumn. The work of Dodd et al. (2001) concludes that April is an appropriate month to begin quantifying adult salamanders. For example, the historic *E. l. longicauda* occurrence at site B was recorded in late May (NCNHP EO 10). Furthermore, salamanders tended to be much more mobile and visible when the ground was wet or it was raining, suggesting that future surveys would be most successful if conducted under wet conditions.

During the sampling period, we found 14 different species of salamanders, represented by 80 individuals, including those of *E. l. longicauda*. Excluding *E. l. longicauda*, we observed 13 species and 76 individual salamanders. The most common species found with *E. l. longicauda* were *Desmognathus fuscus* and *Eurycea bislineata*. When sites were resurveyed, we observed an absence of *E. l. longicauda*, yet a continued presence of both other species. However, both *D.*

fuscus and *E. bislineata* are known to be fairly abundant throughout western North Carolina (Martoff et al. 1980), and we sampled these species several times in multiple locations, often finding them in other areas where *E. l. longicauda* was not present. During our study, *D. fuscus* comprised 15% of the total salamanders sampled, and was found at five out of fifteen sites. *E. bislineata* occurred 12.5% of the time and was present at four out of fifteen sites. Further studies should document the continued presence of *E. l. longicauda* over a period of time to uncover any ecological relationships between these salamander species that could possibly affect their distribution.

Our results show that *E. l. longicauda* populations are few and sparse in the survey area, while other species persist in abundance, which leads us to believe that *E. l. longicauda* is particularly sensitive to some undetermined environmental factors. Remaining environments that host individuals of the species should be given attention through conservation efforts in order to protect the habitat. During the span of our study alone, at least one area that was confirmed to have supported a population of *E. l. longicauda* was essentially destroyed, with the habitat having been drastically altered (Fig. 2). Site C below the Nantahala Dam was sampled five times, the first four indicating a relatively dry environment beyond the small river that bisected our survey area. On our fifth visit, we discovered the effects of dam maintenance which caused the river below the dam to rise alarmingly. What was before piles of rocks resting in sandy substrate had become a raging river in the process of washing away all trees, and presumably the *E. l. longicauda* specimens that were found there. A survey of the surrounding forested area revealed no individuals, leading us to assume that the population of *E. l. longicauda* may have been extirpated or forced to relocate.

FIG. 2. Picture of destroyed habitat below the Nantahala Dam

The lack of occurrence in potentially suitable habitat and the presence of the species in impacted and marginal habitats suggest that populations of *E. l. longicauda* in North Carolina are smaller and more endangered than ever, and remaining populations are persisting in degraded habitats. This has implications for conservation efforts because the distribution of the species in the state appears to have shrunken considerably, and areas that were once known to support healthy populations now showed few occurrences in the present study. Efforts should be focused on further examining locations to uncover additional populations, and preserving those populations confirmed by our study.

Acknowledgments

We would like to thank Brent Martin from the Wilderness Society of Franklin, North Carolina for being an influential mentor throughout this whole project. We would also like to thank Anya Hinkle, Jim Costa, and Patrick Brannon for all their help, as well as Ed Schwartzman of the North Carolina Department of Natural Resources for his direction and expertise. Thank you also to Jeff Southerland for allowing us to survey on his land. A special thanks to Carol Miley for being the most interesting woman we've ever met, for telling us great stories, and for taking us out on her land to do surveys. ☺

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Appendix A

Pictures of some species found in association with *E. l. longicauda*:

Desmognathus ocoee

Eurycea bislineata

Eurycea bislineata

Eurycea bislineata

Plethadon shermani X *Plethadon teyahalee* hybrid

REVEGETATION DESIGNS FOR THE HIGHLANDS PLATEAU GREENWAY

CAMERON HOUSER

Abstract. Revegetation is an important restoration tool for disturbed areas. The main purpose of this project was to create a plan for implementing revegetation of the Highlands Plateau Greenway using native plants. Designs were created for three different sites along the Highlands Plateau Greenway trail system. Plants for the design were chosen based on plant community types found at the sites and the commercial availability of the native species. I determined appropriate designs for areas targeted for revegetation and identified commercial sources and funding opportunities for the required plant materials. The end product was a guide that included instructions for the implementation of the designs, contact information for nursery plant sources, estimation of project costs, and interpretive information that can be used for educational outreach.

Key words: conservation; greenways; landscape design; native plants; revegetation.

Greenways are public corridors of connected public and private lands. *Greenways for America* author Charles Little (1995) defines a greenway as any "open-space connector linking parks, nature reserves, cultural features, or historic sites with each other and with populated areas" (quoted in Guglielmino 1997). Often associated with rivers, stream valleys, mountain ridges, and utility rights-of-way, greenways can be built along scenic roads or other linear features. They provide paths for people and wildlife while protecting forests, wetlands and grasslands. Greenway programs provide abundant recreational, educational and conservation benefits to communities (Guglielmino 1997).

Economically, greenways help to add value to adjacent properties, which in turn can increase local tax revenues. Values tend to increase based on proximity to trails and green space (Lewis 2002). In a 2002 study conducted by the National Association of Home Realtors and the National Association of Home Builders, trail availability ranked as the second most important community amenity to homebuyers, out-ranking 16 other options such as parks, security, and access to shopping or business centers (NAHB 2002). Jobs are created through trail construction, maintenance, recreation enterprises, such as bicycle and canoe rentals and historic preservation.

Greenways also help to encourage bicycle and pedestrian transportation. Increased transportation options are provided by connecting safe routes between residential areas, workplaces, schools, parks, town centers, and cultural attractions. By using greenways as alternative routes, people are able to avoid traffic and reduce fuel use. In addition to economic benefits, greenways provide health benefits by providing accessible, safe and attractive areas for physical activity. A study done by the Centers for Disease Control determined that creating and improving places in communities to be physically active, leads to an approximately 25 percent increase in people who exercise at least three times per week (USDHHS 2002).

As approximately three million acres are lost to urban sprawl each year, fragmentation of wildlife habitat becomes inevitable (Pimentel 1997). Greenways create natural areas that provide habitat and allow wildlife movement among habitats. Moreover, greenways protect water quality by creating natural buffer zones around rivers and lakes by preventing soil erosion and filtering pollution caused by agricultural and roadway runoff.

Greenways can help to establish community identity and cultural awareness. For example, greenways help to highlight and interpret unique areas of historical and cultural significance important to the community. The natural areas that greenways provide create places where people are able to assemble for community events. Community involvement is essential in creating a successful greenway system. Greenways typically involve the community through volunteer opportunities and programs.

North Carolina is regarded as a leader in the American Greenway movement. The Greenway movement in North Carolina began in the early 1970's (Flink 2006). The movement first gained momentum in larger cities like Raleigh, where a combination of environmental, social and economic concerns presented an opportunity for the communities to begin planning and implementing municipal greenway systems. In Raleigh, greenway planning first began after catastrophic flooding caused state and federal officials to reexamine the city's floodplain management and land use plans. Bill Flournoy, a NCSU graduate student in the School of Design's landscape architecture program, proposed a plan that would "use part of the city's floodplain for an open-space corridor system between adjoining land uses." Based partially on Flournoy's thesis, in 1974 the City of Raleigh established a greenway commission to begin the implementation of the Capital Area Greenway program, creating of one of the earliest community-wide greenway programs in the United States. Since the establishment of the program, the Raleigh greenway system has helped to protect approximately 2,000 acres of land, containing an estimated 50 miles of connected recreational trails (Flink 2006).

The success of the Raleigh greenway system has since inspired many communities throughout the state, leading to the creation of local, county-wide and regional greenway programs. Every large city in North Carolina, including Charlotte, Greensboro, Durham, Winston-Salem, High Point and Asheville, has established a successful greenway program (Flink 2006). Many mid-size and small communities in turn realized the benefits of greenway systems and have established similar programs. Currently in North Carolina, the establishment of a statewide greenway system known as the Mountains-to-Sea Trail is underway. Approved in 1977, this trail, which is being built primarily by volunteer efforts, will become one of the most significant long-distance trails in the nation, connecting over 935 miles between Tennessee State line and the Atlantic Ocean (Flink 2006).

In addition to the abundance of local, state and national projects and programs in North Carolina, the state is known for promoting information about greenways both nationally and globally. North Carolina was the first state to commission a study to look at the effects of a statewide greenway program. In 1986, this led to the creation of the first statewide educational conference that focused on the importance and relevance of greenways in communities (Flink 2006).

The Highlands Plateau Greenway is a non-profit organization whose mission is to connect "natural areas and historic sites in the town and provide alternate transportation routes to shopping, educational offerings, and civic destinations" (Highlands Plateau Greenway 2009). In 1995, the first greenway effort was made to connect a route from Sunset Rock through the Town to the Highlands Recreation Park. It wasn't until the spring of 2005 that the Town of Highlands, in cooperation with the Highlands-Cashiers Land Trust, approved a plan for the implementation of a more extensive trail system and the formation of an official Highlands Greenway Committee.

Since 2005, approximately five miles of trails have been added with the purpose of connecting existing and proposed trails that "would incorporate botanical points of interest, historic sites, important birding areas, art, scenic overlooks, and other areas of natural beauty" (Highlands Plateau Greenway 2009). The Greenway is comprised of seven interconnected trails: Highlands Botanical Garden Trails, Coker Rhododendron Trail, Bascom Trail, Sunset Rock Trail, Kelsey Trail, Big Bear Pen Trail and Mill Creek Trail (Fig. 1). The Greenway connects these trails with downtown Highlands, highlighting many historic sites, including several historic structures on the National Register. These trails are located on a mixture of public and private lands. The Botanical Garden trails are part of the Highlands Botanical Garden located at the state-owned Highlands Biological Station. These trails loop through the gardens at the Station and around the lake, connecting then to the Coker Rhododendron Trail, owned by the Highlands Biological Foundation. The Town of Highlands owns the land that Mill Creek Trail runs through as well as the Highlands Recreation Center property. Sunset Rock Trail is part of the North Carolina Birding Trail and both the Kelsey Trail and Big Bear Pen are owned by the Highlands-Cashiers Land Trust. The trails that follow sidewalks through town are private property under land easements and sections along roads are owned by the State. The Bascom Trail is part of the non-profit Bascom Arts Center, which features a historic-style covered bridge and sculpture trail.

As a consequence of new trail construction and town maintenance on Greenway trails, revegetation is needed to restore the natural integrity and connectivity of disturbed areas to encourage the regrowth of native vegetation. Revegetation will also help to accomplish an aesthetic goal that works to foster investment from the Highlands community. Keeping the Greenway maintained and attractive is necessary to draw interest and support. Community investment is mutually beneficial since the Greenway heavily relies on volunteer support, logging approximately 1,500 hours of volunteer trail related effort, and its potential impact on property values and tourism in Highlands.

The use of plants native to the Highlands Plateau was a priority for our revegetation project since the plants were to be placed in natural areas. The definition given by U.S. Fish and Wildlife Service defines native as being "with respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem." For the purpose of this project, native plants were considered to be plants naturally occurring in the Southern Appalachians generally and the Highlands Plateau in particular (Norcini 2009).

The purpose of this project was to create designs to add native vegetation to three separate sites on the Highlands Plateau Greenway that have sustained disturbance. When implemented, these designs will help to display native vegetation for both, aesthetic and educational purposes, while also meeting conservational goals.

METHODS AND MATERIALS

This study focused on creating plans for revegetation at the Kelsey Trail Entrance, the Big Bear Pen Trail entrance and the Mill Creek Trail site. Each of these sites has experienced recent disturbances and can benefit from revegetation. The goal was to use native plants to restore vegetation and aesthetic value.

At the turn of the 20th century, the Kelsey trail connected the Town of Highlands to Whiteside Mountain through five miles of old growth forest. Today, portions have been restored and added to the Greenway system. The Kelsey Trail entrance is located at the end of 5th Street in Highlands, North Carolina and extends about 0.5 miles through Canada hemlock and oak-dominated forest communities (Fig. 1). The entrance to this trail has recently experienced disturbance when the Town of Highlands added a culvert to the adjacent stream channel. Although many of the hemlocks at this site have been treated for hemlock woolly adelgids by the Highlands-Cashiers Land Trust, the dead and dying ones will continue to open this area to more sunlight, making it a great area for adding perennials. A plan for revegetation is needed at this site to restore native vegetation in areas disturbed by the construction of the culvert.

The Big Bear Pen Trail is located on Big Bear Pen Road in Highlands (Fig. 1). This 0.3 mile trail is currently under construction. It connects the second switchback of Big Bear Pen Road with Upper Lake Road and includes a 0.1 mile side trail that connects close to the Kelsey Trail. A small parking area will be added at the entrance of this trail. Revegetion is needed to make the entrance more attractive.

The Mill Creek Trail extends 1.1 miles from the Highlands Recreation Park down to the Mill Creek Bridge and across to join with Oak Lane (Fig. 1). The section that needs to be revegetated was used during trail construction to move in machinery and also as a municipal entrance to reach a water and sewer access. Revegetation would help to discourage pedestrian use of the access area while keeping the right of entry clear for emergency and municipal uses.

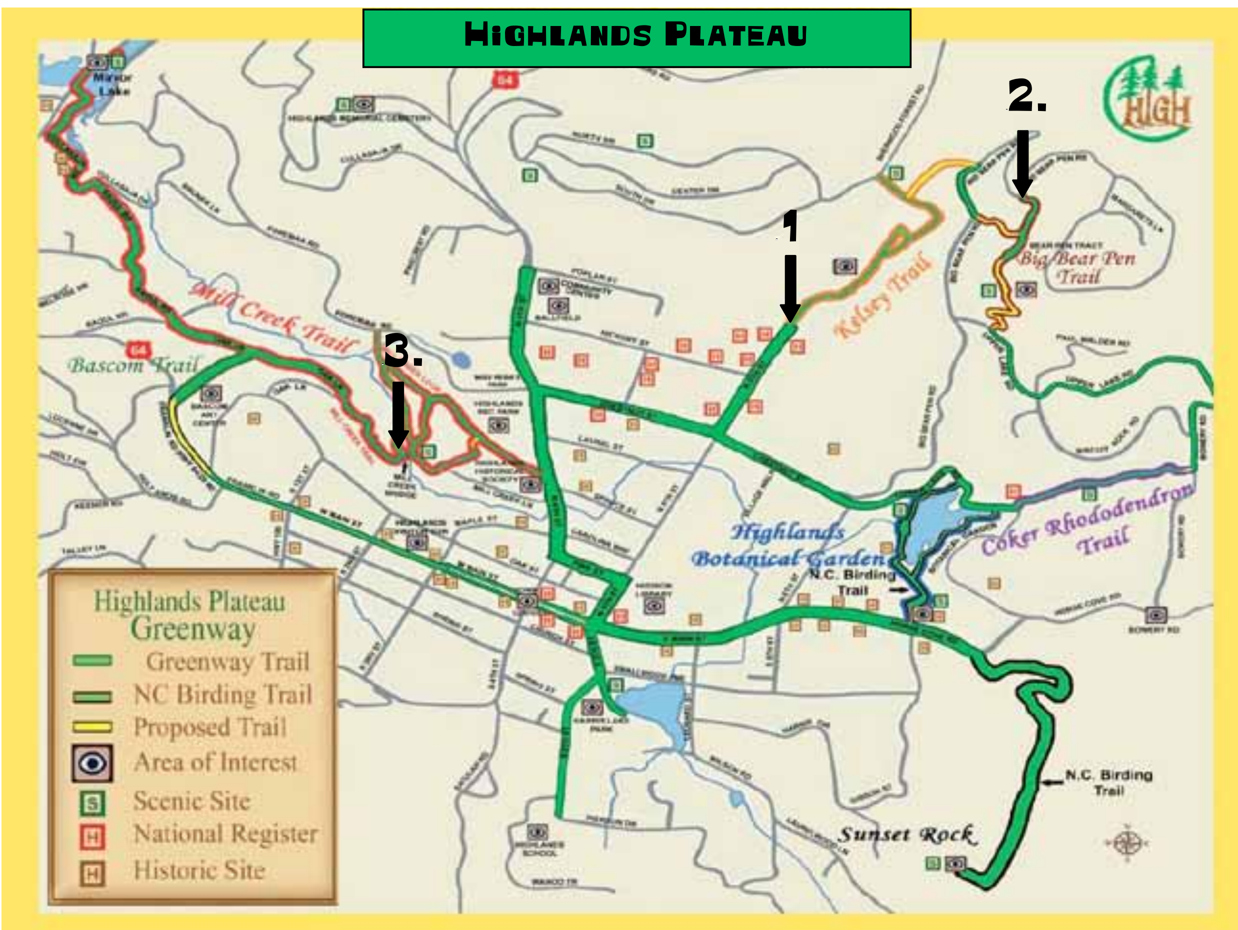

FIG. 1. Map of Highlands Plateau Greenway: 1. Kelsey Trail entrance, 2. Big Bear Pen Trail entrance, 3. Mill Creek Trail.

Assessment of the Kelsey Trail, Big Bear Pen Trail, and Mill Creek Trail sites were first made to characterize existing plant community types and total area available for revegetation (Table 1). This was important in determining appropriate plants for each site. It also helped to give a general idea of the size and number of plants that would be needed for each site.

TABLE 1. Community type and dominant vegetation for project sites.

Site	Community Type	DominantVegetation at Site
Kelsey Trail entrance	Old-growth Hemlock Forest	*Rhododendron maximum* *Kalmia latifolia* *Tsuga canadensis*
Big Bear Pen Trail entrance	Mixed Hardwood	*Rhododendron maximum* *Betula lenta* *Acer rubrum*
Mill Creek Trail	Mixed Hemlock-Hardwood	*Rhododendron maximum* *Tsuga canadensis* *Betula lenta* *Acer rubrum*

A master list of potential native plant material (see Appendix A) was made using the *Native Plants for Landscapes* brochure provided by the Land Stewards of the Highland Plateau. Planting information including common name, scientific name, plant characteristics, growing conditions and propagation information for each plant was taken from the Lady Bird Johnson Wildflower Center database (2009). Plants for the designs were chosen from the master plant list based on the appropriateness of plant habitat type to that of the site, bloom time, bloom color and commercial availability. The final plant list for the designs was approved by Highlands Biological Station horticulturalist, Cyndi Banks, and the availability of the plants was confirmed by local native plant nursery (Chattooga Gardens) owner, Jeff Zahner.

The dimensions of each site were taken using a field tape. The dimensions were converted to feet and inches in order to use an architectural scale for the landscape designs. A design for each site was drawn to scale using Google Sketchup 7.0. The designs were reviewed by local landscape designer Robert Tucker in order to insure appropriate size, spacing and number of plants. Planting guidelines, including planting and maintenance schedules, were developed with the help of both Robert Tucker and Cyndi Banks.

Volunteer support was encouraged by meeting with the Laurel Garden Club. A presentation about preliminary ideas and designs for the project was given at a monthly club meeting. Contacts were also made with the Land Stewards and Chattooga Gardens for help identifying potential plant sources.

RESULTS

Table 2 presents plant species recommended for revegetating each study site along the Highlands Plateau Greenway. The plants included in the designs are perennial wildflowers, small and medium-size shrubs, and ground cover. A total of 157 plants are needed for the revegetation project.

TABLE 2. Plant list and number of plants required for each Greenway site.

Kelsey Trail Entrance		Big Bear Pen Entrance		Mill Creek Trail	
Plant Name	Count	Plant Name	Count	Plant Name	Count
Gentiana andrewsii	5	*Solidago rugosa*	9	*Rhododendron maximum*	17
Aster laevis	21	*Helianthus angustifolia*	5	*Leucothoe fontanesiana*	13
Rudbeckia hirta	25	*Aster laevis*	7	*Polygonatum biflorum*	6
Dicentra eximia	9	*Silene virginica*	seed		
Xanthorhiza simplicissima	5				
Polystichum achrostichoides	6				
Silene virginica	11				
Phlox stolonifera	7				
Chasmanthium latifolium	6				
Leucothoe fontanesiana	5				

Table 3 shows a list of desired characteristics for each plant used in the designs. The goals of plant selection were to pick plants that would survive well at the sites, thus requiring little maintenance, and to have plants blooming for as much of the year as possible.

TABLE 3. Plant species selected for revegetation.

Plant Species	Characteristics
Gentiana andrewsii	Gentian bloom time ranges from August to October and the bloom colors are white, blue and light purple. It requires medium to high water usage, part shade to shade and it does well on humus rich, slightly acidic soils.
Aster laevis	Purple aster is found naturally at the Kelsey Trail entrance and Big Bear Pen Trail entrance. It blooms purple and requires shade to part-shade.
Rudbeckia hirta	Black-eyed Susan blooms yellow June through October. It requires sun to shade and medium water usage. It is found in moist, acidic, well-drained soils. Habitats include woodland edges.
Dicentra eximia	Bleeding Heart blooms from March to October with white, pink and purple bloom colors. The leaf color retention is evergreen. It requires medium water usage and part shade to shade. It prefers moist, humus-rich, acidic, rocky soils. It is found on rich, wooded slopes.
Xanthorhiza simplicissima	Yellowroot blooms in April and May with a purple bloom color. It requires shade and acidic soils. It is a sufficient groundcover at moist sites. The native habitats are moist woods and along stream banks.
Polystichum achrostichoides	Christmas fern is evergreen. It requires medium water usage, part shade to shade and moist, acidic soils. It is found in rich, rocky woods and along stream banks.
Silene virginica	Firepink bloom time ranges from April to August and the bloom color is red. It requires low to medium water usage and part shade. It does best in acidic soils in moist woods or on well-drained slopes.
Phlox stolonifera	Creeping Phlox is a good ground cover. It spreads quickly and can help stabilize banks, preventing erosion. It has a bloom time range from April to May with colors of white, blue and purple. It tolerates sun to shade and requires moist humus rich soils. The native habitat is woods and wooded stream banks.
Chasmanthium latifolium	River oats require medium water usage and are found in shade to part shade. It requires moist acidic soils. The native habitat is shaded slopes, low thickets and stream banks.
Leucothoe fontanesiana	Doghobble blooms in May and June and has a white bloom color. It requires part shade and moist, acidic soils. Its native habitats are rich woods, rocky ravines and stream banks.
Rhododendron maximum	Rhododendron blooms in white and pink in June. It requires part shade and medium water usage. It is found in moist, acidic soils. The native habitats are moist, dense woods, stream banks and mountain slopes.
Polygonatum commutatum	Solomon's Seal blooms from March to June with white, yellow, green and brown bloom colors. It forms quarter to half inch blue and black berries. It requires medium water usage and part shade to full shade. It does best in moist, rich, acidic woodland soils.
Solidago rugosa	Goldenrod blooms in September with a yellow bloom color. It requires medium water usage, sun and moist, well-drained soils. It is found in low woods.
Helianthus angustifolia	Sunflower blooms yellow in October. It requires part shade and medium water usage. It is found in wet acidic soils.

For the Kelsey Trail entrance, I recommend removing the existing rhododendrons planted by the Town of Highlands and moving them to the Mill Creek Trail location. *Kalmia latifolia*, also planted by the town, should be shifted to a sunnier spot at the end of the entrance (Fig. 2). This will permit the rhododendrons to be sited in a more suitable, shadier, location, freeing the space for re-planting with sun-loving perennials. The perennial selection allows there to be plants in bloom from March to October, as well as some evergreen plants such as *Polystichum achrostichoides* and *Dicentra eximia* (evergreen leaf-retention). Removal of *Rubus* is recommended along the slope leading down to the stream. *Phlox stolonifera*, *Xanthorhiza simplicissma* and *Chasmanthium latifolium* are suggested to replace existing *Rubus* as bank stabilizers, helping to reduce soil erosion. Seeds of *Rudibeckia hirta*, *Silene virginica* and *Dicentra eximia* should be distributed on the slope behind and between the planted perennials. This goal of using a combination of planting and seeding is intended to give the area a more natural appearance. Since seeds disperse and germinate unpredictably, inclusion of planted perennials provide insurance that attractive plants exist in the appropriate areas designated by the design.

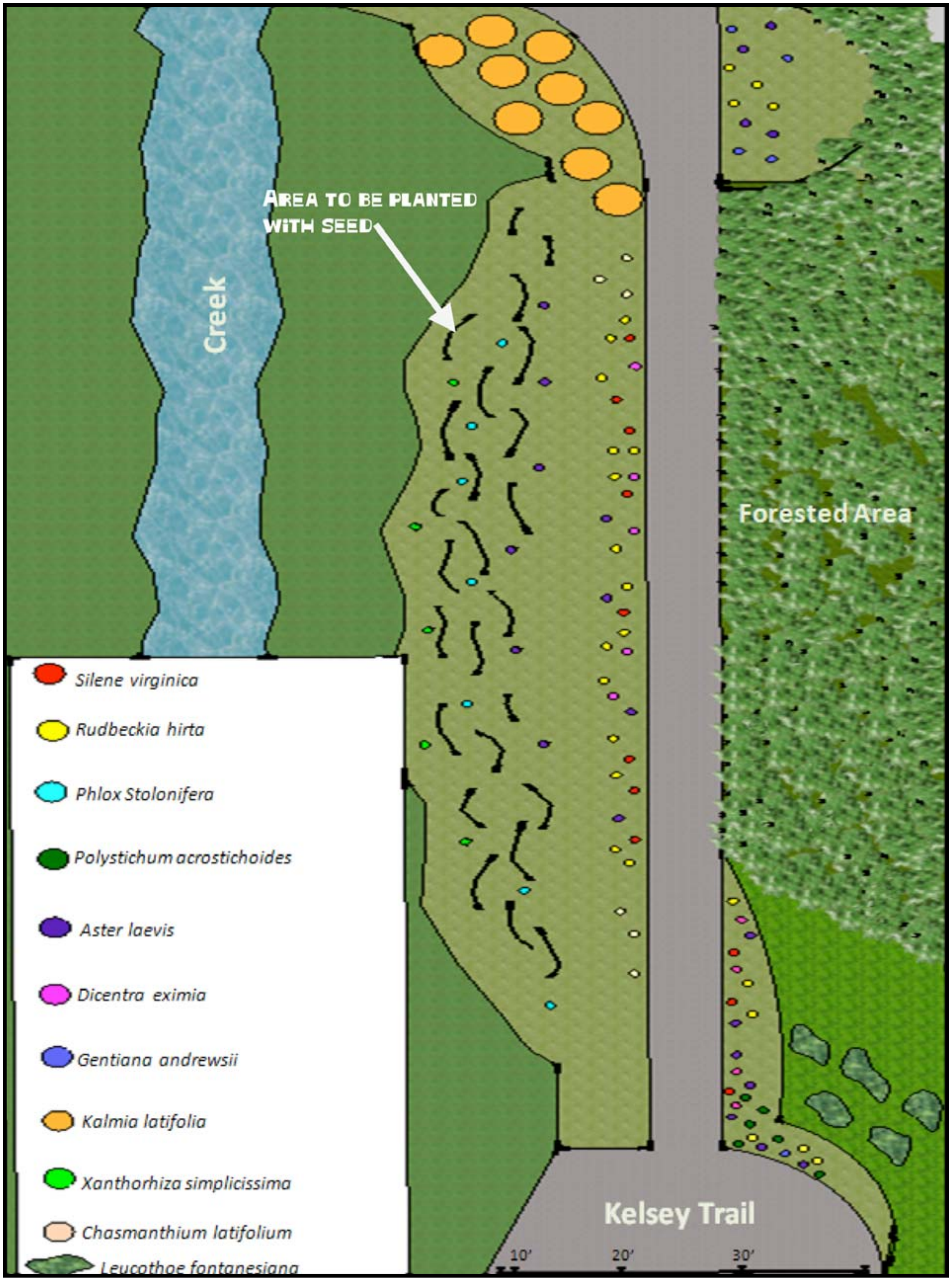

FIG. 2. Kelsey Trail entrance design.

The design for the Big Bear Pen Trail entrance included supplementing existing herbaceous perennials such as *Aster laevis* and *Solidago rugosa* with other complimentary native perennials, e.g., *Helianthus angustifolia* and *Silene virginica* (Fig. 3). Seed was chosen for the same reasons mentioned in the description of the Kelsey Trail Entrance, to create a more natural appearance.

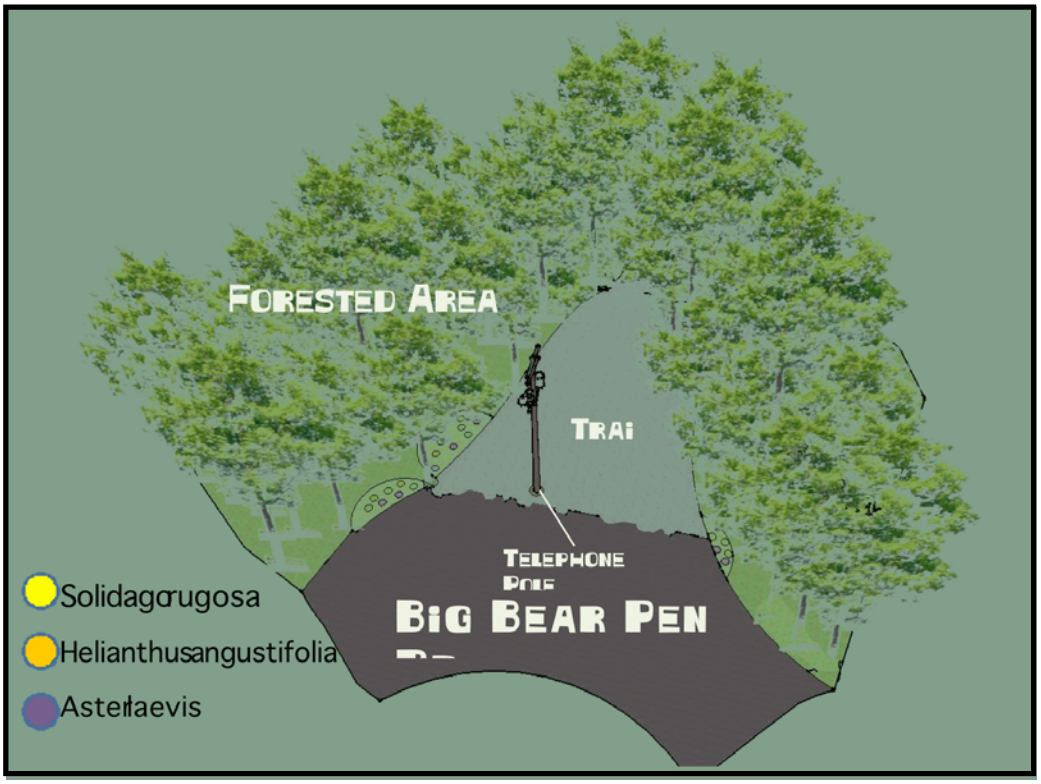

FIG. 3. Big Bear Pen Trail entrance design.

The goal of revegetation at the Mill Creek Trail site emphasizes functionality. The purpose is to essentially hide a path used to move trail construction equipment used by the Town for municipal access. The number and size of rhododendron and doghobble were determined to help close the gap and hide the trail without completely closing it off. Approximately 17 small rhododendron and 13 doghobble plants were needed to fill in the area (Fig. 2). Small sized plants were used for the design because smaller plants are more cost effective. Both rhododendron and doghobble, with appropriate spacing (approximately 2-3 ft apart), will grow to fill the space. Doghobble acts as an aesthetic "skirt" to the rhododendron, creating a variety of texture, but still staying with the green color scheme set by the rhododendron. Solomon's seal (*Polygonatum biflorum*) was added to create diversity in the sparse acidic cove herb layer. For this site, it is suggested that the rhododendron bushes be mulched with a natural pine or oak bark to help protect the root systems.

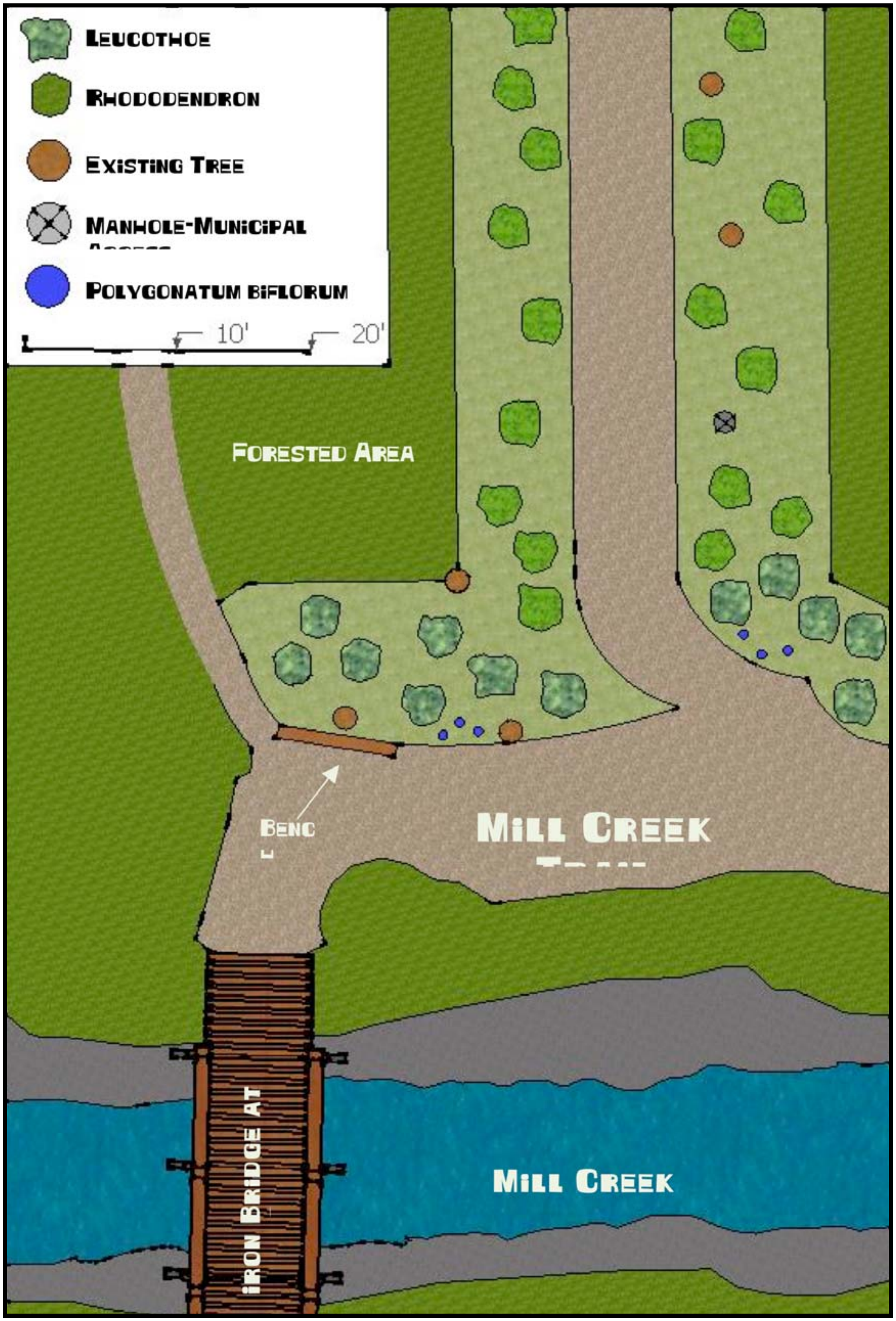

FIG. 4. Mill Creek Trail landscape design.

The price estimate for the plant material of the three sites was determined with the help of Jeff Zahner, totaling $1003 (Table 4.). Chattooga Gardens will be the main source for plant materials and Mr. Zahner has offered to donate native *Polystichum achrostichoides* to the revegetation project. Since the rhododendrons must be removed from the Kelsey Trail entrance before progress can be made on the Mill Creek Trail site, my recommendation is to prioritize the Kelsey Trail Entrance. The price for the Kelsey Trail entrance material is $373.00.

TABLE 4. Project Price Estimate.

Plant	Number	Price	Total per Species
Gentiana andrewsii	5	$3-4/plug	$20.00
Aster laevis	28	$1.50-2/plug	$56.00
Rudbeckia hirta	25	$1.50-2/plug	$50.00
Dicentra eximea	9	$1.50-2/plug	$18.00
Xanthorhiza simplicissima	5	$3-4 gallon pot	$20.00
Polystichum achrostichoides	6	Donated Plants	--------
Silene virginica	11	$1.50-2/plug	$22.00
Phlox stolonifera	7	$1.50-2/plug	$14.00
Chasmanthium latifolium	6	$1.50-2/plug	$12.00
Leucothoe fontanesiana	18	$35.00/gallon	$630.00
Solidago rugosa	9	$8.00/qt	$72.00
Helianthus angustifolia	5	$8.00 each qt. pot	$40.00
Rhododendron maximum	17	Transplanted	--------
Polygonatum biflorum	6	$14.00/qt	$84.00
Total:	157		$1003.00

For each site, plants should be planted in holes at least three times the size of the root system of the plant. The soil should be amended with a planting mix (Daddy Pete's Planting Mix® is the recommended choice) with a composition of one half natural soil to one half planting mix. The base of the plant should remain above the natural ground level. The soil will settle, and if the plant is below the natural level it will sink down further, compromising the root system. Plugs are suggested rather than potted plants. Although plugs tend to be smaller plants, over time they will grow to full size and are more cost effective that potted plants. It is suggested that plants come from trays with fewer than 72 cell plugs because trays larger than this tend to have plugs that are often too small for direct planting. All planting should take place in early March.

DISCUSSION

The goal of this project was the creation of plans for revegetation at three sites on the Highlands Plateau Greenway. In order to make this plan a reality, further commitments on funding must be made in order to make plant purchases. Although contacts have been made and the interested parties are aware of the pending project, currently there is no funding available. Likewise, commitments to volunteer labor will be necessary in order to realize the planting portion of the plan. Initial contacts have been made with interested parties such as the Laurel Garden Club and the Land Stewards.

Once funding becomes available, plants must be purchased. A plant source was determined (Chattooga Gardens) along with price estimates (Table 4.). Potential problems may arise if plant availability or prices significantly change between the time they were determined and the time of purchase. The availability of the master plant list may help to remedy this situation by offering ideas for suitable alternative plants.

The master plant list is potentially useful for other projects in the Highlands area. It can be used as a reference in future restoration projects since it only includes plants native to the Highlands area. It can also be used as an educational tool if made available via the internet (e.g., websites of the Highlands Plateau Greenway, Highlands-Cashiers Land Trust, and Highlands Biological Station) or through other means. This list could also assist with nearby Summit Charter School's planting decisions for their future school yard program. The natives from the list are all suitable species that can be used in demonstrating the importance of using native plants to attract wildlife. The master list indicates whether plants are larval hosts or important food sources for butterflies, moths and other insects.

In conclusion, the outcome of the project was three designs (Figs. 2-4) and plant lists for each design (Table 2) along sections of the Highlands Plateau Greenway. The designs and plant choices were made with both aesthetics and conservation in mind. Guidelines were included to help facilitate the implementation of the designs, as well as information on how to educationally interpret the designs to the public. The information collected for this project will potentially be applicable to future projects undertaken by the Highlands Plateau Greenway.

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APPENDIX A

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THE COWEETA LTER SCHOOLYARD PROGRAM STUDY BOXES: A MODEL FOR HANDS-ON SCIENCE TEACHING RESOURCES

SARA-ELIZABETH C. SENSENEY

Abstract. The effects of hands-on teaching strategies on science achievement have been debated among educators. Scholarship from the past two decades has shown that hands-on experiences increase students' problem-solving abilities, raising overall science achievement. In this paper, I provide the procedure used to assemble the Coweeta LTER Schoolyard Program study boxes, which provide equipment and activities to teachers in schools with limited resources. The study boxes provide a model for teacher resource kits that can be replicated in other counties to encourage hands-on science teaching, which will ultimately improve science achievement among primary and secondary school students.

Key words: constructivism; Coweeta LTER Schoolyard Program; hands-on; science education; teaching resource.

INTRODUCTION

The proper role of hands-on activities in science teaching is a topic of debate in the field of education. Teaching strategies for science education change as new educational theories emerge. Although perspectives on the objectives of teaching science have fluctuated with the changing tides of educational philosophy over time, the goal of science education being put forth by current reformers is one of scientific literacy. The definition of scientific literacy is age dependent, changing with each grade level. For the goals of scientific literacy to be met, however, students should acquire knowledge of the process of conducting science in addition to core concepts and facts required for their particular grade level (Stohr-Hunt 1996).

Lumpe and Oliver (1991) define hands-on science as a learning experience during which the student uses materials to observe the scientific process. Although hands-on strategies are being promoted in all subjects, science, by nature, lends itself to hands-on activities. Hands-on teaching is aligned with the educational theory of constructivism, which proposes that students construct knowledge based on their understanding of scientific phenomena (Tobin 1993). During hands-on activities, students are often confronted with observed results that may be in conflict with their preconceived notions. The student's resulting conundrum promotes higher order thinking and problem-solving skills, which are important for becoming scientifically literate (Lumpe and Oliver 1991).

Stohr-Hunt (1996) studied the effects of hands-on teaching strategies on science achievement in eighth-grade students in public and private schools. She found that the frequency of hands-on experience improved student achievement. Students that conducted hands-on activities at least once per week had higher science achievement scores than students who conducted hands-on activities less frequently (Stohr-Hunt 1996). Glasson (1989) investigated the type of learning benefited by hands-on experience. He found that while hands-on activities did not significantly affect factual or conceptual knowledge, students who conducted activities scored higher on tests of problem-solving abilities than students who watched a teacher demonstrate the same activity. The studies by Stohr-Hunt (1996) and Glasson (1989) show that students who are able to construct their understandings of scientific phenomena through physical manipulation of materials develop higher order thinking skills that contribute to scientific literacy.

The extent to which hands-on strategies are implemented in the classroom depends partially on the availability of lab materials. School budgets for science materials, particularly in elementary and middle schools, are often very small, limiting the resources teachers have for hands-on activities and labs in science. In this paper, I provide the procedure used to compile and advertise the Coweeta Long Term Ecological Research (LTER) Schoolyard Program study boxes, teacher resource boxes aligned with the North Carolina and Georgia standards for middle grades science. The study boxes are meant to provide teachers with equipment and activities for teaching major curriculum units using hands-on methods. Although the Coweeta LTER boxes provide valuable resources to teachers in Macon County, North Caroina and Rabun County, Georgia, there is a need for the boxes to be replicated elsewhere in order to benefit teachers and students in other areas.

METHODS AND MATERIALS

Conception and Funding

The Coweeta LTER Schoolyard Program study boxes were modeled after the science boxes created by the Georgia Museum of Natural History (http://naturalhistory.uga.edu) and the discovery boxes available from the Sandy Creek Nature Center in Athens, Georgia (www.sandycreeknaturecenter.com). Like the science and discovery boxes, the Coweeta study boxes were designed to provide teachers with free equipment and activities to conduct hands-on scientific studies. Funding for the purchase of materials was acquired from the National Science Foundation through a supplemental grant for education and outreach to the core grant for the Coweeta LTER.

Assembling the Boxes

Equipment and activities were selected based on their correspondence to the North Carolina and Georgia middle school science curricula. Equipment was obtained from scientific supply companies, such as Carolina Biological Supply Company. Upon receipt, the equipment was divided into six categories: geology, soils, biodiversity, stream study, light and sound energy, and heat energy. The equipment was placed in six separate large plastic storage boxes. At least one activity was selected for each piece of equipment. The activities included with the boxes are designed to promote hands-on manipulation of scientific equipment and ask students to formulate hypotheses. The activities were taken from teacher resource books, including Friedl and Koontz's *Teaching Science to Children: An Inquiry Approach* (2004), and websites like LEARN NC (http://www.learnnc.org). Activities were divided according to subject, organized in three-ring binders, and placed in each box. Inventory checklists and study box evaluation forms were added to the activity notebooks in each box.

FIG. 1. The stream study box includes materials for students to investigate hydrology, water chemistry, biodiversity, and indicator species.

RESULTS

Study Boxes

Each of the six study boxes contains equipment and activities to promote hands-on teaching (Fig. 1). A complete list of the equipment and activities in each box is included in Appendix A. The notebooks provide teachers with ready-to-use, flexible activities that use the equipment found in each book. Containing activities and equipment, the boxes will enable teachers to use hands-on strategies with reduced planning time and cost.

Outreach, Accessibility, and Improvement

The Coweeta LTER Schoolyard Program study boxes are accompanied by an advertising plan to reach teachers, a system to ensure convenient access to the boxes, and an evaluation procedure for future improvement. Information about the contents and purpose of the study boxes are available via the internet and a brochure, which is included in Appendix B. The brochure has been distributed at teacher conferences, including the North Carolina Science Teachers Association Professional Development Institute in Greensboro. Teachers can read the brochure for a short summary of each box or visit the website for a complete list of the equipment and activities in each box. A press release was published in local newspapers to raise awareness about the study boxes. Teachers can reserve a study box by phone or email. Depending on the teacher's location, the boxes can either be delivered to the teacher or picked up from the Coweeta Hydrologic Lab, which is located in Otto, North Carolina approximately equidistant from schools in Macon County, North Carolina and Rabun County, Georgia. Each box has an evaluation form to be filled out by teachers that use the resource. The evaluation seeks to identify the equipment and activities that are being used most often and those that are used occasionally or not at all. The feedback from teachers given through the evaluations will be used to improve the existing boxes. The evaluations will also be helpful if the Coweeta LTER Schoolyard Program chooses to replicate portions of the boxes by forming mini-boxes that would reach more students at a lower cost.

DISCUSSION

The Coweeta LTER Schoolyard Program study boxes provide teachers with the necessary equipment for hands-on teaching at no cost to schools. Having free equipment available to teachers will likely increase the frequency with which students in Macon and Rabun Counties have hands-on experiences in science class. Based on the conclusions of Glasson

(1989) and Stohr-Hunt (1996) regarding the positive effects of hands-on learning on science achievement and the theory of constructivism proposed by Tobin (1993), the Coweeta LTER Schoolyard Program study boxes should improve science achievement, particularly problem-solving abilities, by allowing students to personally observe scientific phenomena.

The scope of the study boxes is limited, however. With only one set of six boxes, the resource benefits a fairly small number of students, serving middle school students in only two counties. There is a need for similar teacher resource kits to be developed by organizations in other areas in order to support the goal of scientific literacy on a broader geographic scale. Federal funding requires that the Coweeta LTER conduct outreach work. The Schoolyard Program serves as an outreach arm of the Coweeta Hydrologic Laboratory, thereby helping the Coweeta LTER maintain its federal funding. The Coweeta LTER Schoolyard Program study boxes could be replicated by other science research groups, which would satisfy their outreach requirement and further the goals of science education by connecting education to research.

Transportation of the study boxes to teachers wishing to use the resources, particularly in rural areas where the distance between schools can be great, poses a challenge to replication of the study box idea and is an area of the program that needs to be improved. The transportation procedure currently being used by the Coweeta LTER requires time and energy of Coweeta employees or teachers, which may reduce the number of teachers who choose to use the resource. The Coweeta LTER Schoolyard Program study boxes, though limited in their scope, serve as a model for science education programs serving elementary and middle school students in other areas.

ACKNOWLEDGEMENTS

Thank you to Jason Love for an inside view of the interplay between research and education; to Jennifer Love for her initiative in creating the study boxes and for her science teaching wisdom; and to Dr. Anya Hinkle and Dr. Jim Costa for their meticulous editing and kind criticism.

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APPENDIX A

Goals, equipment, and sample activities for each of the six Coweeta LTER study boxes.

I. Geology box

A. Description and goals

The geology box includes materials and activities for students to explore topics outlined in the North Carolina Standard Course of Study for middle school science. The study box covers topics that are included in the sixth grade Competency Goal 3, which include plate tectonics, the rock cycle, and earthquakes. Like the other study boxes, the geology box will help teachers meet Competency Goal 1 for sixth, seventh, and eighth grades, which states that students should develop an understanding of the process of scientific inquiry.

B. Equipment included

Metamorphic Rock Collection
Sedimentary Rock Collection
Igneous Rock Collection
Mineral Study Kit
Mineral Test Kit
Foam Cross Section Earth Model
Sedimentator Demonstration
Plastic Ware Kit
Earth Science Skills Game
Common Minerals Poster
Pangaea Puzzle Kit
The Southern Appalachians DVD and Guide
Geoblox Plate Tectonics Block Models
Geology Demonstration Kit
Paint Tray
Watering Can
Earthquakes Hands-on Activity Book
Become a Rock Detective
AIMS Earth Book
Easy Science Demos and Labs Book

C. Sample activities

Rock Stories – students examine rock samples and group them according to shared traits
Metamorphic Rocks – cookie baking activity that models the formation of metamorphic rock
Crayon Rock Cycle – crayons are melted and cooled to show how different rocks form
Making Sandstone – activity using sand and Epsom salts to model the formation of sandstone
Paper Crystal Models – investigation of the crystal forms of minerals by building paper models
Mountain Building – simulation using clay to model tectonic plate movements
Plants Make the Difference – demonstration of the effects of vegetation on soil erosion
Build a Seismograph – students build a seismograph and record vibrations

II. Soils box

A. Description and goals

Activities in the soils box focus on determining the origins of different types of soils and how the attributes of various soil types affect plants and animals. The equipment and activities in the box will help teachers reach the objectives in Competency Goal 3 for the sixth grade, which relate to soil properties, including pH, particle size, erosion, temperature, and soil moisture. The study box helps students develop an understanding of scientific inquiry and experimental variables.

B. Equipment included

Screen Sieve Set
Bi-metal Dial Thermometer
Light and Moisture Meter
Winogradsky Column Set
Soil Sampling Tube
Lo Ion Test Kit
Soil and Life Earth Science Source Book
The Globe Soil Color Book

Topsoil Tour
Magnifying Sample Box
Aspirator

C. Sample activities

Soil Study – students observe the color, grain size, and living organisms in a soil sample
Looking for Life – students survey and record the organisms in a soil sample
Critter Guide – a field guide to insects and worms found in soil
Soil Temperature – students measure soil temperature at a field site over time
Soil Analysis – students observe soil contents, look for organisms, and measure soil pH
Dirt Pudding – a cooking activity to explore soil profiles with pudding and cookie crumbs
Digging Up Clues – students solve a mystery with their knowledge of soil types
The Sand-trap Blues – students investigate the source and quality of sand at a golf course

III. Light and sound energy box

A. Description and goals

The light and sound energy box groups light waves and sound waves together, so that students may understand the commonalities between the two forms of energy. The study box corresponds to the sixth grade Competency Goal 6, which addresses the topic of energy transfer. The equipment and activities in the study box will help students develop an understanding of properties of sound energy and the anatomy of the ear. Additionally, the box includes aids for teaching about light waves, color, and the anatomy of the eye.

B. Equipment included

Buzzy Bee Sound Investigation
Human Ear Model
Tuning Fork Kit
Physics Essentials DVD
Human Eye Model
Acrylic Prism Set
Acrylic Lens Set
UV Intensity Meter
UV Changing Beads
Purple and White Tube
Light, Lenses, and Lasers DVD
Slinky
Spectroscope
Concave and Convex Mirrors
Diffraction Grating Glasses
Ray Box and Color Filter Set
Slide Whistle

C. Sample activities

Which Way? – students test their hearing ability with only one ear versus two
The Phenomenon of Sound – students observe how sound moves through different materials
The Big Splash – sound vibrations are demonstrated by placing a tuning fork in water
Inside My Eye – a printed handout of a labeled eye to accompany the human eye model
Looking at Lenses – students test convex and concave lenses to see which will serve as a projector
Internal Reflection – a demonstration of the reflective properties of water
Just Passing Through – students observe objects with differing degrees of translucency
Groovy Guitar – students construct a mini-guitar with a rubber band

IV. Heat energy box

A. Description and goals

The heat energy box is correlated with topics covered in the sixth grade Competency Standard 6, including thermal radiation, expansion, thermal conductivity, and convection. The equipment and activities in the box help students experience the scientific phenomenon associated with heat energy.

B. Equipment included

Ball and Ring Apparatus
Thermal Conductivity Bar Set
Convection Apparatus for Gases
Thermal Radiation Kit
Changing States of Matter DVD

C. Sample activities

Hot-Air Balloon – air trapped in a cold bottle inflates a balloon as it warms
Magic Needle – a demonstration of metal contraction and expansion
When Hot and Cold Meet – students observe dyed hot and cold water mixing by convection
The Heat Race – a demonstration of conduction of heat through metal
Smoke-a-Risin' – smoke moves within a convection cell made with a jar
Seeing the Invisible – an activity to show the connections between light and heat energy
When You're Hot, You're Hot – an experiment to test the effect of color on heat absorption
Energy on the Move – an investigation into the transfer of kinetic energy to heat energy

V. Stream study box

A. Description and goals

The stream study box includes materials to explore stream hydrology, biodiversity and indicator species, and water chemistry. Students can use the material to measure stream flow, water pH, and dissolved oxygen. Additionally, the box includes materials to conduct a macro-invertebrate study to assess the health of a stream. The stream study box corresponds to the eighth grade Competency Goal 3, which states that students should understand the hydrosphere on a global and local level, be able to assess water quality, and understand human impacts on water quality.

B. Equipment included

Knowing the Health of Small Streams packet
200' Measuring Tape
Laminated Fish Cards
Orange Flags
Leaf Pack Macroinvertebrate ID Flashcard Set
Small Magnifying Sample Box
Yellow Lidded Magnifying Sample Containers
Stopwatch
Laminated Macroinvertebrate Cards on Strings
Macro Lens
10 Meter Measuring Tape
Hand Lens
Plastic Magnifying Glass
Forceps
Plastic Spoon
White Plastic Tray
Markers
Meter Sticks
Brushes
Droppers
Graph Paper Notebook
Stream Studies Folder
Curriculum Studies Folder
Upper Little Tennessee Watershed Curriculum
60 cm Turbidity Tube
120 cm Turbidity Tube
The Science Source Water Sampler
Turbidity Box
Bag of Plastic Petri Dishes with Lids
Dissolved Oxygen Box
pH Box
Nutrients Box
Yellow Seine Net
Square Dip Net
Field Sieve / Gravelometer
Stream Macroinvertebrates Posters
Laminated Watershed Maps
Hip Waders (available for check out separately)

C. Sample activities

The Water Molecule – explanation of the water cycle that traces a single molecule

All the Water in the World – an activity to explore the major stores of water in the world
Intro Lesson on Water Quality – a general lesson on topics related to water quality
How healthy is your stream? – an activity that incorporates several stream health indicators
Arthropod – an activity that explains the general anatomy of arthropods
Stream Insects and Crustaceans – a field guide to common macroinvertebrates
Where does water run off after school? – a study of water runoff that uses the school as a reference
pH Packet – a packet to give background for stream pH testing

VI. Biodiversity box

A. Description and goals

The biodiversity box includes equipment to explore the vast array of life outside of the classroom. The activities will get students excited about the life outside their classroom and teach them the importance of biodiversity in maintaining the health of ecosystems. The biodiversity box is correlated to the sixth grade Competency Goal 7, which specifies that students will investigate the interactions between organisms and the factors that affect populations of organisms.

B. Equipment included

Aerial Nets
Sweep Nets
Canvas Beat Sheets
Aspirators
Insect Viewing Jars

C. Sample activities

Biodiversity Blitz – students survey the biodiversity in their schoolyard
Children Collecting Bugs! – students survey all of the insects found within a certain area
Monarch Watch Citizen Science – a monarch tagging program to track butterfly migration
Sweep Net Experiment – students collect insects with nets and compare their locations

APPENDIX B

The brochure for the Coweeta LTER Schoolyard Program study boxes.

Coweeta LTER Schoolyard Program

The Coweeta Long Term Ecological Research (LTER) Schoolyard Program engages local school children in conducting their own field research into weather, biodiversity, stream quality, and human use of natural resources in the southern Appalachian Mountains. As in the Coweeta LTER Program, the emphasis in the Schoolyard Program is on collaborative, comparative, and synthetic research and the local and regional application of research results. If you would like additional information on the Coweeta LTER Program, please visit our website at: http://coweeta.uga.edu

Students use aerial nets during a butterfly biodiversity blitz in their schoolyard.

Who's inventorying who? A Monarch butterfly gets up close and personal during a schoolyard insect survey.

Coweeta LTER
(Long Term Ecological Research)
Schoolyard Program

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Coweeta LTER Schoolyard Program

Coweeta Study Boxes

Supplemental Classroom Activities for Teachers

COWEETA LTER

Study Box Overview

Geology Box
The geology box includes materials and activities for students to explore plate tectonics, rock formation, rock identification, and erosion. Sample activities include: Rocking the Rock Cycle, Layer Cake Earth, and Build a Seismograph.

Soils Box
Activities in the soils box focus on determining the origins of different types of soils and how the attributes of various soil types affect plants and animals. The box includes materials for testing the soil temperature, moisture content, pH, and nutrient content. Dirt Pudding, Looking for Life, and Digging Up Clues are some of the activities.

Students sort through leaf litter looking for stream macroinvertebrates.

Study Box Overview (continued)

Light and Sound Energy Box
The light and sound energy box groups light waves and sound waves together, so that students may understand the commonalities between the two forms of energy. The light materials include UV intensity beads and prisms. Tuning forks are available for students to explore sound vibrations. Activities include: Nothing But Blue Skies, A Buzzy Bee, and the Phenomenon of Sound.

Heat Energy Box
The heat energy box materials give students hands-on tools to explore the topics of thermal radiation, expansion, thermal conductivity, and convection. Some of the activities in the heat energy box are Energy on the Move and Smoke-a-Risin'.

Biodiversity Box
The Biodiversity Box includes equipment to explore the vast array of life in your schoolyard. Equipment includes aerial nets, beat sheets, and various field guides. Activities such as Biodiversity Blitz will not only get students excited about all the life outside their classroom, but will also teach them the importance of biodiversity in maintaining the health of ecosystems.

Study Box Overview (continued)

Stream Study Box
The stream study box includes materials to explore streamhydrology, biodiversity and indicator species, and water chemistry. Students can use the material to measure stream flow, water pH, and dissolved oxygen. Additionally, the box includes materials to conduct a macroinvertebrate study to assess the health of a stream.

Students use a kick-net to collect stream macroinvertebreates

Study Box Availability

The study boxes are based on the North Carolina and Georgia standards for middle school science. Boxes may be checked out for up to three weeks. For more information on the Coweeta LTER Schoolyard Program or to reserve a study box, visit:
http://coweeta.uga.edu
Or email:
cwtyard@uga.edu

FISHING FOR ANSWERS: AN ANALYSIS OF BIOMONITORING TRENDS IN SEVEN DIFFERENT WATERSHEDS WITHIN THE LITTLE TENNESSEE RIVER BASIN

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Abstract. The Upper Little Tennessee watershed hosts approximately one quarter of the fish species found in the entire Tennessee River Valley making it an important area to study fish populations as indicators of water quality. Since 1990 Dr. Bill McLarney of the Little Tennessee Watershed Association has been collecting data on fish populations within the watershed. Recently his data has been transcribed into a relational database by John Chamblee of University of Georgia and Coweeta Hydrological Lab. We performed quality assurance and quality control checks on the database and used ArcGIS to map and analyze the corrected data with regard to land use change in seven watersheds within the Upper Little Tennessee watershed. Over the sampling period, we found that there was an overall change in land use from agriculture to deciduous forest and an increase in development in every watershed. Land use appeared to correlate with IBI scores, overall fish abundance, species diversity, and the abundance of indicator species when examined in ArcGIS.

Keywords: darter; fish abundance; fish diversity; IBI, land use; Little Tennessee River; stoneroller; Tennessee River Valley; Upper Little Tennessee watershed; yellowfin shiner; yellow perch.

INTRODUCTION

The Little Tennessee River, which flows from northeastern Georgia through western North Carolina into Tennessee, is host to a diversity of aquatic organisms and stands out among rivers in the Blue Ridge Province because it is largely free of industrial pollution. The headwaters of the Little Tennessee River begin in Rabun County, Georgia. The section of the river near the Georgia – North Carolina state line that flows between Dillard, Georgia and Franklin, North Carolina along the U. S. 441 corridor receives the most industrial pollution. Although increasing sedimentation poses the greatest threat to biodiversity for much of the length of the Little Tennessee, pollution due to chemical runoff from roads and parking lots in the developed areas near the beginning of the Little Tennessee have a larger effect than sediment on water quality in Franklin and in areas to the south. Factories near the state line also add industrial pollution to the Little Tennessee. The Little Tennessee River widens into Emory Lake above Porters Bend Dam, located north of Franklin. The dam slows the river's flow, allowing sediment to fall to the bottom of the lake. Downstream of Porters Bend Dam, water quality improves, as the river flows northwest through the less developed areas of Macon and Swain Counties in North Carolina. As the river winds through mostly forested and agricultural land, sediment replaces industrial pollution as the greatest threat to water quality and organisms living in the Little Tennessee River. Sedimentation is due mostly to residential construction, vegetation removal in riparian areas, and stream bank erosion. Sedimentation in the Little Tennessee is the result of non-point source pollution, meaning that the overall increase in sediment loads in the river and its tributaries is due to many small, widely dispersed sources rather than a single large source. Industrial pollution near the headwaters of the Little Tennessee River and sedimentation along its length threaten the river's biodiversity (LTWA 2002).

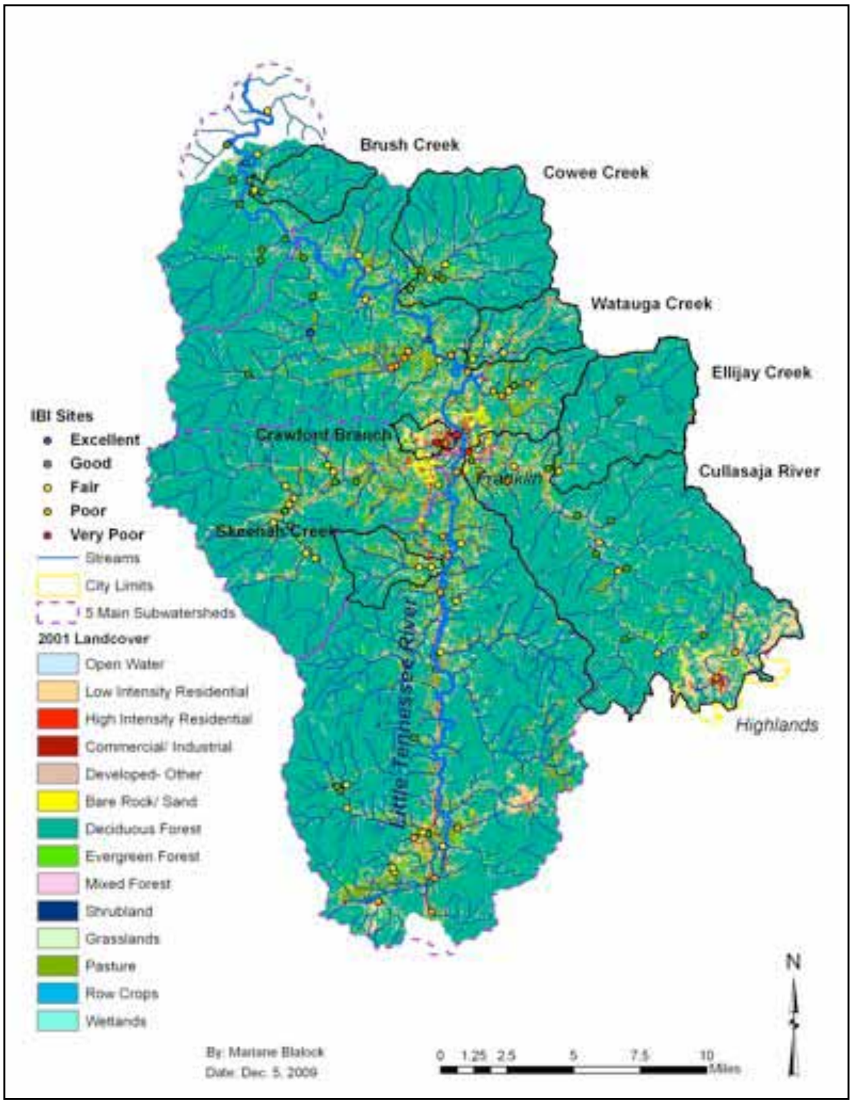

Fig. 1. The Upper Little Tennessee River watershed with the seven watersheds under study outlined in black overlaid on 2001 land cover data. (Land cover data were not available for the northern and southernmost areas of the watershed.)

The Little Tennessee River supports such rich biodiversity partly because of its relatively low levels of industrial pollution. The cool, pristine waters of the Little Tennessee provide habitat for a great diversity of important aquatic life, including many endemic, threatened, and endangered fish species. The area included in the Upper Little Tennessee watershed (the area upstream of Fontana Dam) accounts for just two percent of the total area in the Tennessee River Valley, but one quarter of the fish species found in the entire valley are found within the Upper Tennessee watershed. Although the Little Tennessee River has been impacted by human development, no known native fish species have been lost. The diversity of fish species found in the Little Tennessee River and the potential for improvement of water quality in the area make the Little Tennessee a unique area to study fish populations and stream health (LTWA 2002, NCEEP 2009).

A biomonitoring program was established by Dr. Bill McLarney of the Little Tennessee Watershed Association in 1990 to monitor fish species and to assess stream health in the tributaries of the Little Tennessee River in Rabun County, Georgia and Macon and Swain

Counties in North Carolina (Fig. 1). For the last twenty years, Dr. McLarney has conducted samples at more than 200 sites, including 15 fixed sites, which are sampled annually. An Index of Biotic Integrity (IBI) is used to assess the stream health based on the fish sampled (Table 1). The sample site is given a rating of very poor, poor, fair, good, or excellent based on the IBI score. The IBI scoring protocol used in the Little Tennessee River was adapted from Karr et al. (1986) by Dr. McLarney and is based on twelve criteria, including such metrics as number of native species, relative abundance of tolerant and intolerant species, and the percent of the fish in the sample that show evidence of disease or parasites. As a result of the biomonitoring program carried out by Dr. McLarney, twenty years of water quality data for the Little Tennessee River watershed are available and have already been used to inform policy decisions in the area (LTWA 2002)

TABLE 1. Summary of Index of Biotic Integrity (IBI) classes and their attributes.

Class	IBI Range	Attributes
Excellent	58-60	Sample includes all of the expected species for the type and size of stream. All species, including the least tolerant, are found. A balanced trophic structure is represented. The fish show a low incidence of disease and parasites.
Good	48-52	Species richness may be somewhat below expectations. Some intolerant species are lost. The trophic structure shows signs of stress.
Fair	39-44	Few intolerant species are found. Older age classes and predators may be rare.
Poor	28-35	Pollution-tolerant species dominate. Species with specialized habitat requirements and carnivores may be scarce. Disease and parasites are common.
Very Poor	12-23	Tolerant species dominate the sample. Fish may be either scarce or over-abundant (in nutrient-rich rivers). Disease and parasites are common.

In this report, data obtained by Dr. McLarney from 1990 to 2008 for seven of the watersheds within the Upper Little Tennessee watershed are analyzed. Quality assurance and quality control checks were performed on Dr. McLarney's data for the seven watersheds with the most complete sampling records. Microsoft Access queries were developed to extract data from the databases. The data were then mapped with other layers using ArcGIS® (ESRI 2008). Trends in the data were examined in ArcGIS® with regards to land use change shown by land cover layers. The queried data displayed in ArcGIS® provide a starting point for further analysis.

MATERIALS AND METHODS

Watershed Maps

After first selecting the seven watersheds with the most complete sampling records from Dr. McLarney's biomonitoring efforts, watersheds were delineated by hand in ArcMap® (ESRI 2009) using topographic maps obtained from N.C. One Map (http://www.nconemap.com/), except for the large Cullasaja watershed which was delineated using USGS Hydrologic Unit Maps (http://water.usgs.gov/gis/huc.html). Basic measurements of watershed size (perimeter, area, stream length) were calculated using the XTools Pro Extension for ArcGIS (http://www.xtoolspro.com/). Land use was compared with land use coverages of Macon County for 1986 and 2001. The 1986 and 2001 land coverage data are available at the Coweeta Hydrologic Lab website (http:coweeta.uga.edu). Land cover classes were interpreted using the USGS (LCI) NLCD Land Cover Class Definitions (http://landcover.usgs.gov). Land use data for 1986 and 2001 were converted to percentages for each year using Fragstats® 3.3

(http://www.umass.edu/landeco/research/fragstats/fragstats.html). A difference in percentage of land cover type between years was calculated in Microsoft Excel. Land cover classes were further collapsed by general type (subcategories within the same overall category) for comparison among watersheds. Aerial photographs, available online at the Macon County Mapping Department's website (http://216.119.24.47/website/macgis/) were imported into ArcMap® and cropped to fit the watershed boundaries. Lastly, a shapefile containing Dr. McLarney's sites was created from the Access database and imported into ArcMap®.

Fish Data

Data was collected between 1990 and 2008 by Dr. Bill McLarney of the Little Tennessee Watershed Association. Sites were chosen to represent a variety of stream sizes and impacts, or to document special cases, as in changes in stream health after a recent development. Dr. McLarney's sampling protocol specifies that the portion of each stream monitored contains at least two pools, two riffles and two runs to accommodate all habitats. Two backpack electrofishing units are used to send electric current through the water to stun fish. Fish are captured in dip nets and seines; before they are released researchers count them and note species and, if applicable, presence of disease or damage. All information is recorded into a datasheet that Dr. McLarney uses to calculate IBI modeled after Karr et al. (1986). Datasheets are then transcribed into Microsoft Excel.

In 2008-2009, Dr. McLarney's datasheets were transcribed into a relational database (Microsoft Access) by John Chamblee and K. C. Love with the Coweeta Hydrologic Lab. In this study, the accuracy of the Microsoft Access data was checked against the original data sheets for quality control/quality assurance purposes. Any discrepancies were noted and changed in Access.

Queries were designed to investigate a series of 10 questions developed by the 2009 IE class and Dr. McLarney and written into structured query language (SQL) to run in Microsoft Access. The questions are as follows:

1. What was the IBI (Index of Biotic Integrity) score at each site for each year? IBI is a comprehensive metric that is calculated by considering 12 criteria relevant to stream health, each contributing an equal proportion to the final IBI score. These twelve criteria survey the total number of native species, the number of darter species, the number of centarchid species (other than micropterus), the number of sucker species, the number of intolerant species, the percentage of tolerant species, the percentage of omnivores, generalists, or herbivores, the percentage of specialized insectivores, the number of piscivores, the catch rate per unit effort, the percentage of darters and sculpins and the percentage of fish with disease or anomlies (Karr et al. 1986, LTWA 2002).
2. How many fish were caught at each site for each year? Generally, more fish are found in the larger streams, which are downstream and closer to the main river. The overall fish abundance provides a fundamental metric on which to cross reference other metrics for trends.
3. How many species were caught at each site for each year? Healthy environments, whether aquatic or terrestrial, tend to have high species diversity. Comparing the overall fish abundance to species diversity is especially useful when determining trends, and can infer possible disturbances in the watershed.

4. What is the relative abundance of central stonerollers at each site for each year? Stonerollers are herbivores and feed on algae. Algae increases with increased nutrient input and warmer water from higher light conditions when riparian buffers are removed.
5. What is the overall abundance of the yellowfin shiner at each site for each year? Although the yellowfin shiner in native in the adjacent Savannah River basin, it is an exotic species to the Little Tennessee River that is believed to directly compete with two native species, the Tennessee shiner and the smoky dace. Their range is thought to be expanding (NCWRC 2009).
6. What is the relative abundance of the yellowfin shiner at each site for each year? In many cases, exotic species can outcompete native species because they do not have natural predators and can thrive in disturbed habitats.
7. What is the overall abundance of yellow perch at each site for each year? Yellow perch is also an exotic species, recently introduced to the area in the 1990's.
8. What is the relative abundance of species classified as "intolerant" for each site for each year? Fish species vary greatly in their tolerance of different abiotic factors, such as sedimentation, chemical pollutants and temperature of the water. For the IBI metric, Dr. McLarney classifies 10 species collectively as "intolerant". These species are intolerant of different factors, but are the most extreme cases and disappear first after disturbances.
9. What is the relative abundance of species classified as "tolerant" for each site for each year? Dr. McLarney classifies 13 species as "tolerant" for the IBI metric. These species are the most extreme on the opposite end of the spectrum, and are usually the last to disappear from an area.
10. What is the relative abundance of all darters? There are 6 darter species that live in the Little Tennessee River watershed. Darters are intolerant to sediment because the small particles clog the interstitial spaces between pebbles and rocks in the streambed in which their invertebrate food sources live. Increases in sediment are thought to negatively impact most darter species.

Spreadsheets were generated in Access for each of the ten queries. Spreadsheets were manipulated in Excel to calculate relative abundance in queries 4, 6, 8-10 and then average values for each variable (e.g. average number of darters per site) were calculated for mapping purposes in ArcMap®. Spreadsheets were then joined separately to a copy of the sites layer's attribute table in ArcMap® so that each site now had extra information attached to it, such as the average abundance of darters, which could then be displayed on a map. The displayed data were overlaid on land cover data from the 1986 and 2001 and aerial photos to note any correlations of the query results to land use or land use change. Each watershed was then examined for trends according to the ten queries, between each site within the same watershed and then generally over all seven watersheds. This study was meant to establish a baseline for future analysis of the fish data by assuring accuracy among the data and then visually displaying the information, organized into watersheds, to observe general trends and encourage future research.

RESULTS AND DISCUSSION

Site Characteristics Summary

Using topographic map layers, relevant features were summarized for each of the seven watersheds in the present study (Table 2).

TABLE 2. Site descriptions for each of the seven watersheds under analysis.

Watershed	Site Description
Brush Creek	Brush Creek is located in the Cowee Mountains in Swain County, with the main two branches beginning just north of Flower Cove and just north of Low Gap. The watershed boundary goes through Indian Grave Gap, Pinnacle Knob, Caler Knob, and Low Gap along the Swain and Macon counties border for the southern portion of the watershed. Above the county border, the watershed boundary extends north into Swain County around Flower Cove and west towards Soapstone Knob, and also includes Mica Knob and Gape Cove. Slightly south of the 95^{th} river mile, Brush Creek intersects the Little Tennessee River from the east, halfway between Windy Gap and the Needmore Tract. There are no major cities situated within the watershed, although Highway 441 goes through the western portion of the watershed, upstream of the IBI rated sites.
Cowee Creek	The headwaters of Cowee Creek are located within Nantahala Game Lands in the Nantahala National Forest. The tributaries of Cowee Creek include Beasley Creek, Blazed Creek, Mica City Creek, Huckleberry Creek, Shepherd Creek, Caler Fork, Matlock Creek, Rickman Creek, Wests Branch, Tippet Creek, and Dalton Creek. Cowee Creek flows under Highway 28 near the towns of Wests Mill and Cowee and intersects the Little Tennessee River at the base of Hall Mountain. From its intersection with the Little Tennessee River, the boundary of the Cowee Creek watershed runs NW along the ridge of the Mouse Mountains to Grant Knob. Soon thereafter, the boundary intersects the border between Macon and Swain Counties. The watershed boundary crosses Davis Bald, Shepherd Bald, and Leatherman Knob before it intersects with the border between Macon and Jackson Counties near the lookout tower on Cowee Bald. The boundary follows the county border until Rocky Face Knob, where it cuts SW over Flowers Gap. The watershed boundary continues westward over Lyle Knob and Mason Mountain before intersecting again with the Little Tennessee River.
Crawford Branch	Crawford Branch starts in the Nantahala National Forest on the southeastern slope of the Trimont Ridge. Crawford Branch intersects the Little Tennessee River in downtown Franklin just north of Main St. The watershed boundary follows the Trimont Ridge for the northwest section but then follows nondescript hilltops around the Town of Franklin. Crawford Branch watershed encompasses much of the Town of Franklin including downtown. Major roads that run through the watershed are Main St. and part of Highways 23 and 64.
Cullasaja Main Stem	The many small tributaries to this river have been removed to focus on the main stem of the Cullasaja. In this analysis, the main stem of the Cullasaja begins just below Whiteside Mountain and terminates at the confluence with the Little Tennessee River in the town of Franklin. The watershed boundary runs NE from Franklin over Onion Mountain and Deerlick Knob to the Macon/Jackson County line at Corbin Gap. The northeast side of the watershed follows the county line from Corbin Gap across Kirby, Moss, Wildcat, Eagle and Wolf Knobs on over to Hogback, Blackrock, Yellow, Shortoff and Whiteside Mountains to Highlands. From Highlands, the watershed boundary extends west to Scaly Mountain and then North across the Fishhawks to Franklin. The watershed contains the towns of Highlands, part of Franklin, and the communities of Gold Mine, Cullasaja, Porter Cove, Higdonville, Ellijay, Mountain Grove, Shookville, and Buck Creek.

Ellijay Creek	Ellijay Creek flows into the Cullasaja river, which flows into the Little Tennessee River near Franklin, NC. The head waters come from the Cowee and Higdon Mountain ranges. The high peaks around the perimeter of the watershed include the Higdon and Cowee Mountain ranges, Snowbird Mountain, Deerlink Knob, Corbin Knob, Cedar Knob and Grindstone Knob. The communities of Berry Mill, Higdonville and Mountain Grove exist within the water shed boundary. The main road that runs through the watershed is Ellijay Road which turns into State Road 1001. The entire watershed is within the Nantahala National Forest, partially within the Nantahala Game lands.
Skeenah Creek	Skeenah Creek is fed by tributaries and intermittent streams that begin near the border of the watershed in the hills and mountains. The main stem of Skeenah Creek begins just North of Blaine Knob, flowing SE and finally intersecting with the Little Tennessee River in the town of Prentiss below Sanders Knob. The watershed boundary bisects Prentiss, following the ridgeline NW to Pendergrass Mountain. From here it continues westward to Patton Mountain and then south to Blaine Knob, Kate Knob, Pine Mountain, Skeenah Gap, and Black Mountain. From Black Mountain, the watershed boundary follows the ridgeline eastward to Bates Mountain and then NW back to Prentiss and the Little Tennessee River. The watershed contains a large portion of Prentiss, and the communities of Morrison, Addington Mill, Black Mountain, and Pleasant Hill. The watershed is also intersected by Highway 441 in the town of Prentiss.
Watauga Creek	Watauga Creek is located north of Franklin, North Carolina in the Cowee Mountains. It intersects the Little Tennessee River at Lake Emory, just north of the Porters Bend Dam. Thompson Branch, Coon creek, Hughes Branch, and Brown Creek all flow in to Watauga Creek. The watershed boundary runs north from the creek's intersection with the Little Tennessee to Lyle Knob where it turns East and runs along the border of Macon County to its northern most point at and Rocky Face Knob (elev. 4064 ft). The boundary then turns south, still following the Macon County border through Rattlesnake Knob and Buby Gap, then cuts west across Jane Knob, Brown Gap, Passmore Knob, Jack Knob and further to the Little Tennessee. The watershed includes the communities of Berry Mill and Brendletown and is intersected by Highway 23.

The watersheds varied by size and number of sampling sites. General site characteristics are summarized in Table 3.

TABLE 3. Perimeter, area, and site data for each of the seven watersheds used in the analysis.

Watershed	Perimeter (m)	Area (m^2)	Area (acres)	No. Sites
Brush Creek	21,294	19,726,081	4,874	3
Cowee Creek	36,766	67,165,971	16,597	6
Crawford Branch	13,604	6,338,358	1,566	4
Cullasaja Main Stem	89, 902	242,239,903	59,858.8	10
Ellijay Creek	34,471	53,516,354	13,224	3
Skeenah Creek	22,505	17,988,974	1,799	2
Watauga Creek	23,864	20,839,784	5,150	4

I. Brush Creek Watershed

A) Site Characteristics

The Brush Creek watershed (Fig. 1. *Brush Creek*) is located in the Cowee Mountains in Swain County, with the main two branches beginning just north of Flower Cove and just north of Low Gap. On the southern edge heading east, the watershed boundary goes through Indian Grave Gap, Pinnacle Knob, Caler Knob, and Low Gap along the Swain and Macon counties border. Above the county border, the watershed boundary extends north into Swain County around Flower Cove and west towards Soapstone Knob, passing Mica Knob and Gape Cove. Slightly south of the 95th river mile on the Little Tennessee, Brush Creek intersects the river from the east, halfway between Windy Gap and the Needmore Tract.

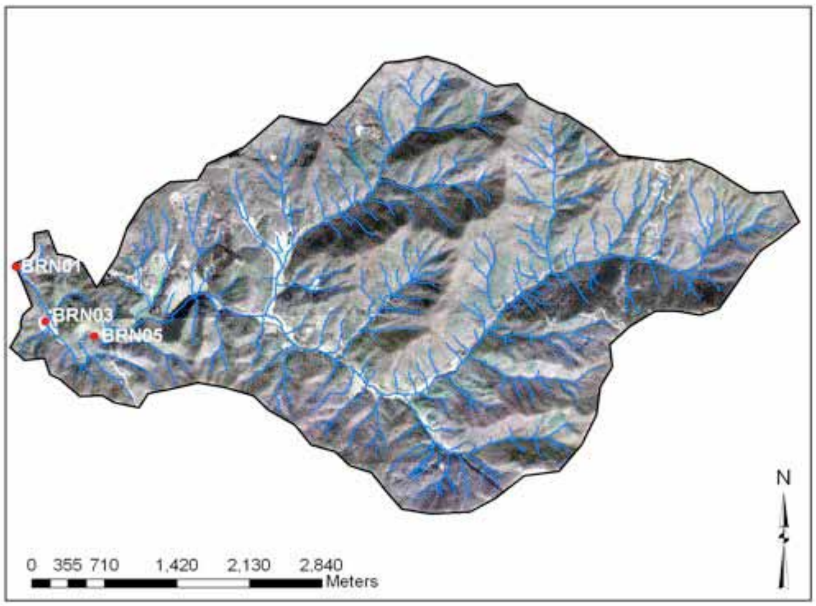

FIG 1. *BRUSH CREEK* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI), labeled by site ID, overlaid on 2001 aerial photographs of the Brush Creek watershed.

At its highest point, the watershed reaches up to 4,128ft, and at the lowest, 1,792ft. There are no major cities situated within the watershed, although Highway 28 goes through the western portion of the watershed, upstream of the three IBI-rated sites (Table 1. *Brush Creek*). The perimeter of the watershed is 21,294m, encompassing 4,874 acres (19,726,081m^2).

TABLE 1. *BRUSH CREEK* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI).

Site ID	Site Description
BRN01	Brush Cr.; RM 0.0-0.3; starting at mouth
BRN03	Brush Cr.; RM 0.5 at Hampton farm
BRN05	Brush Cr.; RM 1.1; upstream end of Needmore Tract

B) Land Cover

The majority of changes in land cover within the Brush Creek watershed between 1986 and 2001 are under 1% (Table 2. *Brush Creek*). Forested land slightly increased (2.14%), though the change for each forest type varied considerably, from a decrease in mixed forest of 0.64% to a very significant increase in deciduous forest of 6.18%. A possible reason for the significant decrease in evergreen forest coverage (-3.24%) could be contributed to different interpretations of coverage types when creating the land cover maps from aerial photographs. Different forest types can be difficult to distinguish on aerials, so evergreen and deciduous forests may have been lumped together under one category. The introduced Hemlock Wooly Adelgid that is drastically affecting Eastern Hemlock populations might also play a role in the decrease of evergreen forest, although by 2001, their affect would not be as evident as if it were to be re-assessed this year.

Another significant change is the overall loss in agricultural lands, with pastoral lands experiencing a decrease of 2.2% and row crops decreasing by 0.25%. This trend is not uncommon in the southern mountain region, nor is the general increase in residential and industrial areas. Though the increase in residential area is not significant for the Brush Creek watershed, high intensity areas appear for the first time in 2001, but only accounting for 0.01% of the entire watershed area. And though wetlands only accounted for 0.01% of the land cover in 1986, it is worth mentioning that they completely disappeared by 2001 (Fig. 2. *Brush Creek*).

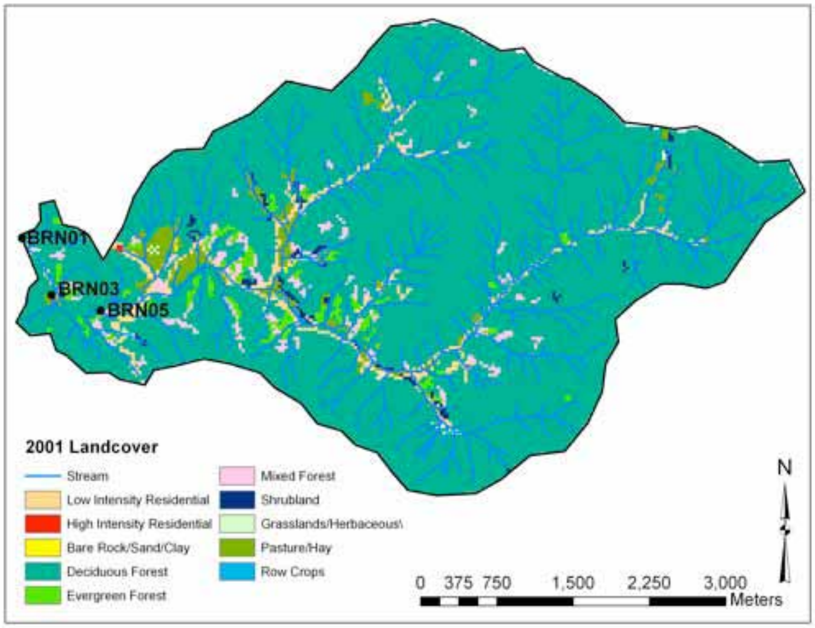

FIG 2. *BRUSH CREEK* – Land cover data from 2001 with sites labeled by site ID.

TABLE 2. *BRUSH CREEK* - Land cover in 1986 and 2001 in the Brush Creek watershed.

NCLD Class	Description	% in 1986	% in 2001	% Change
21	low intensity residential	2.93	3.05	0.12
22	high intensity residential	0	0.01	0.01
31	bare rock/ sand/ clay	0.08	0.05	-0.03
41	deciduous forest	83.46	89.64	6.18
42	evergreen forest	5.06	1.82	-3.24
43	mixed forest	2.64	2	-0.64
52	shrublands	0.55	0.68	0.13
71	grassland/ herbaceous	0.23	0.16	-0.07
81	pasture	4.76	2.56	-2.2
82	row crops	0.28	0.03	-0.25
90	wetlands	0.01	0	-0.01

C) Queries

The three quantitative sites in Brush Creek are within three index of biotic integrity (IBI) points from each other on the lower end of the “good” rating (48-52), if not slightly under (Fig. 3. *Brush Creek*). Out of the three sites, the site with the lowest IBI score of 47 (BRN03) is located at the downstream end of pastures on both sides of the creek. While a lower score is to be expected in impacted areas like agricultural fields, BRN03 maintains a relatively high IBI rating of “good”. The other two sites are situated in a deciduous forest and a sparse low intensity residential section. Unexpectedly, the low intensity residential site (BRN01) has the highest IBI rating, by two points. BRN05, which should have been the highest based on the forested surroundings, was sampled in 2000 and 2008 only, so any changes in land cover that may explain the unexpected outcomes are not illustrated in this map.

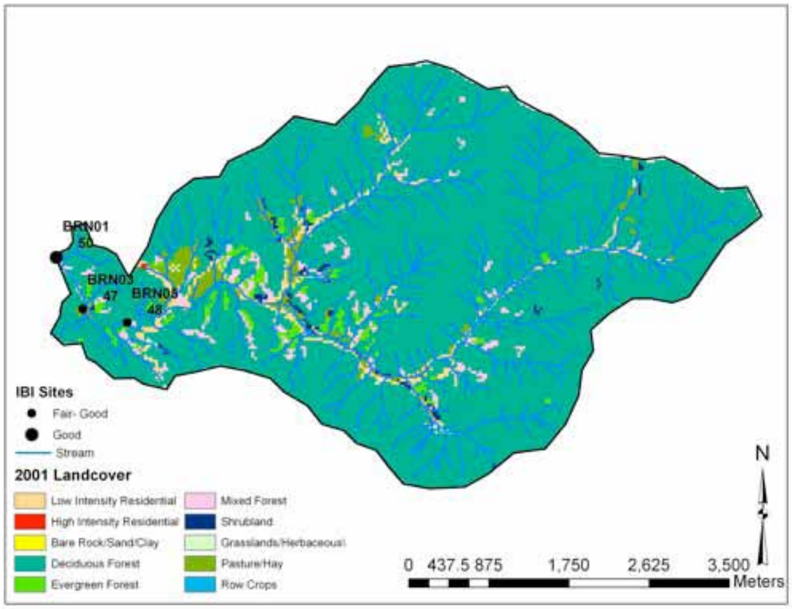

FIG 3. BRUSH CREEK – Index of Biotic Integrity (IBI) scores within the Brush Creek watershed displayed on 2001 land cover data for the

Among the three sites, BRN03 was sampled the most and had the highest average abundance of fish caught. BRN01 and BRN05 were sampled once and twice, respectively, averaging 238 and 300 fish caught. Samples at the sites never surpassed 362 fish caught in a year. BRN03, on the other hand, was sampled 6 times, and with the exception of 1990, the number of fish caught has not dipped below 364. In 1990, BRN03 only had 166 fish caught, but experienced a drastic increase to over 500 in 1998, and even 606 in 2006 before dropping to only 364 in 2008, giving that site an average of 420 fish caught per year.

Species diversity was not significantly different between the sites or through the years at each site, ranging from 14 to 16 species found per site (Fig. 3. *Brush Creek*). The highest of the species diversities found corresponds with the highest IBI, but also the lowest number of fish caught.

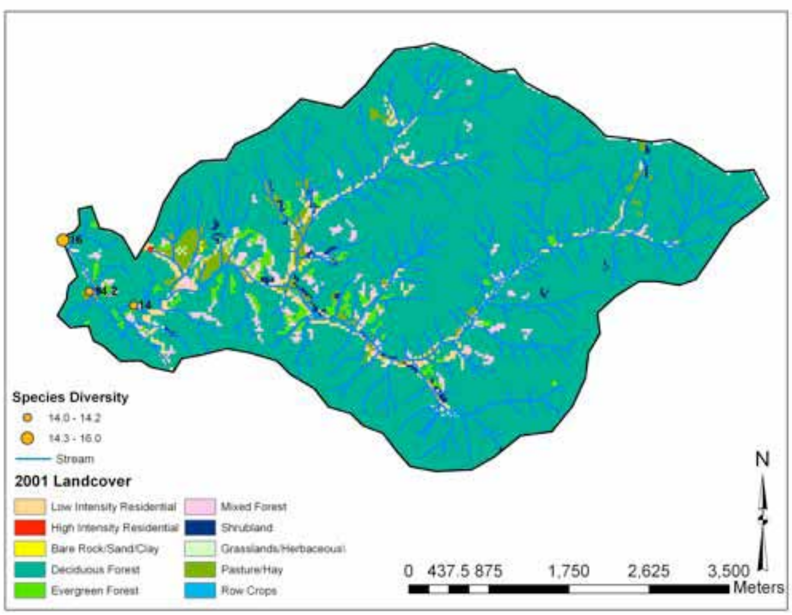

FIG. 4. *BRUSH CREEK* - Average species diversity per site within the Brush Creek watershed.

Relative abundance of two species, stonerollers and darters, were chosen for analysis because certain indicative characteristics they exhibit. The relative abundance of stonerollers was lowest (5.5% and 7.5%) in the sites with the highest IBI scores, and was significantly lower than the average abundances of stonerollers in the other site (16.6%). The highest stoneroller abundance was found at the site situated in pasture land, which is expected because stonerollers are correlated with minimal riparian buffer zones and a high concentration of sediment in the stream. Darters, which are more intolerant of sedimentation, have a mostly reversed trend. The highest relative abundance of darters (14.7%) was found at the site with the highest IBI score, and significantly less than at the other two sites. Interestingly, the lowest abundance of darters (1.2%) was found in the deciduous forest site, when it would have been expected to be at the agriculture site, which instead experienced 6% darters. The two exotic species investigated in this study, yellowfin shiner and yellow perch were not found at any of the Brush Creek sites for any years.

When species were grouped as tolerant and intolerant, general trends were evident through all three sites. The low intensity residential site with the highest IBI score had the highest percentage of intolerant (7.98%), and the lowest for tolerant species (0.84%). The forested site's percentage for tolerant species was not expected, being the highest by far at 6.5%, and only a middle value for intolerance at 6.1% (Fig. 5. *Brush Creek*). Since the forested and most upstream site is expected to have the healthiest stream, in terms of high IBI score, high species diversity, and a higher portion of darters, some explanatory data is missing. The land cover was only made in 2001, and this site was sampled in 2000 and 2008, meaning that a change in land cover which is not visible in these maps may account for the unexpected values. Recent development, whether agricultural or residential is a possibility, and could potentially explain why BRN05 ranked so low comparative to the other sites.

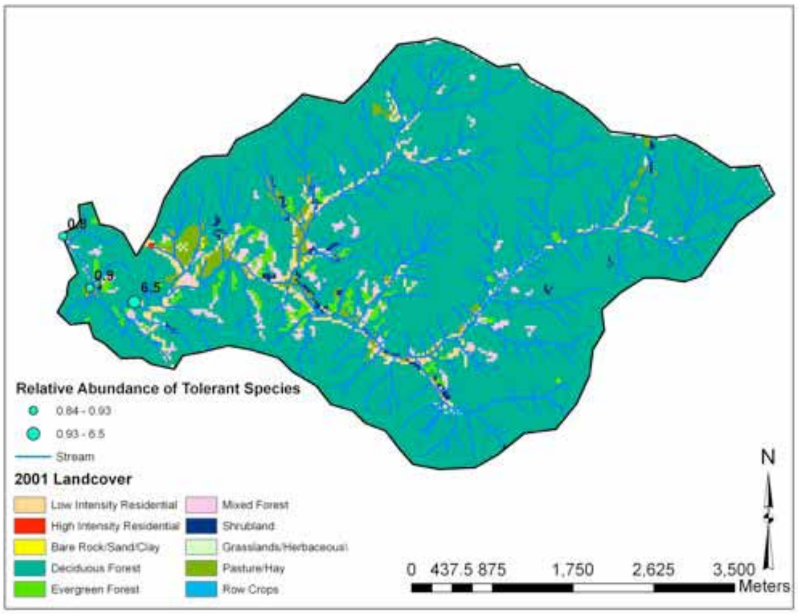

FIG 5. *BRUSH CREEK* – Average relative abundance of tolerant species per site within the Brush Creek watershed.

II. Cowee Creek

A) Site Characteristics

Cowee Creek flows southwest from its headwaters near Cowee Bald into the Little Tennessee River near the town of Cowee (Fig. 1. *Cowee Creek*). For the purposes of this analysis, the Cowee Creek watershed boundary begins at its intersection with the Little Tennessee River and runs NE along the ridge of the Mouse Mountains to Grant Knob. Soon thereafter, the boundary intersects the border between Macon and Swain Counties. The watershed boundary crosses Davis Bald, Shepherd Bald, and Leatherman Knob before it intersects with the border between Macon and Jackson Counties near the lookout tower on Cowee Bald. The boundary follows the county border south until Rocky Face Knob, where it cuts SW along Flowers Gap. The watershed boundary continues westward over Lyle Knob and Mason Mountain before intersecting with the Little Tennessee River again. The headwaters of Cowee Creek are located within Nantahala Game Lands in the Nantahala National Forest. The tributaries of Cowee Creek include Beasley Creek, Blazed Creek, Mica City Creek, Huckleberry Creek, Shepherd Creek, Caler Fork, Matlock Creek, Rickman Creek, Wests Branch, Tippet Creek, and Dalton Creek. Cowee Creek flows under Highway 28 near the towns of Wests Mill and Cowee and intersects the Little Tennessee River at the base of Hall Mountain. A few churches and the Cowee School are located near Highway 28. Cowee Creek Road (State Road 1341) runs from Highway 28 upstream along Cowee Creek before turning into Ruby Mine Road (State Road 1341). There are several other secondary roads within the Cowee Creek watershed.

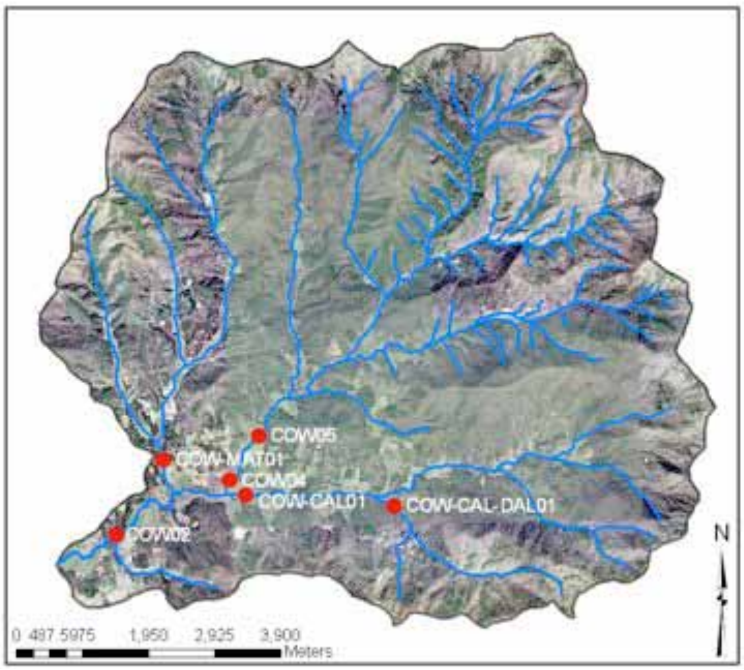

FIG. 1. *COWEE CREEK* – Sites where quantitative data were collected using the Index for Biotic Integrity (IBI), labeled by site ID, overlaid on aerial photographs of the Cowee Creek watershed.

The Cowee Creek watershed has a perimeter of 32,766m and an area of 16,597 acres (67,165,971 m^2). Index of Biotic Integrity (IBI) data were obtained from 6 sites within the Cowee Creek watershed (Table 1. *Cowee Creek*).

TABLE 1. *COWEE CREEK* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI).

Site ID	Site Description
COW02	1-29(1-2), Cowee Creek RM 0.7 at West's Mill
COW04	1-29(3-4), Cowee Creek RM 0.2 above Caler Fork
COW05	Cowee Creek RM 2.4 above Perry's Water Gardens
COW-CAL01	1-29(0-1), Caler Fork RM 0.3 at junction of Leatherman Gap and Ruby Mine Roads
COW-MAT01	1-29-2(0-1), Matlock Creek RM 0.4 at Snow Hill Road
COW-CAL-DAL01	1-29-3-1, Dalton Creek below Dalton Creek Road

B) Land Cover

Land cover data from 1986 and 2001 show changes within the Cowee Creek watershed. The most significant change was a nearly 11% increase in deciduous forest. Evergreen forest and mixed forest decreased by 3.4% and 1%, respectively, making the overall gain in forested land only about 6%. Development in the area increased only slightly, about 0.1%. The area of land devoted to pasture decreased by one half, declining from 12% in 1986 to only 6% in 2001. Row crops also decreased. Land cover changes point to a trend of a decrease in the amount of land used for agriculture and an increase in forested land and developed areas (Fig. 2. *Cowee Creek*).

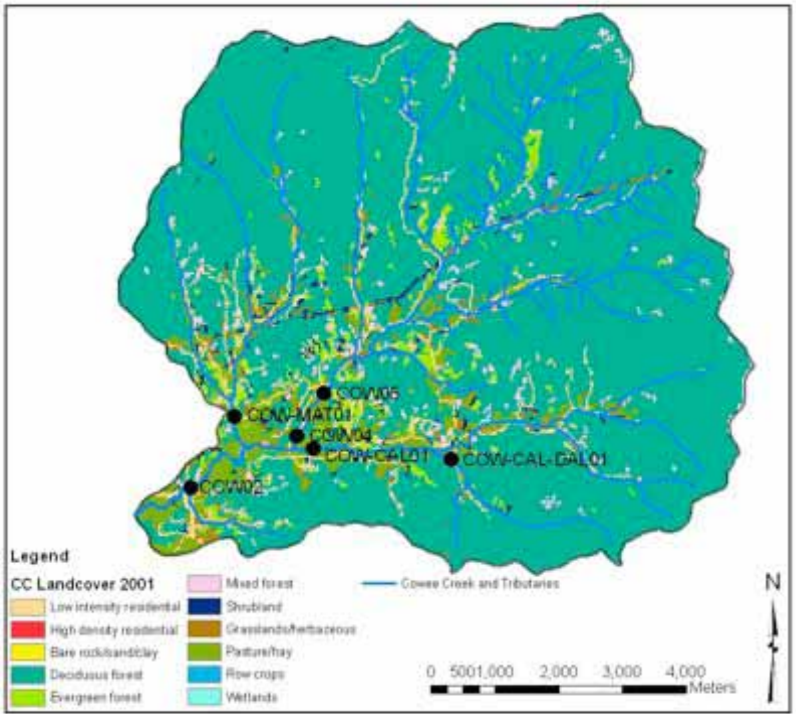

FIG. 2. *COWEE CREEK* – Land cover data from 2001 with sites labeled by site ID.

TABLE 2. *COWEE CREEK* – Land cover in 1986 and 2001 in the Cowee Creek watershed.

LCLD Class	Description	% in 1986	% in 2001	% Change
11	open water	0.005	0.000	-0.005
21	low intensity residential	3.177	3.276	0.099
22	high intensity residential	0.005	0.021	0.016
31	bare rock	0.094	0.026	-0.068
41	deciduous forest	72.615	83.571	10.956
42	evergreen forest	6.050	2.661	-3.389
43	mixed forest	3.185	2.142	-1.043
52	shrubland	1.832	1.081	-0.751
71	grassland/herbaceous (natural/semi-natural)	0.401	1.172	0.771
81	pasture	12.085	5.931	-6.154
82	row crops	0.449	0.032	-0.417
90	wetlands	0.102	0.086	-0.016

C) Queries

Average Index of Biotic Integrity (IBI) scores for sites within the Cowee Creek watershed were all fair or good (Fig. 3. *Cowee Creek*). The highest IBI score, 53.6, was recorded at COW02, which is the farthest downstream of all of the sites. The average IBI score at COW02 was calculated using data from seven samples obtained from 1997 to 2008. Scores were higher in earlier samples at COW02 and fell to 50 in 2002 and 2003 before increasing slightly by 2008. The lowest score, 41.0, was based on a single sample in 2002 at COW05. Three other

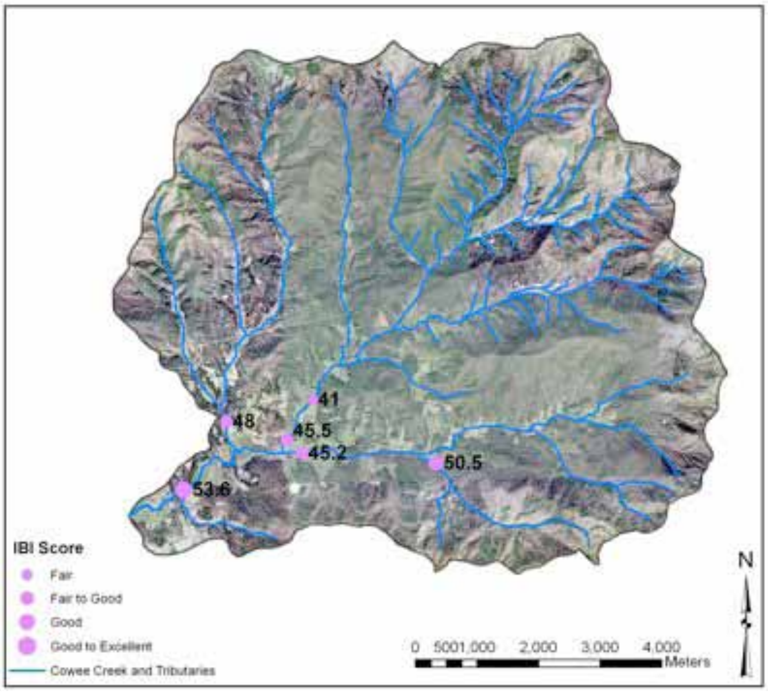

FIG. 3. *COWEE CREEK* – Index of Biotic Integrity scores for Cowee Creek displayed on aerial photographs of the area.

sites (COW-BEA01, COW-CAL-TIP01, and COW-CAL02, not shown in Fig. 3. *Cowee Creek*) were sampled using the IBI protocol but were not suitable for IBI scoring.

Average abundance at the sites was variable, ranging from 109.5 fish at COW-CAL-DAL01 to 602 fish at COW-MAT01. Sites farther downstream had higher average abundance than sites upstream, probably because the larger streams could support a larger fish population. At site COW02, average abundance was 514. At that site in 1990, only 72 fish were caught. The next sample was taken in 1997 and 524 fish were caught. By 2006, the abundance at COW02 reached 883. The low number from the 1990 sample may have been the result of disturbance, but there is no data prior to 1990 to compare with the existing data. Abundance fluctuated greatly over time at all of the IBI sites. For samples at most sites, years with low abundance are followed by years with higher abundance. There is no trend of a steady increase or decrease at any of the sites.

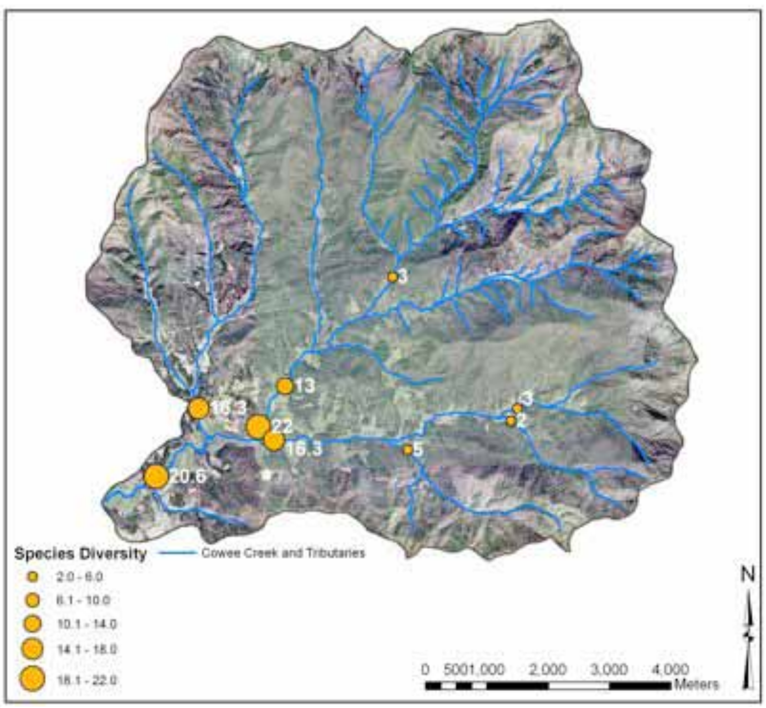

FIG. 4. *COWEE CREEK* – Average species diversity per site within the Cowee Creek watershed.

Average species diversity follows the same general trend as average abundance, with downstream sites exhibiting higher diversity than upstream sites (Fig. 4. *Cowee Creek)*. The highest average diversity, 22 species, was found at COW02, which had the most complete sampling record. Only five species were found at COW-CAL-DAL01. The four sites with the lowest average species diversity were only sampled once. Therefore, the trends shown by the data from these sites are not strong.

The sites with the highest relative abundance of stonerollers were those near the intersection of Cowee Creek and the Little Tennessee River, where there is cleared pasture and cropland along the stream. The agriculture and grazing near COW02, COW04, COW05, and COW-MAT01 increased the amount of nutrients and light available to the stream, which could explain the increased abundance of the herbivorous stoneroller.

The overall abundance of yellowfin shiners was low at all sites throughout the sampling period. The highest average overall abundance was 0.7 at COW02, which is located in the most impacted area of the watershed, near the confluence with the Little Tennessee River. Many sites had no yellowfin shiners. COW-CAL01 had the highest relative abundance, which was only 0.1%. The relative abundance of yellowfin shiners shows no clear trend over the sampling time.

No yellow perch were found at any sites during any of the sampling events.

Relative abundance of intolerant species corresponds with IBI scores and overall abundance. The sites with the highest relative abundance of intolerant species are those near the intersection with the Little Tennessee River. Curiously, these are also the sites in the area most impacted by development.

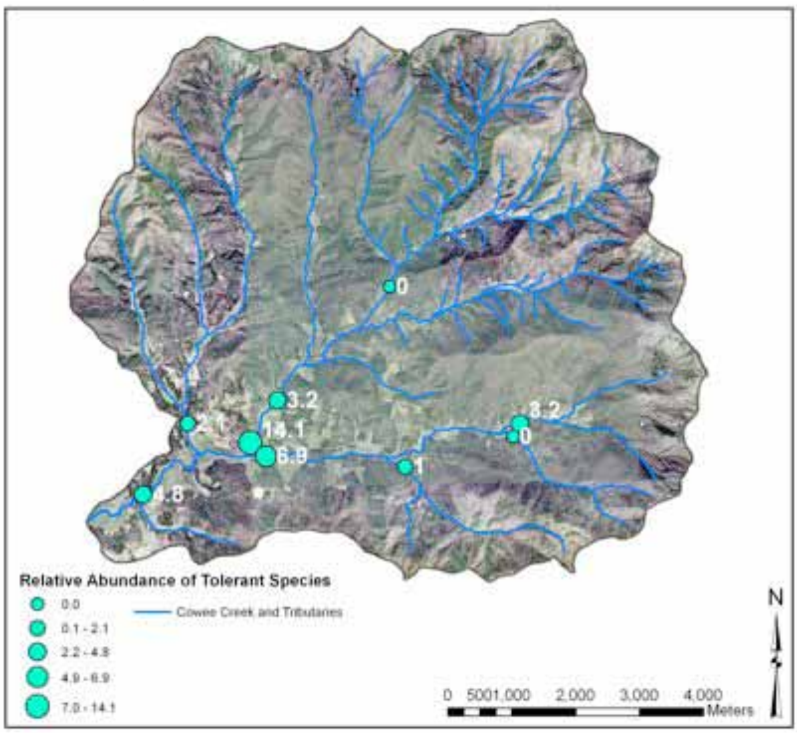

FIG. 5. *COWEE CREEK* - Average relative abundance of tolerant species per site within the Cullasaja watershed.

The average relative abundance of tolerant species varied by site from one at COW-CAL-DAL01 to 14.1 at COW04 (Fig. 5. *Cowee Creek*). COW04 is located within an agricultural area of the watershed and is flanked by pastures. The sites near COW04 also had fairly high relative abundances of tolerant species, probably due to decreased water quality in streams in this area.

The relative abundance of darters ranged from 0 to 24.6. COW02 had the highest relative abundance of darters. All of the sites on smaller tributaries of Cowee Creek had no darters. The cluster of sites near the intersection of Cowee Creek with the Little Tennessee River all had darters, though the relative abundance varied from 24.6 at COW02 to 4.8 at COW-MAT01. The presence of darters at the sites located near the agricultural fields suggests that although the cleared pastures do affect some aspects of stream quality, sedimentation is not a significant issue in the Cowee Creek watershed.

III. Crawford Branch

A) Site Characteristics

Crawford Branch starts in the Nantahala National Forest on the southeastern slope of the Trimont Ridge (Fig. 1. *Crawford Branch*). Crawford Branch intersects the Little Tennessee River in downtown Franklin just north of Main Street. The watershed boundary follows the Trimont Ridge for the northwest section and then follows nondescript hilltops around the Town of Franklin. Crawford Branch watershed encompasses much of the Town of Franklin including downtown. Major roads that run through the watershed are Main Street and part of Highways 23 and 64.

Of all the watersheds studied, Crawford Branch is the most urbanized. The large proportion of paved areas creates large amounts of runoff, sedimentation, and pollution in the creek. The quality of this stream and watershed are considered to be among the worst in the Little Tennessee watershed.

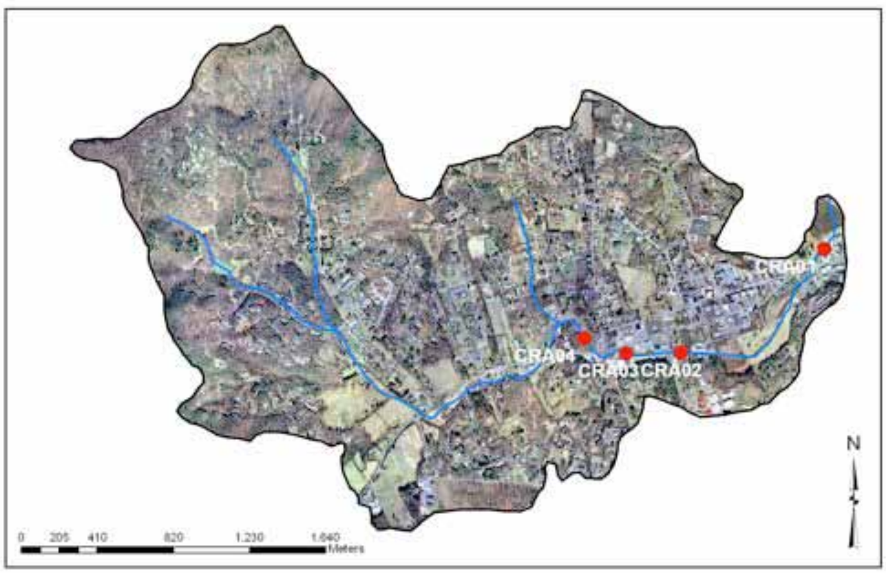

FIG. 1. *CRAWFORD BRANCH* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI), labeled by site ID, overlaid on 2001 aerial photographs of the Crawford Branch watershed.

The Crawford Branch watershed has a perimeter of 13,604m and an area of 1,566 acres (6,338,358 m^2 and 634 hectares). The length of the Crawford Branch with its tributaries is 4.35 miles or 7,013m; however, the main stem of the Crawford Branch is only 3.14 miles or 5,051m. Dr. McLarney collected IBI data from 4 sites in this watershed (Table 1. *Crawford Branch*).

TABLE 1. *CRAWFORD BRANCH* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI).

Site ID	Site Description
CRA01	1-36, Crawford Br., RM 0.3, E. Main St.
CRA02	1-36 Crawford Br. RM 0.5 at Heritage Hollow
CRA03	1-36 Crawford Br. RM 0.7 at Frogtown
CRA04	1-36, Crawford Br., RM 0.9, Franklin Memorial Park

B) Land Cover

Land use in the Crawford Branch watershed is dominated by development, namely low intensity residential (Fig. 2. *Crawford Branch*); high intensity residential and commercial developments in the area are significant as well. The total amount of developed areas has increased by over 3% from 1986 to 2001 (Table 2. *Crawford Branch*). The upper section of the watershed does have a fair amount of deciduous forests (35.6% in 2001), but still relatively low compared to other watersheds in the study. The amount of deciduous forest has increased by almost 12% over the 15 year period, which has most likely come as a result of reforestation of agricultural fields and pastures, which have decreased a combined 10.9% over the 15-year period.

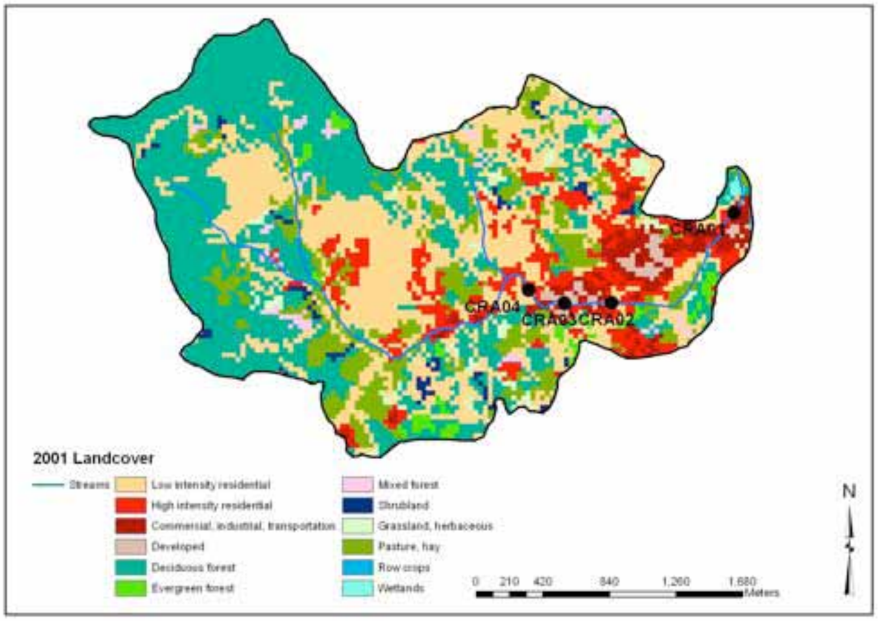

FIG. 2. *CRAWFORD BRANCH* – Land cover data from 2001 with sites labeled by site ID.

TABLE 2. *CRAWFORD BRANCH* – Land cover in 1986 and 2001 in the Crawford Branch watershed.

USGS Class	Description	% in 1986	% in 2001	% Change
11	open water	0.06	0	-0.06
21	low intensity residential	34.75	30.97	-3.78
22	high intensity residential	4.09	9.36	5.27
23	commercial/industrial/transportation	2.68	4.09	1.41
24	developed/other	0.91	1.28	0.37
31	bare rock	0.31	0	-0.31
41	deciduous forest	23.76	35.61	11.85
42	evergreen forest	4.24	1.87	-2.37
43	mixed forest	1.69	1.25	-0.44
52	shrubland	3.17	1.41	-1.76
71	grassland/herbaceous (natural/semi-natural)	0.82	1.70	0.88
81	pasture	21.41	12.30	-9.11
82	row crops	1.86	0.03	-1.83
90	wetlands	0.26	0.14	-0.11

C) Queries

All sites had an average IBI score that was rated as poor or very poor (Fig. 3. *Crawford Branch*). The highest average, CRA04, was furthest upstream but was still in a densely developed area, which could account for its relatively higher score yet still overall poor rating. The low scores are likely attributed to high proportions of developed areas, which create high rates of pollution and sedimentation. The low scores did not fluctuate much across all years of surveying.

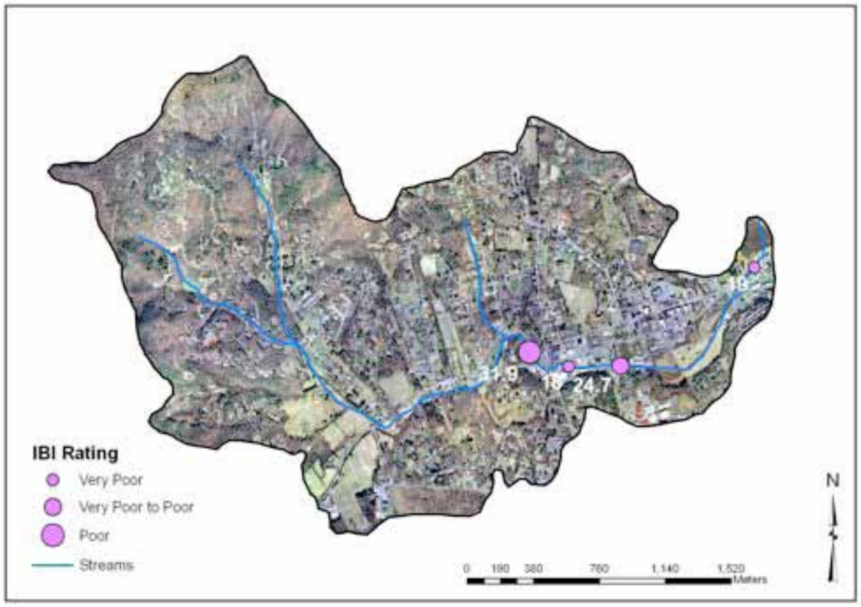

FIG. 3. *CRAWFORD BRANCH* – Index of Biotic Integrity (IBI) scores within the Crawford Branch watershed displayed on aerial photographs of the area.

Fish abundances were consistent across sites usually averaging around 250 fish per survey. There were not significant changes throughout the years at any given site.

Fish species diversity was low at all sites (Fig. 4. *Crawford Branch*). The highest average, CRA01, had 10.8 species, but all other sites averaged 5 or 6. CRA01, the only site not located in a densely developed area, was located in a park and, therefore, may provide more diverse habitats. Overall, the low water quality of the watershed likely only supports a few numbers of species.

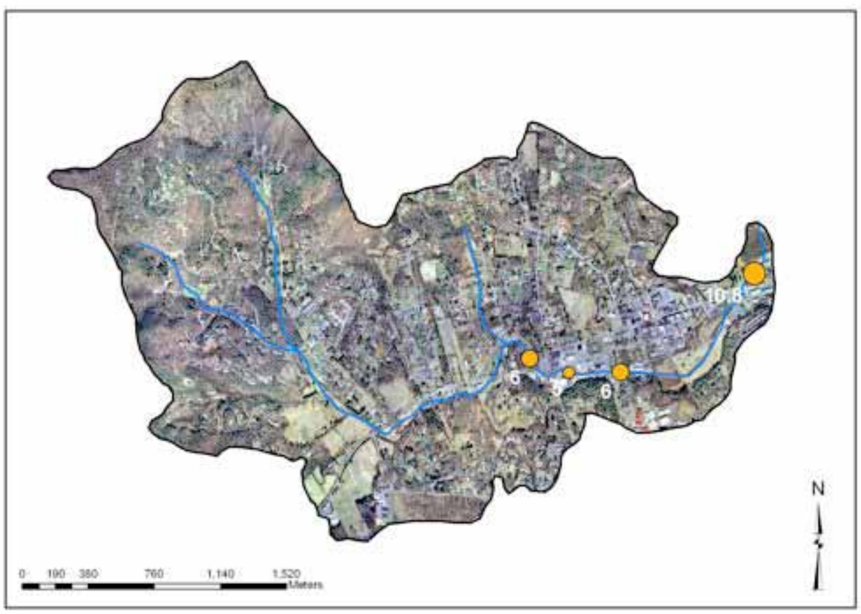

FIG. 4. *CRAWFORD BRANCH* – Average species diversity per site within the Crawford Branch watershed.

Stonerollers were only found at CRA01 and

cant, averaging less than 1%.
ates a site that receives more
:ing sampled within an urban

park, while the other sites were sampled in town near buildings, which block sunlight and, therefore, not provide quality habitat for herbivores.

Yellowfin shiners were only found at CRA01 and only in 3 years. The relative abundances were not significant (<0.1%). This invasive species does not appear to be disrupting fish assemblages in Crawford Branch.

No yellow perch were found in the Crawford Branch watershed. The lack of presence may indicate that this exotic species has not been introduced to the stream or that the conditions are not suitable for their habitat needs.

Intolerant species relative abundances are not very high with averages ranging from about 5-16% at the four sites. The first year IBI ratings were taken at CRA01 there were 0% intolerant species, which could indicate very poor water conditions at this time. In 1996 at CRA02 the relative abundance of intolerant species was 40% but by 2005 the number had dropped to about 4%. This dramatic decline in intolerant fishes may indicate rapid pollution or sedimentation over the nine year period. Intolerant abundances would not be expected to be high due to the low water quality of the entire Crawford Branch watershed.

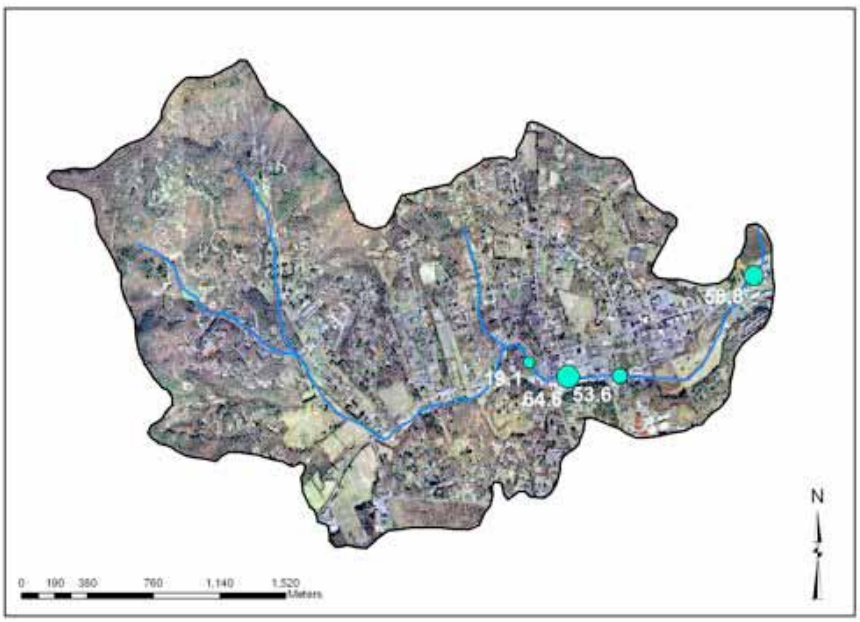

FIG. 5. *CRAWFORD BRANCH* – Average relative abundance of tolerant species per site within the Crawford Branch watershed.

The relative abundances of tolerant species for CRA01, CRA02, and CRA03 are all above 50%, but for CRA04 the average is only 19% (Fig. 5. *Crawford Branch*). The lower abundance of tolerant fish at CRA04 may show that this upstream site is less impacted than other sites or that downstream sites have a buildup of pollutants. The degraded habitat of the creek as a whole should support relatively high number of tolerant species.

There were no darters found at any site in any year in the Crawford Branch watershed. The lack of darters is likely due to high sedimentation. Due to darters feeding habitats, they are extremely sensitive to sedimentation and are not likely to be found in highly developed areas.

Crawford Branch is the most highly developed of any of the studied watersheds. Most metrics including IBI score, fish species diversity, tolerance and intolerance abundances, and abundance of darters all correlate with a highly impacted area. Crawford Branch is unique in comparison to the other watersheds in that it is the only one with a higher percentage of developed land than forested land. The poor water quality in the stream will likely continue to be an issue if the trend of increasing development seen in the past 15 years continues into the future.

IV. Cullasaja River, Main Stem

A) Site Characteristics

The Cullasaja River is a large tributary of the Little Tennessee (Fig. 1. *Cullasaja River*). In this analysis, the main stem of the Cullasaja begins just below Whiteside Mountain and terminates at the confluence with the Little Tennessee River in the town of Franklin. The watershed boundary runs northeast from Franklin over Onion Mountain and Deerlick Knob to the Macon/Jackson County line at Corbin Gap. The northeast side of the watershed follows the county line from Corbin Gap across Kirby, Moss, Wildcat, Eagle and Wolf Knobs to Hogback, Blackrock, Yellow, Shortoff and Whiteside Mountains to Highlands. From Highlands, the watershed boundary extends west to Scaly Mountain and then north across the Fishhawks to Franklin. The watershed contains the towns of Highlands, part of Franklin, and the communities of Gold Mine, Cullasaja, Porter Cove, Higdonville, Ellijay, Mountain Grove, Shookville, and Buck Creek.

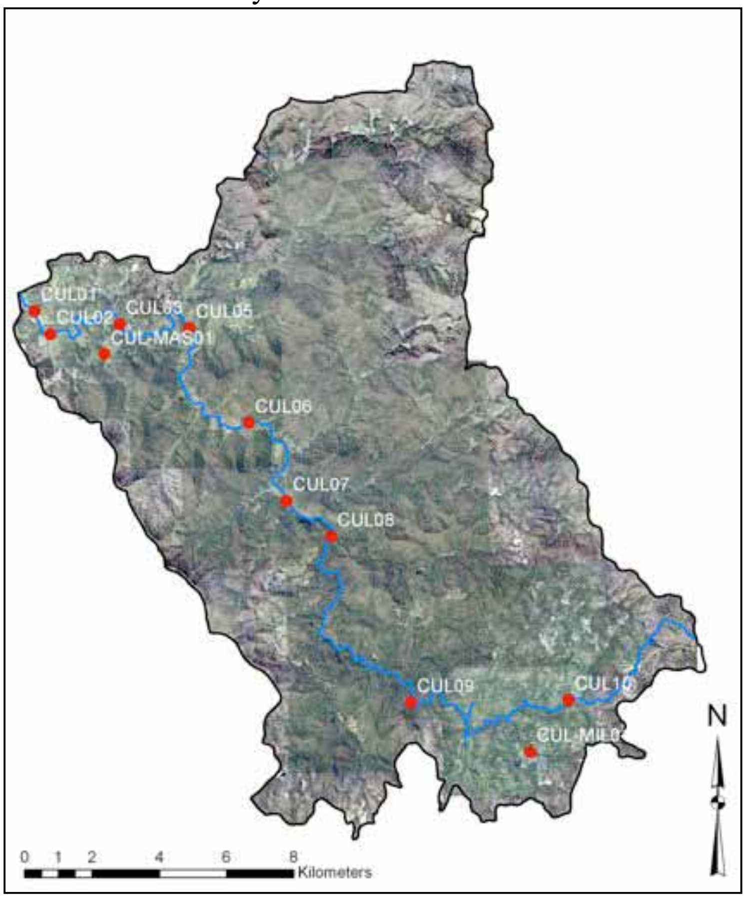

FIG. 1. *CULLASAJA RIVER* – Sites where quantitative data were collected using the Index for Biotic Integrity (IBI), labeled by site ID, overlaid on aerial photographs of the Cullasaja watershed.

The watershed is the largest in the present study, with a perimeter of 89,902m and an area of 59,858.8 acres (242,239,903.6 m^2). The length of the Cullasaja is 1,685,193m or 51.2miles. Dr. McLarney collected IBI data from 10 sites in the watershed (Table 1. *Cullasaja River*).

TABLE 1. *CULLASAJA RIVER* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI).

Site ID	Site Description
CUL01	1-38(0-1) Cullasaja R, RM 0.4, US 23 Bypass (old fixed station) (bypass)
CUL02	1-38(1-2) Cullasaja R, RM 0.9, at Macon Middle School - Fixed Station
CUL03	1-38(2-3) Cullasaja R., RM 3.1, downstream of Rhodes Bros. asphalt plant
CUL05	1-38(4-5) Cullasaja River at upper end of Sugar Fork Rd.
CUL06	1-38(9-10) Cullasaja R. RM 8.3 at Peaceful Cove
CUL07	1-38(13-14) Cullasaja R. RM 10.4, just above Buck Creek
CUL08	1-38(15-16), Cullasaja R. at RM 11.9, Jackson Hole (above Brush Cr.) (above brush creek)
CUL09	1-38(22-23) Cullasaja R., RM 17.0, above Dry Falls
CUL10	1-38(25-26), Cullasaja R., RM 21.3 at Bear Pen (US 64)
CUL-MAS01	1-38-2, Mashburn Br., RM 0.5, Schley-Seaton property
CUL-MIL01	1-38-25(0-1), Mill Cr., RM 0.6 below Old Highlands WWTP

B) Land Cover

Most changes in land cover classes between 1986 and 2001 were less than 1% with the exception of the forest and agricultural categories (Table 2. *Cullasaja River*). Overall, the amount of forested land increased slightly (3.95%), although there were bigger changes within the three forest categories. This may be due to differences in classification criteria between the two years, as many areas that appeared as mixed and evergreen forest were coded as deciduous forest in 2001, particularly along streams. Although hemlock decline certainly will affect the land cover classification during the current decade, the deleterious effects of the wooly adelgid on evergreen hemlocks were probably not obvious enough in 2001 to account for the loss of evergreen forest in the 2001 data.

The other significant change during the 15-year period was a combined 4.73% loss in pasture and row crops. There was a slight increase in high intensity residential development (0.36%) in Highlands and Franklin. Like much of the southern mountain region, the Cullasaja watershed shows increasing proportions of maturing forested land, a loss of agricultural land, and an increase in residential and industrial development around population centers (Fig. 2. *Cullasaja River*).

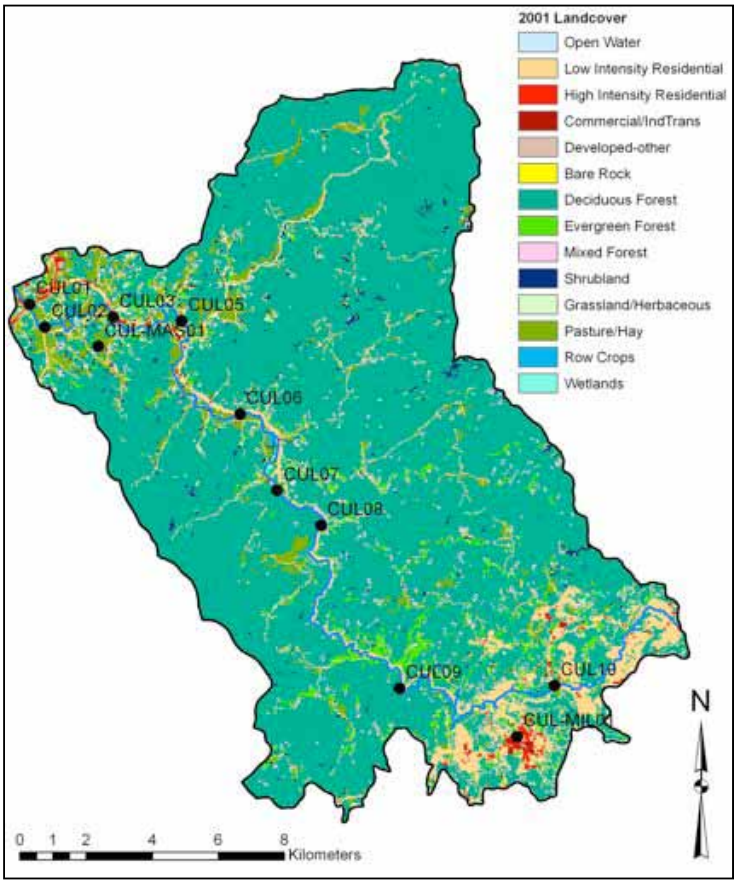

FIG. 2. *CULLASAJA RIVER* – Land cover data from 2001 with sites labeled by site ID.

TABLE 2. *CULLASAJA RIVER* – Land cover in 1986 and 2001 in the Cullasaja watershed.

NCLD Class	Description	% in 1986	% in 2001	% Change
11	open water	0.05	0.09	0.04
21	low intensity residential	8.23	8.30	0.07
22	high intensity residential	0.23	0.59	0.36
23	commercial/industrial/transportation	0.06	0.13	0.07
24	developed/other	0.01	0.03	0.02
31	bare rock	0.13	0.05	-0.08
41	deciduous forest	67.27	79.19	11.92
42	evergreen forest	7.93	3.39	-4.54
43	mixed forest	5.42	1.99	-3.44
52	shrubland	0.95	1.05	0.10
71	grassland/herbaceous (natural/semi-natural)	0.20	0.55	0.35
81	pasture	8.49	4.42	-4.07
82	row crops	0.78	0.12	-0.66
90	wetlands	0.24	0.10	-0.14
95	wetlands	0.01	n/a	n/a

C) Queries

The 10 sampling sites varied widely in terms of their index of biological integrity (IBI) scores, indicating that the stream quality is fairly variable in different areas of the watershed (Fig. 3. *Cullasaja River*). IBI class averages ranged from “very poor/poor” (CUL-MIL01 in Highlands at Mill Creek had an average score of 27.5) to “good” further downstream at the bottom of the gorge (CUL-06 at Peaceful Cove had a score of 49.7 and CUL-01 at the US23 bypass near Franklin had a score of 49.2). The Mill Creek site is located within the Town Limits of Highlands, which likely explains the low score. The watershed is relatively undeveloped below Highlands.

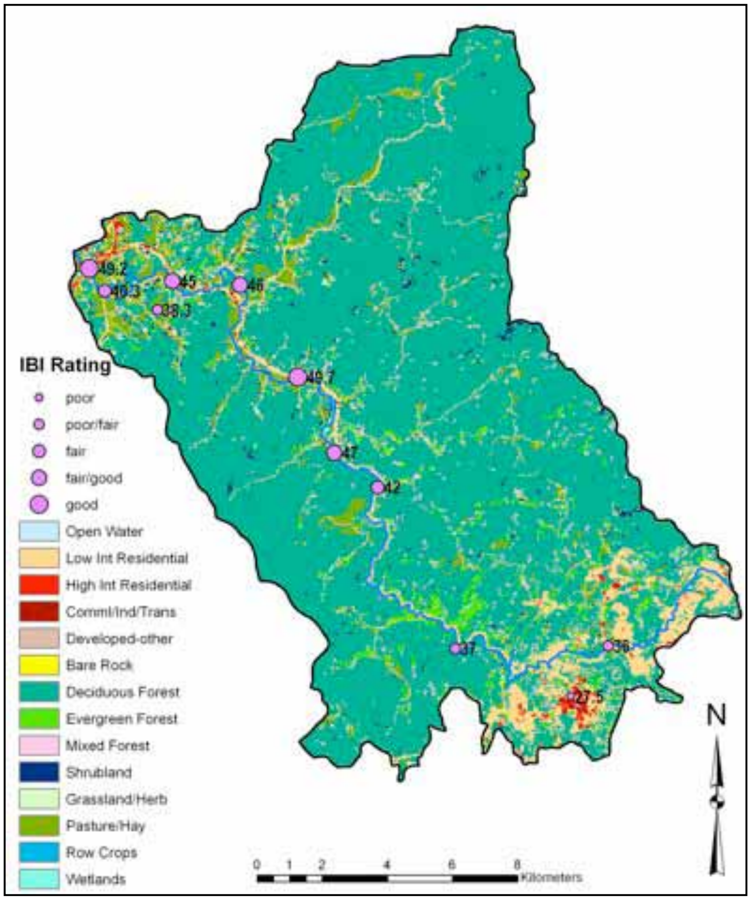

FIG. 3. *CULLASAJA RIVER* – Index of Biotic Integrity (IBI) scores within the Crawford Branch watershed displayed on aerial photographs of the area.

After visual inspection of the data throughout the sampling period from 1990-2008, there were few obvious trends in IBI score at any of the sites. However, CUL-06 at Peaceful Cove Road, which has one of the most complete sampling records over the time period from 1991-2008, showed decreasing IBI scores over the sampling period. Ratings for earlier episodes were at or above 50 until 2000 when the IBI scores fluctuated below 50. In contrast, site CUL-02 at Macon Middle School, which was sampled fairly consistently from 1995-2006, showed steady improvement in scores. IBI ratings ranged from the high 30s in earlier episodes to low-mid 40s in later episodes. Most other sites had either too few data or showed no apparent trends, making the average site IBI score the best representation of the data.

Fish abundance averaged from 112 fish to 646 fish caught per episode. The two sites that had very low fish abundance (112 at site CUL-07 and 160 at CUL-10) are values taken from just one sampling episode at each site, and the site with the highest abundance (646 at CUL-08) was averaged from only two sampling episodes at that site. Sites that were sampled more regularly were somewhat consistent with fish abundance through the sampling period, but fish abundance at some sites varied significantly among episodes.

Species diversity was especially variable within the watershed as well (Fig. 4. *Cullasaja River*). Average diversity per episode per site ranged from one to 20.2 species. The site that averaged one species is CUL-10 on Highway 64 near Bear Pen in Highlands. There was a single sampling episode in 1999 during which all 160 fish that were captured were a single exotic fish species, the redbreast sunfish. Although there was only a single sampling event, it is likely that future sampling at that site would yield low fish diversity given the proximity of the site to waters immediately downstream from several golf courses. In general, species diversity increased downstream, with the lowest average species diversity at the upstream sites (five species at Mill Creek CUL-MIL01, seven species at CUL-09 above Dry Falls, and 9.5 species at CUL-08 at Jackson Hole). The exception to this trend is the low average score of six species at CUL-MAS01 located in a small tributary to the Cullasaja at Mashburn Road at the bottom of the gorge. This site is located in an agricultural area with little riparian buffer and may be impacted by sedimentation. All other downstream sites had an average species diversity ranging from 16-20 species per episode. This result may be expected given that higher order sections of streams have a greater diversity of habitats and may be expected to support higher species diversity, although this tendency might be exaggerated by the compromised stream conditions in the lower order tributaries in the Highlands area.

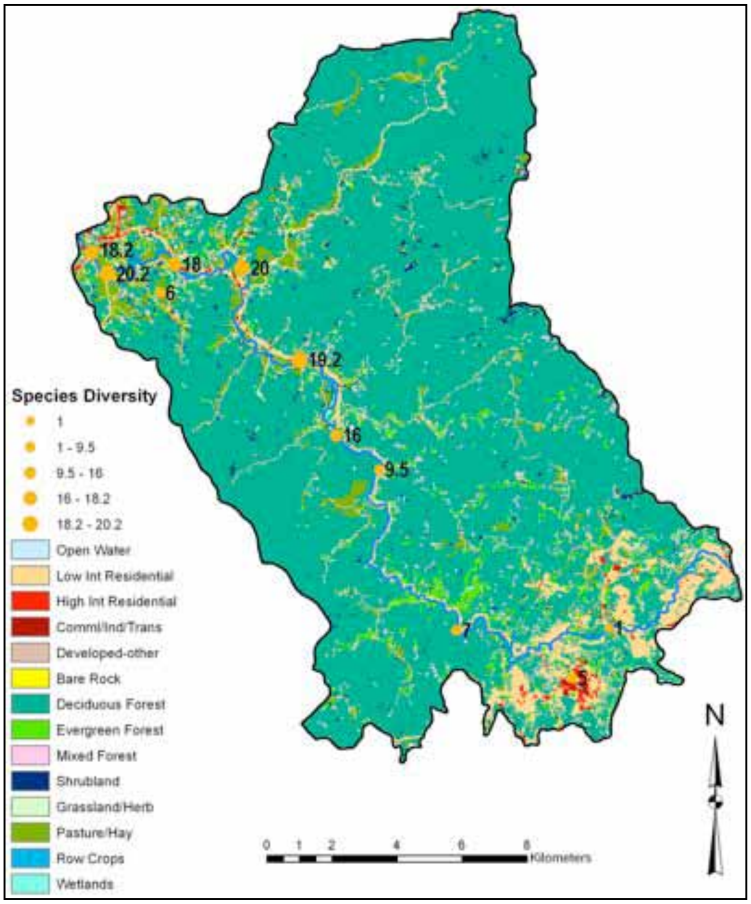

FIG. 4. *CULLASAJA RIVER* – Average species diversity per site within the Cullasaja watershed.

Stonerollers were not present in the watershed until the bottom of the gorge at CUL-06 at Peaceful Cove where they averaged 12.1% of all fish caught per episode. At this site, the proportion of stonerollers appeared to increase over the sampling period (1991-2008). The average relative abundance of stonerollers downstream from CUL-07 ranged from 0.6-7.0%. Most sites either had too much missing data to show any trends or no clear trend was obvious from the data.

Yellowfin shiners, first observed in 1994, were present only in small numbers at the three most downstream sites near the confluence with the Little Tennessee River. Of these sites, only sites CUL-01 and CUL-02 have good enough sampling records to get a sense of their presence in the watershed. Of the five sampling episodes at CUL-01 between 1990 and1994, yellowfin shiners were caught only once, in 1994, when three individuals were caught making up 0.6% of the total sample during that episode. At CUL-02, a site that had 11 sampling episodes from 1995-2007, yellowfin shiners were found during each episode with the exception of three years, 2003, 2005 and 2007. Average relative abundance of yellowfin shiners per episode was 1.1% with no apparent trend over the sampling period.

Yellow perch were found beginning in 2002 and only at two sites at the bottom of the gorge, both with fairly consistent sampling records. CUL-02 is located at Macon Middle School and was sampled 11 times from 1995-2007. Two yellow perch were found in 2002, four in 2006 and ten in 2007, indicating a rare but increasing presence at that site. CUL-06 is located at Peaceful Cove, which was sampled 17 times from 1991-2008. A single yellow perch was found there in 2002 and two were found in 2008.

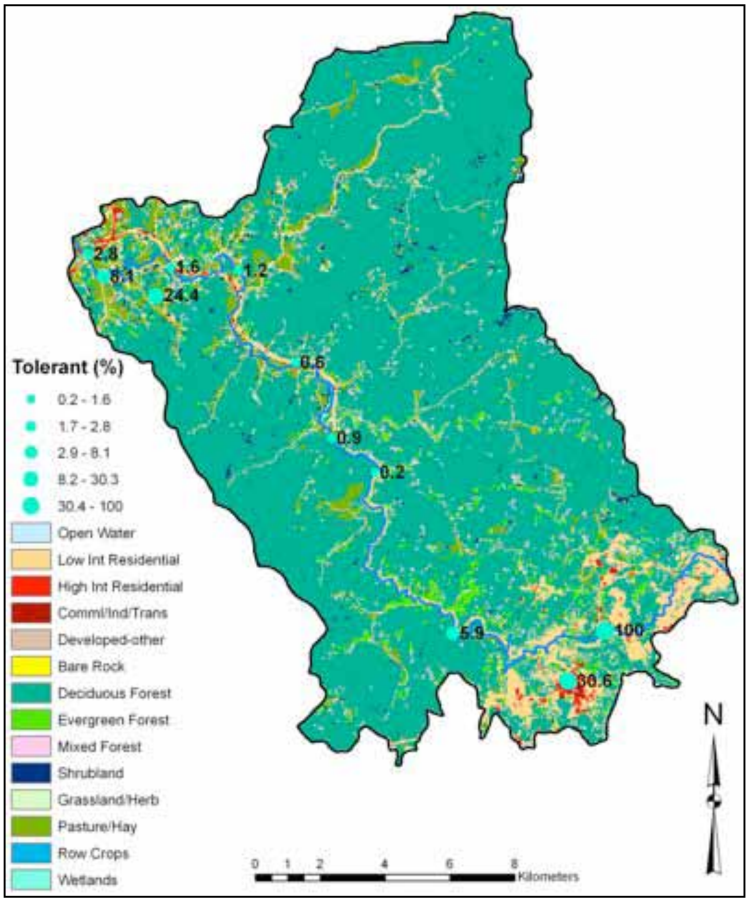

FIG. 5. *CULLASAJA RIVER* – Average relative abundance of tolerant species per site within the Cullsaja River watershed.

In the Cullasaja watershed, the relative abundance of intolerant fish mirrors the IBI ratings, which makes sense given that intolerance is a criterion in calculating IBI scores. The proportion of intolerant species per episode was higher downstream than in the Highlands area, however there were too few sampling episodes at most of the upstream sites to show clear trends. Proportions of intolerant species per episode ranged from zero to 23.4%, although these extreme scores generally were at sites with a single sampling episode. Sites with the most complete sampling records had scores that were under 10% and mirrored the discussion of IBI scores: site CUL-02 showed no apparent trend between 1995-2007, with a slight increase in proportion in the second half of the sampling period, but site CUL-06 showed decreasing proportions of intolerant species between 1991-2008, with an approximate 4% decrease in the second half of the period.

Relative proportions of tolerant species ranged from 0.2% to 100% in the Cullasaja (Fig. 5. *Cullasaja River*). CUL-10 had the most extreme result; however, the average was calculated using the data from a single sampling episode, where 100% of the fish captured were the exotic redbreast sunfish downstream from several golf communities in Highlands. CUL-MIL01 at Mill Creek in Highlands also had high proportions of tolerant species (30.6 %). All other sites were under 10% with the exception of CUL-MAS01 located in a small tributary to the Cullasaja in an agricultural section on Mashburn Road with 24.4%. At site CUL-02 where intolerant species slightly increased during the sampling period, tolerant species also increased almost 3% in the second half of the sampling period. At site CUL-06 where intolerant species slightly decreased during the sampling period, tolerant species did not increase at all. There is no clear picture presented by looking at tolerance as an indicator since a species may be tolerant of one stressor but intolerant of another.

Darters were absent from all upstream sites and CUL-MAS01. Darters made up less than 10% of the average fish captured at all sites except CUL-06 where darters averaged 16.8% (the high score of 23.7% at CUL-05 was taken from a single sampling episode, so more information is needed to interpret that result). Interestingly, for sites with the most complete sampling records, there was a notable decrease in the relative abundance of darter species throughout the sampling period. The trend was especially strong at CUL-06 where the average relative abundance during the second half of the sampling period, which spanned from 1991 to2008, was half of the average relative abundance during the first seven years of the sampling period.

The Cullasaja is quite variable when looking at the various metrics for water quality relating to fish diversity in the watershed. Unlike most watersheds, water quality appears to increase as the river flows downstream; the most compromised sections of the river are in the headwaters. However, the Cullasaja River on the Highlands Plateau (CUL-09, CUL-10, CUL-MIL01) is expected to have reduced diversity and different sets of expectations in terms of fish communities relative to the rest of the watershed and the larger Little Tennessee Watershed, so the same sets of assumptions for calculating IBI and other metrics of water quality may not apply.

V. Ellijay Creek

A) Site Characteristics

Ellijay Creek flows into the Cullasaja River, which flows into the Little Tennessee River near Franklin, NC. Head waters come from the Cowee and Higdon Mountain ranges. The high peaks around the perimeter of the watershed include the Cowee Mountain and Higdon ranges to the north and northeast, Snowbird Mountain, Deerlick Knob, Corbin Knob, Cedar Knob and Grindstone Knob. Berry Mill, Higdonville and Mountain Grove exist within the water shed boundary. Ellijay Road is the main road that runs through the watershed, turning into State Road 1001. The entire watershed is within the Nantahala National Forest. Part of the watershed falls within the Nantahala Game lands.

The watershed has a perimeter of 34,470 m and an area of 13,224 acres (53,516,353 m^2 and 5351 hectares). Dr. McLarney collected IBI data from 3 sites (Table 1. *Ellijay Creek*) in the Ellijay watershed.

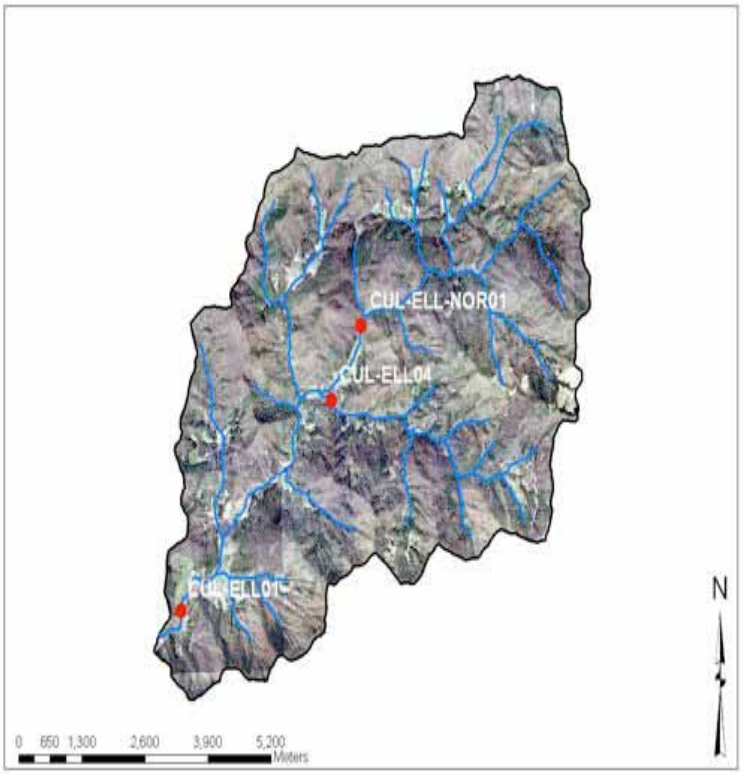

FIG. 1. *ELLIJAY CREEK* - Sites where quantitative data were collected using the Index for Biotic Integrity (IBI), labeled by site ID, overlaid on aerial photographs of the Ellijay watershed.

TABLE 1. *ELLIJAY CREEK* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI).

Site ID	Site Description
CUL-ELL01	1-38-5(0-1) Ellijay Cr., RM 0.6 at Sugar Fork Rd.
CUL-ELL04	1-38-5-(5-6) Ellijay Cr. Above Ellijay Rd. at Little Ellijay
CUL-ELL-NOR01	1-38-5-5(1-0) N. Prong Ellijay Cr. at Ellijay Rd.

B) *Land Cover*

The overall trend in the changes of land cover show an increase in high intensity residential areas, a decrease in pasture land (approximately 4%), and an increase in forests. Changes in land cover from 1986 to 2001 fell between 0.002% and almost 9% across classes (Fig. 2. *Ellijay Creek*). Between 1986 and 2001, the Ellijay watershed experienced a 0.005% decrease in low intensity residential area and a 0.007% increase in high residential development. This can be explained by the low residential areas from 1986 becoming more developed and reclassified as high intensity residential in 2001. Also, decreases in pasture land make room for urban development. Residential areas have important impacts on streams and water quality. Typically as residential areas increase in size and intensity, urban runoff and pollution have larger impacts on stream health.

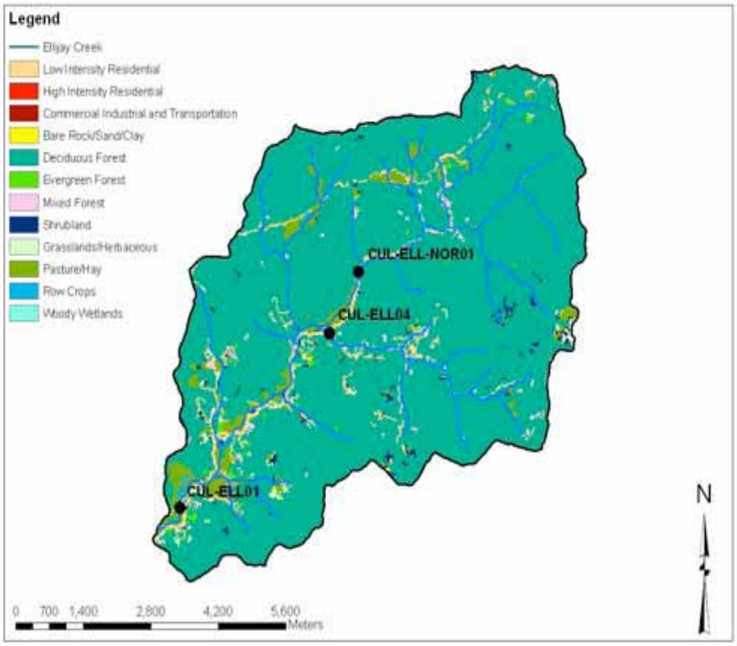

FIG. 2. *ELLIJAY CREEK* – Land cover data from 2001 with sites labeled by site ID.

The other significant change was a 3.7% net increase of forest. However, both evergreen and mixed forests decreased by approximately 2-3% while deciduous forests increased by about 9%. This could be to due classification errors between the two years since areas classified as evergreen and mixed forest in 1986 were mostly classified as deciduous forest in 2001.

TABLE 2. *ELLIJAY CREEK* – Land cover in 1986 and 2001 in the Ellijay watershed.

USGS Class	Description	% in 1986	% in 2001	% Change
11	open water	0.005	0.000	-0.005
21	low intensity residential	3.322	3.317	-0.005
22	high intensity residential	0.002	0.008	0.007
23	commercial/industrial/transportation	0.000	0.002	0.002
31	bare rock/sand/clay	0.074	0.045	-0.028
41	deciduous forest	80.484	89.442	8.958
42	evergreen forest	3.052	0.603	-2.449
43	mixed forest	3.618	0.771	-2.847
52	shrubland	0.585	1.108	0.523
71	grassland/herbaceous	0.187	0.539	0.352
81	pasture/hay	8.314	4.031	-4.284
82	row crops	0.331	0.116	-0.215
90	woody wetlands	0.027	0.019	-0.008

C) Queries

CUL-ELL01 had the lowest average IBI score, 45.8, which is considered good to fair water quality. The lowest score for this site, measured in 2003, was 39, which falls on the low end of fair quality. The highest score, measured in 1998, was 52, which falls at the high end of good water quality. CUL-ELL-NOR01 had the second highest average IBI score of 52.5, which is excellent to good water quality. CUL-ELL04 had the highest average IBI score, 53, which is also excellent to good water quality. CUL-ELL01 is located close to the confluence of Ellijay Creek and the Cullasaja River. Shown in the 2001 land cover map (Fig. 2. *Ellijay Creek*), this site has more pasture, hay, and row crop land. Agricultural runoff could potentially explain why CUL-ELL01 has a lower IBI score than the other two sites upstream.

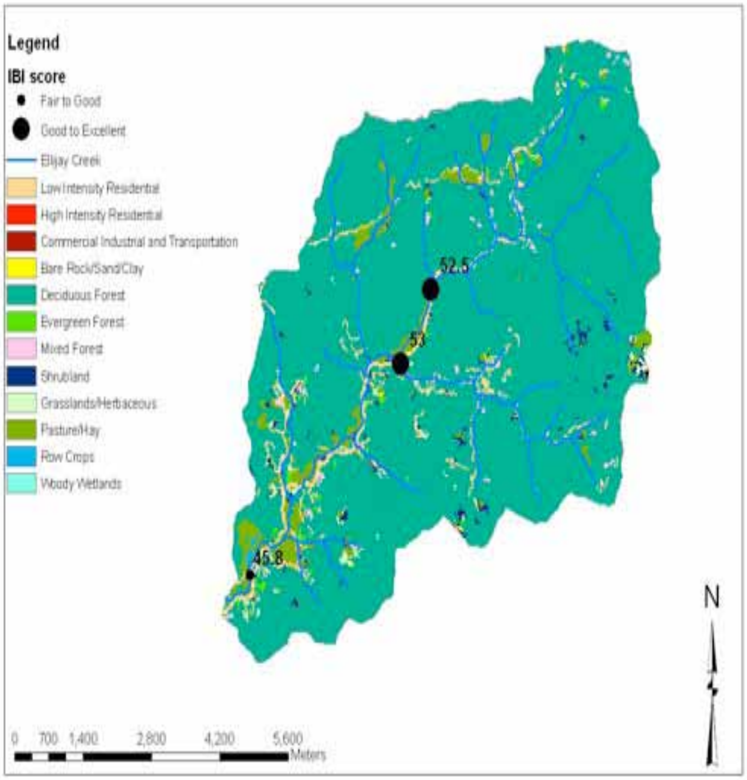

FIG. 3. *ELLIJAY CREEK* – Index of Biotic Integrity scores for Ellijay Creek displayed on 2001 land cover data of the area.

The other sites, CUL-ELL04 and CUL-ELL-NOR01 had very similar IBI scores, differing by only half a point. CUL-ELL04 is fed by the headwaters of the main branch of Ellijay Creek while the CUL-ELL-NOR01 is fed by the headwaters of the North Prong of Ellijay Creek. While the land around the main Ellijay Creek headwaters has more low intensity residential land, the North Prong has more agricultural land. This difference could be the factor causing the CUL-ELL-NOR01 on the North Prong to have a slightly lower IBI score.

At site CUL-ELL01, fish count data was taken in '91, '98, '03, '04 and '06 with a total count of 2333 fish, averaging 466.6 fish per year. The number of fish caught increased each year with the exception of 2003, when the fish abundance declined by 114 from the previous year. At site CUL-ELL04, fish count data was only taken in 2005. A total of 224 fish were caught. At site CUL-ELL-NOR01, fish count data was taken in '91, '99, and '05 with a total number of 753 fish caught, averaging 251 per year. The numbers of fish caught increased each year sampled. CUL-ELL01 is located farther downstream, which may explain why more fish were found at the site despite the lower water quality shown by the IBI score. CUL-ELL01 had the highest species diversity, averaging 20.2 species found per year sampled (Fig. 3. *Ellijay Creek*). CUL-ELL-NOR01 had the second highest with 6.7 species per year sampled. CUL-ELL04 had the lowest species diversity with 6 species per year sampled. CUL-ELL01 had both the highest abundance and the highest species diversity. CUL-ELL04 had the lowest abundance and the lowest species diversity. When compared to the relative abundance of fish found at each site, more species were found at sites were more fish where caught. This may suggest that there is a correlation between abundance and species diversity.

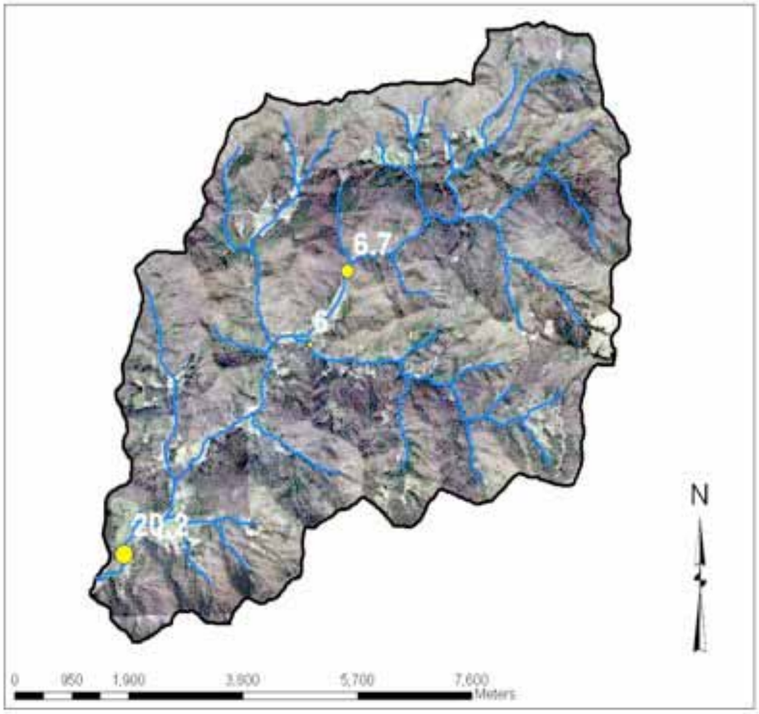

FIG. 4. *ELLIJAY CREEK* – Average species diversity per site within the Ellijay watershed.

The abundance of stonerollers did not seem to change significantly for CUL-ELL01, with the exception of '98 when the abundance was 6.0% and '03 when the abundance was 32.2%. The average was 13.8% stonerollers per year sampled. There were no stone rollers found at CUL-ELL04 for the years sampled. At CUL-ELL-NOR01 the abundance did not significantly change over the years sampled. The average was 1.5% stonerollers per year. Stonerollers are important in determining IBI score because they are bottom feeders who respond to increases in light and nutrient load. Low or stable proportions of stonerollers may indicate that there have not been increases in deforestation and runoff.

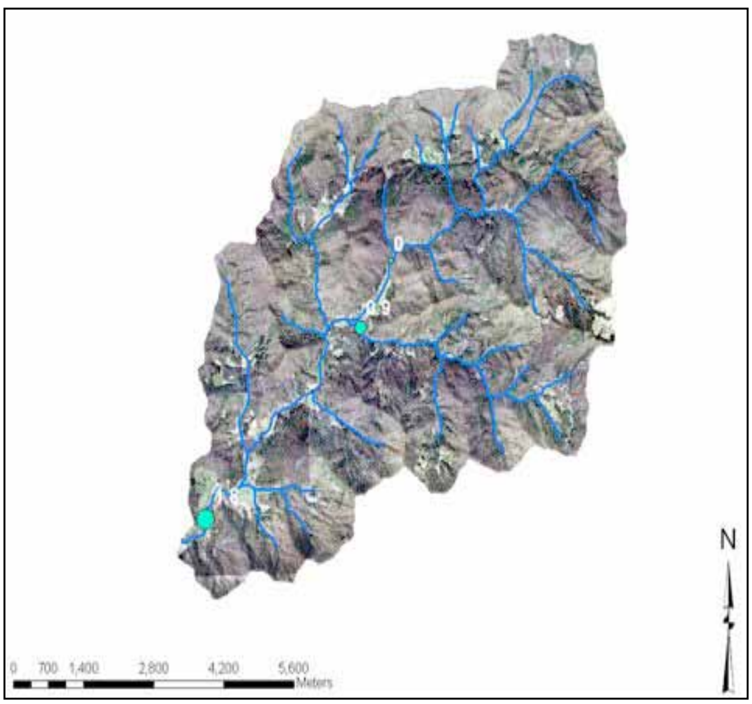

FIG. 5. *ELLIJAY CREEK* - Average relative abundance of tolerant species for each IBI site.

Yellowfin shiners were only found at CUL-ELL01 in 1999. The average overall abundance for the three sites was 0.07 fish and the average relative abundance was 0.03%. Since yellowfin shiners were not found at either of the other two sites and not in significant abundance at CUL-ELL01, exotic yellowfin shiners do not seem to have a considerable impact on the Ellijay Creek watershed.

There were no yellow perch caught at any of the sites for any year tested. Yellow perch is an exotic invasive species, so their absence may indicate more pristine conditions.

The relative abundance of species classified as intolerant was lowest for CUL-ELL01, which had an average of 2.9% (FIG. 4. *Ellijay Creek*). Although this site has greater abundance and species diversity than the other two sites, the percentage of intolerant species causes CUL-ELL01 to have a lower IBI score than the other two sites. The number of intolerant species is an indicator of stream health because intolerant species cannot survive in stream with poor water quality. CUL-ELL04 had the second highest relative abundance of intolerant species, 3.1%, and CUL-ELL-NOR01 had the highest with 3.6%.

CUL-ELL01 had the highest relative abundance of species classified as tolerant with an average of 1.7%. Tolerant species are those that can tolerate poor water quality. Since CUL-ELL01 has the highest percentage of tolerant species and a lower IBI score, the relative abundance of tolerant species most likely indicates reduced water quality. CUL-ELL04 had an average of 0.9% tolerant species. There were no tolerant species at CUL-ELL-NOR01.

Darters were only found at CUL-ELL01. The average relative abundance was 1.5%. No darters were found at CUL-ELL04 or CUL-ELL-NOR01 for any of the years tested. The available data is not enough to make accurate conclusions about the effects of stream water quality on darters.

VI. Skeenah Creek Watershed

(A) Site Characteristics

Skeenah Creek is fed by tributaries and intermittent streams that begin near the border of the watershed in the hills and mountains. The main stem of Skeenah Creek begins just north of Blaine Knob, flowing southeast and finally intersecting with the Little Tennessee River in the town of Prentiss below Sanders Knob. The watershed boundary bisects Prentiss, following the ridgeline northwest to Pendergrass Mountain. From there it continues westward to Patton Mountain and then south to Blaine Knob, Kate Knob, Pine Mountain, Skeenah Gap, and Black Mountain. From Black Mountain, the watershed boundary follows the ridgeline eastward to Bates Mountain and then northwest back to Prentiss and the Little Tennessee River. The watershed contains a large portion of Prentiss, and the communities of Morrison, Addington Mill, Black Mountain, and Pleasant Hill. The watershed is also bisected by Highway 441 in the town of Prentiss.

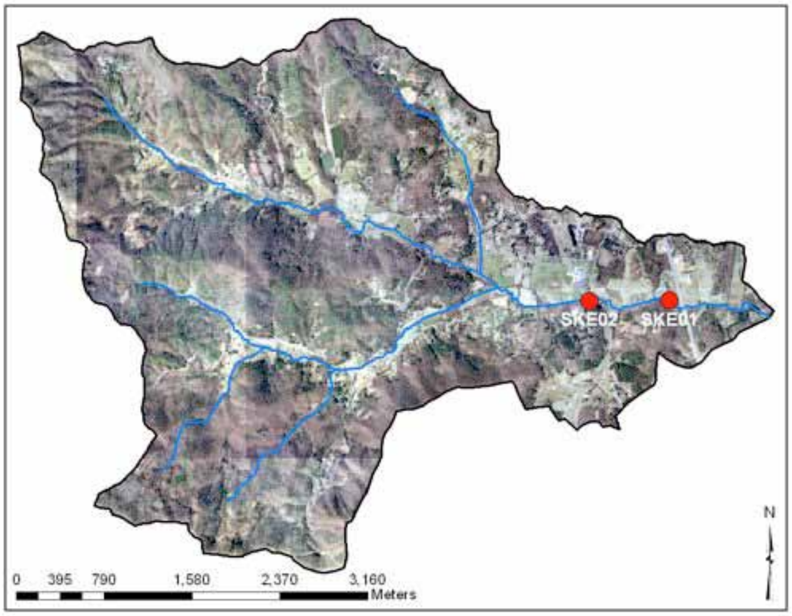

FIG. 1. *SKEENAH CREEK*– Sites where quantitative data were collected using the Index of Biotic Integrity (IBI), labeled by site ID, overlaid on 2001 aerial photographs of the Skeenah Creek watershed.

The watershed has a perimeter of 22,505.2m and an area of 4,445.2 acres (17,988,974.4 m^2, 1798.9 hectares). The length of the main fork of Skeenah Creek is 7,324.5 meters, or 4.55 miles. There were 2 sites within this watershed that had IBI data collected from them by Dr. Bill McLarney (Table 1. *Skeenah Creek*).

TABLE 1. *SKEENAH CREEK* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI).

Site ID	Site Description
SKE01	1-46(0-1) Skeenah Cr. RM 0.6 at NC Welcome Center
SKE02	Skeenah Creek @ Meadow Creek Mobile Home Estates, RM 1.4

(B) Land Cover

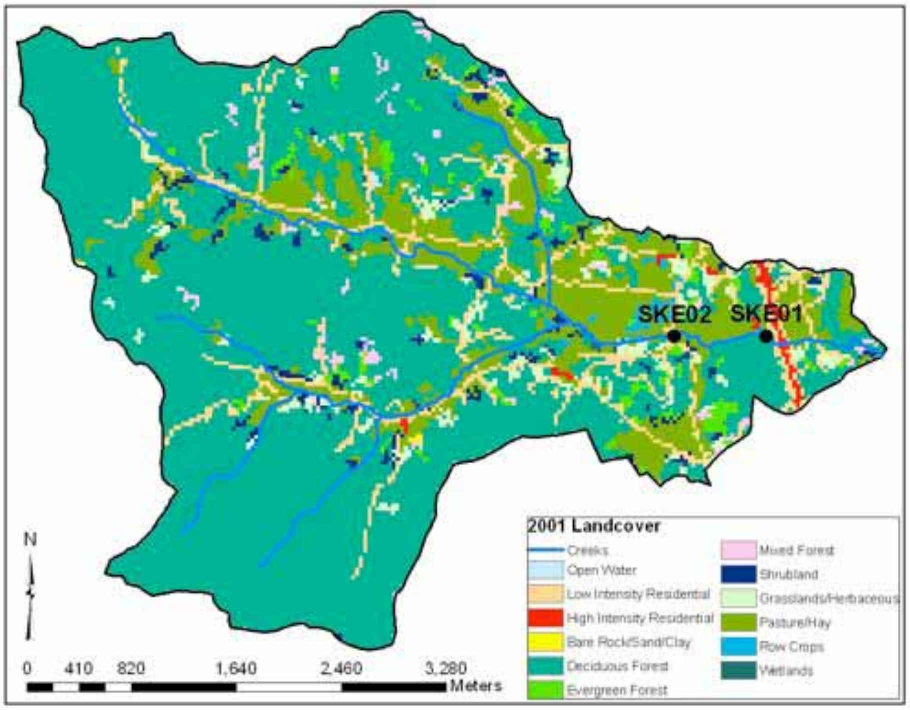

FIG. 2. *SKEENAH CREEK* – Land cover data from 2001 with sites labeled by site ID.

Most changes in land cover between 1986 and 2001 were less than 1%, with the exception of deciduous forest and pasture/hay land. From 1986 to 2001 in the Skeenah Creek watershed, the amount of deciduous forest increased 15.8% (Table 2. *Skeenah Creek*). This is interesting because both other types of forest experienced slight declines during this time. Deciduous forest experienced the largest change, though land used for pasture and hay decreased about 12%. These two changes are similar in magnitude, which may indicate that land that was used for pasture and hay was allowed to grow over and succeed into forest. Other than the changes in forest and pasture/hay lands, most changes from 1986 to 2001 were very small.

TABLE 2. *SKEENAH CREEK* - Land cover in 1986 and 2001 in Skeenah Creek watershed

NLCD Class	Description	% in 1986	% in 2001	% Change
11	open water	0.04	0.04	0.00
21	low intensity residential	6.382	5.41	-0.972
22	high intensity residential	0.035	0.49	0.455
31	bare rock/sand/clay	0.17	0.03	-0.140
41	deciduous forest	53.203	68.977	15.774
42	evergreen forest	4.846	1.94	-2.906
43	mixed forest	2.396	1.265	-1.131
52	shrubland	3.071	2.021	1.050
71	grassland/herbaceous	0.97	2.831	1.861
81	pasture/hay	27.442	15.529	-11.913
82	row crops	1.235	0.395	-0.840
90	wetlands	0.21	0.075	-0.135

(C)Queries

At both sampling sites, the IBI scores were similar to each other, differing by only three points (Fig. 3. *Skeenah Creek*). SKE01 was given a score of 35, which is considered poor. SKE02 received a score of 38, falling into the category of fair to poor. The reasoning for the lower IBI scores at SKE01 may be because of the site's location in the town of Prentiss. This site may also experience the effects of runoff pollution from Highway 441, which runs very close to the site.

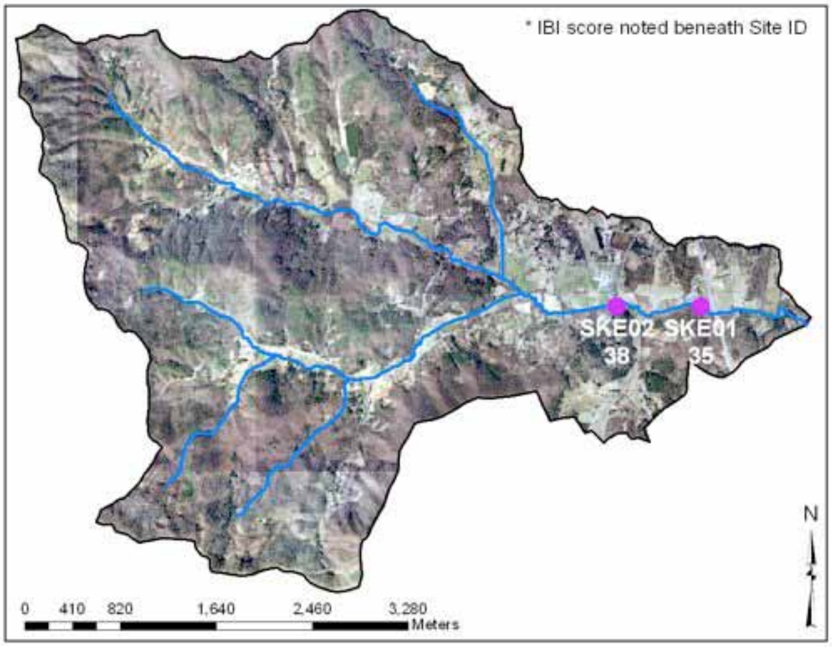

FIG. 3. *SKEENAH CREEK* – Index of Biotic Integrity (IBI) scores within the Skeenah Creek watershed displayed on aerial photographs of the area.

There is a much higher abundance of fish sampled at SKE01 than at SKE02, though this is because the first site was sampled every year from 1994 to 2008 while the latter was sampled only two years (2003 and 2004). An average of 402 fish was collected each year at SKE01. At SKE02 the average overall fish abundance was 376.

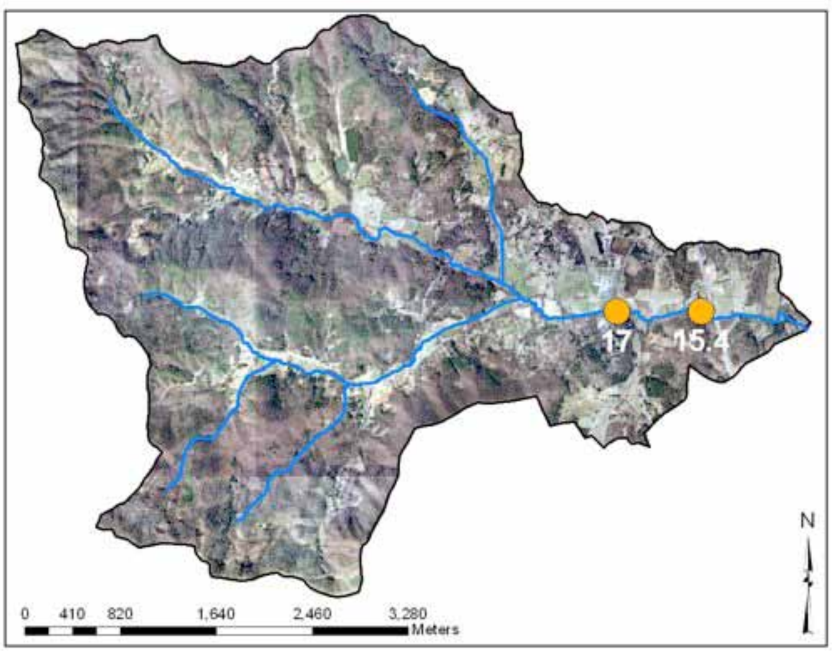

FIG. 4. *SKEENAH CREEK* – Average species diversity per site within the Skeenah Creek watershed.

The average number of species caught at both sites was fairly similar, possibly because of the close proximity of the sites to each other. At SKE02, there was an average of 17 species of fish caught each year, while the average number of species caught at SKE01 was 15.4 (Fig. 4. *Skeenah Creek)*. At SKE02, from year to year there was little change in the number of species caught, with the smallest being 14 species (in 1994, 1998, 2001, 2003, and 2006) and the largest being 18 (in 1995 and 2005). At SKE01, there were 17 species collected both years the site was sampled.

Stonerollers were more abundant in 1994 at site SKE01 and then decreased until 2002 when they completely disappeared there (SKE02 was not surveyed during this year). In 2003 stonerollers began to increase, and in 2005 their relative abundance increased from 1.94% to 9.17%. Since this time they have remained fairly stable. Interestingly, the data from SKE01 and SKE02 do not correspond to each other as they do in other queries, such as IBI score and species abundance. In 2003, when SKE01 had a very low stoneroller abundance (stonerollers accounted for 0.50% of the total fish catch), SKE02 was higher (7.61%). When numbers at SKE01 began to increase, the abundance at SKE02 declined. At SKE01 the average abundance of stonerollers was 4.82%, and at SKE02 the average was 3.96%.

The relative abundance of yellowfin shiners was significant for most years at SKE01, though their numbers peaked during 2002 when they accounted for 33.6% of the total fish catch. From 1994 to 1995 they had low relative abundance, making up less than 1% of the total fish collected. The average relative abundance of this species at SKE01 was 15.33%. For both years sampled at SKE02, the relative abundance was consistently in the low 20% range. The average relative abundance there was 21.31%.

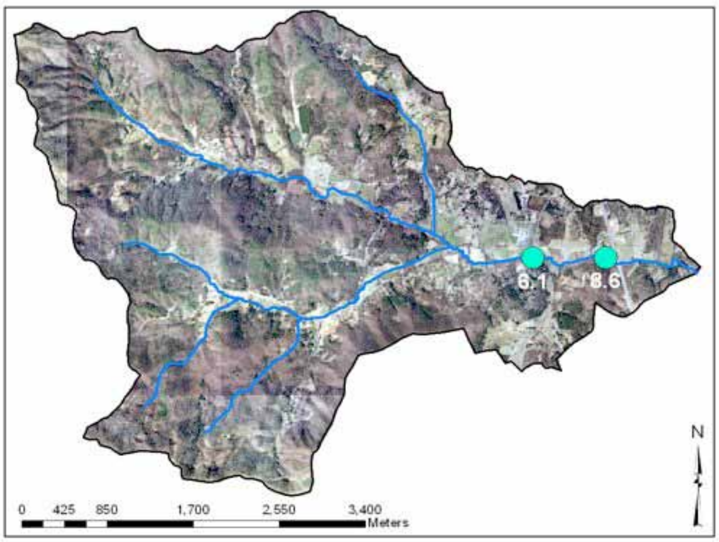

FIG. 5. *SKEENAH CREEK* – Average relative abundance of tolerant species per site within the Skeenah Creek watershed.

For every year at SKE01, less than 10% of the total fish caught were classified as intolerant species. The average relative abundance was 3.57%. This seems to be fairly consistent with the results found at SKE02, where the average relative abundance was 5.93%, with a standard deviation of less than 1.

At SKE01, there were only four years when more than 10% of the total catch was classified as tolerant species. In all other years, the relative abundance of tolerant species was very low, which affected the overall average relative abundances. The relative abundance increased from 7% to 25.6% between 2000 from 2001. Interestingly, the relative abundance of intolerant species was fairly low at SKE02, while there were high abundances at SKE01 (during 2003 and 2004).

Darters were not very abundant at either site, and at SKE01 there was only one year that the relative abundance of this species exceeded 1%. The average relative abundance at SKE01 for all years surveyed was 0.30%. The average relative abundance at SKE02 was just 0.93%.

VII. Watauga Creek

A) Site Characteristics

Watauga Creek is located northeast of Franklin, North Carolina in the Cowee Mountains (Fig. 1. *Watauga Creek*). It intersects the Little Tennessee River at Lake Emory, just north of the Porters Bend Dam. Thompson Branch, Coon creek, Hughes Branch, and Brown Creek all flow in to Watauga Creek. The watershed boundary runs north from the creek's intersection with the Little Tennessee to Lyle Knob where it turns east and runs along the northern border of Macon County to its northern most point at Rocky Face Knob (elev. 4064 ft). Here the boundary turns south, still following the Macon and Swain County border through Rattlesnake Knob and Buby Gap, then splits from the border line and cuts west across Jane Knob, Brown Gap, Passmore Knob, Jack Knob and further to the Little Tennessee. The watershed includes the communities of Berry Mill and Brendletown and is intersected by Highway 441.

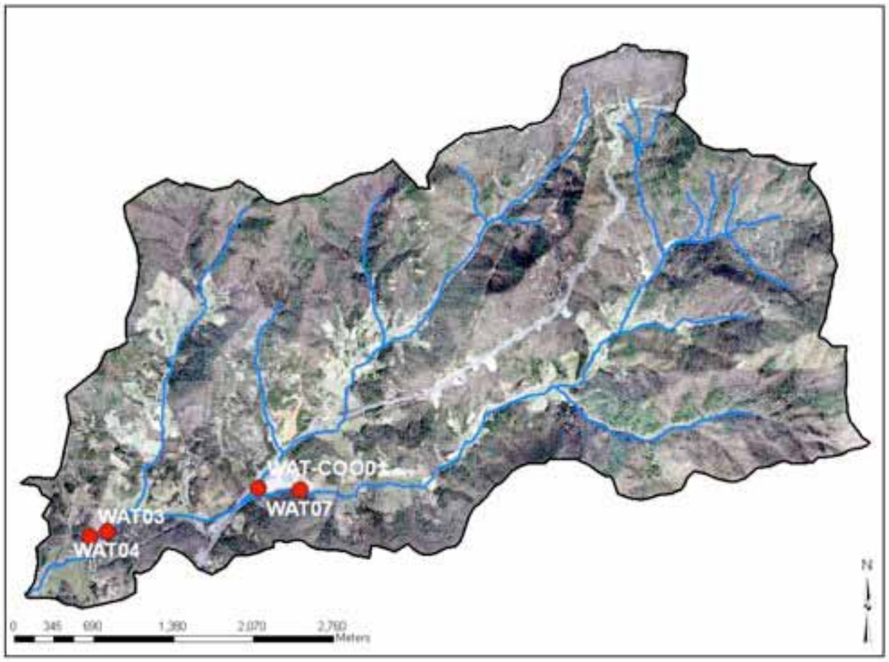

FIG. 1. *WATAUGA CREEK* – Sites where quantitative data were collected using the Index for Biotic Integrity (IBI), labeled by site ID, overlaid on aerial photographs of the Cullasaja watershed.

Watauga Creek watershed has a perimeter of 23,864 meters with an area of 5,150 acres (20,839,784 m^2 and 2,084 hectares). The length of Watauga Creek is 5.2 miles and Dr. McLarney collected IBI data at four quantitative sites (Table 1. *Watauga Creek*).

TABLE 1. *WATAUGA CREEK* – Sites where quantitative data were collected using the Index of Biotic Integrity (IBI).

Site ID	Site Description
WAT03	1-34(R0-1), Watauga Cr., RM 0.7 at Berry Mill (above Jim Berry Rd)
WAT04	Watauga Creek, RM 0.8, above John Brown Culvert
WAT07	Watauga Creek above Watauga Rd. (RM 1.1)
WAT-COO01	1-34-1 Coon Cr. at Gem Show grounds, RM 0.2

B) Land Cover

The largest changes in land cover between 1986 and 2001 occurred in deciduous and evergreen forest types. Deciduous forest made up the majority of land cover in 2001, a 13.19 % increase from 1986 (Table 2. *Watauga Creek*). The large increase in deciduous forest could have been caused by a difference in classification techniques between the two surveys. The residential development at the headwaters of Watauga Creek is categorized as low intensity residential (Fig 2. *Watauga Creek*). Highway 441 appeared as a scar of high intensity residential land cover that cut across the entire watershed. There was a reduction in agricultural land use and evergreen forests over the 15 year period. Residential land cover changed very little between 1986 and 2001, but there is a shift from low intensity to high intensity residential. Land cover data showed a good general assessment of the area but to increase the accuracy of classifications one must survey the area from the ground.

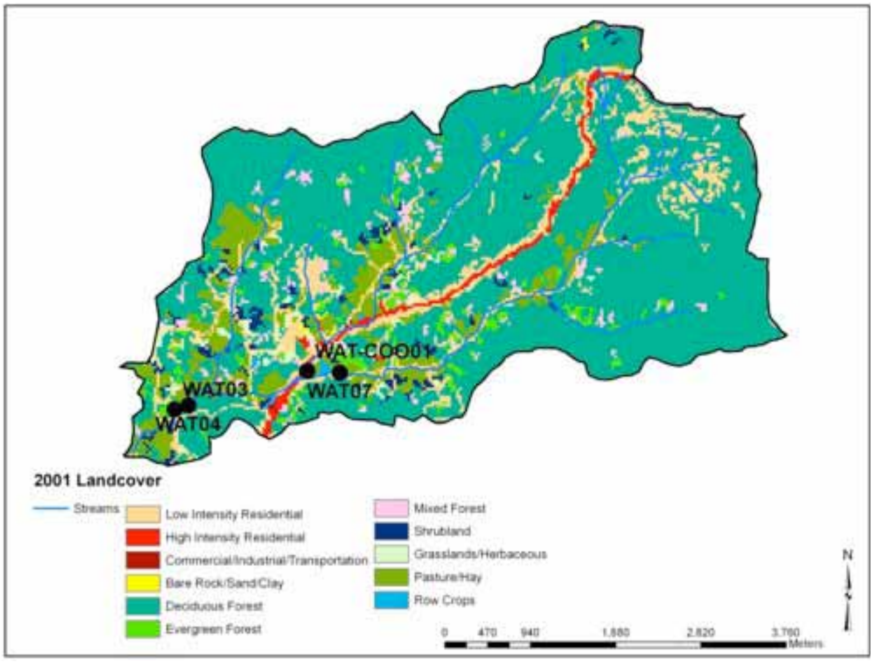

FIG. 2. *WATAUGA CREEK* – Land cover data from 2001 with sites labeled by site ID.

TABLE 2. *WATAUGA CREEK* – Land cover in 1986 and 2001 in the Watauga Creek watershed.

USGS Class	Description	% in 1986	% in 2001	% Change
11	open water	0.02	0.00	-0.02
21	low intensity residential	11.23	10.57	-0.67
22	high intensity residential	0.72	1.62	0.90
23	commercial/industrial/transportation	0.01	0.07	0.06
24	developed/other	n/a	n/a	n/a
31	bare rock	0.30	0.11	-0.18
41	deciduous forest	56.14	69.33	13.19
42	evergreen forest	7.63	2.59	-5.04
43	mixed forest	3.10	2.27	-0.83
52	shrubland	2.15	1.95	-0.20
71	grassland/herbaceous (natural/semi-natural)	0.89	1.22	0.32
81	pasture	17.00	10.02	-6.99
82	row crops	0.79	0.27	-0.52
90	wetlands	0.02	0.00	-0.02
95	wetlands	n/a	n/a	n/a

C.) Queries

IBI scores were calculated for many years at WAT03, which produced more representative sampling averages. In 1990 the scores exceeded 50, which indicated good stream health. However, in 1993, the score dipped to 39, which could be evidence of a disturbance. The stream rebounded slightly in 2003, raising the score from 44 to 47 between 2003 and 207, which classified the stream health from fair to good.

The IBI scores for WAT04 and WAT07 indicate fair stream health; while WAT-COO01 has a fair-to-poor rating. The lower rating of WAT-COO01 could be attributed to its location on Coon Creek. This portion of the creek has a major highway running parallel to it that would introduce chemical runoff, litter and pollution to the stream. In close proximity to this site there is a quarry that would also introduce large amounts of sediment to the stream. An increase in pollution and sediment would lower the overall health of the stream.

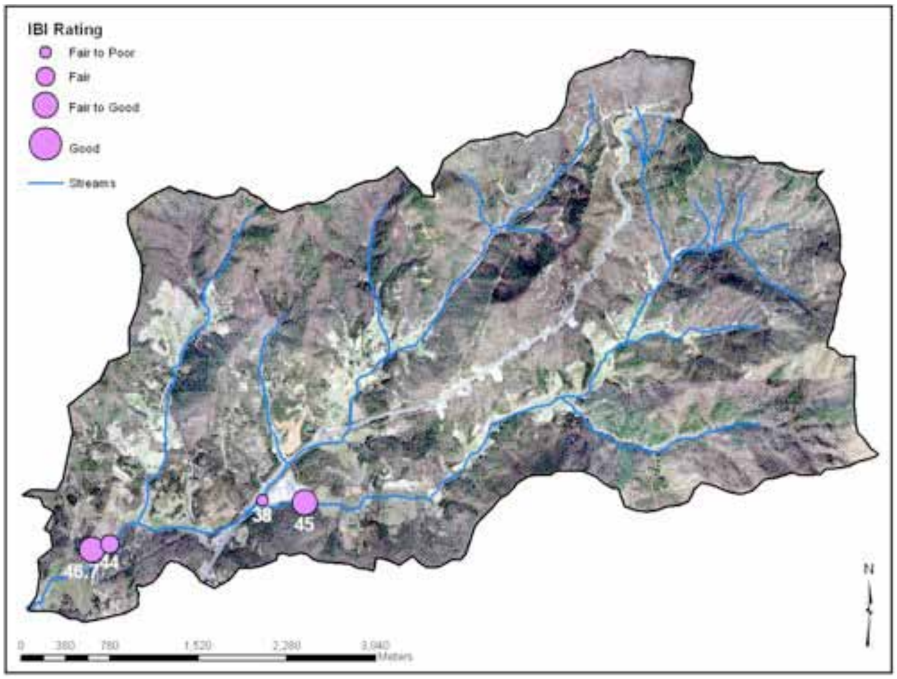

FIG. 3. *WATAUGA CREEK* – Index of Biotic Integrity scores for Watauga Creek displayed on 2001 land cover data of the area.

A significantly lower number of fish were caught, on average, at WAT-COO01. This coincided with this site having a lower IBI score than all other sites in this watershed. The most fish were caught at WAT03 and WAT04, or the two sites with the highest IBI scores. The number of fish caught at WAT03 increased steadily over time which could be attributed to more efficient catching methods or longer periods of collection as it does not follow the trend of its decreasing IBI score.

The average species diversity at each site varied little over time. The greatest diversity occurs at WAT03 and WAT04, the sites with the greatest stream quality. WAT07 and WAT-COO01 had identical species diversities that were relatively low (Fig. 4. *Watauga Creek*). This could be attributed to their low stream quality and close proximity to each other.

Stonerollers are the only herbivore recorded in this study and respond to an increased nutrient and solar input as a result of increased agricultural runoff and the loss of a riparian buffer. The relative abundance of stonerollers at WAT03 increased steadily from 1990 to 2007 and in 2008 there was a large increase in relative abundance. In 2008, the abundance of stonerollers significantly increased from 7 to 40% of the total catch. Without having the most recent land cover data, the high percentage of stonerollers could be evidence for an increase in agriculture or development. At a WAT04, just downstream stonerollers made up 13.72% of the total catch. At WAT-COO01 they were just under 6% of the total catch, and less than one percent at WAT07, suggesting that these two site had low nutrient and solar input.

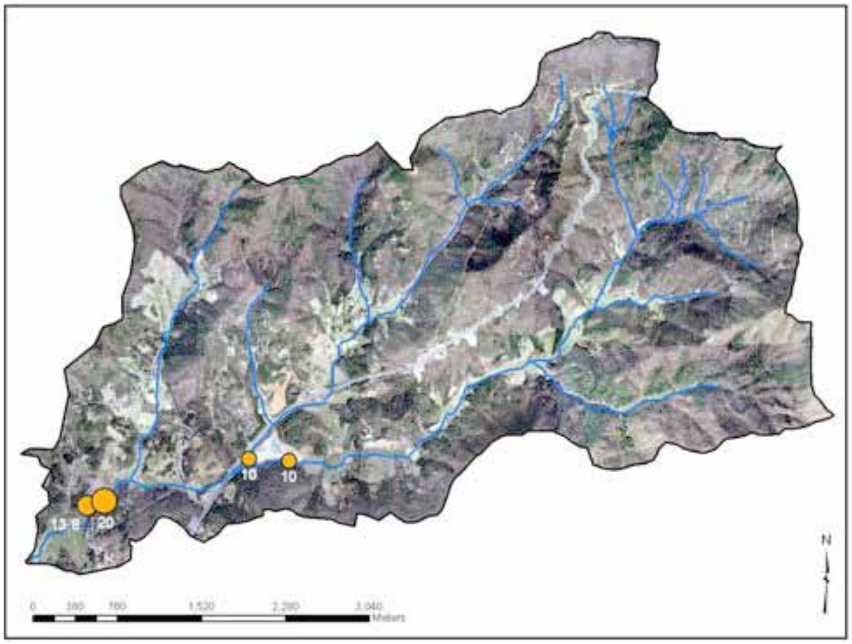

FIG. 4. *WATAUGA CREEK* – Average species diversity per site within the Watauga Creek watershed.

Yellowfin shiner is an invasive species that is theorized to be expanding in the Little Tennessee watershed. At sites WAT07 and WAT-COO01 no individuals of this species were caught. This species was most abundant at WAT03, but their relative abundance never exceeded two percent of the total catch. Their highest abundances were in 2001, 2004, and 2008. Yellowfin shiner was also present at WAT04 in 2008, the only time the site was sampled. Since their highest competitors are the native Tennessee shiner and smoky dace it would be interesting to see if there are any trends in their abundances in these creeks.

Yellow perch is another exotic species beginning to invade the Little Tennessee Watershed. However, it has not yet been recorded as invading the Watauga Creek watershed.

Certain fish species were classified as either tolerant or intolerant depending on their ability to survive in extreme stressed and impacted environments. The highest abundance of pollution intolerant fish were present at WAT04, accounting for 25% of the total catch, and WAT03 where 12% of the total catch were intolerant. Based on IBI scores, these two streams were the healthiest sites and so they would expected to have the highest number of intolerant fish. At WAT07, intolerant species made up less than one percent of the total catch, and at WAT-COO01 they are three percent of the total catch. These two creeks were less healthy and expected to have less intolerant fish. WAT07 was downstream from a

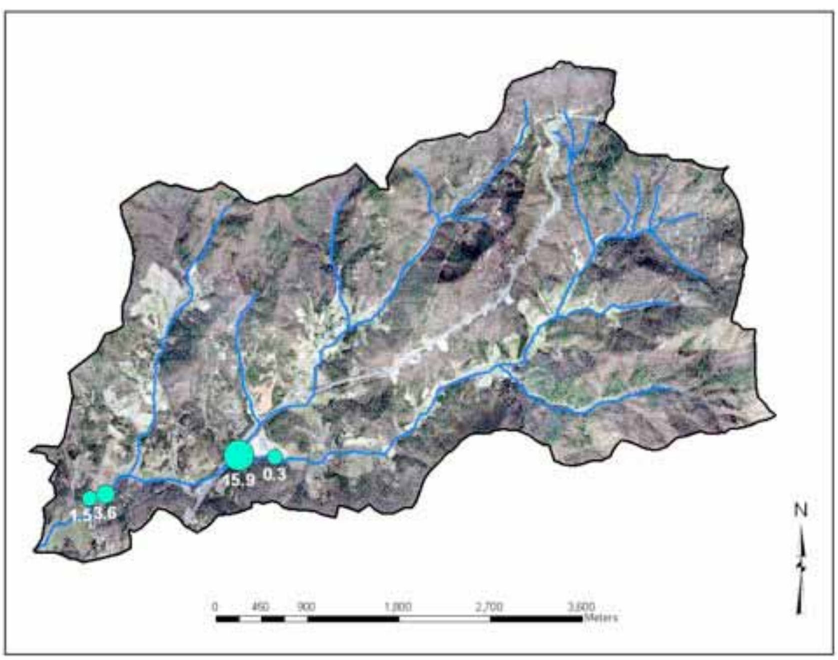

FIG. 5. *WATAUGA CREEK* – Average relative abundance of tolerant species per site within the Watauga Creek watershed.

large development and WAT-COO01 was on Highway 441, both of whose pollution may contribute to the low numbers of intolerant fish.

The highest abundance tolerant fish are present at WAT-COO01, where they made up 15% of the total catch (Fig. 5. *Watauga Creek*). This evidenced that this stream experienced stressors such as a large highway running parallel to this section of the stream and an excavation operation near this site. Tolerant fish made up less than two percent of the catch at WAT03 and less than three percent at WAT04. These were relatively healthy sites, so tolerant fish would be less expected and intolerant fish more expected here. WAT07 has low levels of both intolerant and tolerant fish species which is linked to its low diversity of all fish species.

Darters are a species that have been found to prefer a habitat with little to no sediment. The abundance of darters is highest at WAT03, where they made up nine percent of the total catch, and WAT04, where they made up five percent of the total catch. This correlates to a healthier IBI score. Darters made up less than two percent of the catch at WAT-COO01, which could have been a result of the runoff caused by the excavation operation near the stream, as well as its proximity to Highway 441. At WAT07 darters were never found. A residential development upstream from this site could have been responsible for the lack of darter species.

Comparisons Across Watersheds

From 1986 to 2001 all seven watersheds showed similar trends in three land use categories (Table 4). First, the percentage of herbaceous planted/cropland decreased in each watershed. Skeenah Creek and Crawford Branch saw the biggest decline of cropland with losses of 12.75% and 10.94%, respectively. Second, forested upland increased significantly over the 15 year period. Skeenah Creek and Crawford Branch again underwent the largest changes with increases in forested land of 11.74% and 9.04%, respectively. The combination of decreased agriculture and increased forested land likely indicates the reforestation of once farmed fields since the mid 1980s. The third trend seen across all watersheds was the increase in developed areas. Crawford Branch watershed increased developed land by 3.26% while all other watersheds increased by less than one percent. Such trends corroborate recent analyses of land use change in Macon County (Kirk 2009).

TABLE 4. Summary of land cover data from 1986 and 2001.

	Water	Developed	Barren	Forested Upland	Shrubland	Herbacous Natural/semi -natural	Herbaceous planted/ cropland	Wetlands
Brush Creek								
1986 %	0	2.93	0.08	91.2	0.55	0.23	5.04	0.01
2001 %	0	3.06	0.05	93.5	0.68	0.16	2.59	0
Change %	0	0.13	-0.03	2.3	0.13	-0.07	-2.45	-0.01
Cowee Creek								
1986 %	0.005	3.182	0.094	81.850	1.832	0.401	12.534	0.102
2001 %	0.000	3.297	0.026	88.374	1.081	1.172	5.963	0.086
Change %	-0.005	0.115	-0.068	6.524	-0.751	0.771	-6.571	-0.016
Crawford Branch								
1986 %	0.057	42.427	0.312	29.695	3.165	0.823	23.265	0.256
2001 %	0	45.691	0	38.734	1.406	1.704	12.324	0.142
Change %	-0.057	3.264	-0.312	9.039	-1.760	0.881	-10.941	-0.114
Cullasaja River								
1986 %	0.05	8.53	0.13	80.63	0.95	0.20	9.27	0.24
2001 %	0.09	9.05	0.05	84.57	1.05	0.55	4.54	0.10
Change %	0.04	0.52	-0.08	3.94	0.10	0.35	-4.73	-0.14
Ellijay Creek								
1986 %	0.005	3.324	0.074	87.154	0.585	0.187	8.645	0.027
2001 %	0.000	3.327	0.045	90.816	1.108	0.539	4.147	0.019
Change %	-0.005	0.003	-0.028	3.662	0.523	0.352	-4.499	-0.008
Skeenah Creek								
1986 %	0.040	6.417	0.170	60.445	3.071	0.970	28.677	0.210
2001 %	0.040	6.897	0.030	72.183	2.021	2.831	15.924	0.075
Change %	0	0.480	-0.140	11.738	-1.050	1.860	-12.753	-0.135
Watauga Creek								
1986 %	0.017	11.962	0.298	66.865	2.150	0.894	17.793	0.022
2001 %	0	12.280	0.113	74.184	1.945	1.216	10.292	0
Change %	-0.017	0.289	-0.185	7.318	-0.204	0.322	-7.502	-0.022

The 2001 land use data shows that the watersheds with the highest proportion of forested land are Brush Creek, Ellijay Creek, Cowee Creek, and Cullasaja River. Crawford Branch watershed is the biggest anomaly to the mainly forested region, having only 38.73% forested land, almost half that of the next lowest percentage (Skeenah Creek). At 45.69%, Crawford Branch has the highest percentage of developed land. Watauga Creek has the second highest percentage with 12.28%, approximately a quarter of that found at Crawford Branch. Skeenah Creek is the watershed with the most land used for agriculture with 15.92%. However, Watuaga Creek and Crawford Branch also have over 10% cropland.

Query Discussion

The index of biological integrity (IBI) is a rating that shows how well streams are able to maintain healthy stream function. Its calculation incorporates a number of metrics including the number of pollution tolerant and intolerant species, fish abundance, population composition (i.e. number of predators) and species diversity. Most of the IBI scores calculated for the creeks monitored in the Little Tennessee watershed were within the range of fair to good, with the exception of Crawford Branch, which is the only watershed in the Little Tennessee Watershed that had poor and very poor ratings. Crawford Branch runs through the town of Franklin, North Carolina, and is tunneled through culverts at many points along this stretch. IBI scores were poor or poor to fair near Highlands in the Cullasaja watershed. Lower IBI scores in all watersheds correspond to the proximity of sites to major roads, residential development, agriculture, or other disturbances to the landscape. Lower order streams seemed to have lower IBI scores than higher order streams. This may be due to IBI metrics applying more accurately to higher order streams.

Average abundances of fish were one of the most variable metrics analyzed. Numbers of fish totals varied across watersheds, sites within watersheds, and across sampling years. One noticeable trend throughout the watersheds was that downstream sites tended to have higher fish totals. This appears to be a result of streams getting larger (higher stream orders) as they approach the intersection with a larger river, such as the Little Tennessee or Cullasaja, and simply providing more available habitat for fish to utilize. Fish abundance at some sites varied significantly among episodes, so abundance is possibly not especially informative without a normalizing factor such as time. Such a normalization factor would provide a measure of fish abundance per unit sampling effort and may be useful to calculate in future studies.

The diversity of species within the seven watersheds ranged from 1 to 20 species, averaging 12.85 per watershed. Species diversity among the watersheds seemed to be affected by many different factors including fish abundance, land cover type, and stream order. As might be expected simply by chance, the general trend is that the greater number of fish found, the great number of species are also found. Cowee Creek has the highest average abundance of 446.4 fish and the second highest average number of species with 15.5 species. Similarly, Crawford Branch has the lowest average abundance of 246.5 fish and the lowest species diversity with 6.95 species.

There are exceptions to the trend between abundance and species diversity such as at Brush Creek. At this site, land cover has a greater influence that outweighs the effects of simple abundance on species diversity. Land cover influences species diversity depending on the land cover classes associated with each site. Areas more impacted by urban development or agriculture tend to have fewer species. The IBI site in the Brush Creek watershed that has the highest abundance of fish has an average of two species less than a site with about half the number of fish. This site is the most impacted site in the Brush Creek watershed and the species composition is made up of mostly stonerollers and other tolerant species. Intolerant species are rare at this site. This indicates that just calculating overall diversity masks the true trends that we are concerned about from a conservation standpoint. Retention of endemic highland species that tend to be sensitive to impacts will be the first to go when species diversity is reduced. As this trend continues, the same species tend to appear at all sites (Scott and Helfman 2001)

Stream order also appears to impact fish diversity. Similar to the trend found with fish abundance, as stream order increases, the number of species also increases. Ellijay watershed has the highest species diversity of about 20 species where the branch connects with the Cullasaja. The two sites closer to the headwaters had approximately six species each. Higher order streams are larger streams that can support more varied habitats, supporting a greater variety of species.

Stonerollers are our only herbivore species and can serve as an indicator for increasing light availability and nutrient input. Increased light conditions can indicate a loss of riparian buffer in higher order streams and result in temperature increases. Additionally, runoff from agricultural fields can increase the nitrogen and phosphorus content in the water. Both conditions encourage algal growth which can sustain larger populations of stonerollers in the river. Across most sites, stonerollers increased in relative abundance with proximity to the confluence with the Little Tennessee. In almost all watersheds, relatively higher proportions of stonerollers were associated with agricultural land use. There were few noticeable temporal other than one site in the Cullasaja River (CUL-06) where the relative abundance of stonerollers appeared to increase over the sampling period.

Yellowfin shiners, an exotic species that is new to the Little Tennessee River Basin, were found in all of the seven watersheds except for Brush Creek. In most of the watersheds, yellowfin shiners were found in small numbers. The average relative abundance of yellowfin shiners was below one percent in all of the watersheds except for Skeenah Creek. Skeenah Creek had a high average relative abundance, with the species accounting for 18.3% of the total fish caught at sites within the watershed. In all of the basins, the species was most common at sites that were impacted by forest clearing or development. Many of the yellowfin shiners were caught at sites near the confluence with the Little Tennessee, which is also where development often occurs. The data show no apparent trend over time. The presence of the yellowfin shiner in six of the seven watersheds, however, shows that the exotic species has spread throughout the Upper Little Tennessee watershed. Its range seems to be limited to downstream sites within the watersheds. Since this species competes with the native smoky dace and Tennessee shiner, it would be interesting to look at the relative abundances of these species as well.

Another exotic fish of concern in the Little Tennessee Watershed is the yellow perch which arrived in the area around 1990. Yellow perch were not found in any watershed except the Cullasaja River and only at two sites within this watershed. This invasive species was first seen in the Cullasaja in 2002 and has since shown a slight increase in abundance. Interestingly, two sites without yellow perch are located between the sites where yellow perch was recorded.

Intolerant species may respond to different negative effects (sedimentation, chemical pollution, temperature change, etc.) but their inclusion in the “intolerant” category tends to correlate with their inability to persist in stressed environments. Overall, a heavily impacted watershed with lower water quality resulted in a lower abundance of intolerant species. In Crawford Branch, which scored the lowest IBI ratings of all seven watersheds, had a very low abundance of intolerant species. In Watauga Creek, the sites with the highest IBI ratings also had the highest average abundance of intolerants. This was also the case for Brush Creek, and the highest IBI scores were present at the sites where the highest abundance of intolerant species occurred. This trend indicates that the abundance of intolerant species plays a significant role in IBI scoring. The sites in this watershed which had the lowest abundance of intolerant species were in agricultural areas. Ellijay Creek had a higher abundance of intolerant species in the areas that were less impacted as well, and the sites that had a low abundance were more impacted by agriculture. Cowee Creek did not seem to fit this trend however; the sites that had the highest abundance of intolerant species were also the most impacted by development.

Species that continue to appear in substantial numbers in stressed sites were categorized as "tolerant." In areas that were more heavily impacted by industry and agriculture, the relative abundances of tolerant fish were higher than in watersheds that had sites located in more forested, pristine areas. For example, in Crawford Branch most sites were located in the heavily developed town of Franklin. In this watershed, three out of four sites had a relative average of tolerant species that was greater than 50%, with the fourth site being located further upstream where the area was less impacted. In Watauga Creek, the highest abundance of tolerant species was found at the site with the lowest IBI score. Other sites were considered healthier and also had a lower abundance of tolerant species. The watershed that did not fit this trend was Brush Creek, where there were two sites located in impacted agricultural areas that had an average abundance of tolerant species that was less than 1%. In this watershed the site that was located in a forested area had a higher abundance of tolerant species (6.5%).

Darters have small mouths and are generally restricted to feeding on small organisms that tend to become rare if sedimentation fills their habitat. Therefore, darters can provide some indication of water quality, particularly the degree of sedimentation. The relative abundance of darter species varied across watersheds. For three watersheds, Crawford Branch, Skeenah Creek, and Ellijay Creek, the abundance of darters was less than 1% on average. In fact, no darters were found at any site in any year for Crawford Branch. The lack of darters at Crawford Branch likely results from the high percentage of developed land in the watershed which causes runoff and sedimentation to occur at high rates. The low number of darters at Ellijay Creek is an anomaly because the watershed had both a high IBI score and a low relative abundance of darters. There may have been disturbance in the past, and darters may not have recolonized afterward. The other four watersheds, Cowee Creek, Brush Creek, Cullasaja River, and Watauga Creek, had at least 4% of darters on average. The relatively high abundance of darters at these latter four watersheds could indicate a low rate of sedimentation. Cowee Creek and Cullasaja River had individual surveys that consisted of almost 25% darters, which might indicate many sites within these watersheds are free of heavy sedimentation. However, some sites, especially in the Cullasaja, showed a decrease in the abundance of darters over time, which may indicate that streams are subject to more sedimentation now than in years past. Sculpins also feed on small organisms but have larger mouths and a more diverse diet; they may be expected to have a competitive advantage over darters in streams with increasing amounts of sediment. A comparison of darters to sculpins might confirm whether sculpins are increasing while darters appear to be decreasing at several sites in the study.

A summary of the query data for all seven watersheds is provided in Appendix A.

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APPENDIX A

Summary table of data from the ten queries for the seven watersheds under analysis.

Watershed	Average IBI score (range)	Average abundance (range)	Average diversity (range) %	Average relative abundance of stonerollers (range) %	Average overall abundance of yellowfin shiners (range)	Average relative abundance of yellowfin shiners (range) %	Average overall abundance of yellow perch (range)	Average relative abundance of intolerant species (range) %	Average relative abundance of tolerant species (range) %	Average relative abundance of darters (range) %
Brush Creek	48.3 (47-50)	319.4 (238-420)	14.1 (14-16)	9.9 (5.5-16.6)	none	none	none	6.5 (5.3-8.0)	2.8 (0.8-6.5)	7.3 (5.5-16.6)
Cowee Creek	47.25 (41-53.6)	446.4 (109.5-602)	15.5 (5-22)	3.5 (0-6.3)	0.2 (0-0.7)	0.04 (0-0.1)	none	9.1 (0-20.1)	5.3 (0.5-14.1)	8.1 (0-24.6)
Crawford Branch	23.4 (18-31.9)	246.5 (224.6-281.3)	6.95 (5-10.8)	2.1 (0.4-8)	0.1 (0-0.4)	0.02 (0-0.09)	none	10.1 (5.4-16.4)	49 (19.1-64.6)	0 (N/A)
Cullasaja Main Stem	41.6 (27.5-49.7)	331.5 (112-646.5)	12.7 (1-20.2)	6 (0-23.7)	0.5 (0-3.8)	0.2 (0-1.8)	0.14 (0-1.3)	7.76 (0-23.4)	16 (0.2-100)	6.2 (0-23.7)
Ellijay Creek	50.43 (45.8-53)	313.9 (224-466.6)	11.0 (6-20.2)	5.1 (0-13.8)	0.07 (N/A)	0.03 (N/A)	none	3.2 (2.9-3.6)	0.9 (0-1.8)	0.5 (N/A)
Skeenah Creek	36.5 (35-38)	389 (376-402)	16.2 (15.4-17)	4.4 (4-4.8)	66.4 (52.4-80.5)	18.3 (15.3-21.3)	none	4.8 (3.6-5.9)	7.4 (6.1-8.6)	0.6 (0.3-0.9)
Watauga Creek	43.4 (38-46.7)	427.8 (226-714)	13.5 (10-20)	9.4 (0.9-17.1)	0.8 (0-2.2)	0.2 (0-0.5)	none	10.1 (0.3-25.2)	5.4 (0.3-15.9)	4 (0-9.4)