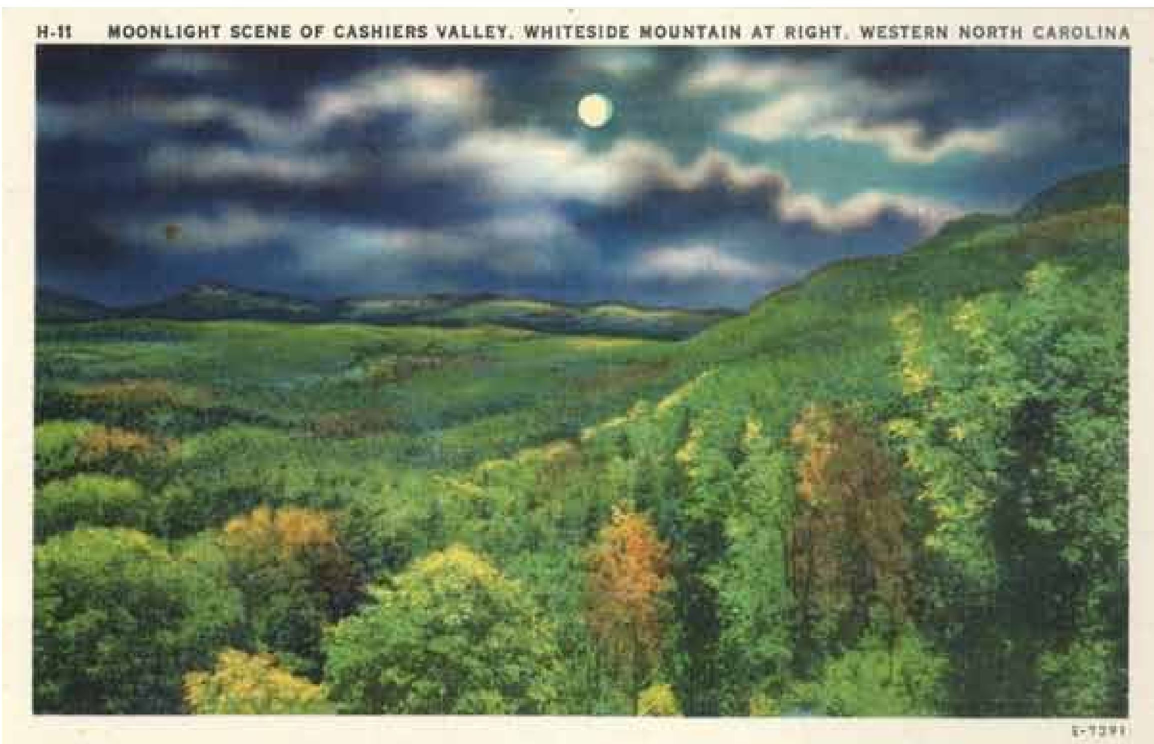
Institute for the Environment
Highlands Field Site
2011 Internship Research Reports



Highlands Biological Station

Highlands, North Carolina

INTRODUCTION

The View from Atop the Blue Wall: where we are, and why we are here…

In 1728 Colonel William Byrd of Virginia was part of a party surveying the Virginia-North Carolina border — the Dividing Line, as it was called — and from a hilltop he looked to the west and saw the Blue Ridge front looming in the distance. "Our present circumstances," he lamented, "wou'd not permit us to advance the Line to that Place, which the Hand of Nature had made so very remarkable."

"So very remarkable," indeed!

Byrd beheld what the Cherokee called the Blue Wall, the eastern front of the Blue Ridge running from Virginia to South Carolina as a steep escarpment rising from the Piedmont. This long sinuous front reaches its greatest height of 2500 feet near Blowing Rock, North Carolina. Viewed from a distance, it appears as a continuous blue wall of mountains.

And we are perched atop it.

The Blue Wall was forbidding to some, but beckoned others. The lush southern Appalachian Mountains seemed to inspire a sense of mystery and primeval power to all who ventured to explore them. When Philadelphia naturalist William Bartram penetrated deep within what was then Cherokee country of western North Carolina in May 1775, he was staggered at his first elevated view of the region. As he wrote in his famous *Travels*, "I beheld with rapture and astonishment, a sublimely awful scene of power and magnificence, a world of mountains piled upon mountains."

Modern travelers are no less astonished; the vast Blue Ridge Physiographic Province, anchored by the Great Smoky Mountains at their heart, boasts highly complex geology with the highest peaks in all of eastern North America, and rainfall and biological diversity worthy of tropical rainforests. Seven major river gorges dissect the southern escarpment alone, creating a wild watery landscape where creeks and rivers rush past lush slopes wreathed in the mists that put the "blue" in the Blue Ridge and the "smoky" in Great Smoky Mountains. This verdant landscape is a major biodiversity hotspot — perhaps the most biodiverse region of all the temperate regions of the earth.

This is where we are. And in part, *why* we are here.

We are here in part to study, understand, what makes this landscape tick ecologically, to celebrate the geological and biological circumstances that render this place wondrous. But the other reason we are here is rather less cheery. The view from atop the Blue Wall has inspired for millennia, but like no other time in the history of the region, when you look more closely the view is one of a "world in pieces," in David Quammen's words, with inexorable habitat fragmentation, the march of invasive exotics, urban and suburban sprawl… all of which tear at the ecological fabric of this place.

The IE program is here — these students are here — to better understand this landscape, as a case study for what shapes landscapes and the organisms upon it, and what threatens the viability of this and other landscapes.

The land may wait us out; it's proven to be very patient in the past…

Edward Abbey captured a sense of the antiquity of this landscape back in the early 1970s. Abbey wrote of his return back east to the Smokies, and although we're a bit south of the there on the Blue Ridge Escarpment, his sentiment certainly resonates:

> "Going back to the Big Smokies always reminds me of coming home…
> The thin blue haze…that diaphanous veil…
> The trees…Vegetation cradle of North America…
> All those trees transpiring patiently through the wet and exhilarating winds of spring, through the heavy, sultry, sullen summers into the smoky autumns…
> Through the seasons, years, millennia. Sensitive and sensible plants, with who knows what aspirations of their own…"

Now, admittedly I'm not sure about the aspirations of the local botany, but sensitive and sensible as our students are, certainly they had and have great aspirations, and we've strived to help them along by immersing them for an entire semester in this fabulously bio-rich environment.

--from remarks by James Costa at the IE Student Symposium, December 14, 2011

ACKNOWLEDGEMENTS

On behalf of the IE-HFS class of 2011, 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. Many thanks to those that mentored our 2011 internships, including: Melissa Delany (Old Edwards Inn), Adrian Boutwell (Waste Reduction Partners), Jenny Sanders, Jason Meador and Bill McLarney (Little Tennessee Watershed Association), Brent Martin (The Wilderness Society), Chelcy Ford, Steven Brantley and Katherine Elliot (Coweeta Hydrologic Laboratory), Woody Malot (Rabun Gap-Nacoochee School), Dennis Desmond (Land Trust of the Little Tennessee) and Peter Bates (Western Carolina University). Thanks also to Steve Foster and Dave Penrose (Watershed Science, Inc.) and James Aaron (NC Department of Environment and Natural Resources) for their leadership and assistance with the capstone research project.

We are grateful to Gary Wein of the Highlands-Cashiers Land Trust for once again teaching the Landscape Analysis course and helping with any GIS components of this year's internships. We appreciate, too, to the many guest instructors and speakers that contributed to this year's program, including Tom Hatley, Jerry Wolfe, Travis Knowles, George Ellison, Ted Coyle, Joe Gatins, Susan Sachs, John Turner, Rich Baird, Curtis Smalling, James Reynolds, and Robert Warren; and the efforts of the HBS staff — Michelle Ruigrok, Guy Cook, Patrick Brannon, Max Lanning, Cynthia Soderstrom and Sonya Carpenter — for facilitating the students' work and living experience in Highlands. We thank Lindsay Leonard of the IE for her assistance in recruiting students to the program and organizing the internships, and the IE and Study Abroad staff at Chapel Hill for their support. Special thanks to Jessica Webb at *The Highlander* newspaper for 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 2011

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ANALYSIS OF PHYSIOLOGICAL VARIATIONS TO ESTIMATE LEAF GAS EXCHANGE IN A MIXED HARDWOOD FOREST

AUTUMN ARCIERO

Abstract. Leaf gas exchange curves are often used to model the physiological responses of plants. Variations in carbon dioxide intake though photosynthesis (net assimilation or A_{net}) can vary based on leaf physiological status, according to species, exposure (whether the leaf is exposed to full sun or is in a shady environment), and season. In this study, the assimilation rate of plants in response to CO_2 concentration was investigated comparing data based on leaf physiological status, exposure and season. Leaf gas exchange measurements modeled to fit the variations in different environmental variables can assess the annual canopy carbon assimilation. Assimilation rate results and A-C_i curve analysis conclude that shade leaves fix intercellular carbon dioxide at a much slower rate than sun leaves. The observable differences between seasons were not significant. However, identified groups of species indicate that one group is so different from the other group of species that their net intake of carbon is noticeably different than the net intake of carbon by the other species. These data will help to predict future CO_2 atmospheric values as carbon concentrations increase.

Key words: A-C_i curves; CO_2 assimilation; Coweeta Hydrologic Laboratory; intercellular CO_2; leaf gas exchange; photosynthesis.

INTRODUCTION

Knowing the capacity for plants to use or store CO_2 could significantly assist the long-term measurements of ecosystem CO_2 fluctuations (Peek 2002). Considerable research has been done on measuring carbon dioxide levels in forested areas, including studies that make use of eddy flux towers. An eddy flux tower is a tool that measures flux densities of carbon dioxide, water vapor, and energy between vegetation and the atmosphere. An eddy flux tower is able to measure mass and energy fluxes over short and long timescales with minimal disturbance to the underlying canopy (Baldocchi et al. 2001).

The eddy flux tower at Coweeta Hydrologic Laboratory is unique in that it is located in a mountainous area, where changing elevation and slope may affect the tower data readings of carbon dioxide, water vapor, and energy (Baldocchi et al. 2001). The tower site is located in the southern Appalachian Mountains of western North Carolina, in one of the two watershed basins that make up Coweeta Hydrologic Laboratory. The Coweeta basin is a mixed hardwood forest and it was extensively logged at the turn of the 20^{th} century and has been strictly managed since 1934 as a site for various watershed studies. As a result of management, numerous vegetation community types surround the site, covering 80% of the surface area within a 30 km radius. Trees representing 25 genera are found within this region (Guenther et al. 1996). The expansiveness and tree diversity of the Coweeta Basin make it a perfect location for studying gas flow dynamics within the canopy and nonlinear ecological processes within and above the canopy (Feigenwinter et al. 2008).

Extensive studies have been conducted to better understand leaf gas exchange and the factors that play key roles in the rate of photosynthetic processes. Plant physiological ecologists measure how different variables affect photosynthetic responses of leaves to intercellular CO_2. Environmental variables that affect the photosynthetic rate of a plant include temperature, humidity, light, and carbon dioxide concentration (Peek et al. 2002). Part of the process in better understanding plant gas exchange at the intercellular level is to monitor the net assimilation of CO_2 in a forest over time, which is possible with the use of an eddy flux tower.

Different plant species have different capacities for carbon dioxide assimilation (*A)*. Carbon dioxide assimilation rate (*A)* is the rate at which a leaf fixes carbon using photosynthetic processes (Manter and Kerrigan 2004). Biochemical components of CO_2 assimilation and intercellular gas exchange are increasingly being used to simulate models depicting the carbon balance of leaves, canopies, and ecosystems (Wullschleger 1993). There are many models making use of the biochemical values, including the widely used Farquhar model. The Farquhar model, formulated in 1980, provides an equation for the well-defined relationship between assimilation rate A and intercellular carbon dioxide concentration C_i (hereafter referred to as the A-C_i curve) (Katul et al. 2000). Despite the popularity of the Farquhar model for describing the daily and seasonal gain of carbon through CO_2 assimilation, the model is not straightforward in its parameterizations of the many species that make up the ecosystem. Therefore, studies are frequently conducted to measure assimilation of many plant species to better understand how species differ in their gas exchange characteristics (Wullschleger 1993). Examination of factors such as exposure and seasonality, along with species composition, would provide a more comprehensive metric for determining gas exchange characteristics. Studies that analyze the driving mechanisms for plant photosynthesis and respiration are important to understanding the processes that influence uptake rates of atmospheric CO_2 levels (C_a).

The purpose of this paper is to compare variations in A-C_i curves across multiple variables, examining how leaf assimilation rates for multiple species, leaf exposures, and seasons differ in their gas exchange characteristics. All of these comparisons reveal which variables have the greatest affect on the patterns and processes of leaf gas exchange. The primary objectives were to determine the influence of changing leaf physiology on assimilation rates, and to compare A-C_i curve estimates. Seven different woody species found in the Coweeta basin around the eddy flux tower were used for the measurements, and physiology of the leaf was noted by species, sun or shade, and time of year.

MATERIALS AND METHODS

Data for this study were obtained from leaf gas exchange response curves of seven different plant species found in the Coweeta basin. The study was conducted using six canopy species including *Acer rubrum*, *Betula lenta*, *Liriodendron tulipifera*, *Nyssa sylvatica*, *Oxydendron arboreum*, and *Quercus alba*. Shade leaves, or leaves found in the lower 50% of canopy depth, from all six canopy species were also studied with the addition of *Rhododendron maximum* (Xu and Griffin 2008). *Rhododendron maximum* was not included in the sun analysis because it only occurs in the understory of the study site. These seven species were chosen for this study based on leaf area canopy and sub-canopy in the forest surrounding the eddy flux tower.

I used the Li-Cor® 6400XT™ (Li-Cor Biosciences, Lincoln, NE, USA), a temperature controlled photosynthesis monitoring machine, to obtain accurate and systematic curves for all the data. The first curve is the light response curve, created by exposing the leaf to increasing light or photosynthetic active radiation (PAR) and recording the level of stomatal conductance to CO_2. The second curve is an A-C_i curve and is the focus of this paper. To create this curve, leaf samples are bombarded with increasing atmospheric CO_2 concentrations and net assimilation is measured as the plant fixes carbon inside the leaf. Data were obtained by attaching the machine to a healthy portion of a leaf. A leaf was determined to be healthy if it had few brown spots, and few holes. The leaf remained connected to the branch during the entire time that the machine was conducting an A-C_i curve. Leaf measurements were not taken after 1PM, because the stomates close and the plant stops conducting water to the leaves in order to conserve water. This process is characteristic of C_3 plants, or all the plants included in this study. Testing done after 1PM was done on branches that had been cut earlier in the morning. The branches were placed in a water bucket to induce the plant to continue to take up water even after the heat of the day.

Water potential measurements were taken using a Model 610 pressure chamber (PMS Instruments, Corvallis, OR, USA). The water potential for all samples was calculated from the average of three leaves on the same branch, to correct for any outlying data. A leaf was placed in the pressure chamber, with the end of the stem visible through a rubber stopper, keeping the air from exiting the chamber. As pressure was slowly added to the chamber, I watched the end of the cleanly cut stem for any sign of air bubbles or the tip dampening. The moment the water potential was equalized with the air pressure inside the chamber I recorded the measurement.

I analyzed these data using SAS® 9.0 (SAS Institute, Cary, NC, USA). Separate programs were formulated to compare the statistical significance of the three variables, season, exposure, and species ($p<0.05$). The program parameters were changed according to which variable was being analyzed. The program ran on estimates obtained from the basic logarithmic equation $A_{NET} = \alpha * ln(C_i) + \beta$, where A_{NET} is the net assimilation in μmol CO_2 m^{-2} s^{-1}, α signifies the rate of net photosynthetic assimilation, and β signifies the intercept of the logarithmic equation. The Farquhar model provided the equation for defining the relationship between photosynthetic assimilation and C_i values. Physiological response curves that are measured in response to an environmental treatment are often nonlinear.

To detect variation in the effect of leaf age and leaf chemistry on physiological response curves, data were taken at three different times in the year. The first dataset was collected in the spring at the beginning of the growing season, immediately after full leaf-out. The second data collection was during the summer at the peak of the growing season. The third collection was completed in the late growing season, before leaf senescence (Xu and Griffin 2008).

For each seasonal dataset, three shade leaves were analyzed from an individual tree from all seven species. In addition, three sun leaves were analyzed from the six species that have sun leaves. The leaves were taken from separate branches on the same tree to get a comprehensive sample of each species. Species were grouped based on the closeness of alpha or beta values to each other. Species with similar assimilation and intercept coefficients were combined into a group with like species. Coefficients of species in the same group show no statistical significance, meaning that the differences between their rate of photosynthesis is likely due to chance.

RESULTS

Analysis of A-C_i curves for all species combined within a given season indicated that A-C_i curves did not vary seasonally (all p>>0.95). A-C_i curves for spring, summer, and autumn were almost identical: neither slope nor intercept varied significantly, and this was true for both sun and shade leaves (Fig. 1), indicating that season has very little effect on the net assimilation of individual leaves.

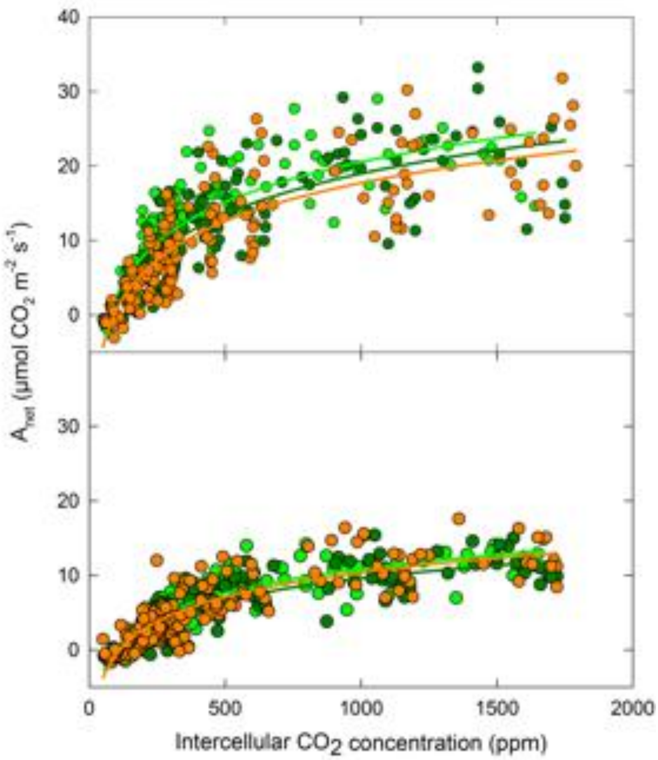

FIG. 1. The scatter plots of carbon dioxide assimilation against intercellular CO_2 concentration show that gas exchange does not change with seasonal variability. The top plot of sun leaves have much higher A-C_i curves than the represented shade curves on the bottom plot.

The sun leaves for all three seasons follow similar average trends, and the same can be said of the shade leaves. However, there is variation from sun to shade for all three seasons. According to the appearance of the logarithmic curves in Fig. 1, sun leaves tend to have higher assimilation rates than shade leaves. Exposure to sun clearly has a positive effect on the assimilation rate of all the species studied. The slope of sun A-C_i curves is noticeably different from shade A-C_i curves (Fig. 1).

The SAS® results are able to compare sun and shade leaf carbon fixation for each season (Tables 1a, 1b, 1c). Based on the majority of comparisons between seasons and assimilation of carbon it appears that the slope and intercept of the curves are hardly impacted by season. The coefficient α (rate of net photosynthetic assimilation) was consistently 7.67ppm CO_2 for sun and 4.60ppm CO_2 for shade leaves. The coefficient β (intercept) was consistently 34.10ppm CO_2 for sun and 21.40ppm CO_2 for shade leaves. The comparisons for exposure parameters resulted in all statistically significant coefficient values. These results suggest that the differences between the sun and shade leaves are directly related to the amount of sun the leaves absorbed, increasing the ability for a plant to take up carbon dioxide.

These three tables contain further evidence that seasonal variations are not significant in effecting A_{NET}. The p-values were almost identical from season to season for both presented coefficients. All the β values were <0.0001. These SAS results were consistent with the A-C_i curve models, highlighting the assumption that shade and sun leaves were a significant determining factor in photosynthetic rates, but season was not (Fig. 1, Tables 1a, 1b, 1c).

TABLE 1a. Spring statistical comparison of sun and shade photosynthetic rates (α), intercepts (β), *df*, *F* values, and statistical probability (*p* value), taken from carbon dioxide assimilation rate (A_{NET}) models and the equation $A_{NET}=\alpha*ln(C_i)+\beta$. The parameter estimates were based on sun and shade coefficients from spring data.

	Sun	Shade	*df*	*F* value	*P* value
α	7.6735	4.6033	21	7.52	0.0122
β	34.0874	21.3864	21	72.90	<0.0001

TABLE 1b. Summer statistical comparison of sun and shade photosynthetic rates.

	Sun	Shade	*df*	*F* value	*P* value
α	7.6908	4.6183	21	7.53	0.0121
β	34.1083	21.4074	21	72.90	<0.0001

TABLE 1c. Autumn statistical comparison of sun and shade photosynthetic rates.

	Sun	Shade	*df*	*F* value	*P* value
α	7.6654	4.6051	21	7.47	0.0124
β	34.0732	21.3903	21	72.69	<0.0001

Nyssa sylvatica had the lowest and *Quercus alba* had the highest values. All other species were categorized somewhere in between the two extremes. It is evident that the rate of net assimilation depends upon the species in question. Sun leaves resulted in different groups than the shade leaves groups. The difference in grouping sun and shade leaves may indicate exposure to the sun has more of an effect on some species than others. The shade leaf results showed *Betula lenta* and *Liriodendron tulipifera* on the slower end of the spectrum, and *Rhododendron maximum* and *Quercus alba* as the faster photosynthesizing species. Groups two and three indicate that those species have shared qualities with groups one and four. Therefore, groups two and three have moderate slopes and intercepts. Comparisons of species parameters reveal that species type makes a difference in the assimilation rate. This means that the species that dominate a forest canopy and sub-canopy should be taken into account when measuring daily forest carbon dioxide intake.

TABLE 2a. Summary of slope α parameter comparisons made based on the equation $A_{NET}=\alpha*ln(C_i)+\beta$. Sun species are shown grouped into similar species, based on $p<0.05$.

	Group 1	Group 2	Group 3
Nyssa sylvatica	5.3666		
Betula lenta		7.3515	
Oxydendron arboreum		8.2976	8.2976
Liriodendron tulipifera		8.3238	8.3238
Acer rubrum		8.3497	8.3497
Quercus alba			9.3093

TABLE 2b. Summary of slope β parameter comparisons. Sun species are shown grouped into similar species, based on $p<0.05$.

	Group 1	Group 2	Group 3	Group 4
Nyssa sylvatica	23.8257			
Betula lenta		32.8110		
Oxydendron arboreum		35.1202	35.1202	
Liriodendron tulipifera			37.6161	
Acer rubrum			37.7216	
Quercus alba				41.9574

TABLE 3a. Summary of slope α parameter comparisons. Shade species are shown grouped into similar species, based on $p < 0.05$.

	Group 1	Group 2	Group 3
Betula lenta	3.9314		
Liriodendron tulipifera	3.9892		
Nyssa sylvatica	4.4431	4.4431	
Acer rubrum		4.6779	
Oxydendron arboreum		4.7741	
Rhododendron maximum			5.5079
Quercus alba			5.5824

TABLE 3b. Summary of slope β parameter comparisons. Shade species are shown grouped into similar species, based on $p < 0.05$.

	Group 1	Group 2	Group 3
Betula lenta	18.4880		
Liriodendron tulipifera	18.6209		
Nyssa sylvatica	20.6242	20.6242	
Acer rubrum		21.8190	
Oxydendron arboreum		22.9393	22.9393
Quercus alba			25.3272
Rhododendron maximum			25.3302

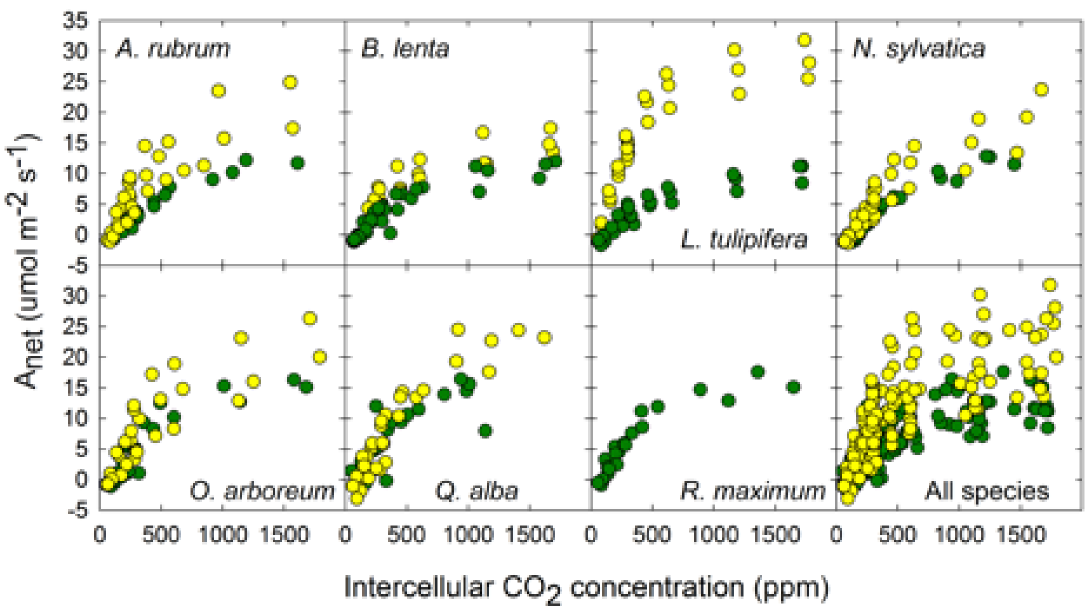

FIG. 2. The scatter plots of the natural logarithm of carbon dioxide assimilation against intercellular CO_2 concentration show that leaf gas exchange differs between sun (yellow dots) and shade (green dots) leaves for the seven species studied during the autumn.

The A-C_i curves taken from the autumn sample show that leaves appear to assimilate carbon differently among species. *Liriodendron tulipifera* appears to have the fastest net assimilation rate for sun leaves in the autumn, and the greatest difference between sun and shade leaves. All the species, except for *Rhododendron maximum* because it has no sun leaves, reflect a difference in sun and shade leaf assimilation. The obvious trend across all species is that shade leaves fix intercellular carbon at a much lower rate than sun leaves, because photosynthesis is a light dependent process.

There has been much debate about how increasing carbon levels in the atmosphere will affect the net primary productivity of forests. This study can help to predict how much carbon a forest is able to use given the season, tree species, and exposure. Looking at whole forest level processes from the parameters, such as exposure, impacting the assimilation of carbon in individual species is one step in the direction of obtaining a good idea of a forest's carbon budget. A mixed hardwood forest, such as the one where this research was conducted, will have similar species, and therefore similar net carbon dioxide assimilation rates. An eddy flux tower has the ability to sample forest carbon assimilation, however the eddy covariance method used to assess the collected data from the tower has its weaknesses. The method is not suitable for measuring fluxes in rough mountainous terrain or near distinct landscape transitions. The quantitative results from this study can be formulated in the future to make the eddy covariance system better suited for the carbon dioxide flow in mountain forest ecosystems. Based on the findings in this study, differences in shade and sun leaves will be a significant factor in estimating a forest's carbon budget. More conclusions can be made from the results once they are compared to sap flux evapo-transpiration and soil respiration research experiments, because all these data can be compared to the net ecosystem exchange interpretations of eddy covariance data. A comprehensive analysis of leaf, root, and soil net assimilation of carbon dioxide will provide an accurate account of the gas exchange within a forest ecosystem. This gas exchange study based on leaf physiology has a great potential to accurately represent spatial and temporal variations in a target ecosystem community.

ACKNOWLEDGMENTS

I would like to acknowledge Dr. Steven Brantley and Dr. Chelcy Ford of the Coweeta Hydrologic Laboratory for the protocol and format for the methods of this study. Also, thank you to Dr. Brantley for instructing me on how to use all the equipment involved in this study, for helping me assess the data, and for the time and effort he put into editing my paper. Thank you, Neal Mundoon for helping me fix the tripod and Li-Cor and for keeping me company during data collection. Dr. Anya Hinkle also deserves many thanks for the support and commitment to editing my paper.

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AN ASSESSMENT AND MAPPING OF WHOLE-TREE REVETMENTS AND OTHER BANK EROSION CONTROL METHODS ALONG THE LITTLE TENNESSEE RIVER

MORGAN BETTCHER AND AUSTIN BROOKS

Abstract. The Upper Little Tennessee River has been the target of a number of conservation and restoration efforts attempting to counteract erosion, sedimentation, and other forms of habitat degradation. Although assessments have been conducted on this section of river before, a historical analysis of riparian buffers and restoration projects has not been performed. We mapped restoration project sites as well as other important sites along the banks of the river using GIS analysis. Whole-tree revetments were generally successful at rebuilding banks and promoting the growth of vegetation. The change in riparian buffer extent was mapped and measured using historical aerial photography. The condition of riparian habitat has improved over time, as the amount of non-vegetated bank has decreased since 1998. This study supports the continued use of whole-tree revetments on similar river systems, and suggests the continued promotion of riparian habitat along the banks of the river.

Key words: GIS analysis; Little Tennessee River; Little Tennessee Watershed Association; riparian buffer; riparian habitat; riprap; tributary; whole-tree revetment.

INTRODUCTION

The Upper Little Tennessee River is one of the most biologically intact river systems in the Southern Appalachians. However, it has been rife with sediment, erosion, and pollution problems since the beginning of the twentieth century (LTWA 2011). Beginning in 1995 several groups, namely the Little Tennessee Watershed Association, the Little Tennessee Land Trust, and the Macon County Soil and Water Conservation Department began efforts to protect and restore the Little Tennessee River. Their methods include the installation of whole-tree revetments, erecting livestock fences, restoring vegetation buffers, and preserving existing riparian habitat. The first study to provide the informational framework for bank stabilization projects was completed by Dr. William O. McLarney in 1997. His study assessed the bank characteristics and quality of riparian buffers on all the properties along the Upper Little Tennessee (McLarney 1997) from the Georgia line to US 441. A subsequent study of riparian zones on the Upper Little Tennessee River was also completed in 2003 by Jason Love of the Coweeta Hydrologic Laboratory, in cooperation with the Little Tennessee Land Trust and Macon County Soil and Water Conservation Department.

No comparisons of riparian buffer conditions over time have been made for this section of river; therefore, the focus of this study was to map and analyze restoration and conservation practices along the banks of the Upper Little Tennessee River. We analyzed the extent of change in vegetative cover along the banks of the Upper Little Tennessee River in the 14 year period since the completion of Dr. McLarney's study (1997).

METHODS

Our main objective was to document and assess the location and conditions of restoration practices as well as other bank alteration projects on the Upper Little Tennessee River. Various features of interest were mapped and analyzed, including whole tree revetments, riprap, raw bank, rock placements, livestock access, and tributary streams/ditches. We also documented the change in riparian buffers over time using GIS analysis and aerial photos. We took both quantitative and qualitative data on every feature, and compared this to past studies and information. All mapping data is available in the Appendices at the end of the report (Appendix A-).

Study Area

The Little Tennessee River, located in the Southern Appalachian Mountains, begins in Rabun County, Georgia on private land and joins the Tennessee River in Lenior City, Tennessee. The Little Tennessee River is approximately 135 miles long. The area of our study was 20 miles of the Upper Little Tennessee River. The segment stretches from the Georgia/North Carolina border to the start of the Little Tennessee Greenway on the left bank and to the mouth of the Cullasaja River on the right bank, all within Macon County, North Carolina.

Revetment Assessment

Whole-tree revetments are an erosion control device, constructed out of defoliated trees implanted into a river bank in order to catch sediment. In order to map revetments, a GPS (Garmin® Map60 CSX) was used to take the location of each restoration practice from a kayak. To map whole-tree revetments we used a map of parcels on which restoration projects had been done, and visually located revetments from the river. The identifying features we looked for included arranged logs embedded in the bank, defoliated branches placed facing upstream, and some method of attaching the structure to the bank (in most cases several embedded cables). The location and length were recorded and added into an ArcGIS® data layer (ESRI 2011). Qualitative assessment of revetments included a photograph of each one, commentary on sedimentation and visibility of the revetment, and vegetative growth. For a whole-tree revetment to be deemed successful, clear signs of vegetative growth must be evident, including shrubs, saplings, and mature trees. In addition, the revetment must have at least appeared to have been incorporated into the soil of the bank. Unsuccessful revetments had little or no vegetation, evidence of bank erosion or undercutting behind the revetment, or was no longer attached to the bank.

Additional Assessments

Areas of raw bank and excessive erosion were identified visually from the river. Raw bank was designated as section of river bank with no vegetation that was of a significant length (over 20m) and showed signs of exposed and constantly eroding soil. Areas of severe erosion were vegetated, but showed signs of rapid or excessive erosion. The position of each segment was recorded as well as the length along the river bank.

Points at which livestock entered the river were recorded with the GPS, and photos were taken of the bank at these locations. Riprap and placed rocks used for bank armoring were identified visually from kayak and mapped in ArcGIS®. Length along the river bank was measured, and commentary on the effectiveness of each project was added in the layer file.

Tributary Streams

Tributary streams and drainage ditches were mapped with a Garmin® Map60 handheld GPS unit by visually identifying the mouth of the waterway and recording the position as it intersects with the Little Tennessee. Each stream was designated as either perennial or intermittent, as could be judged visually. Stream type was determined by observing at both a time of high flow and a time of low flow based on the amount of flow present. Stream data were then compared to existing GIS and map data, and each was labeled if a name was available.

Historical Riparian Buffer Analysis

In order to determine the status of buffers along the study area that had been previously studied, buffer width was measured using the computer programArcGIS®. Using aerial photographs from surveys in 1998, 2003, 2006, and 2010, a polyline was created following the extent of woody vegetation along the Little Tennessee River. The distance from the bank of the river to the outermost extent of woody vegetation buffer was measured and classified into four distance categories, 0 feet, 1-30 feet, 30-100 feet and >100 feet. The buffer width was then ground-truthed from the river by visual assessment. After evaluating our method of assessing buffer width using aerial photos with ground-truthing, we were confident that we could assess the change in buffer width of previous years.

RESULTS

Revetment Assessment

In our survey of the twenty mile stretch of the Little Tennessee River, we were able to locate 19 revetment sites. 75% of these (14) were successful while 25% (5) were inadequate, or had failed completely. The total length of bank with revetments installed was 985m, and the average length of all revetments was approximately 50m. All successful revetments provided some measure of aquatic habitat, as logs were somewhat exposed at the water level and would be submerged during periods of higher water level. More revetment sites may have been constructed along the Upper Little Tennessee River; however if they were extraordinarily successful or completely destroyed, there would be no way to identify them.

Additional Observations

During our study we found various sections along the river that were either of concern to us or were alternate restoration methods, these include areas of raw bank, highway riprap, natural rock placement and livestock access. We recorded eight sites of excessive raw bank. The total extent of raw bank along the river was 390m, with the average consecutive section where vegetation was completely absent down to the water level was approximately 43.3m in length. Vegetation on top was restricted to grasses and plants with very shallow roots (as could be visually determined from water level), if any growth was present at all. Sections of bank that had sediment recently fall or were clearly going to fall into the river were also considered raw bank.

Raw bank was mostly associated with pastures or fields with no buffer cover, and was also more common on the outside of bends.

We marked two sections of river as having severe erosion, a separate category from raw bank, because they were sections of particularly bad erosion in areas where vegetation was present. The total length of this section was 90m, and the average was 45m. In these sections the roots of hardwoods, mostly mature trees, were being undermined as the sediment was eroded. Trees were falling into the river at these sections.

We recorded eight separate sections of highway riprap as well as riprap placed in other contexts. Vegetation was generally absent on the face of these rocks, although growth was present at the tops of some. The total length along the river was approximately 275m, and the average length was approximately 35m. Most were located on sections of the river that were adjacent to US Highway 441. All of these sites seemed successful at preventing erosion, and could also provide aquatic habitat.

We recorded eight sections of natural rock deemed purposefully placed for the purpose of bank armoring. This category of stream bank made up approximately 385m of the total, and the average continuous section was about 50m. Some degree of vegetative growth was almost always present among the rocks and down the bank to the water level. Riparian buffer was not always present at the top. Often this category was located very near residential structures. Rocks usually created some aquatic habitat, but to a lesser extent than riprap.

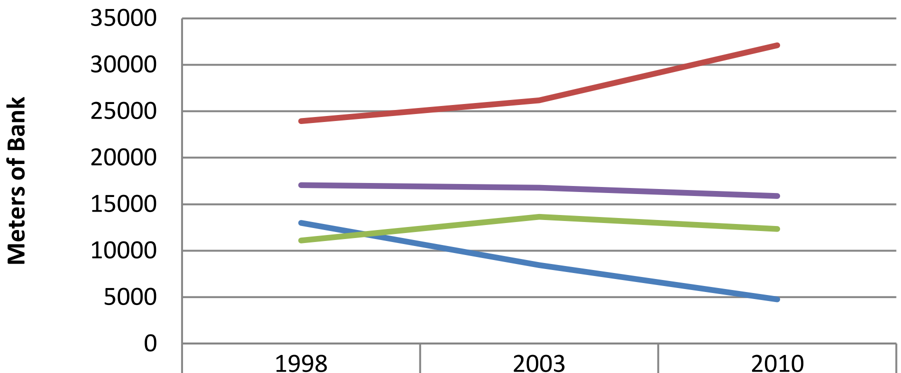
We recorded one point at which livestock; in this case cattle were entering the river and standing along the bank. This section of bank was associated with only one parcel.

Tributary Streams

We were able to identify 35 streams flowing into the river in total. Of the 35 streams, 18 (51%) were classified as intermittent, 17 (49%) streams were classified as perennial, into our study area. It was also found that 15 of the streams mapped during this study were unmarked and there were a total of 18 unnamed streams were located along this section of the Upper Little Tennessee River.

Riparian Buffer Analysis

Over the 14 year scope, a dramatic change in riparian buffer was noticed. The two larger categories (30-100ft and >100ft) showed relatively little change over time. The 30-100ft category fluctuated by 4%, and remains near baseline levels in 2010. The largest category, over 100ft, only decreased by 2% over fourteen years, and this value could be attributed to error. In 1998, 20% of the bank within the study area lacked any form of vegetative buffer. This percent decreased consistently over time until 2010, where it makes up only 7% of the total bank. In response, bank categorized as < 30ft increased from 37% to half the total study area (Fig. 1).



	1998	2003	2010
0 ft	13006	8450	4780
<30 ft	23922	26168	32077
30-100 ft	11090	13656	12323
>100 ft	17038	16782	15876

FIG. 1. Change in riparian buffer width over time.

During the on-site verification of buffer assessment from the aerial photographs, only two sections of river had to be revised. These were the result of photographic resolution as well as canopy obscuring the visibility of ground cover. In both cases, it caused an overestimation of buffer extent.

DISCUSSION

River bank features

Whole-tree revetments appear to have been a fairly successful restoration practice in the Upper Little Tennessee. About three out of four revetments visible from the river were successful at trapping sediment and providing footing for riparian vegetation. The revetments that Love (2003) assessed had shown an increase in woody vegetation since their installment, and from our observations this trend has continued. Grasses and shrubs dominated on most revetments, while young trees had clearly established themselves. However, most areas of restoration were still in early successional stages, and large hardwoods are generally absent from areas in which revetments have been installed.

The locating and mapping of revetments was limited by our ability to visually identify whole-tree revetments from the river. Successful revetments would ideally be completely buried by trapped sediment and overgrown with woody vegetation. This would make them practically invisible without knowing the precise location. While the location of parcels where restoration projects had been completed was documented by the Little Tennessee Land Trust and made available to us, the practices that were carried out on each property were unknown. For this reason, it is possible that successful revetments escaped our survey. Likewise, if a revetment fails completely, it will likely be ripped from the bank in which it was implanted, leaving nothing but raw bank. This is impossible to distinguish from severely eroded banks unless it is known to be the site of a previous revetment. There was only one such case in this survey, namely the revetment on the Little Tennessee Land Trust property located on the Tessentee Preserve

(RE13). Therefore, the success or fail rate of revetments on the Little Tennessee might actually be higher or lower than this study would indicate.

Riprap was a fairly common feature on the Upper Little Tennessee, although it did not make up much length along the river. In all the locations it was placed, however, it was very successful at preventing erosion, and provided aquatic habitat for fish and various aquatic invertebrates. A significant riparian buffer (>30ft) was usually present between the riprap and the highway; however, practically no growth was present on the riverbanks since riprap does not provide suitable habitat for vegetation. Likewise, it looks unnatural, and is aesthetically unpleasant.

Rocks were a common feature of the river, and made up more total bank length than riprap. Protecting stream banks with rock placements can be done by anyone that lives along the river, and so was in many cases not associated with roads or with river restoration groups. Many of the rock sites we recorded were not associated with parcels marked as the site of a restoration project, indicating that some were probably individual efforts carried out by landowners as well as rocks leftover from the Tallulah Falls Railroad construction (1882-1907). Many rock placements were associated with residential buildings that were built very close to the river bank, and might otherwise be in danger of erosion damage. Distinguishing between natural and unnatural rocky stretches was usually straightforward, but since rocks used along the banks were generally the same type as found in natural stretches, there is the possibility that some confusion occurred. Almost all examples we found were successful at preventing the erosion of the riverbanks along which they were located. They also showed more growth along the riverbank than riprap, since rocks were usually placed at the water level and were not as densely placed. The age of these rock placements may have allowed enough time for regeneration of the bank to occur.

The stretches of bank we designated as raw made up 390m of bank along the river. Raw bank was mostly associated with riverside fields and pastures, since in this type of land use there is no root growth to hold the bank in place. The measured length of raw bank along the river may be misleading, since we only measured areas completely devoid of roots and vegetation as raw. From our observations many other sites were eroding, but could not be classified as raw. Likewise, we recorded two sites as being excessively eroded despite heavy vegetation, but again many other sites showed erosion where a fair amount of vegetation was present. Those sites marked as eroded bank stood out because erosion was undermining very mature hardwoods with what appeared to be adequate root structure. The sites that did not fit into the two categories of bank were not recorded for the sake of feasibility, since many mile-long stretches of river showed mild to severe erosion problems periodically.

We recorded only one point at which livestock were entering the river along the entire stretch on which this survey was conducted. In that area the bank of the river was trampled, and the livestock were obviously causing the erosion of the bank as well as entering the water regularly. However, the scale of the problem is relatively small; only about 40m of bank was affected by trampling, and relatively few cattle seemed to enter the river at all. Compared to the level of livestock presence along the banks of the river during McLarney's study (1997), there has been significant improvement in this area. From our observations livestock is now only an isolated problem along this stretch of river. Livestock access to the river presents a concern when discussing river health, especially water quality. Watersheds with livestock populations that are able to access rivers and streams have shown to discharge as much as ten times more nutrients than watersheds without. Livestock with access to streams have been shown to increase the amount of sediment introduced to streams. Livestock also present a concern to water quality because of pathogens being introduced into the water (Hubbard 2004). The river would benefit greatly both physically and chemically from Best Management Practices such as fencing along this river.

Tributary Streams

The designation of streams as perennial and intermittent is subject to error. Data collection occurred at a time of high flow (well above mean flow, December 1st and 2nd) in order to make visual identification possible. Stream pour points were also observed during a time of low flow (well below mean flow, week of September 10th), so that smaller streams could be classified (Fig. 2). However, since these streams were only observed twice during one season, it is possible that their flows fluctuate less or more than we estimated, and so might have been designated incorrectly.

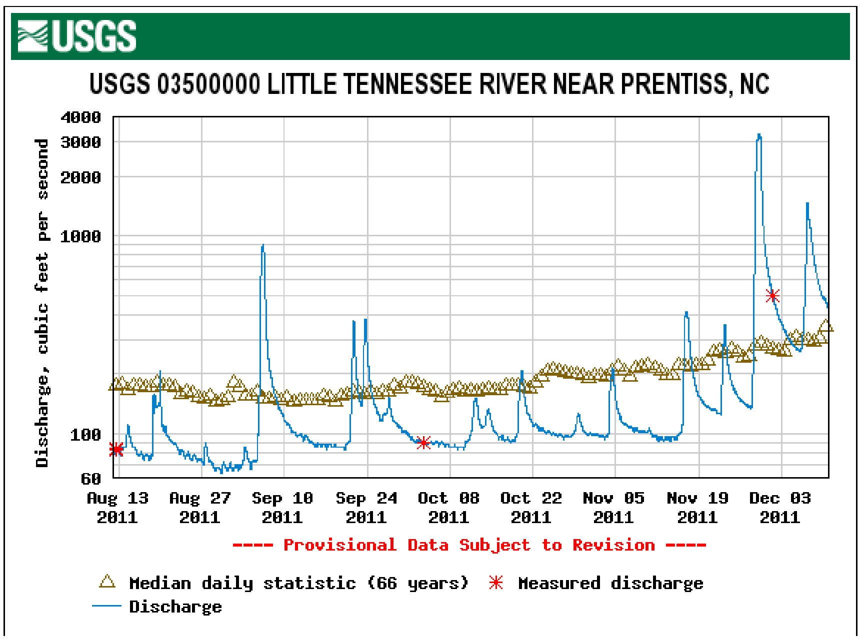


FIG. 2. Little Tennessee River discharges in 2011(USGS 2011).

Riparian Assessment

The decreasing amount of unbuffered stream bank suggests that this section of the Little Tennessee has responded positively to efforts to restore woody vegetation along the banks after McLarney's study in 1997 (Table 1). The growth can be attributed to the shift of land-use practices from agricultural to light residential as well as the increased conservation efforts on the river. Small amounts of vegetation have been allowed to grow along the river on many properties, increasing the amount of bank with at least minimal riparian habitat. This practice of regeneration of riverside vegetation has not increased the percentages of the larger buffer categories since most of the new buffer is a single row of trees and shrubs, and therefore <30ft in width. Although increasing the amount of bank with wider riparian buffers would be ideal, any increase in woody vegetative cover improves the health of the river.

TABLE 2. Change in buffer categories since 1998.

Buffer Width	1998	2003	2010
0	20%	13%	7%
<30	37%	40%	49%
30-100	17%	21%	19%
>100	26%	26%	24%

The main source of error in our assessment of buffer width was the quality of aerial photos as well as our ability to distinguish cover types from these data. Since this assessment is based on historical information, it was impossible to ground-truth most of our classifications. We verified the accuracy of the 2010 photos from the river, and found only a few discrepancies. However, it should be noted that these photos were over a year old at the time this study was conducted.

ACKNOWLEDGEMENTS

We would like to thank Jason Meador, Jenny Saunders and Bill McLarney of the Little Tennessee Watershed Association for their support and guidance throughout our internship. We thank the Nantahala Ranger District for supplying us with topographic maps of the region. We thank Gary Wein for helping us with GIS technology, as well as Justin Setser for providing us with aerial photography. We also would like to thank Jim Costa, Anya Hinkle, and Michelle Ruigrok for help with revision. Finally, we would like to thank Kelder Monar, for without this good friend's help, many times we would have found ourselves up a certain creek without a paddle.

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APPENDIX A

GPS locations of river bank features.

GPS Point Name	Feature	Successful/Unsuccessful	Length on Bank in meters
RAW1, RE1	Raw Bank	Unsuccessful	60
RE2/RE3	Revetment	Successful	110
RE5	Revetment	Successful	40
RE6	Revetment	Successful	30
RE7	Revetment	Unsuccessful	40,30
RE8	Revetment	Successful	20

RE9	Revetment	Unsuccessful	40
RE10	Revetment	Successful	50
RE12	Revetment		
RE13	Revetment	Unsuccessful	30
RE14	Revetment	Successful	60
RE15	Revetment	Successful	80
RE16	Revetment	Success	15
RE17	Revetment	Unsuccessful	20
RE18	Revetment	Success	30
RE19	Revetment	Success	50
RE20	Revetment	Successful	50
RE23	Revetment	Successful	70
RE24	Revetment	Successful	30,120
RE26	Revetment	Successful	70
RI1	Riprap		20
RI1	Riprap		40
RI2	Riprap		50
RI4	Riprap		40
RI5	Riprap		30
RI6	Riprap		20
RI7	Riprap		70
RI14	Riprap		5
RO1	Rocks		70
RO2	Rocks		30
RO20	Rocks		20
RO21	Rocks		30
RO3	Rocks		120
RO14	Rocks		80
RO16	Rocks		20
RO17	Rocks		15
COW1	Cow Access		60

APPENDIX B

Tributaries Along the Upper Cullasaja

Identification Number	Name	Stream Type	Additional comments
O21	Waterloo Branch	Intermittent	
O22		Intermittent	
O23	Mulberry Creek	Perennial	
O28		Intermittent	Culvert
O29		Perennial	Live animal trap found at mouth
O30		Perennial	Live animal trap found at mouth
O31		Intermittent	

O32		Intermittent	
O33		Intermittent	
O35		Perennial	
O36		Perennial	
O37		Intermittent	Culvert
O38		Perennial	
O41		Intermittent	
O43		Perennial	
O44	Tessentee Creek	Perennial	
O49	Coweeta Creek	Perennial	
O50	Hickory Knoll Creek	Perennial	
O53		Intermittent	
O55	Bates Branch	Perennial	
O56		Intermittent	
O57		Intermittent	
O58	North Fork Skeenah Creek	Perennial	
O59		Intermittent	
O60		Intermittent	
O61		Perennial	
O62	Dowdle Branch	Perennial	
O63	Fulcher Branch	Intermittent	
O64		Intermittent	
O66	McDowell Branch	Perennial	Culvert
O67		Intermittent	
O68	Hayes Creek	Perennial	
O69		Intermittent	
O70		Intermittent	
O71	Owenby Branch	Perennial	
O72	Cartoogechaye Creek	Perennial	

APPENDIX C
Bank Features GPS Points

APPENDIX D
1998 Riparian Buffer

APPENDIX E
2003 Riparian Buffer

APPENDIX F
2010 Riparian Buffer

APPENDIX G
Photos

OVERFLOW WILDERNESS STUDY AREA: A CASE STUDY OF WILDERNESS AND THE PROPOSED BOB ZAHNER WILDERNESS

RYAN C. EVANS AND ALICE H. KIM

Abstract. The Wilderness Act of 1964 established the first designations of wilderness by law in the world. Wilderness is protected because of its ecological, geological, scientific, educational, scenic and historical values. Wilderness Study Areas are similarly protected because of their potential for official designation and study. Here we discuss the history and importance of the Overflow Wilderness Study Area (WSA), and its failure to gain an official Wilderness designation and become the Bob Zahner Wilderness Area (BZW) in the past two years. We examine the Overflow WSA through the lens of interviews and personal communications with individuals and groups involved in the process in order to understand its failure to gain permanent protection. While the proposed BZW has a large support base in the town of Highlands, NC, it has little support in the rest of Macon County due primarily to misinformation about the implications of wilderness designation and fear of governmental restrictions.

Key words: Overflow Wilderness Study Area; Wilderness; Wilderness Act of 1964; the Wilderness Society.

INTRODUCTION

Since its implementation on September 3, 1964, the Wilderness Act has protected 757 individual wilderness areas that cover 109,512,959 total acres of land (USFS 2011). Such a figure does not take into account the multitude of Wilderness Study Areas (WSAs) that also receive protection from the act. Wilderness study areas have been protected for further study by the U.S. Forest Service (USFS), the Bureau of Land Management, and the Fish and Wildlife Service because of their potential for future wilderness designation. In order to preserve their wilderness character, WSAs are maintained in the same way as designated wilderness areas until it is determined that they should receive official designation. Designation as an official wilderness area, however, is an extensive process that requires an act of Congress. The complex nature of designations is largely due to the complexities of the Wilderness Act and, as a result, conflicting interpretations of its text have arisen.

In order to understand the complexities of the Wilderness Act, it is important to look at its history. Many prominent names in conservation were involved with the creation and advancement of wilderness law, such as John Muir, Aldo Leopold and Bob Marshall. None stand out in the history of the Wilderness Act as much as Howard Zahniser. In 1945, Zahniser moved into a prominent position within the Wilderness Society, an organization dedicated to the preservation of America's wild landscape (Scott 2004). Created in 1935, the Wilderness Society has been at the forefront of the campaign to protect wilderness. Zahniser was then paired with director Olaus Murie, and the two, who were driven by their experience with wild land legislation, began to formulate a vision of wilderness preserved by federal law.

Eleven years later Zahniser introduced the Wilderness Bill, which would provide the foundation for the Wilderness Act. Just before he introduced the bill, Zahniser addressed the National Citizen's Planning Conference on Parks and Open Spaces and said: "[We need] areas of the earth within which we stand without our mechanisms that make us immediate masters over our environment…by very definition this wilderness is a need" (Scott 2004). It took eight years for the Wilderness Bill to successfully pass and become the Wilderness Act, even after John F. Kennedy endorsed it as part of his election campaign in 1960. Finally, in 1964 a change was made to the bill that required an act of Congress to add new wilderness areas and Lyndon B. Johnson then signed the Wilderness Act into existence. Zahniser died just four months before the Wilderness Act was created, but his widow Alice stood next to President Johnson to witness the signature (Scott 2004).

Unfortunately, complications with the Wilderness Act did not end with its passing, as the language used within the definition of wilderness led to a broad range of interpretations. In the Wilderness Act, wilderness is defined as: "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain…retaining its primeval character and influence…and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable…" (U.S. Congress 1964). Words such as "untrammeled," "primeval," "generally," and "substantially unnoticeable" all leave the act open to individual interpretation. Since the Wilderness Act was commissioned, the USFS has developed criteria to determine whether land is suitable for wilderness designation, as well as a seven step process for official designations.

The issue of individual interpretation first became evident in 1967 with the Roadless Area Review and Evaluation (RARE). A program carried out by the USFS, RARE was a study of all roadless forest areas in the 187 million acre National Forest System to evaluate their suitability for wilderness designation. It was concluded that the areas must be "totally pristine and removed from the sights and sounds of civilization to qualify" (Beach et al. 2004). Under the USFS's strict interpretation of the act, not a single roadless area east of the 100th meridian was found to be eligible. It was not until the 1975 Eastern Wilderness Areas Act that areas were formed in the eastern United States. Indeed, the Forest Service's interpretation of wilderness is even mentioned in the U.S. Senate report of the Eastern Wildness Areas Act as having come under heavy attack by citizens groups. As a result, Congress concluded an urgent need to find, study, and include eastern areas in the National Wilderness Preservation System (Beach et al. 2004). From 1977-1979, the USFS conducted their second evaluation, RARE II. It was during this time that many areas within western North Carolina were recommended for wilderness study or further planning.

The North Carolina Wilderness Act of 1984 established the Overflow WSA, which lies adjacent to NC 106 in Macon County, just southwest of Highlands (U.S. Congress 1984) (Fig.1).

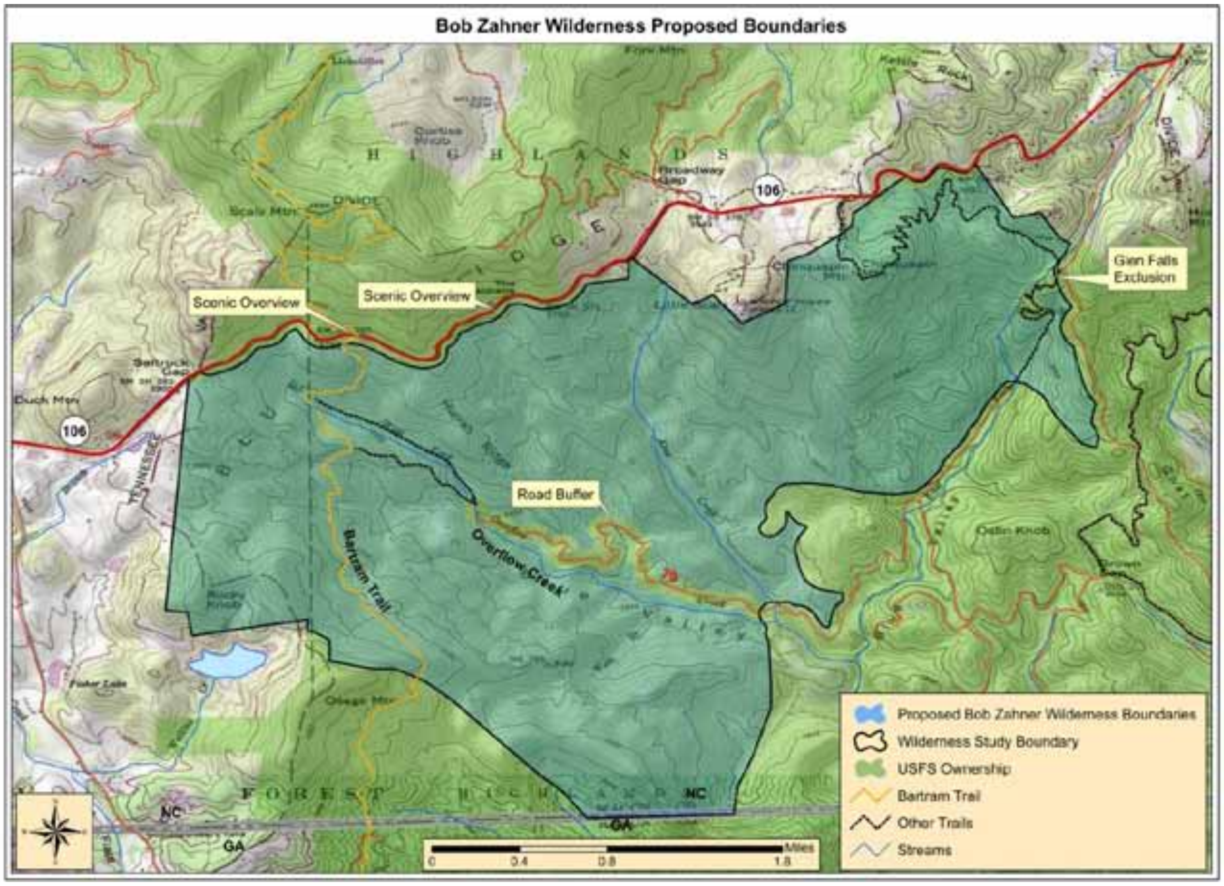

FIG. 1. Map of the Overflow Wilderness Study Area and proposed Bob Zahner Wilderness Area. Key features include U.S. Forest Service Road No. 79 and the Bartram Trail, which both run through the area.

Covering approximately 3,200 acres in the Three Forks – Blue Valley area, Overflow WSA is currently under the Management Area 5 plan, which emphasizes semi-primitive, non-motorized recreation. Overflow WSA is located next to the popular Glen Falls area, with a segment of the Bartram Trail running through it. Due to its primitive nature, it is popular destination for hunting, fishing, hiking, and backpacking. Although it was logged in the past, today it appears relatively untouched, with extensive areas of upland oak forest, cove hardwoods, and white pines that are sixty to eighty years old. These forest stands provide beautiful and relatively untouched scenery, and offer recreational users a chance to distance themselves from everyday human constructs.

Recommended for further planning in 1979 during RARE II, Overflow WSA was one of five study areas designated under the NC Wilderness Act. The area was deemed unsuitable for wilderness in 1987, however, because the USFS did not feel there was enough potential for solitude. Additionally, Forest Road 79 runs into the middle of the area and was seen as a major obstacle in achieving designation. Then in 1991, U.S. Representative Charles Taylor proposed a bill that would have released the Overflow WSA from all protection, but the bill failed to make it out of committee. Because it is still a wilderness study area today, Overflow WSA is managed as if it was an official wilderness area under the U.S. Forest Service Management Area 5 plan. The plan protects the area from practices such as timber harvesting and mining, but the protection is not permanent.

Recently, a bill called the "Wilderness and Roadless Area Release Act," or H.R. 1581, was proposed by Congressman Kevin McCarthy of California. The bill would eliminate the

Forest Service roadless rule, which protects nearly 58 million acres of roadless national forest, as well as all wilderness study areas. If the bill were to pass, these 58 million acres of land, including Overflow WSA, would potentially be opened to logging activities. Timber harvesting within Overflow WSA could provide economic benefits, but proponents of Wilderness would argue that it potentially destroys many species habitats. The clearing of trees not only directly removes them for potential habitat, but it also creates edges in the forest. These edges cause forest to be disconnected, and many species require large uninterrupted stretches of forest for their habitat. Consequently, the Wilderness Society and other conservation groups have felt increased pressure to attain more permanent protection for Overflow WSA through an official wilderness designation.

Included in the effort for an official designation is a change in name to the Bob Zahner Wilderness Area (BZW). The name change would honor the late Dr. Robert Zahner, who was a fervent conservationist, ecologist and Highlands, NC local. Dr. Zahner was a research assistant for the USFS for six years, and taught forestry and ecology at both the University of Michigan and Clemson. The effort for the BZW has been spearheaded by the Wilderness Society's Southern Appalachian Director, Brent Martin. Martin, who has formerly worked with Georgia Forestwatch and the Little Tennessee Land Trust, first met with Congressman Heath Shuler of NC's 11th District in the spring of 2010 to discuss the proposed BZW. At that time, Congressman Shuler expressed his support for an official designation but only with a signed resolution from the Macon County commissioners. Since that time, the Wilderness Society has attempted to gain the support of the commissioners but in February 2011, a majority voted against the designation. As a result, the proposed BZW has been tabled, but could be reconsidered if the commissioners were to give it their support in the future. The commissioner's opposition comes despite signed resolutions in support of the proposed BZW from a number of groups, including the Town of Highlands and the Highlands Area Chamber of Commerce who support the designation primarily in recognition of the aesthetic and recreational benefits that protected wilderness would provide for the area's tourist-based economy.

Central to the idea of an official designation is the permanent protection that it would provide for Overflow WSA. Permanent protection would ensure that the area could not be logged in the future, and all of its benefits as a wilderness area would remain intact. The benefits of wilderness land as stated by the Wilderness Act include ecological, geological, scientific, educational, scenic and historical values. Beyond these values is the direct value of recreation, as well as the knowledge that wilderness is protected, or the value gained merely from knowledge of its existence. In this paper, we seek to explain the controversial history of Overflow WSA and why it has failed to achieve an official Wilderness designation. We will examine both the proponents and opponents of the designation in order to understand the current public opinion on the BZW.

MATERIALS AND METHODS

Extensive research on the background of wilderness designations was conducted by studying a broad spectrum of government documents and publications, including: the Wilderness Act of 1964, "Western North Carolina's Mountain Treasures," a guide published by The Wilderness Society in conjunction with the Southern Appalachian Forest Coalition, and *The Enduring Wilderness: Protecting Our Natural Heritage through the Wilderness Act* by Doug Scott. Furthermore, we referred to the reports of the Recreation, Wilderness, Urban Forest, and

Demographic Trends Research Group, a USFS organization that focuses on America's perception of recreation, the values of wilderness, and the demands for wilderness. In order to gain more specific insight into the Overflow Creek Wilderness Study Area's history, we referenced the North Carolina Wilderness Act of 1984. Additionally, the original Environmental Impact Statement (EIS) for the Overflow area was viewed at the Nantahala Ranger District office in Franklin, NC. We also accessed government documents including Roadless Area Review and Evaluations (RARE I & II) at Western Carolina University's Hunter Library in Cullowhee, North Carolina. Dr. Robert Zahner's *The Mountain at the End of the Trail: A History of Whiteside Mountain* was referenced to provide insight into his unique perspective on the environment and conservation, as well as several articles published on his life for biographical information. In order to assess health in Macon County, the 2010 State of the County Health Reports were referenced, specifically looking at obesity ratings for elementary and high school students.

To understand the origin and basis for the lack of consensus surrounding the designation of the Overflow WSA, both proponents and opponents of the legislation were interviewed via phone, e-mail, and in person. Because we spoke with a diverse group of people with varying degrees of knowledge on the subject, there was not a structured set of questions. First, we interviewed Glenda Zahner, Dr. Robert Zahner's wife, who was able to provide background on him and Overflow Creek. Next, Macon County commissioner Ronnie Beale was interviewed via email, and commissioners Brian McClellan and Robert Kuppers were interviewed via phone. The president and secretary of the Macon County Coon Hunters Association, Ralph Sander and David Cabe, respectively were contacted via phone. Kelly Sheehan-Martin, Congressman Heath Shuler's grants and projects coordinator, was reached at the Asheville branch of the congressman's office by phone. Russell Regnery, president of the Highlands Plateau Audubon Society, was contacted via email. Michael Wilkins, the Nantahala district ranger, was reached by phone.

RESULTS AND DISCUSSION

Legislative History of Overflow WSA

The history of the Overflow WSA began during RARE II when it was recommended for further planning. In order to understand the implications of the RARE II Overflow WSA recommendation, it is important to consider the U.S. Forest Service's (USFS) approach to the process. During a visit to the USFS Nantahala office in Franklin, NC, a document entitled "RARE II – Questions and Answers" and dated March 15, 1978 was found. In the document, RARE II is defined as a "methodical national approach to speed up resolution of controversy which has, for a number of years, stalled effective planning and management of much of our public land." RARE II sought to identify areas of high wilderness potential, while at the same time identify previously recommended areas that could be released because of important non-wilderness values. The document goes on to say that RARE II is a controversial natural resource issue because of the continuing commodity-production-versus-wilderness debate involving public lands, which has simmered and boiled throughout the decades. A number of factors were considered when evaluating areas for wilderness study designation including the economic factors, the potential for wilderness, the social impacts and local sentiment, and national needs, among other factors. The evaluation of roadless areas, which was claimed to be a town-meeting on a national scale, emphasized public involvement. People and groups across the nation attended 227 workshops, submitted 35,000 written comments on individual areas, proposed additions or deletions of areas, and read and evaluated draft Environmental Impact Statements (EIS) based on field observations. An EIS, which is required under the National Environmental Policy Act, evaluates the positive and negative environmental effects of human interaction with an area.

Another section of the RARE II Q&A claims that if new roadless areas are identified after a certain time it may be too late for their full evaluation because of the deadlines set by the program. In such a situation, the areas identified after the original assessment will be considered between the time of the draft and final versions of the EISs, which was the case for Overflow WSA. While documents on the RARE II process were researched at the USFS Nantahala office, a map dated September 23, 1977 was found that depicted all public suggestions for wilderness study areas as well as existing wilderness areas in NC. Overflow WSA is not represented on the map. However, another document dated October 7, 1977 and sent by the Deputy Forest Supervisor James R. Beavers showed that although Overflow WSA did not meet inventory criteria and was not recommended by the forest supervisor, it was recommended by the regional forester (Beavers 1977). Further investigation led to the discovery of a document dated July 24, 1978 sent by the Planning Staff Officer Robert L. Phillips to district rangers and staff (Phillips 1978). The document explains that the Overflow WSA originally met the basic criteria for inclusion in the inventory, but was later dropped because it included the Blue Valley Experimental Forest. After reassessment, the Chief excluded the Experimental Forest portion in Georgia and included the remaining NC portion, which became the Overflow WSA. Phillips ends the letter with “To say the least, this is complicated business. If you have questions, let me know.” An attachment to the letter provides a list of areas added and Overflow, which is said to meet inventory criteria, is clearly circled.

One final document found at the USFS Nantahala office is a document from District Ranger Larry N. Phillips that provides requested data from the Overflow WSA for the Forest Supervisor. Attached to the message is an inventory of resources found within the area, including timber and minerals. Section eight of the inventory provides the number of sales and volume which had been scheduled in Overflow WSA’s action plan prior to RARE II. Four hardwood sawtimber sales that totaled 1.6 million board feet (MMBF) were planned, as well as four sales of softwood sawtimber that totaled 1.9 MMBF. Clearly, the RARE II recommendation prevented the Overflow WSA from timber activities that would have occurred sometime between 1979 and 1982. If there was that much timber to be harvested at that time, it is likely that much more would be available after thirty years of continued growth and that the area would be even more alluring to timber companies.

Subsequent to RARE II in Overflow WSA’s history was the North Carolina Wilderness Act of 1984, which was proposed by U.S. Representative James Clarke and granted the WSA designation to Oveflow. Subsequently, U.S. Representative Charles Taylor opposed Overflow WSA becoming wilderness, and instead favored the release of the area for general use, which includes logging (Horan 1997). Taylor, who owns Champion Cattle and Tree Farm and is closely aligned with the timber industry, proposed a bill in 1991 that would have released Overflow WSA but the bill failed to make it out of the committee. In an interview with Glenda Zahner, widow of the late Dr. Zahner, she recalled that Taylor came to Highlands to promote Overflow WSA’s release. Coincidentally, the Western North Carolina Alliance was holding a meeting on clear cutting on the same day in Highlands. All of the members attended Taylor’s meeting; he later claimed the conservationists had “stacked” the meeting.

After the failure of Taylor's proposed bill, Overflow WSA maintained its study area status and little happened to threaten its status or to gain it an official designation until the campaign for the Bob Zahner Wilderness began. The campaign began with Brent Martin's meeting with U.S. Representative Heath Shuler in the spring of 2010. Rep. Shuler (D-NC), who was a local football star in nearby Swain County, NC, says he "[has] made the protection of our national forests one of [his] top priorities" during his time in Congress (Shuler 2011). During a phone interview, Kelly Shehan-Martin, Rep. Shuler's representative in Asheville, said Rep. Shuler's opinion on the proposed BZW had not changed, but that he wants to follow the lead of the county commissioners. Additionally, she added that Rep. Shuler would need to see a broad support for the designation from the local community. Rep. Shuler will be up for re-election in 2012 after a redrawing of districts that will eliminate most of the constituents in Asheville, an area of strong Democratic support, from the 11th district.

Shehan-Martin was also asked for Rep. Shuler's opinion on HR 1581 the "Wilderness and Roadless Area Release Act," and said that Rep. Shuler does not take positions on bills until they are voted on as many things can change before a bill is on the floor. HR 1581 was first introduced by US Representative Kevin McCarthy (R-CA) to the Committee on House Natural Resources Subcommitte on National Parks, Forest and Public Lands on July 26, 2011 (McCarthy 2011). Rep. McCarthy points out that there are over 42 million acres of land that have been deemed unsuitable for wilderness by the Bureau of Land Management and the U.S. Forest Service. He explains that these lands remain tied up until Congress releases them for multiple-use or designates them wilderness. He then goes on to call HR 1581 a common sense bill that would release Wilderness Study Areas and Inventoried Roadless Areas so they are no longer needlessly held in regulatory limbo. The purpose of the bill, Rep. McCarthy argues, is to potentially allow for reasonable resource development, better forest management, more reliable grazing and numerous recreational activities that are currently prohibited in the areas. Along with Rep. McCarthy, 33 other Republicans introduced the bill.

In Support of the Proposed Bob Zahner Wilderness

The vast majority of the proponents of the proposed Bob Zahner Wilderness (BZW) consisted of groups and individuals associated with the town of Highlands. Brent Martin of the Wilderness Society created a resolution template within which he outlines the rationale for the proposed BZW. The resolution describes the area's importance in the preservation of outdoor recreation, wildlife and plant habitat, clean water, and as a significant headwater stream of the Chattooga Wild and Scenic River. It also illustrates that the proposed BZW will protect outstanding natural features, which is important to the quality of life and local economy of Macon County citizens. The resolution goes on to explain that the name change from Overflow to the BZW honors Dr. Robert Zahner for his life-long dedication in the conservation movement. Interestingly, while Glenda Zahner expressed her desire for the area's name to honor the work of her late husband, she also emphasized the area's need for protection regardless of the name (G. Zahner, Interview). Groups that have signed resolutions for the proposed BZW include, but are not limited to: the Highlands Plateau Greenway, Highlands Biological Station, Highlands Area Chamber of Commerce, Highlands Plateau Audobon Society, Jackson-Macon Conservation Alliance, the NC Bartram Trail Society, and the Highlands-Cashiers Land Trust. In addition, the Town of Highlands Board of Supervisors has unanimously voted in favor of the proposed BZW. In response to his opinion on the proposed BZW, Russell Regnery, President of the Highlands

Plateau Audubon Society, said that although there are few areas within the eastern U.S. that have never been touched by the hand of man, he believes the BZW has a nearly complete collection of naturally occurring ecologic assets and comes as close to wilderness as can ever be hoped for.

When interviewed for his opinion on the proposed BZW, a local outdoor store owner in Franklin, North Carolina voiced his concern about the question of boating rights. Initially, he was under the impression that the proposed BZW would in some way restrict boaters' access to the Chattooga River and prohibit the use of the U.S. Forest Service Road No. 79. After he was informed that boating is allowed in all Wilderness areas and that the road would remain open, however, he voiced his support for the designation. He went on to say that he thinks the area should be managed in the same way as the Joyce Kilmer-Slickrock Wilderness Area because of its success and the opportunities it offers users. The owner's misunderstanding and confusion in regards to the BZW may be representative of a broader public misunderstanding of Wilderness.

Proponents of the BZW feel that the designation would preserve ecological, educational, and recreational values from further human encroachment. They believe that WSAs protect the natural habitats of various wildlife species and serve as sources of great species richness of numerous flora and fauna. For example, Mountain Camellia (*Stewartia ovata*) is a deciduous flowering small shrub and tree species only found in the southern Appalachians specifically in the Overflow WSA in Macon County. Supporters argue that the proposed BZW will protect this rare, valuable species from endangerment and extinction. They are of the opinion that WSAs have long been sites for science and educational research functioning as the basis for field trips, study areas, and instructional classes. Furthermore, supporters contend that WSAs also conserve recreational areas as they prohibit the use of motorized vehicles and tools; they encourage and promote most primitive recreation activities which include hiking and camping, backpacking, fishing and hunting, boating of unmotorized vehicles, horseback riding, and the use of pack animals. As a result, wilderness advocates argue that wilderness areas are experiencing a steady increase in visitors as urban environmentalists seek escape from the nation's fast-paced industrialized society, and there is an increasing need for additional wilderness areas.

In Opposition to the Proposed Bob Zahner Wilderness

Although the proposed BZW was widely accepted in the town of Highlands, the designation met opposition in Macon County, as the county commissioners there did not feel support was strong enough to sign a resolution. Outside of Highlands, the county commissioners did not feel that there was a difference in management between WSAs and permanently protected Wilderness Areas, and consequently saw no reason to make any changes. During a commissioners meeting held on October 11, 2010, Commissioner Bobby Kuppers explained that he was worried about the hidden consequences associated with the designation, as he feared that the rules would change in regards to public use of the area. Kuppers went on to say that he wanted the resolution to include language that more adequately states that the public use of the land will not change as a result of an official designation. Not all of the commissioners were against the designation, however, as former commissioner and Chairman Brian McClellan said he received many phone calls in support of the designation. Although attempts to contact the commissioners in regards to the proposed BZW were made, we had no success in reaching them for comment.

The Macon County commissioners' hesitation reflects local opposition to the proposed BZW. One group in particular, the Macon County Coon Hunters Association (MCCHA), strongly opposed the proposal (Cabe 2011). In his letter to the Chairman of the Board of Commissioners Brian McClellan, David Cabe wrote that the fifteen directors of the MCCHA all voted to oppose the BZW. Cabe was contacted by phone during our study, but he said he had no knowledge of the subject and recommended we speak with the President Ralph Sanders, who had previously been contacted but declined to comment. The letter, which discusses the MCCHA's community involvement and contribution, closes by saying "We ask you to help us keep this area for use by the majority of Macon County folks, their children and grandchildren without additional government regulations" (Cabe 2011). Cabe's letter provides a clear illustration of public concern that recreational opportunities will be limited if an official designation is made for Overflow WSA.

Although we did not have a chance to speak to anyone in the MCCHA, Brent Martin of the Wilderness Society related that another of their major concerns is the U.S. Forest Service Road that runs into the middle of the area. We were surprised to find such opposition from a group of hunters, as hunting is a recreational activity that is allowed in all Wilderness areas. Furthermore, hunting seems to be an activity that goes hand in hand with wilderness. A study conducted by Shawn Good (1997), a hunter and holder of a diploma in fish and wildlife management technology, analyzed the contents of more than forty accounts from outdoor magazines for common hunting themes. Of those accounts, 92% included the theme of experience - hunting and wilderness, 65% beauty, 63% scenery, 58% at one with nature, and 46% wilderness. Other common themes included excitement (87%), companionship of others (68%) appreciation of animals (63%), and tradition (56%). Nevertheless,

The issue of government involvement seemed to be a common theme even beyond the MCCHA. David James, a Macon County resident, addressed the board of commissioners at a meeting and said "A lot of people are afraid of Wilderness" (Carpenter 2011). His comment was directed towards the federal designation restrictions. Such an expression of fear is reminiscent of the emotional time of RARE II in the area (G. Zahner, Interview). When the Overflow Creek area was recommended for study, people began driving around trucks with signs on them that said "No more Wilderness! Stop RARE II," because they were told they would lose their jobs as a result of the WSA. The history of America is significantly steeped in opposition to regulation, and much of this likely stems from themes such as manifest destiny and an aversion to any limitation on personal freedoms. In the nation's past, wilderness was seen as something to be conquered.

Another issue that Brent Martin said many locals expressed concern over is fire management. While this directly relates to the opposition surrounding U.S. Forest Service Road 79, fire management is also an issue in Wilderness areas because the use of machinery is not allowed and the lack of logging could in some ways promote wildfires. Nonetheless, the Wilderness Act (1964) specifically authorizes exceptions to the general restrictions in wilderness areas for managing wildfires saying in section 4(d)(1) that "such measures may be taken as may be necessary in the control of fire, insects and diseases, subject to such conditions as the Secretary deems desirable." Additionally, the U.S. Forest Service Land and Resource Management Plan for the Nantahala and Pisgah National Forests provides information on wildfire management. The management plan allows routine aerial detection for wildfire, as well as the use of helicopters and air tankers. In instances where there is an imminent threat to life or private property and the fire cannot be controlled by other means, tractor-plow units or bulldozers are also allowed (USFS 1994a). Although these actions may be taken, they are not measures to prevent wildfires, but merely to stop them once they have occurred.

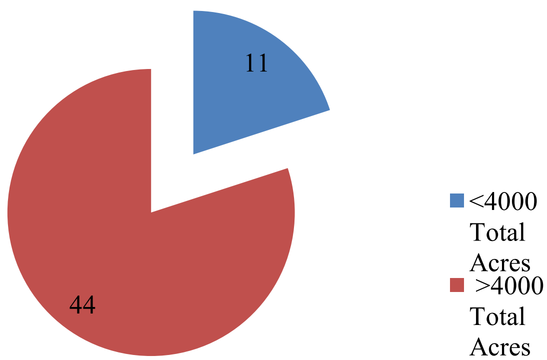

FIG. 2. Wilderness designations since 2009. Of the 55 areas designated in the past two years, 11 are smaller than 4,000 total acres.

One final issue concerning the proposed BZW is its small size. Chad Boniface, a retired Forest Service Ranger, said the area is small by wilderness standards and its proximity too close to developed and well-trafficked areas (Carpenter 2011). While the U.S. Forest Service criteria do state areas must contain at least 5,000 acres and may not contain roads, it also adds that areas may contain less than 5,000 acres if they meet other criteria (USFS 2007). Furthermore, areas east of the 100th meridian are given separate criteria, one of which states that the area contains no more than half a mile of forest roads under USFS jurisdiction for each 1,000 acres. Because of the additional criteria, Overflow WSA still qualifies for Wilderness designation. In the past two years, a fifth of the Wilderness areas designations across the nation have been less than 4,000 total acres (Fig. 2). Nonetheless, Overflow WSA's proximity to NC 106, a commonly used road, may be seen as a major hindrance to the solitude of the area. The area's proximity to Highlands, which has a year-round population of 3,200 but a population of over 18,000 during the warmer months, also detracts from the area's potential for solitude.

The question of solitude was also an issue for the U.S. Forest Service. Throughout the process of designations, the U.S. Forest Service takes no position on the merits of any proposed legislation, but the agency may provide comments regarding management considerations the agency believes members of Congress should be aware of. In the end, it is a Congressional designation that determines Wilderness, but the Forest Service still performs an Environmental Impact Statement (EIS) on all WSAs. In their EIS for the Overflow WSA under Solitude, the Forest Service says the area has a low potential for solitude because of external human influence along the roads and private lands located along the northern and western boundaries (USFS 1994b). Additionally, the EIS states that there are wildlife openings within the area, which are human cleared areas of the forest that provide habitat sites, food, and brooding areas for species.

The Public and Wilderness

In a study carried out by the USFS under the National Survey on Recreation and the Environment (NSRE) (USFS 2002), 49.2%, or 101.9 million people felt that Congress has not designated enough land as wilderness, 29.6% of people felt the amount was about right, while only 5.9% felt too much has been designated. In the survey, a majority of the people who responded said that wilderness areas were important because they: protect water quality, provide the knowledge that future generations have wilderness areas, provide recreation opportunities, protect wildlife habitat, provide spiritual inspiration, preserve natural areas for scientific study, preserve unique wild plants and animals, provide the option of visiting wilderness areas, protect air quality, and provide income for the tourist industry. One question that directly relates to the Overflow WSA is how important it would be to not hear or see other people while in a wilderness area, to which 6.9% responded it is extremely important, 14.7% said it was very important, 27.7% moderately important, 17.1% slightly important, and 30.7% not important at all. Interestingly, the poll also showed that 40.2% or 83.3 million people responded true when presented with the idea that hunting is not allowed in wilderness areas, while 39.6% answered false and 20.2% said they did not know. The final question of the survey asked whether or not the person was a member of an environmental or conservation group, to which 91.6% answered no (USFS 2002).

A common theme we encountered in discussions about wilderness was the opportunity that wilderness offers people to distance themselves from everyday human distractions. In his book *Last Child in the Woods*, Richard Louv (2005) discusses what he calls nature-deficit disorder. Louv, who references many tests in the book, claims that problems such as Attention Deficit Hyperactivity Disorder (ADHD) and obesity are linked to a lack of nature in humans' lives. An examination of the Macon County State of the County Health Report, published by the Macon County Health Department (MCHD 2010), revealed that 31% of high school kids and 35% of elementary school children were either overweight or obese. Outdoor areas that are open to the public provide a variety of social benefits and could help mitigate these problems.

Considering the lack of current public knowledge on the Overflow WSA, this case study provides a baseline of information to educate readers on the area. Currently, the proposed BZW is at a standstill, but with the support of the Macon County commissioners the designation would likely be reconsidered. Future studies on the area should seek to carry out a broader public opinion poll on the Overflow WSA within Macon County.

Acknowledgements

We would like to thank our mentor Brent Martin for all of his advice, support, and enthusiasm throughout our project. Your dedication to Wilderness is truly an inspiration. We would also like to thank Jill Gottesman for her assistance. Thanks to Russell Regnery, and Kelly Shehan-Martin for their responses. Thanks to Glenda Zahner for her extensive interview and inspiring stories. We would also like to thank Mike Wilkins and the U.S. Forest Service Nantahala Office for compiling information and allowing large amounts of copies to be made. Thanks to Anya Hinkle for her help throughout the project and dedication to drafts. Thanks to Michelle Ruigrok for always being there. Finally, we would like to thank Jim Costa for suggesting the project.

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EXPLORING ENERGY EFFICIENCY AND AWARENESS AT THE OLD EDWARDS INN AND SPA

MARY NELL JOHNSON

Abstract: Evaluating, planning, and promoting energy efficiency within the hospitality industry is key to encouraging green practices and sustaining the environment. As the Developing Energy Leaders Through Action (DELTA) intern for the Old Edwards Inn and Spa (OEI), I assisted in an energy audit, contributed to marketing green initiatives, instigated behavioral changes, and formulated a Strategic Energy Plan. As a result, the OEI is equipped with strategies to effectively implement energy efficient practices throughout their buildings. OEI has an energy team with the knowledge and enthusiasm to protect the environment.

Key words: energy audit; energy efficiency; NC Green Travel Old Edwards Inn and Spa; strategic energy plan; sustainability; Waste Reduction Partners.

INTRODUCTION

Total energy bills for the hospitality industry exceed 7.5 billion dollars each year, with signs indicating utility use increasing 12% annually (USDEO 2010). Thus, it is important to analyze how hotels can implement energy savings in order to reduce consumption of fossil fuels. Energy audits help pinpoint excess energy waste in hotels so that they can save energy, reduce solid waste, and increase sustainable practices.

Public, private sector, and non-profit corporations offer energy-auditing services that include analyzing overall energy consumption and appliances in a facility. Centered on energy consumption and appliance type, a final report is formulated that includes energy efficient and cost saving recommendations. Audits identify areas for improvement including improving lighting, associated labor costs, environmental impact, and comfort (Lubinski 2008). After an audit, the next step is to complete a strategic energy plan (SEP). A SEP outlines steps toward reduction of water and energy. For example, recommendations found in a SEP to improve efficiency might include installing energy star appliances, LED or CFL light bulbs, or low-flow toilets. Incorporating energy efficient practices can result in energy savings from 10 to 30% (USDOE 2010).

Green strategies should be practiced because of energy and cost savings, but also because of consumer demand. In the 1990s the "green" consumer emerged, with participants having an environmentally friendly perception and purchasing power for "green" products. As a result, companies have adopted the "green" morale by having an environmental perspective in order to create "green" products that appeal to the "green" demographic. Hospitality industries recognize how the growing "green" industry can benefit them if they participate because studies illustrate that 90% of hotel guests prefer staying in hotels that care about the environment (Lee et al. 2010). The hospitality sector can protect the environment and appeal to guests by adopting green management practices, which is reducing energy, water, and solid waste. An example of green management is implementing optional laundry services. Hotels should initiate energy saving and environmental practices, without hesitation of how a hotel guest will respond because 75% of hotel guests will partake in environmentally conscious initiatives. Partaking in green management strategies would be beneficial because 65% of people think that effective green management boosts a hotel's appearance and competitive edge (Lee et al. 2010).

In Highlands, North Carolina, a holistic wellness resort with a focus on organic culinary and spa programs, Old Edwards Inn and Spa (OEI) works toward more sustainable and energy efficient operations throughout their property. To this end, OEI established a sustainable farm that brings organic and local food to their guests, installed Icynene insulation reducing their energy bills by 50%, replaced all T-12 bulbs with an energy efficient alternative T-8 bulbs, and participated in the Global Soap Project which distributes recycled soap to those in need. OEI sought to continue to incorporate energy and resource efficient practices into their establishment because their team wanted to protect the environment and recognized a growing customer demand for a sustainable experience. The purpose of this internship was to identify how the OEI could become more energy efficient and estimate cost savings through an audit. In addition, I investigated how OEI could publicize its efforts through marketing objectives. I developed a strategic energy plan that identifies specific projects that can be implemented by OEI management. This paper is an overview of the projects, results, and further recommendations for the OEI completed during fall 2011 semester.

METHODS AND MATERIALS

Old Edwards Inn and Spa

OEI is an award-winning hotel located in Highlands, NC. *Condé Nast Traveler Annual readers choice survey* recognized OEI as the number one hotel and spa with the first ever perfect score. In addition, OEI has received the *Forbes* four stars rating for both hotel and spa, which means the establishment meets the industry's highest standards of excellence. *Trip Advisor* named OEI as the fourth best relaxation spa hotel in the United States, the second best hotel for romance, and their restaurant, Madison's, with the certificate of excellence. OEI has consecutively received AAA Four Diamond rating since 2004 and is one of only twenty-seven hotels in North Carolina to hold this prestigious title.

OEI was established in 1878 and purchased by Art and Angela Williams in 2001. Madison's restaurant was the most recent renovation, completed in 2004 to the hotel (OEI 2011). Tucked away in the mountains of North Carolina, OEI, provides luxury amenities. Some of the services received by guests are access to two 24-hour "butler's pantries" with chocolate Dove bars, champagne at arrival, fine linens, room service, plush robes, valet parking, and a fitness center. While staying at OEI, guests can enjoy fabulous shopping at Acorns, and phenomenal dining at Madison's Restaurant and the Wine garden.

Energy Audit

To promote and address energy research, the Department of Environmental Sciences at the University of North Carolina and the State Energy Department created the Developing Energy Leaders Through Action (DELTA) program. I worked as the fall 2011 DELTA intern at the OEI to aid in incorporating energy and resource efficient practices into their management. The first step was identifying the current energy efficiency at OEI by conducting an energy audit. An energy audit consists of examining the existing energy usage of a facility and finding more energy efficient alternatives (Boutwell 2011). Information gathered in an energy audit is as follows: utility data, equipment, and bills, building design (insulation and weathering), hours of operations, occupancy, and square footage. Analyzing these data assists an assessor in completing a report with energy recommendations. The materials needed for an energy audit are a notepad, camera, pen, flashlight, and laser distance measurer.

I initially met with Adrian Boutwell, retired engineer, from Waste Reduction Partners (WRP), to discuss in detail how an energy audit worked. WRP offices are located in Asheville and Durham. WRP is a team of volunteer engineers and scientists that provide free consultations about energy, water, and solid waste to governmental, private, and non-profit establishments in North Carolina. WRP receives funding from governmental sectors, NC Department of Environment and Natural Resources (NCDENR), Division of Environmental Assistance and Outreach (DEAO), NC Department of Administration of State Energy Office (NCSEO), US Environmental Protection Agency (EPA), and US Department of Agricultural Rural Utility Services (USDA). Other partners who make WRP services possible include, the City of Asheville, Cherokee Preservation Foundation, Mecklenburg County, and Solid Waste Management.

In order to determine what areas of the Inn would be included in the audit, Charles Foraker, OEI engineer, gave Adrian Boutwell and I a tour of the property. Due to the size of the property and the duration of time allotted for this internship, the whole area could not be completed. We chose to include the pool, main building (including spa), guest rooms, Madison's restaurant, and fitness center in the study. Next, utility bills from the previous year were collected from Sherry Owens, Vice President of finance. Using Microsoft™ Excel 2010, graphs were created to illustrate the monthly kilowatt-hours (kWh) and water usage.

In order to formulate recommendations for the report, the total numbers of light bulbs were counted. Light bulbs were categorized according to type, wattage and amount per room. Tony Ponce and Tim Hanson, OEI engineering staff, showed us to rooms 3, 15, 6, 9, 10, 19, 14, spa suite 23, and 25. In addition to rooms, light bulbs were counted in main sitting rooms, the restaurant, the hallways, fitness center, and spa areas. A laser distance measurer was used to estimate the square footage of the main building in order to determine the number of kWh needed per square footage.

Heating and cooling units were examined to obtain a picture, model number, series, and capacity size for the heating systems, chiller, cooling tower, air handling units, domestic hot water heater, air conditioners, and heat pumps. This information determines the current efficiency of each heating and cooling unit and then is used to calculate energy efficient recommendations for the OEI. The final report consists of an executive summary, which is an overview of all recommendations, associated costs, estimated energy savings, and estimated annual emissions. In addition, the report has five parts, background, facility description, utility analysis, recommendations, and follow up evaluation (Appendix A).

Marketing of Green Initiatives

In order to discuss improved auditing forms for assessors and DEAO new award program, NC Green Travel, Jan Foster, Solid Waste Manager, and Terry Albrecht, WRP State Director, held a Waste Reduction Partners (WRP) training session for assessors at the Land of Sky Regional Council building in Asheville, NC on October 19, 2011. DEAO and in compilation with the Center of Sustainable Tourism at East Carolina created the NC Green Travel award in hopes of encouraging the tourism industry to go "green". DEAO is a governmental branch of the NCDENR. NCDENR strives to protect the natural resources of North Carolina. The NC Green Travel award recognizes businesses that have established an energy team, recycles material, excels in water efficiency, practices energy conservation, and strives to practice green standards. WRP assists any companies who desire to attain NC Green Travel award by conducting energy audits and providing advice on application material for the award. Following the training session, marketing initiatives are discussed.

WRP suggested that the OEI should apply for NC Green Travel award as a marketing angle. The application for the NC Green Travel award consists of sixteen sections that includes an overview of accomplishments, a description of the energy team, the company's energy policy statement, and where the policy is displayed (Appendix B). The OEI did not have an energy policy statement or an energy team; as a result both were created. According to Tom Rhodes (2011), an energy policy statement is an affirmation to protect the environment by committing to follow to environmental regulations, striving to improve one's environmental performance, protecting the health of employees and the community, and efficiently using natural resources, raw materials, energy, and water. Because of application requirements an unanticipated behavioral change program was added to the internship. An energy policy was created and distributed throughout the OEI property (Appendix C).

The NC Green Travel application asked questions about waste reduction and recycling, energy conservation, water efficiency, grounds keeping, kitchen, air quality, environmental measurements, housekeeping, green meetings and catering, green purchasing, LEED certification, environmental management system, certification by other agencies and additional practices at the facility. Each section had specific green practices that received points. The following people were used as referrals during the application process: Charles Foraker, OEI engineer, Chris Huerta, OEI chef, Jan Foster, and Tom Rhodes, NC Green Travel Award Coordinator. After a final review with Melissa Delany, director of sales at the OEI, the application was submitted on November 6, 2011 (Appendix B).

Strategic Energy Plan and Resource Efficiency Plan

The Strategic Energy Plan and Resource Efficiency (SEPRE) is a set of action items that organizations implement after an energy audit is completed. For OEI purposes this report was also considered as a resource efficiency plan because it included recommendations that were not related to energy efficiency (Appendix D). For instance, a portion of the plan focused on incorporating "green" meetings into OEI infrastructure. A "green" meeting might use recycled material and local food to make an ordinary meeting more environmentally friendly.

The structure used for the report is categorized into six sections: action, location, summary, estimated costs and benefits, next steps, and completion (Washington Lodging 2011). Recommendations from the final report of the energy audit were included in the SEP (Boutwell 2011). If the OEI decides to reapply for the NC Green Travel application, suggestions that would receive additional points are incorporated into the SEPRE. The final report was presented to Sherry Owens, Melissa Delany, Jan Foster, Terry Albrecht, Charles Foraker, and Amanda Sullivan, director of marketing at OEI, on November 18, 2011 (Appendix E).

Results And Discussion

Energy Audit

The energy audit was completed October 11, 2011. Adrian Boutwell completed the final report of the energy audit on October 12, 2011 for Old Edwards Inn and Spa (Appendix A). The first section provides information on specific dates of data collection, location of the OEI, and the people involved in the energy audit. The following individuals are involved:

- Adrian Boutwell of Waste Reduction Partners
- Mary Nell Johnson, UNC-Chapel Hill - DELTA Intern
- Charles Foraker, Old Edwards Inn - Director of Engineering
- Melissa Delany, Old Edwards Inn - Director of Sales
- Sherry Owens, Old Edwards Inn - Vice President of Finance
- Amanda Sullivan, Old Edwards Inn - Marketing Director
- Patrick Leonard, Old Edwards Inn - Director of Human Resources
- Frank Canzone, Tony Ponce and Donald Taylor, Old Edwards Inn - Engineering Staff

The second section is facility description, which examines the structure of the building in order to decide if any improvements should be made. The building has double pane windows and doors, which are properly weather insulated. Dual panes are two layers with Oxygen, Aragon, or Krypton trapped between; this space acts as an insulator. Installing double pane windows prevents 25% less heat from escaping. No improvements were made to windows because the OEI has efficient window structure.

Icynene was added to the roof insulation in 2010, which reduces their heating and cooling costs by 50% percent. Another benefit of this energy efficient insulation is that it is unlike traditional insulation because icynene is water spray foam that is hydrofluorocarbon free. In addition, all walls are energy efficient, constructed out of brick, stone, or poured concrete. Compared to wood, these materials aid in 50% more heat retention, weather resistance, and are overall environmentally friendly. No recommendations were made on adding insulation or outside structure because OEI has an existing energy efficient option.

The next section is the utility analysis and is grouped into subsections: Electricity, Propane, Water, Water Heating, HVAC, Lighting and Recycling and Solid Waste. For instance, the summed total of light bulbs are 1,656, consisting of MR16, PR20, candelabras, flood, halogen and incandescent variety, with an additional 46 lighted exit signs. None of these light bulbs are considered to be energy efficient. The average incandescent lasts 41 days; a CFL or LED lasts for 344 days because an incandescent only lasts for 1000 hours and an energy efficient light bulb lasts 20 times longer (Appendix F). Results from the utility analysis stated total energy cost as $205,655 per year and 10,733 million BTU per year with great potential for improvement (Appendix A). Specifically, if OEI decides to replace all of their incandescent light bulbs and exit signs to LED or CFL counterparts 2,971.9 million BTU and about $32,000 can be saved annually. Furthermore, installing a 60 ton ($9,400) and 20 ton ($3,940) Heat Recovery water-heating units is strongly recommended. These heating ventilation and air conditioning systems are recommended because they have a low payback period of two to four months and would save OEI $36,952 annually. Overall, it is recommended that Old Edwards Inn and Spa review suggestions during annual budgeting to determine the best suggestions to incorporate. Grouping suggestions into cost, payback time, and completion period aid in prioritization (Woofter 2011).

To continue to improve energy and resource efficiency and maintain a relationship with

WRP it is recommended that the OEI request WRP free services to complete water use management and solid waste reduction audit and Environmental Management Systems (EMS) training course. In the past 11 years, WRP efforts have helped reduce 197,600 tons of solid waste and conserved 601 million gallons of water (WRP 2011). These audits would help determine target areas for improvement water efficiency and solid waste reduction. Establishing an EMS training session would aid OEI's commitment of environmental stewardship (International Organization of Standards. 2011). These strategies would help the OEI receive enough points toward a third dogwood, the highest award given to a lodging facility.

Behavioral Changes

The Old Edwards Inn did not have an energy policy statement before this project was started. An energy policy statement was created, reviewed, and edited by Melissa Delany. Using Microsoft™ Word the Old Edwards Inn and Spa logo is added to the top of each statement. Two statements per sheet are used in order to save paper (Fig. 1). The signs are printed on neon yellow for visibility purposes and then laminated. I conducted a visual audit of the OEI facilities to determine designated places for the policy statement. A total of 12 sites have the policy statement hung up for employees. No changes can be calculated; however, the employees are now better informed of OEI effort to support sustainable practices (Appendix C). Extending the energy policy statement to guests in the form of brochures or on the company's website is recommended because hotel guests find sustainable practices appealing. A green image increases customer appeal, loyalty, satisfaction, and partiality for a hotel. In addition, the energy policy statement could possibly attract new investors (Lee et al. 2010).

OLD EDWARDS INN Spa

The Old Edwards Inn and Spa seeks to protect our shared environment; in order to constantly improve the quality of our establishment for the betterment of our employees, guests and other stakeholders. To support this common goal, we will:

Policy Statement:

Old Edward Inn and Spa will support and follow all local, state, and federal environmental laws.

We will protect the health of employees, guests, surrounding ecosystems, and communities. Furthermore, we aim to efficiently use water, energy, natural resources, and sustainable materials.

In doing so, we strive to purchase local foods and products to support our local supply chain and economy, the community, as well as reducing our carbon footprint.

In addition, we strive to establish a corporate precedent for surrounding businesses, while sharing the knowledge, efficiencies, and resources that we posses in order to make the community and businesses more aware of how to be a better steward of the Highlands Cashiers Plateau and beyond.

FIG. 1.Example of a behavioral change distributed throughout the OEI facilities.

While interning at the OEI, I recognized that the staff is very team oriented. Therefore, a way to encourage employees to be "green" is by awarding a green champion in each department. A green champion is someone that illustrates environmentally friendly practices (recycling or carpooling to work). Another strategy that can be practiced between departments is to see which sector can reduce the most lighting, waste, etc. The department with the most energy savings could receive a CFL light bulb or a prize that is green related. Creating a green champion would encourage employees to go green, but studies infer that green practices boost employee morale (Woofter 2011).

NC Green Travel Award

As a result of applying for the NC Green Travel lodging recognition award, the Old Edwards Inn became the first hotel in North Carolina to be recognized as a green property. On November 16, 2011, two dogwoods were awarded to the Old Edwards Inn and Spa. The NC Green Travel Award is designated by dogwood flower symbols.. To achieve a dogwood, properties must meet or exceed the bar-setting green practices, which are outlined in the NC Green Travel application. Each individual dogwood represents a certification level based upon how many total points are received from the application An additional eleven points are added to the hotel for recycling in administration offices, upgrading T-12 to T-8 fluorescent bulbs, sustainable gardens onsite and the addition of blown insulation. OEI received a total of 106 points, exceeding the 93-point criteria for two dogwoods (Appendix B).

In order to publicize the NC Green Travel Award, an interview with Jessica Webb, from the Highlander newspaper was completed. On December 6, 2011, an interview was conducted by Wiley Sloan from the Laurel Magazine, a local Highlands publication and will be apart of the January issue. A radio interview is scheduled for December 16, 2011. I wrote a press release for the OEI that will be published nationally (Appendix G). Further marketing efforts are outlined in the SEPRE and should be taken by OEI to illustrate their sustainable efforts. For instance, monthly blog updates about any new green practices that the OEI accomplishes (Appendix E).

Strategic Energy Plan and Resource Efficiency (SEPRE)

The finalized SEPRE is a 14-page report that outlines energy efficient and resource efficient strategies that OEI can implement in the next five years (Appendix E). This plan is a user-friendly format of the energy audit that outlines conservation objectives in 11 categories that I created for OEI to address the areas that are most relevant to the company. Each category is further subdivided into specific projects that can be implemented individually during a five-year period (Table 1).

TABLE 1. The 11 categories and the objectives of the SEPRE.

Category	Objectives
Past 12 to 24 months	Examples of all efficiency related activities completed at the OEI during the past 12 to 24 months.
Recyclables	Places where recycling receptacles should be placed in the facility and a subcategory that denotes incorporating recycled content paper.
Lighting	Different energy efficient options outlined by location, cost and benefit and next steps.
HVAC	Three HVAC related projects to consider implementing because all can reduce utility bills and increase energy savings.
Kitchen	Two methods to incorporate to make the kitchen more resource and energy efficient.
Green Meetings	Steps to make green meetings a service conducted by the OEI staff.
Water Heating	Two water heating strategies to boost water savings and reduce long-term costs.
Water Efficiency	Three improvements to reduce water consumption at the OEI.
Irrigation	Steps outlining how to purchase a rain collector for landscaping in order to use less water.
Hybrid or Electrical Vehicles	OEI should purchase a green vehicle and create a designated parking spot for hybrid or electric cars in order to promote clean energy and sustainable practices.
Marketing	To increase green marketing the OEI should consider including three marketing strategies to increase the publics awareness of new green management.

Table 2 illustrates the format of the SEPRE for the Kitchen category (Appendix E). OEI is only thirty-three points away from receiving the third dogwood. In order to win another dogwood for NC Green Travel, application criteria not originally achieved are included in the SEPRE. OEI can receive more points if the teams decides to reuse used cooking oil (1 point) and over 5 years purchase 75% energy star appliances in the kitchen (5 points). OEI should reapply for the NC Green Travel award in the future.

TABLE 2. The Kitchen section of the Strategic Energy Plan and Resource Efficiency (Appendix F).

Projects	Location	Summary	Estimated Costs/Benefits	Next Steps	Completed
Collect used cooking oil	Kitchen	Store and save all used cooking oil, to be collected and recycled	Less waste	• Contact Joel Ostroff, Recycling Coordinator of Macon County (828) 349-2252 • Purchase collection bin • Coordinate collection times	
Purchase Energy Star Appliances	Kitchen	Once kitchen equipment dies, purchase energy efficient counterpart	TBD Less energy used	• Research energy efficient models • Meeting with chief and engineer for best option	

Two examples illustrate how the management at OEI can continue their progression of "green" polices by using the SEPRE. For instance, the lighting section contains suggestions such as switching to LED light bulbs, installing occupancy sensors in common restrooms, installed daylight sensors, de-lamp vending machines and installing vending misers. OEI has already installed daylight sensors and de-lamped vending machines. OEI plans to install LED lights in the lobby as their first step towards energy efficiency. Over the course of the next five years the OEI should expand lighting installation by progressively switching to energy efficient light fixtures in order to reduce labor costs, save energy, and save money on their energy bills.

TABLE 3. Sections of the lighting category of the SEPRE. (Appendix F).

Projects	Location	Summary	Estimated Annual Costs	Benefits	Next Steps	Completed
Switch to LED	Hotel Rooms	Phase out of incandescent	$7,409	$4,605	• Contact light supplier • Research rebates	
Switch to LED	Spa	Phase out of incandescent	$4,886	$2,276	• Contact light supplier • Research rebates	
Switch to LED	Public areas	Phase out of incandescent	$17,467	$16,029	• Contact light supplier • Research rebates	
Installed occupancy sensors	Common Restrooms	Install sensors that turn and off with motion	15 to 5o dollars per unit	Save over 30% in lighting	• Identify how many restrooms • Select ideal model	
De-lamp vending machines	Vending machine in Kitchen	Remove light bulb from machine	Labor to remove (minimal)	Save $150	• Determine who will de-lamp	✓
Install vending misers	Vending machine in kitchen	Automatic on/off switch	TBD	$600	• Contact vending supplier	

FIG. 1. Slide from SEPRE presentation.

In the recyclable section, it is recommended that the OEI insert recycling bins for guests in the office, rooms, lobby, outside building, hallways, guest rooms, and kitchen. Providing guests and employees with places to recycle will reduce waste and appeal to guests that desire to recycle. Jan Foster, WRP, suggested having a local artist construct recyclable containers in order to better fit with the ambiance of the hotel. Otherwise, inserting black trashcans would be a great non-descript type of container for recycling. The next steps are purchasing containers for the designated areas and choosing a person to distribute the containers (Appendix E).

SEPRE report should be used during the next annual budget meeting to determine how energy costs fit into their budget. With the strategic energy plan, OEI has roadmap for energy savings with the tools, knowledge, recognition, and inspiration to make an environmental difference.

ACKNOWLEDGEMENTS

I would like to thank the staff at Old Edwards Inn, including Melissa Delany, Amanda Sullivan, Charles Foraker, Sherry Owens, Tony Ponce, Frank Canzone, Tony Ponce, Donald Taylor, Patrick Leonard, and Richard Delany. Thank you for always answering my questions, advice, and having me in your office. Melissa Delany, thank you so much for your enthusiasm throughout this experience. To HBS staff, Anya Hinkle and Michelle Ruigrok, thank you for all your guidance and suggestions during the project. To the staff at Waste Reduction Partners, Adrian Boutwell, Jan Foster, and Terry Albrecht, thank you for making me feel apart of the WRP team. Mr. Boutwell, thank you for the corn, chocolate milkshakes, and teaching me so much about energy audits. I have learned so much from everyone. Thank you, finally, to the DELTA program at the UNC Institute for the Environment for letting me be apart of this amazing program.

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APPENDIX A

Energy Audit Report for Melissa Delany prepared by the Waste Reduction Partners for Old Edwards Inn and Spa (digital archive on attached CD).

APPENDIX B
NC Green Travel Application for the Old Edwards Inn and Spa (digital archive on attached CD).

APPENDIX C
Behavioral Change Energy Policy Statement (digital archive on attached CD).

APPENDIX D
Strategic Energy Plan and Resource Efficiency for the Old Edwards Inn and Spa for the 2011-2012 fiscal year (digital archive on attached CD).

APPENDIX E
Strategic Energy Plan and Resource Efficiency Presentation for the Old Edwards Inn and Spa (digital archive attached on CD).

APPENDIX F
Energy Audit Presentation for the Old Edwards Inn and Spa (digital archive on attached CD).

APPENDIX G
All publication material marketing NC Green Travel (digital archive on attached CD).

PLANNING FOR AGRICULTURAL SUSTAINABILITY AT RABUN GAP-NACOOCHEE SCHOOL

ALYSSA M. KRAG-ARNOLD AND MALLORY G. NICKEL

Abstract. In order to protect water and land quality and continue to sustainably farm school property into the future, Rabun Gap-Nacoochee School needs to monitor those who lease school property for agricultural and grazing use, and ensure their operations are run in an environmentally sustainable manner. To this end, we consulted government agricultural policy professionals and synthesized relevant practices recommended by university agricultural departments and agricultural industry leaders. From these findings, we created a series of recommendations for what the school should require leasers to include in sustainable agriculture or grazing land plans. These guidelines are a first step in ensuring that school land is managed more proactively and used in an environmentally sustainable manner.

Key words: best agricultural practices; land use management; Rabun Gap-Nacoochee School; sustainable agriculture.

INTRODUCTION

Rabun Gap-Nacoochee School (RGNS) is a private, preparatory high school in Rabun County, Georgia. The school was created in 1903 as a place where students could receive an education as well as work on the school farms to support their families. Although much of the land is now leased rather than farmed by students, the school still owns more than a thousand acres of land, the majority of which is agricultural or forested. Maintaining the agrarian character of the surrounding land is a priority for RGNS for aesthetic and historical reasons. Since the school does not have the resources to maintain agricultural operations, it leases property for outside parties to use as crop and grazing land. In order to maintain the health of this land and allow it to be successfully farmed into the future, RGNS requested a plan outlining sustainable agricultural and grazing practices for those leasing school property. The purpose of this plan is to recommend practices for agricultural and grazing land leased out by the school, and provide a template for lessees to create a detailed plan of how their operation will meet recommended practices. Since lessees have individual goals and constraints, we determined that the most appropriate format for the plan is that of an outline of requirements a complete plan should include, followed by resources and background information to assist lessees in creating the plan.

METHODS AND MATERIALS

To determine which conservation practices would be best for RGNS crop and grazing land, we used information from Natural Resources Conservation Service (NRCS) District Conservationist Doug Towery and materials published by NRCS, a division of the US Department of Agriculture (USDA). We also spoke with RGNS maintenance and farm manager Scott Henson and RGNS physics teacher Woodrow Malot about their goals for the land and knowledge of current land-use. Finally, we drew from a number of agricultural resources published by the University of Georgia and other established industry leaders to establish standards that are appropriate for the goals and resources of RGNS.

To create a map of school property and various environmental features, we used ArcMap10™ (ESRI 2011). We used parcel data from the Rabun County Tax Assessor's Office to create property lines, and acquired various layers such as soil types, aerial photography, streams, roads, geology, soil, and buffers, from ArcGIS Online®, the U. S. Geological Survey (USGS), NRCS's SoilDataMart, and earlier studies at the school by the NRCS (Figure 1).

We selected monitoring sites based upon ease of access and value of site. Ease of access was determined by the proximity of the site to the school and whether school vehicles used for transporting students would be able to access the site entrance. Monitoring sites on streams needed to allow students to easily access them. Therefore, stream sites are at locations near road crossings and free of densely vegetated buffers. Value of the site was based on suggestions from the teachers as well as our own assessment of what areas would correspond with the various factors requested by teachers. Science teachers also gave us information about sites that students currently use for stream quality monitoring. A Trimble® GeoExplorer® 2005 series GeoXM™ handheld was used to acquire latitude and longitude at specific sites (Trimble Navigation Limited). The latitude and longitude coordinates were transferred into a Google Docs™ programs spreadsheet and then mapped using a Maps gadget. This yielded a map with markers with labels at each suggested monitoring site.

To create lesson plans for monitoring sites, we spoke with RGNS teachers Woodrow Malot, Brian Phillips, and Amy Jenkins about how they would like to use monitoring sites. Educational resources were then created by compiling related lesson plans and then revising them to fit the needs of the school.

RESULTS

Cropland

Conservation crop rotation should be a priority for RGNS because of its potential to reduce soil erosion and manage soil nutrient levels. While the creation of a conservation crop rotation plan is best left to current land managers, there are two key steps we recommend that land managers take toward creating a successful conservation crop rotation plan. First, land managers should monitor soil quality, nutrient balance, the presence of pests, and soil compaction. Second, land managers should create a rotation plan that includes field number and acres, purposes of the crop rotation, sequence of crops to be grown, length of time each crop will be grown, and total length of rotation.

A cropland nutrient management plan is essential in order to protect soil quality for the future and minimize the detrimental effects of nutrient runoff. A nutrient plan will monitor levels of nitrogen, phosphorus, and potassium and specify the source, amount, timing, and method of nutrient application needed to achieve planned yields. In addition, nutrient application rates will be based on University of Georgia recommendations and industry practice. Components of a complete nutrient plan for RGNS land should be as follows:

- A soil survey or map of the area in order to help determine nutrient input levels
- The location of sensitive areas that require different nutrient levels
- Current crop rotation

- Results of soil test
- Yield goals for crops
- Nutrient budget for Nitrogen (N), Phosphorous (P), and Potassium (K) for each crop in rotation
- Quantified listing of all nutrient inputs and sources
- Recommended nutrient application rates, timing, form and method of application for each CMU
- Plan for recordkeeping. Records should include: any soil, water, manure, or plant analyses done; quantities and sources of nutrients applied; dates and methods of applications; weather conditions and soil moisture at time of application; crops planted, planting and harvesting dates, and yields; and recommended changes resulting from reviewing records.

A cropland Integrated Pest Management (IPM) plan is also important in order to minimize the levels of pesticides needed and minimize pesticide risks to the environment. A complete IMP plan will have two components: (i) it will follow Prevention, Avoidance, Management, and Suppression (PAMS) practices and (ii) it will follow the four tiered approach of IMP. PAMS practices keep pest populations below economically damaging levels, minimize pest resistance, and protect soil and water quality. The four tiers of the IMP plan are an action threshold, monitoring and identifying pests, prevention, and control. The lessee of RGNS land must specify how they will fulfill each of the four tiers in a way that will keep pesticide use at the lowest practical levels.

Grazing Land

Considering the features of the land used for grazing and the surrounding environmental features at RGNS, we determined that critical components of the plan should specifically focus on sustainable practices for four components: nutrient management, pest management, water systems, and prescribed grazing.

A nutrient management plan for grazing that carefully balances nutrient flow is critical at RGNS. This plan can be created by considering key components and with careful monitoring. The key components of a nutrient management plan for grazing are: a nutrient budget, a plan to mitigate pollution, and a plan for correctly applying manure. Factors that are important to consider in grazing land include nutrient levels, soil organic matter, and manure (NRCS 2008). The most important monitoring tools for nutrient input management in grazing land include soil quality tests and manure composition tests. The first step in developing the nutrient management plan is to determine the nutrient availability provided by the soil and the nutrient content of manure. Second, land use managers can use the information on nutrient availability to determine how much fertilizer and supplemental feed is needed in grazing land and how to use manure on crop land. Third, the plan should be carried out with close monitoring of nutrient levels and runoff risks.

An ideal pest management plan for RGNS will focus on using Integrated Pest Management strategies to decrease the amount of pesticides used and to promote whole agro-ecosystem health. Pest management in grazing land is crucial for maintaining livestock health and productivity. It is recommended that land managers create the grazing land pest management plan such that it follows PAMS practices and the four tiered approach as described in the croplands section.

Watering systems are also a critical component of grazing land; however, they can often become highly polluted from agricultural and grazing run-off. The streams on the RGNS campus feed into the headwaters of the Little Tennessee River and Betty Creek – important area streams. Protecting these water bodies is critical, so it is important to plan watering systems carefully. The basic steps for designing a sustainable watering system is to determine the amount of water needed daily, the water sources, and how water levels and quality will be monitored. At RGNS, although water is readily available from local streams and ponds, a best practice would be using remote water sources. In addition, because livestock rotation is practiced and because streams are numerous, stream crossings and riparian buffers should be monitored and maintained.

In order to maintain grazing land and livestock health and to promote economic and ecological sustainability, prescribed grazing should be planned for in the grazing land management plan. The first consideration in creating a prescribed grazing plan is to understand the impact of the cattle on RGNS land – three classes of environmental impacts must be considered: herbivory, physical impact, and deposition. A comprehensive prescribed grazing plan delineates the forage types planted, rotation cycles, and paddock design. The plan considers the duration of time spent in each paddock, fodder stocking, plant removal, and protects soil, water, air, and animals. Prescribed grazing can be used as part of an IPM plan to reduce invasives by allowing animals to graze in areas where land managers are trying to control invasive plants.

Mapping

The results of the school mapping project is digitally archived in the accompanying CD and in Figure 1 below. We used the Calculate Geometry feature to determine the acreage that RGNS owns; the total was 1344 acres.

Lesson plans

According to RGNS science teachers, students will play a role in monitoring the environmental quality of school land and water resources. Amy Jenkins, the school's lead Biology teacher, expressed interest in using the monitoring sites to teach students to use geographical information systems, primarily utilizing GoogleEarth™ mapping service and Google Maps™. Science teachers expressed strong interest in getting students outside to engage with the field sites and school property. They hope to use monitoring sites around campus for soil testing, water quality testing, and biological surveys. With these goals in mind, two lesson plans were created. The "Stream Walk Lesson Plan" introduces students to assessing stream health via riparian buffers and related plants, in-stream and streamside habitat, erosion, benthic macroinvertebrates, stream sediments, and chemical testing. Through "Soil Tests Lesson Plan" students will learn about the importance of soil composition and nutrients when planting crops. All homework and lab sheets for the lessons are provided (there are digitally archived in the accompanying CD). In addition, there is a list of other on line resources teachers may explore when planning lessons. The chosen monitoring sites are displayed in a Google Document Maps gadget.

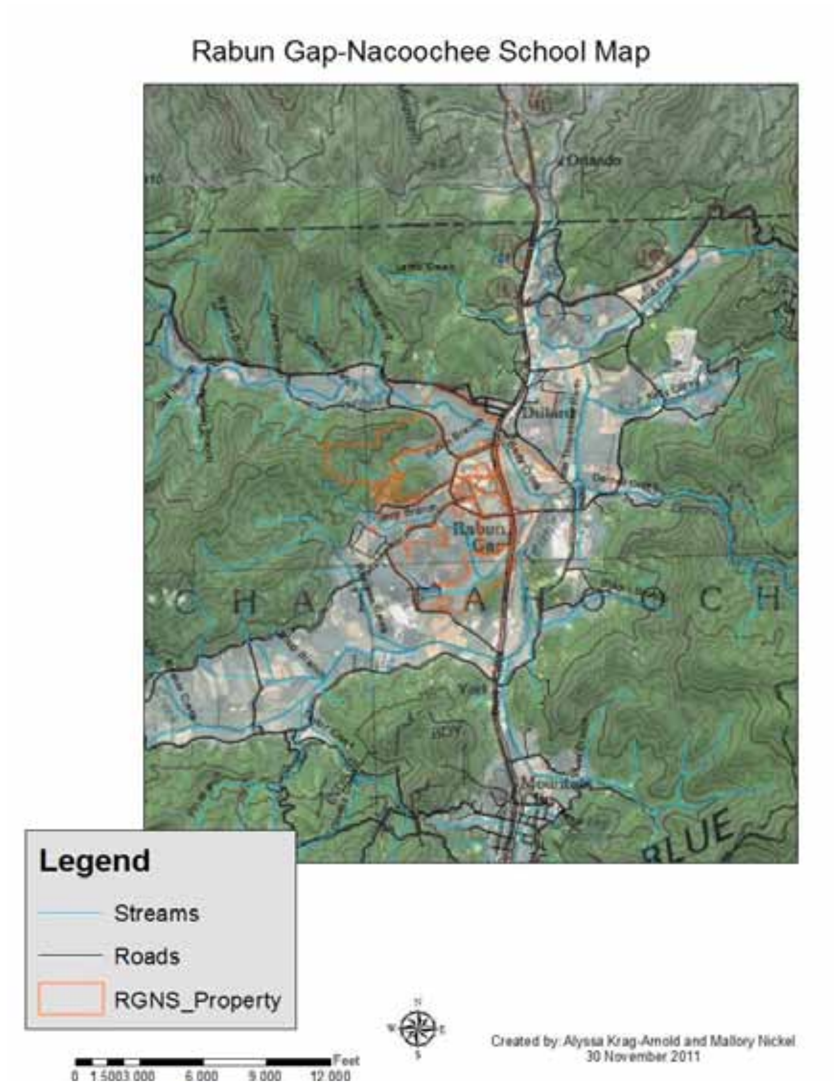

FIG. 1. Map of the school property showing the topographic layer over aerial photography.

DISCUSSION

Cropland

After speaking to Doug Towery, the Rabun County conservationist for the NRCS, we concluded that are three essential components to a cropland management plan at RGNS: conservation crop rotation guidelines, nutrient input guidelines, and pest management guidelines. While a number of additional components can be added to a cropland management plan as needed, these three guidelines are the most critical and relevant to the cropland under ownership of Rabun Gap-Nacoochee School. RGNS's goal is a basic farm plan outlining recommended practices to ensure the land is used in such a way that it can continue to be successfully farmed into the future. These three components accomplish this goal by addressing the most significant aspects of sustainable agriculture production. In addition, since RGNS does not have any staff members directly responsible for monitoring how the school's cropland is being used, the school grants a large degree of autonomy to the farmers who lease school land. Therefore, we concluded that the most appropriate management plan for the school would be one that fulfills RGNS's goal of mandating sustainable farming practices, while not imposing excessively restrictive guidelines on the farmers.

Conservation crop rotation

Conservation crop rotation is when crops are grown in a recurring sequence on the same field, and should be applied on all land where annually-planted crops comprise at least one-third of the crop sequence. The practice does not need to be applied to land where crops are grown only occasionally. Crops can be planted in combination with other crops, or with grasses and legumes. The purposes of conservation crop rotation are as follows:

- Reduce sheet and rill erosion
- Reduce soil erosion from wind
- Maintain or increase soil organic matter content
- Manage the balance of plant nutrients; improve water-use efficiency
- Manage plant pests (weeds, insects, diseases)
- Provide food for livestock
- Provide food and cover for wildlife (Green et al. 2005, NRCS 2011).

Although all of these objectives serve a purpose, conservation crop rotation should be a priority for RGNS primarily because of its positive impact on soil erosion and soil nutrients.

The creation of a functional conservation crop rotation plan is best left to the farmers and land managers who rent cropland from RGNS and have experience in running agricultural operations. Nonetheless, there are several components that plans should include; including field number and acres, purposes of the crop rotation, sequence of crops to be grown, length of time each crop will be grown, and total length of rotation. Although rotations can be as simple as alternating between two crops such as corn and soybeans, several basic factors that should be considered when creating a conservation crop rotation plan. These include following a legume crop by a crop that demands high amounts of nitrogen; growing less nitrogen-demanding crops (small grains) the second year after a legume crop; not growing the same crop in consecutive years in order to decrease insects, weeds, diseases, and nematodes; following a crop with one that is not a closely related species (plants within the same taxonomic family tend to have similar pests and pathogens); rotating deep-rooted and shallow-rooted plants; maintaining organic matter, rotating high-residue crops with low-residue crops or using cover crops (Magdoff 1992, Liebig 2007).

In terms of erosion, growing cover crops with low-residue crops and rotating high-residue crops with low-residue crops are effective ways to combat erosion with crop rotation (NRCS 1996). In addition, land managers should examine the criteria that should be monitored in an established crop rotation system (detailed in the following paragraphs), and create goals and standards they want their future system to meet. The following paragraphs will outline basic criteria that should be monitored in an established conservation crop rotation system. An assessment of how well these criteria are being fulfilled indicates the level of success of a conservation crop rotation management plan.

First, soil quality should be improved and monitored. Soil quality is assessed in terms of the capacity of soil to function. These functions can be described as: sustaining biological activity, diversity, and productivity; regulating and partitioning water and solute flow; filtering and buffering, degrading, immobilizing, and detoxifying organic and inorganic materials; and storing and cycling nutrients (Seybold et al. 1999). Farmers should choose crops that produce the amount of plant biomass needed to maintain or improve soil organic matter content, which can be determined using the Soil Conditioning Index (SCI) (NRCS 2003b). The SCI models the top four inches of soil, which is sufficient depth for monitoring soil quality. The SCI equation is as follows: SCI=OM + FO + ER. The organic material (OM) or biomass factor accounts for the effect of biomass returned to the soil from plant or animal sources as well as material imported to the soil or grown and retained in the soil. Field operations factor (FO) accounts for the impact of field operations that encourage the breakdown of organic matter, such as tillage, planting, application of fertilizer, harvesting, etc. These field operations increase rates of decomposition of organic matter. The erosion factor (ER) accounts for the impact of removing soil organic matter through sheet, rill, or wind erosion.

A program designed to allow land-owners or farmers to monitor SCI is available on the USDA's website, and only requires the input of location, soil texture, all crops in current crop rotation, typical yield for each crop, applications of organic matter such as manure, field operations (such as tillage, fertilizer applications, and harvesting), and rates of wind and water erosions (another calculator is available for this). A successful crop rotation system should maintain or increase SCI values. If the SCI value is negative, the input values should be studied to determine which changes will bring the SCI value back to neutral or positive numbers. This also makes the SCI a useful tool for predicting how modifying a management system will impact soil organic matter. It is useful to note that soil organic matter levels are more sensitive to tillage than to long rotations with perennial vegetation. Therefore, reducing tillage will increase soil organic matter faster than rotations with several years of perennial vegetation. Despite its usefulness, SCI cannot be the only method of assessing soil quality. Even with an acceptable SCI number, if there are problematic visual symptoms such as issues with infiltration or runoff, these override a formula indicating otherwise (Hubbs et al. 2002, NRCS 2002).

In addition to completing the SCI on a periodic basis, there are a number of soil quality indicators that we recommend farmers on RGNS property assess. These indicators fall under three categories: physical, chemical, and biological properties. All descriptions of these properties and guides for how to complete these assessments can be found on the USDA's website (http://soils.usda.gov/sqi/assessment/assessment.html). Soil conditions should be monitored consistently, but deciding which tests are necessary for which fields is a choice best left to farmers with a better familiarity with specific soil and plant needs. Under physical properties, soil quality factors that can be assessed include soil structure, soil crusts, slaking, infiltration, bulk density, available water capacity, and aggregate stability; under chemical properties, the main factor that can be assessed is soil pH; and under biological properties, soil quality factors that can be assessed are earthworms, particulate organic matter, respiration, soil enzymes, and total organic carbon (Fenton et al. 1999, Liebig 2007). Again, detailed instructions for the completion of these assessments are available at the link listed above, and the choice as to which soil assessments are necessary should be left up to those farming the property. A soil quality test kit that the USDA helped develop facilitates all the assessments previously listed, and allows farmers to complete these assessments on their own. The online in "Soil Quality Test Kit" provides a detailed step-by-step account of how to complete each soil test as well as information on when the tests are recommended and how to interpret the results (USDA 2001).

A second criterion that should be monitored to determine the best crop selection and sequence and assess the efficacy of a conservation crop rotation program is the nutrient balance. If there are excess nutrients in the soil profile, levels can be reduced by using crops that fit the following criteria: have quick germination and root system formation; have a rooting depth sufficient to reach the nutrients not removed by the previous crop; and have nutrient requirements that mean they will utilize the excess nutrients that the land manager desires to remove. Crop rotation in general is meant to prevent the occurrence of nutrient depletion, and will be covered in more detail in a later section (National Agronomy Manual 2002, Al Kaisi 2008).

A third criterion that should be monitored is the presence of weeds, insects, and pathogens. Monoculture promotes increases in insects and diseases. By rotating crops through different fields, pests' life cycles are broken because they can no longer establish themselves and adapt to the narrow ecological niches associated with monocultures. Crop rotations also allow the use of multiple different herbicides as different crops cycle through, which reduces the change of herbicide resistance in weeds. In addition, rotations that increase organic matter improve the environment for biological activity that will increase the breakdown of pesticides (NRCS 1996). This is a critical reason that crop rotation is important to a sustainable agricultural management plan: it reduces the reliance herbicides and pesticides by creating an environment which is less conducive to the proliferation of these pests. If insects and weeds are making a resurgence, it is time to consider a change to the crop rotation schedule to better control these pests (Reeves 1994, National Agronomy Manual 2002, Green 2005).

A fourth criterion is the level of soil compaction, which impacts water infiltration and the ability of root systems to develop. Soil compaction can be reduced by rotating crops with deep roots that can penetrate compacted soil with crops with shallow roots. As the roots decay, channels in the soil open up, which improves water movement and aeration by allow water to filter down to deeper soil layers (Fenton et al. 1999, Seybold et al. 1999).

In sum, effective crop rotations are important for sustaining soil health, land productivity, erosion control, insect and weed management, and nutrient and water usage.

Nutrient management

The next component of a cropland management plan is nutrient management. Nutrient management involves managing the amount, source, placement, form, and timing of the application of plant nutrients and soil amendments. The purposes of nutrient management in cropland are as follows:

- To budget and supply nutrients for plant production
- To properly utilize manure or organic by-products as a plant nutrient source
- To minimize agricultural nonpoint source pollution of surface and ground water resources
- To protect air quality by reducing nitrogen emissions
- To maintain or improve the physical, chemical, and biological condition of soil (NRCS 2003a, 2008).

Most fertilizers that are commonly used in agriculture contain nitrogen (N), phosphorus (P), and potassium (K). A general nutrient plan will account for all three and will include all possible sources of these nutrients, such as animal manure, other organic by-products, waste water, commercial fertilizer, crop residues, legume credits, and irrigation water. In creating a nutrient management plan, the land manager should specify the source, amount, timing, and method of nutrient application needed to achieve planned yields (NRCS 2006). These levels should be determined through soil testing on a regular basis (at least every three years). The local NRCS branch recommends that nutrient application rates should be based on University of Georgia recommendations and industry practice. These recommendations take into account current soil test results, yield goals, and management practices (Towery, D. District Conservationist, NRCS, pers. comm.) These recommendations can be found in the "Soil Test Handbook for Georgia" (Kissel and Sonon 2008).

In terms of nutrient application timing, land managers should ensure that the application of nitrogen corresponds as closely as possible with plant nutrient uptake to minimize nutrient loss and maximize availability to the plant. In addition, nutrients should be applied uniformly to the application area and should not be applied to frozen or saturated soil due to the risk of run-off. Another consideration in nutrient planning is that erosion control and runoff reduction practices can improve soil nutrient and water storage and infiltration. Management practices such as buffers, cover crops, and filter strips reduce runoff and subsequently reduce nonpoint source water pollution (Gruhn et al. 2000, NRCS 2006).

Conservation Management Units (CMU) can simplify the process of creating a nutrient management plan. A CMU is a field or group of fields with similar treatment needs and planned management. By creating a single plan for the CMU rather than a number of separate plans for each area of cropland, the management process can be substantially simplified (NRCS 2003a).

In sum, the land manager should create a nutrient management plan for N, P, and K primarily by consulting the recommended nutrient application levels in University of Georgia's "Soil Test Handbook for Georgia," but also by practicing the standards noted above (Kissel and Sonon 2008). A complete nutrient management plan should include components that both assess land conditions and state the nutrient input levels required to maintain land conditions. Components of a nutrient management for RGNS land should be as follows:

- A soil survey or map of the area in order to help determine nutrient input levels
- The location of sensitive areas that require different nutrient levels
- Current crop rotation
- Results of soil tests
- Yield goals for crops
- Nutrient budget for N, P, and K for each crop in rotation
- Quantified listing of all nutrient inputs and sources
- Recommended nutrient application rates, timing, form and method of application for each CMU
- Plan for recordkeeping. Records should include: any soil, water, manure, or plant analyses done; quantities and sources of nutrients applied; dates and methods of applications; weather conditions and soil moisture at time of application; crops planted, planting and harvesting dates, and yields; recommended changes resulting from reviewing records (NRCS 2003a, Oenema et al. 2003).

As with the crop rotation plan, the nutrient management plan is best be created by a land manager with knowledge of the past, current, and future production goals for the land.

Integrated Pest Management

Integrated Pest Management (IPM) is a system of pest Prevention, Avoidance, Monitoring, and Suppression strategies (PAMS). This system is intended to minimize the levels of pesticides needed, keep pest populations below economically damaging levels and minimize pest resistance. Overall, the purpose of a pest management plan is to minimize or prevent pesticide risks to water quality, soil, air, plants, animals, and humans from runoff and leaching. IPM is different from an ordinary pest management program in that it integrates the environment into the pest control process and incorporates management and control rather than favoring only elimination or eradication of pests (Green and Petzoldt 2009).

The components of PAMS are as follows. Prevention is the practice of keeping a pest population from infesting a field, and is essentially the first line of defense. It involves strategies such as using seeds and transplants that are pest-free, preventing weeds from reproducing, scheduling irrigation in such a way that it is no conducive to disease development, and cleaning tillage and harvesting equipment between fields. Avoidance is practiced when pests exist in a field, but the pests' impact can be mitigated through crop rotation, choosing crops with genetic resistance to pests, and choosing crops that can be harvested before pest populations develop. Monitoring and identifying pests through surveys is important, as it forms the basis for practices such as choosing crop rotations and suppression tactics. Finally, suppression of pest populations is a final action taken if prevention and avoidance are not successful. Suppression can include cultural practices, physical controls, biological controls or pesticides.

Cultural practices such as narrow row spacing, cover crops, mulches, or no-till/strip-till systems should be used whenever possible, as they have the least impact on the environment. Physical controls, such as mowing weeds, pest traps, pest barriers, and segregation are also an environmental sustainable solution. Biological controls, such as pheromones, growth regulators, predators/parasites, or toxin-producing microbes are a more environmentally invasive solution, but still preferable to pesticides. Chemical controls, or pesticides, are often necessary but should be applied as a last resort and should be applied using the following approach. First, the benefits should be confirmed before using; unnecessary pesticides will damage the environment and potentially create resistance among pests. Second, pesticides that have the least negative effects on environmental health should be selected when possible. Third, the same chemical should not be used continuously on the same field, as it could increase resistance and therefore increase the amount of pesticide that must be applied. Fourth, buffers should be used wherever possible to minimize chemical runoff into water sources (Johnson and Lucas 2000, Green and Petzoldt 2009).

PAMS is a part of the four-tiered approach that IPM follows. The four tiers roughly correspond with the different aspects of PAMS and are a crucial aspect of IPM. It will be the responsibility of the land manager renting from RGNS to fill in the specifics of these tiers. The first step is the action threshold. An IPM plan will first set a threshold, or a point at which pest populations reach a point that pest control action must be taken. The second step is monitoring and identifying pests. Not all insects and weeds require control: many are harmless or beneficial. By monitoring the pests that are present, the land manager can identify when pesticides are really needed, and what kind will be most effective. The third step is also a part of PAMS: prevention. The land manager should select various preventative measures and describe how and when they will be implemented. The fourth step is control. The land manager should develop a system of which control methods will be chosen in a variety of circumstances. As mentioned previously, less risky and environmentally damaging controls should be chosen first, and only if these are ineffective should additional pest control methods be employed (Green and Petzoldt 2009, NRCS 2010).

When developing the standards for IPM, the land manager should be aware that Integrated Pest Management systems function along a continuum from least environmentally risky (no pesticide application) to most environmentally risky (broadcast spraying of non-specific pesticides). It is RGNS's goal that land managers try to keep their IPM as the lowest possible end of the spectrum given financial and logistical constraints.

Grazing land management

There are four essential components to a grazing land management plan: nutrient input guidelines; pest management guidelines; water source guidelines; and prescribed grazing guidelines. While there are numerous other factors that may be considered when managing grazing land, per the recommendations from Doug Towery of the NRCS, a plan including these four components is sufficient for the purposes of RGNS. By focusing on these four components, this plan will ensure that sustainable practices are being used while still allowing leasers the flexibility to specify how they will manage their land based on their years of experience and goals for their operation.

Nutrient management

A complete nutrient management plan can improve both economic and environmental sustainability of grazing land. At RGNS, the nutrient management plan is intended to reduce need of supplemental livestock feed and to mitigate runoff into sensitive surrounding streams. In grazing land, livestock impact nitrogen cycling and soil organic matter. Since grazing and cropland often have interconnected nutrient flows, a management plan must consider a balance in nutrients cycling from soil to plants to livestock. Without a balance in nutrient flow, the risks of harmful nutrient runoff into nearby aquatic systems increase. Excess nutrient input from manure poses the largest threat to water quality in this region (Risse 2001). Planning for runoff reduction is especially important at RGNS since school property includes streams that are tributaries to larger order rivers such as the Little Tennessee River.

Nutrient management in grazing land shares several features with nutrient management in cropland. As with cropland, the key the first step in creating a nutrient management plan for grazing land is to create a nutrient budget. This is done by testing nutrient levels – particularly nitrogen, phosphorous, and potassium – in all nutrient sources, including animal manure, other organic by-products, waste water, commercial fertilizer, crop residues, legume credits, irrigation water, and soil. The plan will then consider the source, amount, timing, and method of nutrient application needed to meet the nutritional needs of the grazing livestock and reach productivity goals. Nitrogen test results are critical in grazing land management plans since nitrogen is a macronutrient that is often a limiting nutritional factor in livestock. Knowing the available nitrogen levels will allow land managers to determine the characteristics of supplemental feed that is needed and to ensure that residual soil nitrogen is minimized (Follett 2008). Based on soil tests and nitrogen levels, land managers can decide if planting high-protein alternative fodder crops is an alternative to buying supplemental feed (Risse 2001). For the most part, though, nutrient input in grazing land is essentially the same as in croplands, the main difference being that nutrient cycling in grazing land happens more quickly since grazing animals eat plants year-round.

In grazing land, manure is a source of nutrients but it can also promote pests, runoff, and uneven nutrient input. If properly applied, manure can be an efficient use of organic byproducts to provide nutrient input for cropland. Excretion is not distributed evenly due to selective grazing by livestock and the location of water sources. This creates pockets of grazing land with different nitrogen levels (Follett 2008). In addition, the amount of nitrogen in manure is highly variable and is affected by age, livestock type, livestock health, and other factors (Follett 2008). Due to the uneven distribution of nutrient input from manure, there must be multiple nutrient test sites to accurately determine nutrient levels. The process of applying manure begins by determining the total nutrients provided by manure and the nutrient levels in soil. The regional NRCS office provides established levels of the amount of nutrients in each pound of manure. These measurements are given in pounds of nutrients per pounds of manure by type of livestock per month. Nitrogen levels in manure change over time, necessitating manure composition testing. After testing, because P_2O_5 and K_2O are stable in soil, the amount of commercial fertilizer can be reduced by a pound for each pound of P_2O_5 and K_2O in the manure. Then, the amount of commercial fertilizer needed is determined by subtracting the amount of nutrients provided by manure from the total of each nutrient needed. Since manure can pose a threat to air and water quality laws, its application must be regulated. Manure cannot be applied to areas that flood often or on steep slopes, and should be applied after cutting and before regrowth (NRCS 2008). Monitoring the effects of manure use to make sure that soil is not overloaded with specific nutrients is critical. If expanding the area treated with manure, nutrient levels need to be tested at least yearly (NRCS 2008).

The final nutrient management plan for grazing land at RGNS should comprise the same components as the nutrient management plan for cropland. These components are:

- A soil survey or map of the area in order to help determine nutrient input levels
- The location of sensitive areas that require different nutrient levels
- Current pasture rotation
- Results of soil tests
- Nutrient requirements of livestock and cropland (if applying manure as fertilizer)
- Nutrient budget for N, P, and K
- Quantified listing of all nutrient inputs and sources
- Recommended nutrient application rates, timing, form and method of application for each CMU
- A plan for recordkeeping.

Integrated Pest Management

An Integrated Pest Management (IPM) plan for grazing land considers common livestock pests and how to reduce their impact on livestock. IPM practices can decrease chemical pesticide input on cropland and grazing land and therefore reduce harmful effects of agricultural runoff. In addition, IPM can reduce cost for land managers. As in cropland, PAMS and the four tiers system should be used as the framework for a grazing land pest management plan. Refer back to the cropland IPM section for details.

The most critical step to pest management in grazing land and pastures is to determine the most common pests and diseases in the herd. This falls under monitoring and identifying in the PAMS framework. Pest identification allows farmers to create a plan that is tailored to their needs. There are two main pest categories that affect grazing land productivity, these include weeds and insects. Many weeds are avoided by livestock because they are too thorny. This reduces the available forage for livestock in a pasture which decreases the livestock productivity (Green et al. 2008). Common pests in Georgia include: parasitic nematodes, especially ostertagia; Coccodia (a one-celled organism that can contaminate plants and manure); ticks; flies, specifically horn flies; grubs; beetles; lice; mites; and wasps (Hinkle 2006, Strickland 2009). Insects aggravate cattle, impacting their grazing habits, which in turn can impact their weight and dairy productivity. In addition, insects can spread diseases that reduce the health and numbers in herds (Loftin and Corder 2010).

Prevention and avoidance of the impact of pests can be facilitated in numerous ways. Providing clean pens and pastures is the most crucial prevention and avoidance strategy. Cleanliness cuts down on the spread of disease and reduces parasites, which subsequently reduces the amount of chemical pesticides needed. Pastures can be kept clean by avoiding long-term grazing in one area or with extensive tilling. Manure piles can be broken up and dispersed to prevent the growth of populations of parasitic worms. Other cultural practices that can be included in a livestock IPM plan include dust bags, back rubbers, walk through fly traps, sticky tape, screens, sealing gaps under feed bunks, and spreading manure thinly and are all practices that should be considered (Watson et al. 1994). Potential biological controls include the use of small parasitoids to control fly populations. Parasitoids can be purchased and released, but this should be done with care – land managers need to make sure they release the correct parasitoid for the type of pest they are trying to control. If pesticides are used, it is important to make sure that the pesticide targets the pest and not the parasitoid. Chemical control options include larvicides, space sprays, baits, residual-premise sprays, and whole animal sprays. Ear tags treated with pesticides can reduce the impact of flies and other pests depending on the pesticide treatment (Wilson et al. 2006). Space sprays and baits work well with parasitoids. Whole animal sprays have short-lived results (Watson et al. 1994). The Georgia Pest Management Handbook provides information about chemical pesticides for common livestock pests (Hinkle 2011). Pesticide use recommendations for common livestock pests are provided by the University of Georgia Cooperative Extension. Specific instructions on mixing pesticides for sprays and dusts and for how to create baits are listed, as are correct application techniques (Hinkle 2011). In addition, insects and plant specimens with diseases can be sent to the Cooperative Extension to be identified, enabling correct pesticide use.

Monitoring can also be done as part of a government initiative to facilitate the tracking of disease spread in livestock. Registering to be a part of this initiative is free and it can benefit the wellbeing of livestock in the event of a disease outbreak. Farmers can register their sites by simply providing address and description of where livestock are kept.

Water systems

Watering facilities for livestock have three goals: providing water for livestock, encouraging livestock distribution, and protecting water quality. Best management plans for a given water system are dependent on the type of water body, types of pollution present, climate conditions, and affordability (Osmond et al. 2002). Direct water source systems can include streams, ponds, wells, gravity-flow systems, and springs (White et al. 2009). At RGNS, water is readily available from numerous streams. However, these streams flow into Betty Creek or the

Little Tennessee River, both of which are sensitive waterways. While the quality of these streams can be protected by following best practice guidelines for grazing, tilling, nutrient input, and pesticide input, water resources for livestock and downstream habitats will inevitably be impacted. Based on these factors, RGNS land managers should consider remote water sources. In addition, to conserve the health of the stream systems on the RGNS campus, riparian buffers and stream crossings should be carefully planned. Water quality must be tested on a regular basis to ensure that cattle are being provided with clean water and that the watering facilities are protecting the health of nearby water bodies.

Watering facilities planning accounts for the amount of water needed daily, the water source, and monitoring practices. Remote watering is often a better practice than direct watering because when cattle's water source is a lake or stream the area is often trampled to the point of extreme muddiness. Erosion increases, feces build up, and diseases can spread. Pumping water to troughs can eliminate or reduce these risks. Design of the system depends on the type of livestock and the daily water requirements. Designs should consider how water will be kept clean. The height of watering troughs for cattle should fall between 22 and 36 inches. Cattle require 20 gallons of water per animal per day and 25 gallons of water per head per day for beef cattle and dairy cattle respectively. A watering facility should be placed where water can drain easily (NRCS 2008). Cleaning is required to decrease debris and algae build up. Goldfish can be added to water storage units to control algae. Uniform grazing can be promoted by placing the watering source such that cattle have to travel no more than 800 feet to reach it. If more travel is required, cattle will stay clustered near the water source increasing erosion and manure build up (NRCS 2008).

Streams are fragile water systems that are significantly impacted by agricultural practices. A key practice is to create riparian buffers around streams. Riparian buffers prevent erosion, protect stream hydrology, and reduce runoff of chemicals and nutrients into streams. RGNS installed buffers around the streams on crop and grazing land in the late 1990s. However, these buffers are currently in disrepair. The primary species in the riparian buffers are multiflora rose (*Rosa multiflora)* and privet grass (*Ligustrum* sp.), both of which are invasive species and species that cattle enjoy eating. In addition, while the riparian buffers were fenced out, the fences no longer effectively keep the cattle out of the buffer zones. As a result, the width of the buffers are steadily decreasing. The riparian buffers should be re-fenced to prevent livestock from destroying the riparian buffers. If the riparian buffers are not re-fenced, deterioration of these buffers will increase stream temperatures and damage the health of fish populations (Osmond et al. 2002).

Buffer width depends on stream characteristics and the slope of the surrounding land. A study done on a stretch of the Little Tennessee River used 40 foot buffers and saw a subsequent reduction of 90 percent of nitrate-nitrogen levels and a 40 percent decrease in fecal coliform bacteria (Osmond et al. 2002). The steeper the slope, the greater buffer width required to perform the desired ecosystem services. Provided the pastures are well-maintained and not used intensely, nitrate-nitrogen levels can be kept at acceptable levels with a buffer as small as 15 foot or one row of trees, but to keep phosphorous levels at an acceptable level a 30 foot buffer is often more effective. The riparian buffer plantings should be plants with a controllable spread and that will not be eaten by livestock. Riparian plantings should be chosen in consideration with local herbicides used: for the buffer to be maintained, it needs to be tolerant of applied herbicides. Along the grazing lands bordering the Little Tennessee River, black walnut trees are a suitable buffer plant. Within and near riparian buffers, plant residue should be left on the land.

Decomposing organic matter improves the structure of the soil and reduces sediment influx into streams. Once buffers are in place, shade should be provided elsewhere to eliminate the necessity of direct stream access for livestock (Hoorman and McCutcheon 2005). Stream crossings are necessary to allow livestock to travel to new grazing areas and they provide a water source. Controlled stream crossings can maintain riparian buffers by decreasing trampling from livestock. Stream crossings should be planned carefully on stable bank areas. Fences should be placed on the banks around both sides of the crossing. The shade from riparian buffers near streams makes stream crossings an ideal place for cattle to congregate. This can increase erosion and nutrient input into the stream. To mitigate high traffic near these areas, shade can be reduced by pruning (NCRS 2006).

Prescribed grazing

Prescribed grazing is a practice in which grazing occurs in specific locations during a designated season and at an intensity that allows vegetation management goals to be achieved (USFWS 2009). Grazing animals impact the environment in three main ways: herbivory, physical impact, and deposition. Grazing animals eat leaves, fruits, roots, and stems of plants and thus their grazing patterns shape the surrounding plant communities in terms of structure, productivity, and composition. As animals graze they compact soil, disturb soil surfaces, mix seeds into the soil, and change the nutrient cycle within the pasture (USFWS 2009). Grazing patterns promote soil moisture, shoot growth, and nutrient availability through defoliation, but reduce biomass through trampling (USFWS 2009). Animals are important seed dispersers – dispersing seeds by digestion or by transport when seeds get stuck to animal fur and are carried to new locations (USFWS 2009). In developing a prescribed grazing plan for RGNS, land managers need to consider the long term health of livestock and grazing land. A successful grazing plan will consider the type of livestock, the number of livestock, grazing distribution, and length of grazing in each available location. As with any management strategy, monitoring is crucial when using prescribed grazing. It is necessary to observe grazing patterns and their impacts, and to continuously rotate pastures. A prescribed grazing plan at RGNS can protect streams and riparian buffers, improve soil quality, facilitate habitat maintenance for species of concern, and promote economic sustainability.

A grazing plan is dependent on the unique forage requirements of and grazing impacts caused by each type of livestock. Cattle have specific grazing characteristics and impacts on the pastures in which they graze. They graze uniformly over large pastures. While cattle are sensitive to secondary compounds in plants (such as tannins and alkaloids) and therefore limit suitable forage crops, they will eat almost any part of a plant (USFWS 2009). Each type of cattle has specific forage supply and rotation requirements. Dry beef cows require continuous forage stocking and a lactating beef cow requires slow rotation between three and four pastures, while stocker and heifer cattle requires moderate rotation between five and seven pastures. Lactating dairy cows require fast rotation between eight to ten pastures. Bulls require daily rotation. There are proper grazing heights and rest time for pastures for each forage type (NCRS 614 2008). The amount of rest time a pasture needs is higher (25-30 days) in the summer than in cooler seasons (15 days) (White et al. 2009). Understanding forage growth patterns is necessary for planning for sustainable grazing practices. Fall is a critical season for forage because growth points form and roots regenerate during this season. Land managers can check to see if root regeneration is occurring by digging out a root, rinsing it free of dirt, and looking for white roots (Pirelli and

Fransen 1997). Young grass shoots (tillers) from the previous spring turn brown by the fall and look dead so they are often mowed over. However, tillers store carbohydrates that allow growth for the next seasons shoots. Three to four inches seems to be the critical height - mowing tillers under that range stunts their ability to provide nutrients for growth (Pirelli and Fransen 1997).

With steady rotation of grazing livestock through pastures, it is important to plan fencing and positioning of paddocks. Fixed, semi-fixed, and changeable resources must be considered as fencing placements are made. Fixed resources include slope, aspect, soil type, and acreage. Semi-fixed resources include water supplies, current fences, and trees. Changeable resources are forage type, moveable fences, and travel lanes. Irregularly shaped paddocks are often more sustainable than designs focused around a water source. A central water source will result in congregations of cattle at the water source leading to erosion and pollution of their water source. Pasture fences should circumscribe homogenous areas (Gay et al. 2009). Water availability needs to be considered. Lactating cows need a water source within 500 to 600 feet while other cattle can be as far as 1000 or 1200 feet from a water source. It is impractical to have a pond in every paddock, and as discussed in the watering systems section direct-access water systems are often unsustainable. Fencing should be planned to protect waterbodies on RGNS land. Streambanks should be fenced off as grazing should not be practiced on saturated streambanks because this can damage the soil structure and runoff risk is higher when water discharge is higher (NRCS 1999). Alternative plans should be outlined for emergencies such as droughts and floods.

Prescribed grazing can be used to control invasive plants. Prominent invasive plants at RGNS are privet (*Ligustrum* sp.) and multiflora rose (*Rosa multiflora)*. However, these are buffer species and riparian buffers are not a suitable place for grazing. For other areas with invasives, grazing can be an excellent biological control method at no extra cost to land managers. Land managers can change the amount of provided forage so that livestock are essentially forced to eat the undesired invasives in an area (USFWS 2009). Pasture rotation allows for plant recovery and often means that multiple grazing cycles in one area are required to eliminate unwanted plants (USFWS 2009). Grazing can be prescribed to address invasives at any stage and to multiple desired extents. Grazing at early stages in an invasion can prevent colonization. Invasives can be suppressed and maintained by grazing strategies, and if combined with other methods, grazing can help eliminate invasives.

In conclusion, the recommended agricultural and grazing practices detailed throughout this paper are intended as a first step toward more environmentally sustainable and hands-on management of RGNS leased land. The next step is for those leasing agricultural land from RGNS to create specific templates and plans for their operations. Worksheets and resources for creating these templates are already available from the NRCS's Field Office Technical Guide for Georgia. All involved parties must also be able to easily access data, recommendations, and records associated with the leased land. Subsequently, we recommend that a data repository be created. This can be as simple as an open system of Google Documents. Such a repository will allow RGNS to more closely manage and monitor farm operations and will allow leasers to easily collaborate with RGNS administrators. In addition, this repository will allow teachers and students to compare their monitoring results with what farmers and land managers are finding. Sharing collected data will increase the efficiency of future planning.

There are many aspects of this project that can, and should, be expanded upon in the future. A future internship at this site could focus on helping teachers carry out the lessons created with a focus on inventorying the resources the school owns. Teachers were particularly interested in providing basic instruction in GIS use for students; helping meet this goal could become a component of an internship at RGNS. Another study could focus on determining how the suggested best practices are being used by farmers and what might be limiting farmers and land managers from following the outlined suggestions. A third internship or future study could focus on mapping projects at the school. More layers could be added to analyze and summarize new projects on school property. Wind data could be collected and mapped to find ideal locations for wind turbines as the school moves forward in their plans of adding a wind turbine to the school property.

ACKNOWLEDGEMENTS

We thank Dr. Anya Hinkle, Dr. Jim Costa, and Michelle Ruigrok for their guidance, Gary Wein for his GIS assistance, RGNS teachers Woody Malot, Brian Phillips, and Amy Jenkins for their insight, and Doug Towery for this valuable knowledge on agricultural practices.

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APPENDIX A

Using School Land as a Classroom: Resources for Teachers
(digital archive on attached CD)

APPENDIX B

Rabun Gap-Nacoochee School Property ArcMap®
(digital archive on attached CD)

APPENDIX C

Rabun Gap-Nacoochee School Topography ArcMap®
(digital archive on attached CD)

APPENDIX D

Rabun Gap-Nacoochee School Aerial Photography ArcMap®
(digital archive on attached CD)

APPENDIX E

Rabun Gap-Nacoochee School Geology ArcMap®
(digital archive on attached CD)

APPENDIX F

Rabun Gap-Nacoochee School Aerial Soils ArcMap®
(digital archive on attached CD)

APPENDIX G
List of Online Resources
(digital archive on attached CD)

APPENDIX H
Template for Land Use Planning
(digital archive on attached CD)

TRACKING CLIMATE CHANGE IN THE SOUTHERN APPALACHIANS THROUGH PHENOLOGICAL GARDENS

JOSEPH ALEC MCCONNELL

Abstract. In order to help understand the effects of climate change in the past, present, and future, it is important to consider how climate change affects biological systems. To this end, phenology, the study of the timing of biological events in the life cycles of plants and animals, has become an important approach in the study of climate change. Phenology observation gardens have been widely implemented to facilitate the collection of phenological data and educate the public about the ecological effects of climate change. Comparisons can be made between different phenological gardens across the world to detect trends. Phenological monitoring has the potential to provide data on shifts in the timing of biological events in response to climate change as well as providing an educational opportunity from citizen-science to K-12 and college levels. This study contributed species accounts and weather data analysis for the Highlands Biological Station phenology garden. When complete, this garden will permit comparison of climate trends and the timing of phenological events in the southern Appalachian region with climatically similar regions across the globe.

Key words: botanical garden; climate change; global warming; Highlands Biological Station; phenology; phenological garden; phenological monitoring.

INTRODUCTION

During the fall of 2011, I assisted in the development of a phenological monitoring garden at the Highlands Biological Station. The Richardson scholarship was funding the project so that I could work on this phenological garden. (Unfortunately the scholarship was broke in 2011). I created species accounts and graphical weather data for the gardens website (that is still under development).

The International Panel on Climate Change (IPCC) fourth assessment has observed a large change in both precipitation and climate change patterns over the last century (IPCC 2007). The future predicted warming for every decade is approximately 0.2° C. Even if all greenhouse gases and aerosol emissions were to stop, the warming per decade would still be approximately 0.1° C (IPCC 2007). While the fact that climate and precipitation rates have changed is undeniable, it still remains unclear how these factors have and will change the environment and specific ecosystems. It is clear, however, that changing temperature and precipitation patterns impact species phenology. Phenological monitoring of biological changes due to climate change has, accordingly, become an important tool to the understanding of environmental change. Phenology is the study of plant and animal reactions to changes in the ecosystem such as climate change and precipitation change. More generally, it is the study of occurrence, timing, and interaction of biological events in plants and animals.

Overview of phenology and climate change

Phenology is not a new science. Many poets, philosophers, and naturalists observed phenological changes in their environment, e.g.: Thoreau, Jefferson, and Emerson. Scientists are now using their notes and historical datasets to compare with modern conditions. For instance, both Thoreau and Jefferson recorded when certain types of flowers bloomed. This information is very useful today because we can make comparisons of the time periods that they lived in with today. Jefferson's records are not that extensive and give little insight what the flowering periods were like when he lived, but some of his information has been useful. Thoreau's records are incredibly extensive and have shed light on the flowering periods of certain plants. One great example is *Oxalis europaea*: this is a plant that Thoreau recorded to bloom approximately 155 days into the year. Now this plant is recorded to bloom approximately 120 days into the year (USA-National Phenology Network 2011), a significant change in 150 years. These examples demonstrate why phenological records from the past are extremely important and why keeping records at this time is still important. This is also an example of the ecosystem becoming warmer and a plant blooming earlier than it should be, instead of blooming later.

Plant and animal species vary considerably in their sensitivity to the changing precipitation and temperature regimens associated with climate change. Although many of the effects of climate change remain unclear, scientists have begun observing irregularities in blooming periods in plants (either too early or too late). Some animals are so sensitive rainfall that they are unable to survive in areas where rainfall increases in the slightest. Even better studied is phenological changes in plants, which are affected by temperature change because plants start blooming at certain specific temperatures. Some studies on the National Phenology Network (NPN) recorded many phenological events changing over the past 50 years (USA-National Phenology Network 2011). One study by Schwartz and Caprio (2003) looked at *Syringa vulgaris*, the common lilac. The observation that was made across multiple phenological gardens in the US was that the blooming period was occurring at a progressively later date. The data recorded from year 1957 through 1972 and in some cases later. Initially blooming began approximately 70 days after the beginning of the year, but, by 1960, the blooming period was delayed to approximately 100 days after the beginning of the year, a shift in 30 days over just 15 years. This is a textbook example of a change in a phenological event. This occurrence is consistent across most of the phenological gardens that were examined by Schwartz and Caprio (2003).

It may seem counter intuitive, but many plants are blooming later in the year, while some are also blooming earlier. Climate change does not necessarily mean that the earth is becoming warmer. It means that the natural climates are changing, which may in some cases make ecosystems colder. This affects plants in different ways. If the area is getting warmer, then plants will bloom earlier, but if the ecosystem is getting colder the plants will bloom later in the year. Phenological shifts reveals changing world environments and ecosystems. This is why the study of phenology could help us benefit greatly by understanding its relationship to climate change, which could increase ecosystems predictability as to their reaction to greenhouse gases, CFCs, aerosols, etc. Once ecosystem reactions to these chemicals are better understood, future predictions will be much more accurate than they are today.

As individual species experience phonological shifts, species interactions and interdependencies will inevitably be affected and may be disrupted. The term phenological mismatch was coined to describe when two species that used to rely on one another can no longer do so (Amano et al. 2010). Phenological mismatch occurs, for instance, when a type of bird migrates to an area for food that it is dependent upon for survival, but in that area the insects and plants have not yet produced or released this food. The plants are not providing the food for the birds because of phenological shifts in, for example, budbreak or flowering. This hinders the birds' ability to find the resources that it has come to depend upon to survive. Another example of this is the honeybee's reliance on certain flowers blooming at a certain time period, but if the flowers bloom too early or too late the bees is not able to collect enough pollen. These types of phenology mismatches are becoming common (Amano et al. 2010).

Phenological changes have been recorded and are being recorded across the U.S. at different rates. Another study done in the vicinity of Washington, D.C. indicates that the temperature is rising in the area and has created earlier blooming in 89 of the 100 regional species that were investigated (Shetler and Wiser 1987). This study was also conducted in 1987, which means that there could have been further, later drastic changes (IPCC 2007).

Phenological changes do not have to occur in the same direction. Schwartz and Caprio (2003) discovered that blooming in lilac species is occurring later in any given year, which is a significant change in phenology. Shetler and Wiser (1987) discovered that in the D.C. area flowering was occurring earlier in any given year in most native species. Both of these studies show significant phenological changes but one study demonstrated earlier flowering, the other, later. (Some skeptics use such apparently contradictory discrepancies as arguments to debunk the theory of global warming. Tendentious viewpoints are not appropriate and muddy scientific analysis: the point is that climate change has varying effects on many different ecosystems and study of all phenological changes is important to determine actual causal relationships and their implications).

Project objectives

Two main objectives for phenological observation are: (1) to obtain long-term data, and (2) to use a monitoring system—such as a garden—as an educational resource. Long-term data are important because trends in climate and phenological change only become apparent with observations accumulated over a long period of time. Monitoring also facilitates predictions of changes and the effects the future changes might have. Without long-term data it will be harder to predict future changes and the reasons for these phenological changes, which might mean that we will not be able to stop these changes from occurring, or that we will attribute the changes falsely to potential putative causal factors.

The second objective, using monitoring programs as an educational resource, is equally important. Monitoring phenology in a certain area with specific plants provides a focus for community and school groups to contribute observations. This can also connect them to other similar gardens across the world. It serves as an educational program for students—of all ages—and visitors of any kind. A garden would teach the concept of phenology, climate change, and the ecological effects of changing climate. Educating people on the subject is the most powerful way to make people understand and take action against global warming and climate change.

The phenological garden at Highlands Biological Station presently under development is intended to serve both objectives. It will provide a focus for an ongoing phenological observation program, generating phenology data and serving as a resource from K-12 to college/university instruction. There is a need for long term studies and data collection in the Appalachian Mountains, especially in phenology. It is still unclear how mountain regions react to climate change and the associated shifts in temperature and precipitation regimes. School groups, scientists, and conservation organizations may conduct individual small-scale studies, but providing a focal study area while also making the resulting phenological observations freely available (via the web) will provide a larger body of data for groups to make use of, as well as the supplemental educational resources made available on the eventual website.

MATERIALS AND METHODS

Species accounts

The first step of my study was to develop species accounts for the plants in the phenology garden at the Highlands Biological Station (HBS). These will form the basis of species pages for the HBS phenology garden website. Eleven accounts were written, each limited to a very short and concise paper no longer than a page. The accounts include brief information about the species such as: their preferred type of soil, and whether they do well in different environments. There is also a picture of the species in a natural environment and a sketch of that particular plant's blossom or seed. A list of the species as well as their importance, whether they are native or non-native, and other information is listed in Table 1, modified from Nash (2010). The species accounts were based on research in the Highlands Biological Station library and various Internet sources (Appendix A).

TABLE 1. Cumulative species list for all four sites and criteria evaluated for species selection.

Species	Nationally Important (NPN*; PB**)	Native to southern Appalachian Region
Acer rubrum	Yes NPN & PB	Yes
Aster patens		Yes
Eupatorium purpureum		Yes
Iris cristata		Yes
Juniperus virginiana	Yes NPN	Yes
Narcissus sp.		No
Panicum virgatum	Yes NPN	Yes
Rhododendron calendulaceum		Yes
Solidago sp.		Yes
Syringa patula	Yes* NPN & PB	No
Tradescantia virginiana	Yes** PB	Yes

Notes: National Phenology Network (NPN); Project Budburst (PB); * *Syringa patula* was used because *Syringa vulgaris* is regionally susceptible to a stem borer; however *S. vulgaris* is the species listed on the NPN and PB lists; ***T. ohioensis* is the species listed on the PB list, however I chose to use *T. virginiana* because it is a native species and should yield comparable results.

Weather data

The second part of my study entailed summarizing and graphing weather data from the Highlands Biological Station records. These records, including daily precipitation and maximum and minimum temperature data, have been recorded at the Biological Station since 1961. I compiled the data in a spreadsheet and generated graphs for visualization of trends.

Website

The Scully Group (Asheville, NC) is working with garden projectionists to develop a website for the garden. It was important that the website reiterated what phenology was, its importance, and how everyday people could help. It was also extremely important that the Internet site be very clear and well organized. For this part Brian Howell and his students have been devising a site possibly with a 24-hour live feed from a camera to observe the botanical garden at all times. The website map (what the layout of the website will look like) is in Appendix B.

The ultimate goal is to disseminate information in the educational applications of the phenology garden. The purpose of schools and teachers visiting the botanical garden and the website is to educate them, and it is a free source of information. The more that this is emphasized, the more likely it is that phenology will be built into the curriculum of the schools. The teachers' manual created by Emma Nash in 2010 is an extremely useful resource for this task. The implementation of the above steps is the main challenge, especially with such large budget cuts and other problems the public school systems face.

RESULTS AND DISCUSSION

The Highland Biological Station has been documenting local temperatures and precipitation rates for the past 50 years, since 1961. Fig. 1 shows the annual temperature lows and figure 2 shows the annual temperature highs, whilst Fig. 3 shows the average precipitation values. The graphs were made to help demonstrate the overall trend of rising temperatures. The trend lines for temperatures—both high and low values—are rising steadily since this time (Figs. 1 and 2). In contrast, precipitation in Highlands has been erratic. The trend line has actually decreased slightly but this is most likely just a fluke and will not remain declining. Future predictions for the area and globe are that temperatures will continue to rise (IPCC 2007). The same trend is observed in the temperature high averages (Fig. 2) and the precipitation has surprisingly been found to have a slight decrease. This is probably an anomaly because, according to Amano et al. (2010) and the IPCC (2007), precipitation values (Fig. 3) have been rising all across the United States and are creating a major problem because the plants and animals are not used to this amount of precipitation in certain times of the year.

Precipitation is not the only thing that is changing. Temperature has drastically been rising in the Appalachian Mountains in comparison to other parts of the world. The average global temperature is rising at approximately 0.1 degrees Celsius every year. This refers to the current time period and not that of 1961 (IPCC 2007). Fig. 1, as well as Fig. 2, show a warming trend and Fig. 1 has a higher slop, which indicates that the low spectrum of the temperature is rising faster. This could have drastic effects on nocturnal animals that rely on the cooler temperatures at night and have some severe phenological affects. These trends are regional and seem to be happening across the Appalachian Mountains but not across the entire US. Some areas are not experiencing much temperature rising at all. The climate across the globe is changing. What seems to be happening is that more drastic whether fluctuations are occurring but on the broad scale temperatures seem to be rising (IPCC 2007). The temperature rising—

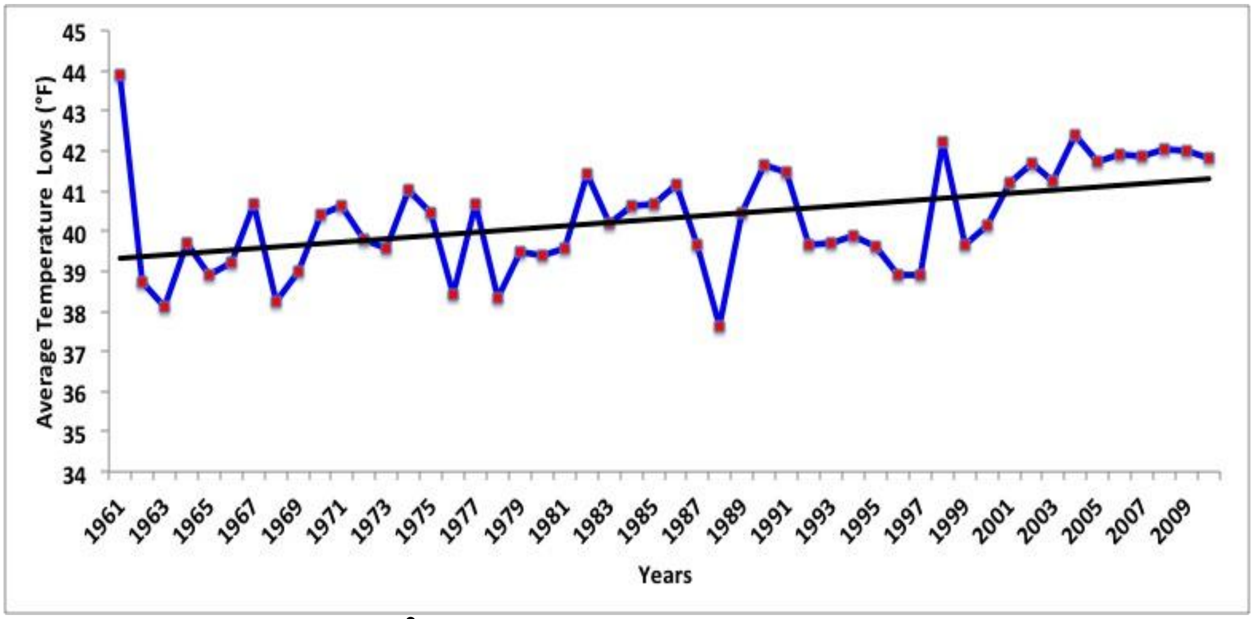

FIG. 1. Average low temperatures (°F) for the years 1961-2009. All the values were recorded at the Highlands Biological Station.

according to the data given by the Highlands Biological station—is more drastic than expected in figure 1. This temperature increase is not normal for this region, especially not at this rate. This is a great reason to have a phenological observatory garden at the Highlands Biological Station.

The phenological garden will provide information by observing the plants. If they begin to bloom later or produce seeds later or earlier in the year—which seems more likely due to the

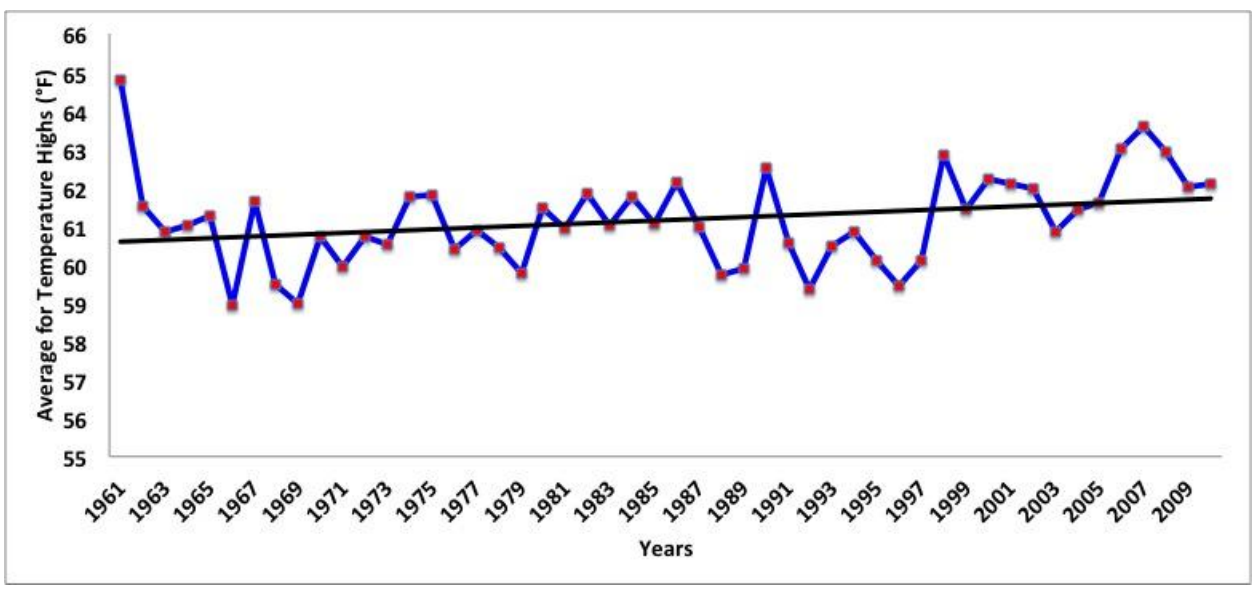

FIG. 2. Average high temperatures (°F) for the years 1961-2009. All the values were recorded at the Highlands Biological Station.

warming—then scientists will record this. They will be able to compare this to other places where warming might not be as drastic. It could be that it is happening all over and not just here. This would most likely be due to warming across the globe but if it this is only happening in this region the logical conclusion would be the drastic temperature change in this region. The scientists would also be able to observe if warming is affecting all the species in the same way, which is unlikely because all species seem to have different tolerances for many different things. This would also be a unique opportunity to teach children and people of all ages how important phenology can be, especially because it would be changing species now and they could observe this change. It might encourage people to make more of a change if they truly understand the effects of phenological change.

Ultimately other phenological gardens are observing trying to see if their gardens are being affected by the climate change in their area. Comparing phenological gardens with similar temperatures reveals species that are closely related or of the same species have almost exactly the same reactions from one garden to the other (USA-National Phenology Network 2011). This research has not been conducted thoroughly enough to be sure that this is always the case but the hope is to be able to continue to compare and contrast until the evidence is conclusive. That is one aspiration of the Highlands Biological Station's phenological garden. Hopefully the website will be a success and influence enough people to create more phenological gardens and to make additions to the species that are currently in the phenological garden. The aspirations are to have more gardens spread across as much of the world as possibly with as many species as possible. The hope is to also make all the data available to everyone through the use of the Internet. These are very high goals that will not all be reached soon but with time and effort they are not unachievable.

In summary the meaning of the temperature graphs going up and the precipitation graph staying at approximately at the same level is a clear indication that climate change is occurring. The botanical garden is one of the ways to document and observe phenological changes in data, which is why it is important to put all the available data online and to be able to monitor it. This is also meant to be an example for other botanical gardens for comparison and observation around the world.

Thanks to new technology and being able to make websites, we could even have botanical gardens in places where nature is undisturbed and far from civilization to see if this has

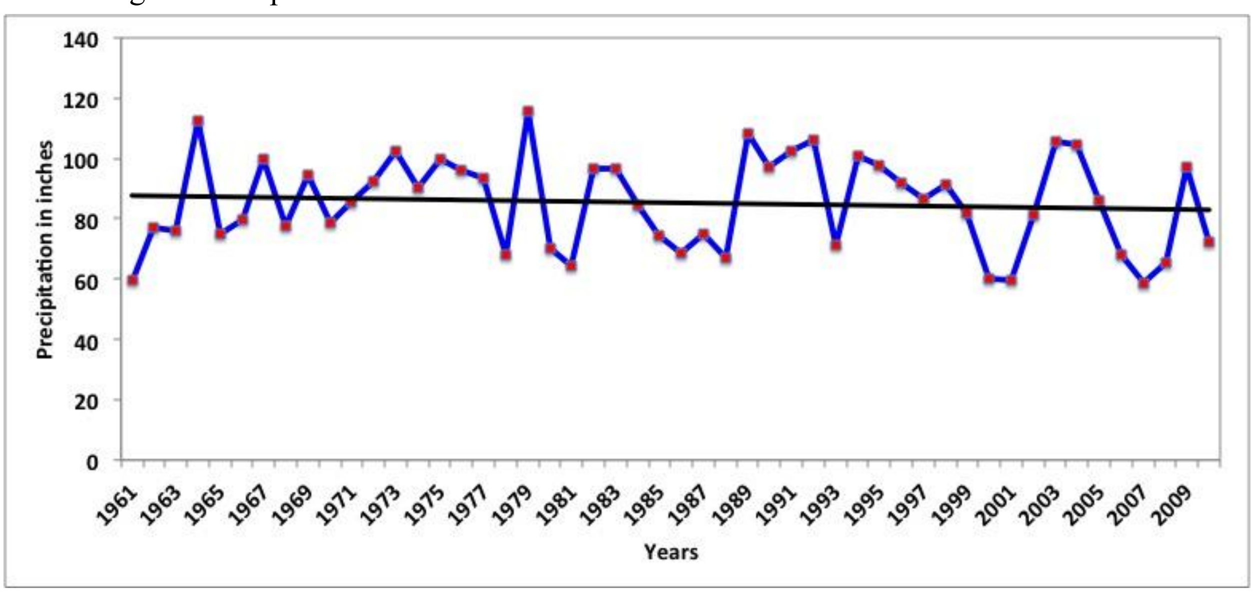

FIG. 3. Average precipitation (inches) for the years 1961-2009. All the values were recorded at the Highlands Biological Station.

any effect. These type of ideas are not too far off into the future and the Highlands Biological Station is making the first step in the right direction by setting up a website with information and data.

To truly make large steps forward, we need to implement Emma Nash's 2010 teachers' manual. The way to the future is through the next generation. It is important to start educating the children about phenology and its importance.

In 2010 the NPN released its 2009 report and listed the successes it has had as well as upcoming challenges. It also listed the partnerships it had created in 2009, among which were multiple programs that focused on the east coast. These programs were creating species lists for phenological gardens and expecting to be able to compare phenological data once the gardens had been created (USA-National Phenology Network 2011). Noteworthy programs that seem to be making headway in phenological work are the NPN, Project Budburst, the Wilderness Society, and HoneyBeeNet. These programs have been working with NPN to make considerable progress in phenology studies.

The Highlands Biological Station botanical garden is taking these first steps to educate the public about the utility of monitoring phenology. Following the suggestion of Nash (2010), it is to be hoped that in years to come similar gardens will be established at Coweeta Hydrological Laboratory, the Appalachian Highlands Science Learning Center at Purchase Knob, and the Great Smoky Mountains Institute at Tremont, enabling simultaneous comparisons of phonological events associated with the same set of species, across the elevational and precipitation gradients of the region.

In many years to come these gardens might be replicated in other countries with similar climates. Ideally a program will be built that helps educate as many people as possible and operates on a global scale in as many countries as possible. The best-case scenario would be comparing similar species across the world in similar ecosystems and recording the phenological observations, which would lead to identification of the cause of the changes and a possible solution. And for this to happen more people need to be taught and educated about phenology.

AKNOWLEDGEMENTS

I would like to thank Dr. Anya Hinkle, and Michelle Ruigrok and of course my main mentor Dr. James Costa. All of these people have been very supportive. I would also like to thank Brian Howell and his students because without them there could never be an Internet site spreading the enthusiasm and importance of Phenology. My thanks also goes to Max Lanning for helping out with the botanical garden and helping plant and seal off the garden. Although I never met her I feel that Emma Nash also deserves my thanks. She was doing my internship last year and made an excellent start on the botanical garden, and I am essentially continuing her work. I feel like we were almost a team. Thank you all for you amazing help and support on the phenology garden.

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APPENDIX A

Species information sheets for the botanical garden website
(digital archive on attached CD)

APPENDIX B

Internet site map
(digital archive on attached CD)

AN ASSESSMENT OF WOODY AND INVASIVE PLANT COVER AT RESTORED SITES IN THE LITTLE TENNESSEE WATERSHED

KELDER MONAR

Abstract. Stream bank restoration and vegetated riparian buffers have reduced rates of erosion along the Little Tennessee River and tributaries. A 2003 study found a diverse assemblage of plants at restored sites within the watershed. Many exotic invasive plant species were also present. This study looked at the change since 2003 by estimating percent cover of exotic invasives for points at a site. Using a line-intercept method, woody vegetation was also sampled. Percent cover and diversity were compared between 2003 and 2011. Tree cover and species richness were found to have marginally increased. Exotic invasive cover and richness were found to have greatly increased. The rapid rise in exotic invasive cover and especially in exotic invasive species richness suggests that exotic invasive control is needed to maintain habitat at these sites.

Key words: exotic invasive plants; Japanese honeysuckle; Lonicera japonica*; Little Tennessee Watershed; restored stream bank; riparian buffer; vegetative cover.*

INTRODUCTION

The Little Tennessee River, together with its large tributaries, is a defining geographic feature of Macon County, NC. The area was once primarily agricultural but is now undergoing considerable development pressure as agricultural parcels are being subdivided into residential properties (Love 2003). There has also been a parallel trend of increased interest in conserving and restoring the Upper Little Tennessee and its watershed (McLarney 2003). Though rivers naturally sculpt and remake their channels, stream banks in the upper Little Tennessee Watershed have been eroding at an unnaturally accelerated pace due to livestock entering streams along banks, loss of vegetative cover (especially trees) along the banks, and unnaturally high sediment loads in the river that hasten the scouring of the riverbanks (McLarney 2003). The Macon Soil and Water Conservation District (MCSWD), in collaboration with the Little Tennessee Watershed Association (LTWA), has enrolled several properties in its revetment and buffer program, beginning in 1997. These properties are generally located along the Little Tennessee mainstem between the Georgia border and the city of Franklin, NC, although properties are also located below Franklin and along tributaries of the Little Tennessee.

The combination of whole tree revetments and vegetative buffer restoration had proved successful in permitting natural restoration of stream banks and eliminating major sources of erosion and sedimentation as of 2003 (McLarney 2003). Whole tree revetments consist of entire logs tethered to the bank and meant to trap sediment that would otherwise wash into the stream. Buffers are vegetated areas adjacent to the stream bank, the roots of which hold soil together. Protecting buffers can include either planting, livestock fencing to allow natural regeneration, or both. Love (2003), also found that the 20ft-50ft vegetative buffers proved beneficial to flora and fauna in the area, providing habitat for some and corridors for others. Love also noted a slight trend for increasing percent cover of exotic invasive plant species the longer a site had been enrolled in the program. Exotic invasives, which respond positively to disturbance and edge habitats, can dominate and disrupt native vegetation. Furthermore, they can use riparian zones as corridors to colonize new areas.

The purpose of this study was to assess the change in exotic invasive vegetative cover in these riparian buffers using Love's 2003 study as a baseline. Since the buffer and revetment work there has been little or no restoration on these sites, making them examples of post restoration ecosystem trajectory. An additional goal was to make management recommendations to the Land Trust for the Little Tennessee (LTLT), which is considering using grant money to do further restoration work on riparian sites on the Little Tennessee.

METHODS

Study Sites

Ten sites were used for this study. (Fig. 1). The sites were distributed along the upper Little Tennessee River and two of its major tributaries in Macon County. Six were on the Little Tennessee, three were on Cartoogachaye Creek and one was on the Cullasaja River. Each site had been part of the riparian buffer and revetment program. The buffers had been installed in 1998 (three sites), in 2000 (three sites) and 2002 (four sites). I measured woody vegetation and exotic invasive plants at each site. Site names are those used in the 2003 study, based on the landowner at that time (Appendix A). I used ArcGIS (ESRI 2011) in my study to create Fig. 1.

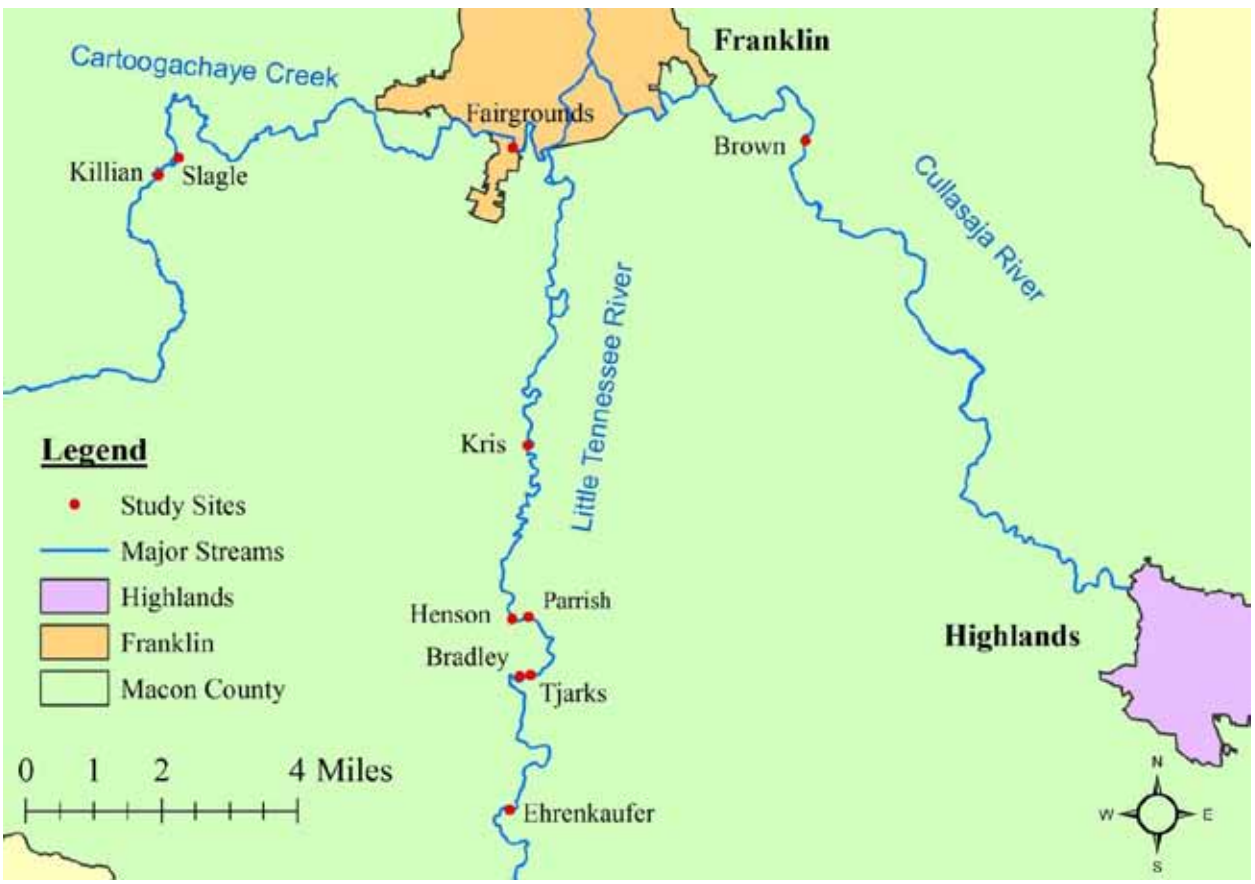

FIG. 1. Location of study sites within Macon County.

Tracking Changes in Tree Cover

Woody vegetation was measured using a 100ft line-intercept method (Fiala et al. 2006). The location of both ends of the transect were recorded with a Garmin® Legend Cx Etrex GPS unit. Both percent cover and species composition were recorded. Any woody vegetation over one meter in height was included. Approximately one 100ft transect was recorded for every 500ft of riparian buffer at a site. Transects were taken parallel to the river bank halfway between the buffer edge and bank edge, or as close as field conditions permitted. Trees were identified using *A field guide to the trees and shrubs of the Southern Appalachians,* by Robert E. Swanson, and *Identifying trees: an all-season guide to Eastern North America*, by Michael D. Williams. Samples of trees unidentifiable in the field were brought back to Max Lanning, Highlands Botanical Garden Supervisor, for identification.

Tracking Changes in Exotic Invasive Cover

Exotic invasive plant cover was sampled using an ocular estimation of a 25ft radius around a marked data point within the buffer. Cover was estimated to the nearest 5% unless it was only trace, in which case it was assigned the value of 1% cover. Percent cover was recorded for 14 of the most common and problematic species (Table 1), as suggested by Dennis Desmond, Land Stewardship Director of the Land Trust for the Little Tennessee. One sampling point was installed every 100ft of riparian buffer. The location of each sampling point was recorded using the Garmin® Legend Cx Etrex GPS unit. Sampling points were located midway between buffer edge and bank edge. Additional data also collected at these points included percent cover of river cane (*Arundinaria gigantea*) and estimated light availability. For the latter, each sampling point was categorized as either sunny (<25% shaded), partly sunny (>25% and <50% shaded), partly shady (>50% and <75% shaded) or shady (>75% shaded) based on tree cover.

TABLE 1. List of exotic invasive species from the LTLT.

Common Name	Scientific Name
Princess tree	*Paulownia tomentosa*
Tree of heaven	*Ailanthus altissima*
Multiflora rose	*Rosa multiflora*
Chinese privet	*Ligustrum sinense*
Autumn olive	*Elaeagnus umbellata*
Bush honeysuckle	*Lonicera maackii*
Japanese knotweed	*Fallopia japonica*
Oriental bittersweet	*Celastrus orbiculatus*
Japanese honeysuckle	*Lonicera japonica*
Ground ivy	*Glechoma hederacea*
Kudzu	*Pueraria montana*
Cinnamon vine	*Dioscorea batatas*
Japanese stilt grass	*Microsteguim vimineum*
Johnson grass	*Sorghum halepense*

Two indices were used to measure diversity: species richness and the Shannon-Weiner Index. Species richness (S) was calculated by counting number of species from each sample. Woody vegetation was sampled separately from exotic invasive vegetation. The Shannon-Weiner Index (H) for measuring diversity is affected by both the number of species and their evenness throughout the sample (Love 2003). This index assumes all species are represented in a sample and that the sample was obtained randomly: $H' = \left| p_i(\ln(p_i)) \right|$ where p_i is the proportion of individuals found in the ith species and *ln* is the natural logarithm. Values for the Shannon-Weiner Index for real communities typically fall between 1.5 and 3.5 (Love 2003).

The data from individual transects and sampling points were averaged by site. Site averages were compared for tree cover, tree richness, tree Shannon-Weiner, exotic invasive cover, exotic invasive richness and Shannon-Weiner and any percent cover of any species found at half or more sites.

Percent tree cover, tree species richness and Shannon-Weiner index, percent exotic invasive cover, exotic invasive species richness and Shannon-Weiner index, and cover by species present at half or more sites in both years were compared. Any change between 2003 and 2011 was recorded.

Site averages were assumed to be a representative sample of the site in both studies. The change between 2003 and 2011 was compared using a *t*-test in Microsoft™ Excel. If this change was found to be significant ($p < 0.05$), an analysis of variance was performed using Excel to assess whether age of buffer establishment was a factor.

The 2011 results for tree cover are directly comparable to the 2003 results, as both were recorded using a line-intercept method. However, exotic invasives were estimated using different methods during the two studies. In 2011, I visually estimated exotic invasive cover to the nearest 5% around each sampling point, while in 2003, exotic invasive cover was measured using line transects. I chose this visual estimation procedure to improve chances of recording species at the expense of accurately estimating percent cover. Thus the results between the 2003 and 2011 studies may not be directly comparable.

Converting 2003 data

Some conversions were necessary when comparing the data from 2003 and 2011. Love's study differentiated between trees, shrubs and herbs. For this study, any woody vegetation over 1m tall was counted as a tree. Both Love's shrub and tree categories met these criteria. I combined Love's tree and shrub categories and omitted obvious non-trees, such as vines and herbaceous plants.

The 2003 study recorded all plant cover, including invasive exotic plants not included on the LTLT list. In order to compare 2003 to 2011, I created a subset for each site in 2003 based on exotic invasives on the LTLT list that were found in 2003. This subset was also used for the Shannon-Weiner index.

RESULTS

Changes in Tree Cover

Between 2003 and 2011 tree cover increased at seven of ten sites from a 2003 average of 82.5% to a 2011 average of 108.4%. This was not shown to be statistically significant. All four of the most common tree species showed an increase in cover, including black walnut (*Juglans nigra*), black cherry (*Prunus serotina*), red maple (*Acer rubrum*) and sycamore (*Platanus occidentalis*). Of these, only the increase in black walnut was shown to be statistically significant ($p<0.05$) (Table 2).

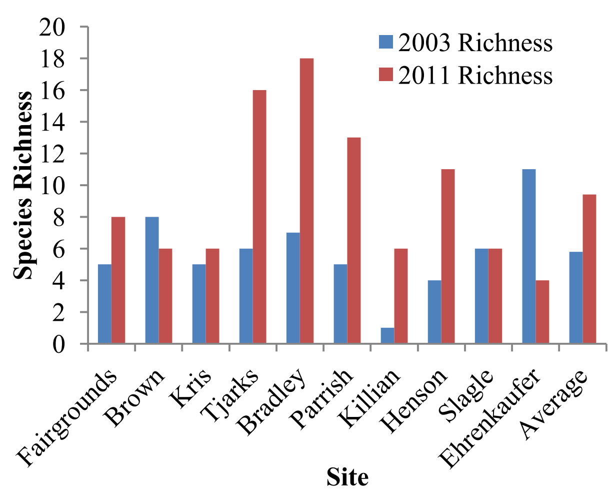

FIG. 2. Tree species richness in 2003 and 2011.

Tree species richness increased at eight of ten sites from a 2003 average of 5.8 to a 2011 average of 9.4 (Fig. 2). This change was shown to be statistically significant (p=0.0265). Site age did not play a statistically significant role, however. The Shannon-Weiner index of diversity also increased at eight of ten sites, from a 2003 average of 1.2391 to a 2011 average of 1.5814. This change was not shown to be statistically significant.

TABLE 2. Site averages for all variables in 2003 and 2011.

	2003		2011		
Variable	Mean	Standard Error	Mean	Standard Error	*t*-Test *p* Value
Tree cover	82.45	14.14	108.40	16.00	0.0819
Tree richness	5.80	0.83	9.40	1.53	0.0265
Tree H	1.24	0.18	1.58	0.13	0.0677
Exotic invasive cover	15.91	6.03	83.42	8.09	0.0000
Exotic invasive richness	2.40	0.50	7.60	0.31	0.0000
Exotic invasive H	0.42	0.14	1.35	0.07	0.0000
Multiflora rose	2.89	1.46	7.98	3.19	0.0818
Japanese honeysuckle	8.66	6.22	36.43	5.63	0.0019
Black walnut	20.79	7.49	33.01	8.86	0.0108
Black cherry	6.96	3.32	8.17	2.98	0.3766
Red maple	4.50	3.86	7.81	2.93	0.2518
Sycamore	3.37	1.75	10.37	4.31	0.0893

Changes in the Presence of Exotic Invasives

Eleven out of 14 invasives were recorded at one site or more in 2011. Three (*Ailanthus altissima, Elaeagnus umbellata, Fallopia japonica*) were not recorded at any sites in 2011. *Ailanthus altissima* and *Elaeagnus umbellata* were also not present in 2003, so this represents no change. Japanese Knotweed, *Fallopia japonica*, was present at three sites in 2003, so it has disappeared from these sites since 2003. Between 2003 and 2011 exotic invasive plant cover increased at nine out of 10 sites, from a 2003 average of 15.9 to a 2011 average of 83.4 (Fig. 3). This change was shown to be statistically significant. While site age was almost shown to be a significant factor in 2003 (p=0.0565), it was clearly not in 2011 (p=0.9330).

Between 2003 and 2011 exotic invasive plant species richness increased at all ten sites, from a 2003 average of 2.4 to a 2011 average of 7.6 (Fig. 4). This was shown to be statistically significant. Site age was not shown to be a significant factor, however. The Shannon-Weiner index for invasive exotics increased between 2003 and 2011 from 0.0432 to 1.352. Age was not shown to be a significant factor in 2003 (p=0.6341) or 2011 (p=0.6468), however.

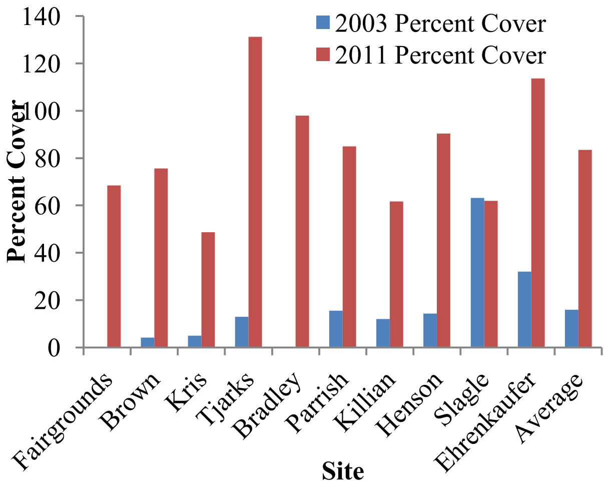

FIG. 3. Exotic invasive cover in 2003 and 2011.

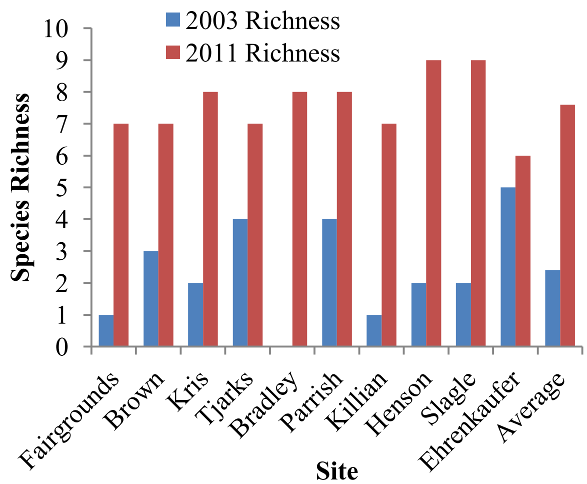

FIG. 4. Exotic invasive species richness in 2003 and 2011.

Only two species were present in over half of all sites in 2003, multiflora rose (*Rosa Multiflora*) and Japanese honeysuckle (*Lonicera japonica*). The percent cover of multiflora rose increased from a 2003 average of 2.9% to a 2011 average of 8.0%. This species was present at six sites in 2003 but was found at all ten in 2011. Site age was not shown to play a significant role. The percent cover of Japanese honeysuckle increased from a 2003 average of 8.7% to a 2011 average of 36.4%. This species was present at six sites in 2003 but was found at all ten in 2011. Age of the site may have played a role in the presence of honeysuckle in 2003 (p=0.1341) and 2011(p=0.1687).The p-values are above the 0.05 threshold, but may nevertheless indicate that age was a factor given the small sample size and variability in the data.

DISCUSSION

Analysis of changes in percent cover by native trees and exotic invasive species show that the two variables follow two different patterns in post-restoration vegetated riparian buffers along the Little Tennessee River and its tributaries. Tree cover increased over the eight year period by a small, non-statistically significant amount. While tree diversity and cover increased, the increase can probably be attributed to natural growth and recruitment in the buffers in response to livestock fencing. As Love (2003) found, the buffers continue to function to promote vegetation.

In contrast to the slight increase in tree cover, the increase in percent cover by exotic invasives was pronounced and extreme. With the exception of one outlier site (Slagle) that was already dominated by invasive exotics, the proportion of exotic invasive cover rose at all sites. While the increase in cover showed a great deal of variability among sites, the average increase was more than fivefold. Despite the fact that different sampling techniques were used to estimate exotic invasive cover in 2003 and 2011, this suggests that exotic invasive populations have had more success recruiting and growing than woody vegetation.

The dramatic and uniform increase in diversity among exotic invasives between 2003 and 2011 suggests that these weedy species are readily able to disperse into these sites from outside. Four species were present at every site in 2011, *Lonicera japonica, Microsteguim vimineum, Ligustrum sinense* and *Rosa multiflora,* while no single species was present at all sites in 2003. Further research may be necessary to determine the source of dispersal. The ease with which new species establish in the absence of management suggests that management is needed to control invasives and promote a native plant community.

Kudzu (*Pueraria Montana)* was present on only one site in this study, Brown, where it made up 16% of vegetative cover in the buffer. Kudzu is an aggressive invader, and this represents a tenfold increase since 2003. The landowner, Ralph Brown, seemed amenable to working with the LTLT to control invasives on his property.

Despite efforts to prevent identification errors, these may have occurred during plant identification. This study was carried about between mid-September and early November. Successful identification of dormant plants was possible with the resources available, however the extent of those plants may have been under-recorded. Efforts were taken to minimize this error, such as sampling as early in the season as possible and recording dormant plants when appropriate. Aside from deciduous tree species, the main species that may have been affected by seasonal error was the invasive grass *Microstegium vimineum*.

The location of the transect ends and the data points are limited by the accuracy of the Garmin® Legend Cx Etrex model GPS unit, which has a GPS accuracy of 15m. This error is evident in the detailed site maps and may also interfere with the accuracy of future studies in the area.

With the possible exception of Japanese honeysuckle cover, no measured variable seemed to have been affected by site age in 2011. The small range of ages and the fact that age does not reflect any state of succession, rather the time since a site was enrolled in the buffer and revetment program (Love 2003), suggests that site age may no longer be a relevant variable for future studies.

Recommendations for Management

The increase in woody vegetation at most of my sites shows that the buffers are serving their function by allowing vegetation to stabilize the banks. Despite the overwhelming presence of exotic invasive plants in the buffers, I also noted a variety of native plants and wildlife, such as ground hog (*Marmota monax*), beaver (*Castor Canadensis*) and great blue heron (*Ardea harodias*), which suggests that buffers continue to provide habitat. The buffers should not be abandoned to exotic invasives.

Three of the 14 exotic invasive species (*Ailanthus altissima, Elaeagnus umbellata, Fallopia japonica)* of interest to this study were not present at any of the ten sites. A special effort should be made to eliminate them in the early stages of establishment if they are detected in the future. Anecdotally, many of the exotic invasive species present were in the early stages of establishment, so

In the absence of management, exotic invasive plants already present at sites show a propensity to greatly increase their percent cover. New species seem to readily establish. I encourage the LTLT to include follow-up exotic invasive management in future agreements with landowners, and to negotiate remedial exotic invasive control with the current landowners of the ten sites in this study. In the case of many landowners, the urge to preserve the character of their land will be stronger than fear of allowing outsiders in. In a quickly developing region, perception of buffers may shift from marginal areas to a focal point of the natural areas we have left.

ACKNOWLEDGEMENTS

I thank my mentor, Dr. Peter Bates, for guiding me through the steps of this study. I thank Dennis Desmond and the LTLT for providing this research opportunity. Thanks also to Jason Love, who was so helpful in locating the sites from 2003, and to Max Lanning, for educating me on many species of tree. Final thanks to Dr. Anya Hinkle, for her editing, and to the entire Highlands Biological Station staff.

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APPENDIX A: DATA BY SITE

USING GPS TECHNOLOGY TO RELATE CANOPY COVER AND OTHER ECOLOGICAL PARAMETERS OF *RHODODENDRON MAXIMUM* L.

TYLER J. TRAN

Abstract. In the southern Appalachians, *Rhododendron maximum* is a key understory species, often forming an evergreen subcanopy in forest stands. However, little is known about the significance of *R. maximum* canopy cover compared to other ecological variables. I selected twenty 20m x 40m permanent plots at Coweeta Hydrologic Laboratory to employ a variety of methods (x-y coordinate measurements, GPS, visual estimates) to calculate canopy cover of *R. maximum* in these plots. I found a significant correlation between GPS and the more accurate x-y coordinate measurements. I compared the results of these calculations to archived ecological data for *R. maximum* and surrounding overstory trees and found statistically significant relationships between *R. maximum* canopy cover and basal area, total biomass, leaf area index, and stem density. The methods utilized in this study could be used to estimate more difficult to measure parameters, given the significant relationships found from this study.

Key words: canopy cover; evergreen understory; GPS; Rhododendron maximum.

INTRODUCTION

Rosebay rhododendron (*Rhododendron maximum* L.), an evergreen shrub, is a prominent species in the southern Appalachians. Along with mountain laurel (*Kalmia latifolia* L.), it is one of the most abundant understory taxa in forest stands of the region (Elliott et al. 1999), forming a dense subcanopy in many areas of the Coweeta Basin of western North Carolina. *R. maximum* favors mesic, cove-like environments, often in riparian zones, with high soil organic matter with schist present (Graves and Monk 1985). Although generally a clonal species, *R. maximum* can reproduce both sexually and asexually and can reproduce under its own canopy despite light availability restrictions (Royo and Carson 2006).

Rhododendron maximum alters ecosystem processes through its contributions to photosynthetic activity and net primary productivity (NPP), hydrologic processes, and nutrient exchange (McGinty 1972, Monk et al. 1985). *Rhododendron maximum* and canopy tree saplings compete for light availability, water, and nutrients such as nitrates, ammonium, and phosphates (Nilsen et al. 2001). A study by Clinton and Vose (1996) supports the results of Nilsen et al. (2001) by finding that *R. maximum* outcompeted canopy tree species *Acer rubrum* not only for light, but for other resources as well. Debate over *R. maximum* expansion is present in the literature, with several researchers supporting the hypothesis that *R. maximum* has expanded in frequency, biomass, and canopy cover over the last century, though the empirical evidence to support these hypotheses is sparse (Elliott and Vose 2011, in review). Regardless, *R. maximum* is currently abundant and where present, it could translate to alterations in several ecosystem processes.

Though a few studies have examined canopy cover of *R. maximum* (Elliott and Vose 2011, in review), none have used global positioning systems (GPS) and geographic information systems (GIS) to calculate cover. The purpose of this study was to assess the viability of GPS to accurately measure *R. maximum* canopy cover and to determine if canopy cover was related to other *R. maximum* abundance variables, overstory variables, and environmental factors.

Methods and Materials

Study area

Coweeta Hydrologic Laboratory is an experimental forest of the Southern Research Station, USDA Forest Service. Established in 1934, Coweeta is located (latitude 35°03' N, longitude 83°25' W) within the Nantahala National Forest, western North Carolina. The basin was commercially logged before Forest Service acquisition (Douglass and Hoover 1988). Since then, numerous studies have been conducted at Coweeta, creating a collection of comprehensive ecological data. The Coweeta Basin is 1626ha within the total 2185ha outdoor laboratory and study area, with elevations ranging from 675m to 1592m and steep slopes ranging from 30 to over 100%. Soils are deep sandy loams underlain by folded schist and gneiss. Mean annual temperature is 12.6°C and mean annual precipitation is 1800mm. Vegetation surveys were performed in permanent plots during the twentieth century, and though some of the plots have not been re-surveyed since their establishment in 1934, their locations have remained consistent and largely undisturbed. Primary overstory genera in the watershed include *Quercus, Carya,* and *Liriodendron,* with *Tsuga canadensis* and *Pinus rigida* being more secondary species in the canopy (Elliott and Swank 2008). In many of the permanent plots in the basin, evergreen understory species *Rhododendron maximum* and *Kalmia latifolia* are present and sometimes abundant (Elliott et al. 1999).

Evergreen cover surveys

I measured evergreen cover, specifically of understory species *Rhododendron maximum* and *Kalmia latifolia,* in 20 of the 987 original permanent plots at Coweeta Hydrologic Laboratory. As an examination of the efficiency and accuracy of different available methods to estimate cover, three surveying techniques were used: visual estimates, mapping with a global positioning system (GPS), and x-y coordinate measurements. One purpose of this study was to evaluate different methods of measuring canopy cover of evergreen species in the 20 permanent plots and to assess their advantages and disadvantages.

The 20 plots were chosen to represent an array of estimated evergreen cover percentages. Also, the plots were chosen for maximum accessibility from roadways at Coweeta. Though the plots were not chosen randomly, the results were not affected because the determining factors in site selection did not bias the data collected.

Performing visual estimates of percentage of *Rhododendron* and *Kalmia* cover within the permanent plots was both the easiest method and least accurate method. To evaluate visually, an observer scanned the 20m by 40m plot as a whole and estimated the percentage of the plot covered by the evergreen understory species of interest. Though this method is very simplistic, it was performed to act as a self-checking method to ensure that data collected from GPS or physical x-y coordinate measurements were not highly skewed and also because archived data in the form of visual estimates were the only information available for *Rhododendron* and *Kalmia* from the 1934 survey.

Percentage cover of evergreen understory was also calculated using a GPS; I will refer to this as the GPS method. Though any GPS system could potentially be used to conduct this experiment, a Trimble® GeoExplorer® XH™ handheld unit was used in this case because of its capabilities for sub-meter accuracy. The unit was used with TerraSync™ 5.21 (Trimble Navigation Limited 2011) software and the data were post-processed using base station information after collection. To collect data using the GPS method, pin flags were first placed around all of *Rhododendron* and *Kalmia* patches in the plot, with enough flags to convey the general shapes of the patches. Though more flags and vertices of the patches could indicate a higher level of precision in calculating percentage cover, it was necessary to find a balance between precision and time efficiency. In this experiment, enough flags were used to collect data at all major inflections of the patches. After placing the flags, a GPS point was taken at each flag, with 30 satellite positions collected for each point recorded so that the unit would yield higher accuracy by averaging all 30 positions. Each GPS point was labeled to clearly indicate which point belonged to an individual patch. In each permanent plot, GPS points were also recorded at the plot corners. In many cases, it was difficult to accurately and quickly record thirty positions at each GPS point because of a lack of satellite reception in the mountainous terrain of the Coweeta basin. For this reason, a range pole that extended to 3.70m with a Trimble® Hurricane external antenna was used to avoid the blocking effects of the evergreen cover and mountain ridges on the GPS satellite reception. To ensure quality resolution with the GPS method, a maximum position dilution of precision (PDOP) of 6.0 was set and a minimum signal to noise ratio (SNR) of 30dB Hz was used.

To calculate the percentage of evergreen understory cover in the permanent plots, the GPS data were uploaded to a computer using Pathfinder Office 5.1 (Trimble Navigation Limited 2011) software and post-processed using a differential correction with data from the Franklin, North Carolina base station. The corrected files were then exported as shape files compatible with ArcGIS 10.0® (ESRI 2011). Using the ArcGIS® suite, the labeled GPS points were connected, creating polygons to represent the evergreen patches or open patches. Polygons were also drawn around the plot corner points, and then a ratio of patch area to total plot area was found in ArcGIS®, giving the percentage of evergreen cover.

Using the x-y coordinate measurement system (henceforth referred to as the x-y coordinate method), a grid was created in each permanent plot, with the x-axis (north-south direction) being the 40m side of the rectangular plot and the y-axis (east-west direction) being the 20m side of the plot. Using the same pin flags that were placed for the GPS method, x-y coordinates were recorded at each point using meter tapes laid out along both axes. On graph paper, rough sketches of the patches were drawn to be used for later reference. For reasons of ease, four meter tapes were laid out in each plot, though this did not affect the accuracy of the measurement of the x-y coordinates. In both the x-y measurement method and the GPS method, the patch plotting was sometimes inverted. In cases where there was noticeably more evergreen cover than open area, pin flags were placed around the perimeter of the open patches rather than the evergreen patches and these points were recorded instead.

Evergreen cover percentage was calculated similarly with both the x-y coordinate method and the GPS method. Instead of connecting GPS points, a coordinate graph template was used for each plot and the x-y coordinates were plotted using ArcGIS 10.0®. Polygons were then drawn around the points in the same way as with the GPS method to calculate a ratio of evergreen cover area to total plot area.

Species-specific allometric equations from Martin et al. (1998) were used to calculate aboveground biomass (foliage and total) of deciduous trees; equations from Santee and Monk (1981) for hemlock; and equations from McGinty (1972) for rhododendron and mountain laurel stems. Leaf area index (LAI, $m^2\ m^{-2}$) was estimated by multiplying the specific leaf area (SLA, $cm^2\ g^{-1}$) of individual species by their foliage mass ($g\ m^{-2}$) (Martin et al. 1998).

Simple linear regression (Zar 1984) was calculated using PROC GLM (SAS 2002-2003) to compare methods (GPS, x-y coordinates, visual) and compare cover of *R. maximum* to the most recent vegetation survey for these 20 plots (Elliott and Vose 2011, in review). Trees and shrubs ≥ 2.5cm dbh (diameter at 1.37m height) were measured to the nearest 0.1cm at dbh and recorded by species in each plot. Measurements included *Kalmia latifolia* and *Rhododendron maximum*, but *Kalmia* was a minor component of the evergreen understory in these plots; it contributed less than 8% to the total understory canopy coverage.

Site variables used for the stepwise regression analysis (Zar 1984) calculated with PROC REG (SAS 2002-2003) included percent slope, elevation, modified azimuth, terrain shape, soil depth, depth of A-horizon, soil clay content, soil organic matter content, mean temperature during the growing season, growing season precipitation, and potential solar radiation. Values of site variables were determined by direct measurements or calculated by digital GIS mapping methods (Elliott et al. 1999). During the 1970s survey, percent slope, aspect, elevation, and slope position (ridge, upper slope, middle slope, lower slope, or cove) were recorded for each plot. Terrain shape, mean temperature, and potential solar radiation were derived using ARC/INFO™ (ESRI 2011). Soils data for the 20 individual plots used in this study were obtained from a first-order soil survey completed in 1985 by the Natural Resources Conservation Service (Thomas 1996). This soil survey map was overlain onto the permanent plots map using ARC/INFO™. Only three of the 11 environmental variables were significant ($P \leq 0.05$) and entered into the step-wise regression model.

Results and Discussion

Comparisons of GPS, x-y coordinates, and visual estimates

All three methods used in this experiment had clear advantages and disadvantages, and all methods were used throughout the study to solidify understanding of these pros and cons. Visual estimation was easy and quick, and though it was significantly related to measured x-y coordinate cover data, the results could differ depending on who performed the visual estimates. The GPS method was less time-consuming than physically measuring x-y coordinates in each plot and was significantly related to the x-y coordinate measurement method. *Rhododendron maximum* cover calculated by x-y coordinate measurements was related to both GPS ($r^2 = 0.983$, $P < 0.0001$) and visual estimates ($r^2 = 0.971$, $P < 0.0001$) (Fig. 1). Though the x-y coordinate method is the most accurate, it is not feasible to use this method on a large scale. If all 987 plots at Coweeta were to be measured for evergreen cover, the best method would be GPS plotting.

Data from this study could be used to validate studies using light detection and ranging (LiDAR) data, a relatively advanced technological method using remote sensing through lasers on low altitude aircrafts to create landscape models often used to calculate area, biomass, and other variables in forest stands. LiDAR is particularly relevant to this study, since it can be used to detect the presence of understory shrub vegetation (Martinuzzi et al. 2009, Estornell et al. 2011).

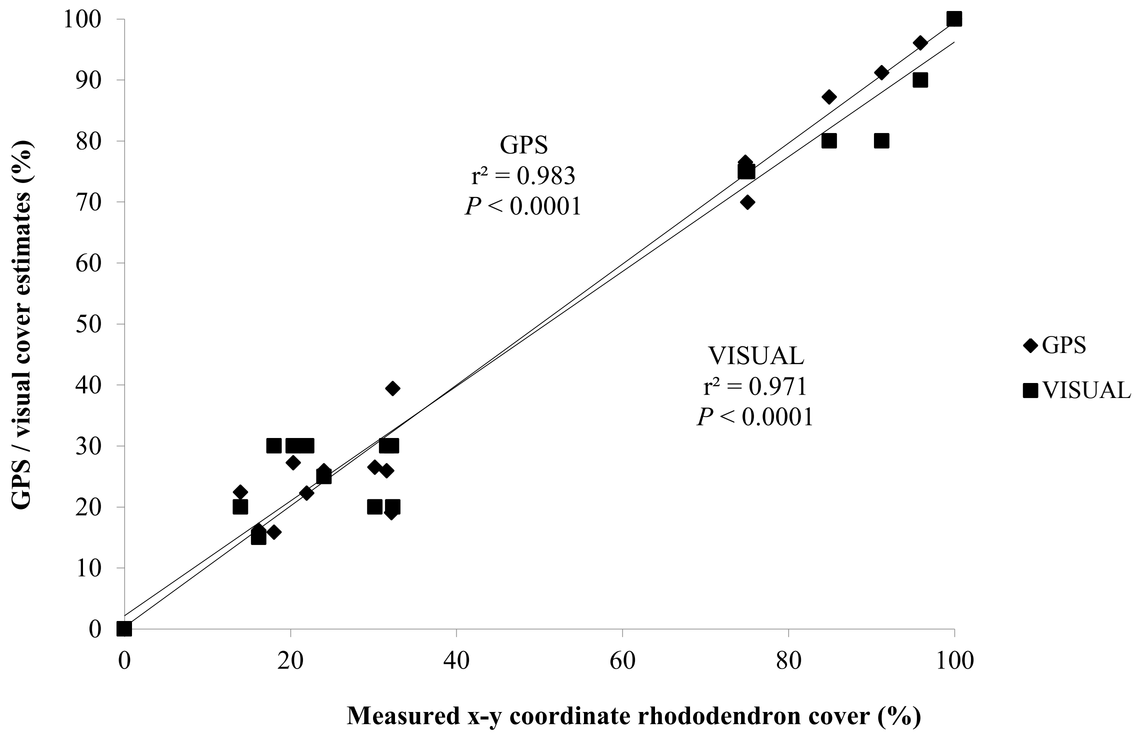

FIG. 1. Effectiveness of GPS and visual methods to estimate *R. maximum* canopy cover through comparison to x-y coordinate method.

The various methods (GPS or x-y coordinates versus LiDAR) represent a change in scale, in this case from the Coweeta Basin to the larger scale of the southern Appalachians. GPS data, as used in this study, could be used to ground-truth LiDAR data on a smaller scale like that of the Coweeta Basin, and apply the results to a larger studied area.

Comparisons with other R. maximum *variables*

Measured rhododendron cover was significantly related to *R. maximum* basal area (r^2 = 0.850, P < 0.0001), total biomass (r^2 = 0.847, P < 0.0001), LAI (r^2 = 0.847, P < 0.0001), and stem density (r^2 = 0.862, P < 0.0001) in the permanent plots (Fig. 2). Both the GPS and x-y coordinate cover values were statistically significant with the above factors, showing a strong relationship between the two methods. Though these relationships may seem intuitive, they do not necessarily hold true for all species. For example, canopy cover of the ponderosa pine (*Pinus ponderosa)*, a coniferous overstory species common in the western United States, did not have a significant correlation with its density and only had a correlation with basal area up to 60% canopy cover. Beyond 60% cover the relationship was no longer statistically significant (Mitchell and Popovich 1997).

In this study, percent cover of the evergreen understory explained 85.0% of the variation in *R. maximum* basal area (Fig. 2a). The canopy cover of the evergreen understory had a positive relationship with basal area of the clonal shrub. Basal area information for *R. maximum* can be very telling: rhododendron basal area and species richness in the forest regeneration layer (woody stems < 1cm diameter at base) have been shown to have a negative exponential relationship (Baker and Van Lear 1998). In other words, species richness in the regeneration

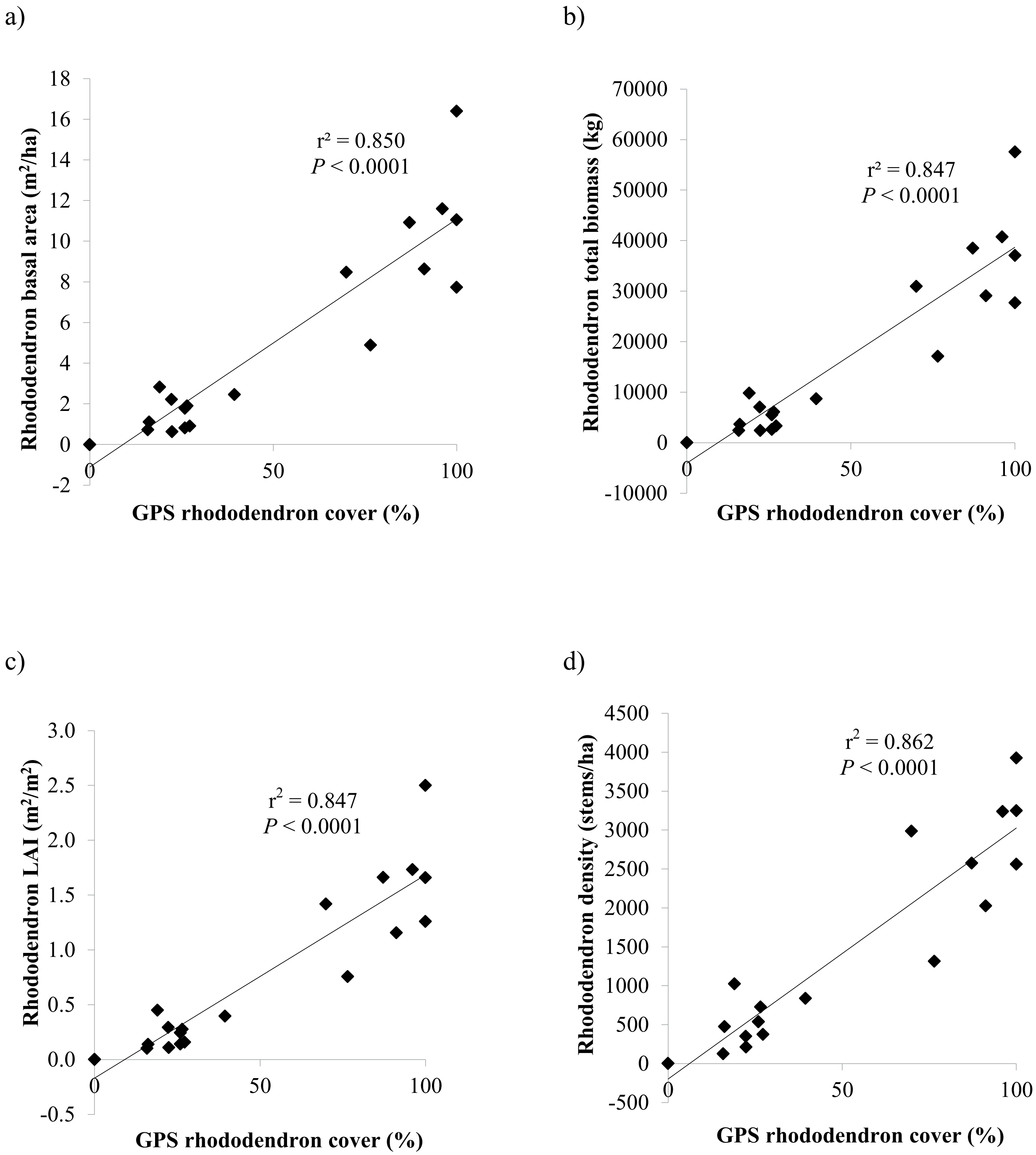

FIG. 2. Relationships between *R. maximum* canopy cover and *R. maximum* a) basal area; b) total biomass; c) LAI; and d) stem density.

layer decreases exponentially as *R. maximum* basal area increases. This relationship is important because species richness in the forest regeneration layer is often a good predictor of future biodiversity in the mature forest, especially in the absence of highly-altering disturbance events. Therefore, a high percent canopy cover of *R. maximum* and subsequently, high rhododendron basal area can result in low species richness in a forest stand.

Total biomass (leaves+stems) of *R. maximum* also had a significant relationship with percent cover of evergreen sub-canopy, with percent cover explaining 84.7% of the variation in total rhododendron biomass (Fig. 2b). Biomass is often used to quantify the prominence of certain species within a forest ecosystem. For example, *R. maximum* ranked sixth out of 40 woody species (> 2.5cm dbh) in total standing crop biomass in a small watershed in the Coweeta Basin (Day and Monk 1977). This illustrates the relative abundance of *R. maximum* in southern Appalachian forests in terms of biomass, but also because biomass can often indicate net primary productivity (NPP) in an ecosystem. According to Day and Monk (1977), *R. maximum* contributed 8.1% of the NPP in the studied forest stand.

Rhododendron maximum canopy cover explained 84.7% of the variation in LAI (Fig. 2c), or the ratio of surface area of leaves to the surface area of land occupied by the plant. LAI, along with vegetation type, is one of the most important ecological variables in estimating photosynthesis and CO_2 exchange within a forest stand. In addition, it can be used to determine the amount of light intercepted by the canopy (Bonan 1993). Percentage canopy cover and LAI of *R. maximum* were positively related, with LAI being necessarily higher than canopy cover because of leaf overlap. Therefore, rhododendron canopy cover could potentially be used to assess photosynthetic processes in the understory and to estimate *R. maximum*'s contribution to primary productivity in southern Appalachian forests.

Canopy cover of *R. maximum* explained 86.2% of variation in stem density (Fig. 2d), a factor which makes understory species such as *R. maximum* and *K. latifolia* unique in their high number of stems per ha when compared to other understory and overstory species. According to Elliott et al. (1999), both of these understory evergreen species had the highest importance values of all 42 woody species surveyed in permanent plots across the entire Coweeta Basin largely because of their high stem densities.

Rhododendron and overstory species

Measured rhododendron percent cover was not related to LAI (r^2 = 0.005, P = 0.6505), total biomass (r^2 = 0.009, P = 0.5624), basal area (r^2 = 0.004, P = 0.7074), or density (r^2 = 0.082, P = 0.0734) of deciduous trees of all sizes. Also, there were no significant relationships with deciduous trees by size classes ≥ 10 cm dbh or < 10cm dbh, except for density of deciduous trees < 10cm dbh (r^2 = 0.298, P = 0.0127). Though this relationship is statistically significant, *R. maximum* cover explained only 29.8% of the variation in density of smaller deciduous trees. The poor relationships between rhododendron cover and overstory trees were most likely an artifact of the sampling design. Only 20 plots were surveyed in this study; this small sample size was not sufficient to find a more explanatory relationship between evergreen cover and overstory trees. In addition, relationships between *R. maximum* canopy cover and overstory tree variables may have been stronger had I been able to separate trees within patches of rhododendron and trees in the open spaces between rhododendron patches. For example, Elliott and Vose (2011, in review) showed that overstory tree density was much lower (148 stems ha^{-1}) within a *R. maximum* subcanopy than tree density in the absence of a *R. maximum* subcanopy (737 stems ha^{-1}). The differences in procedures between this study and those of Elliott and Vose (2011, in review) likely explain why no relationship was found with overstory trees in my study, as Elliott and Vose had a larger sample size and differentiated between patch areas and non-patch areas.

Environmental factors

Canopy cover of *R. maximum* had a statistically significant relationship with soil organic matter, modified azimuth, and temperature, with these three environmental variables explaining 59.8% of the variation in rhododendron cover (Table 1). The correlation with temperature is likely due to the shading properties of *R. maximum*, which create a microclimate that is cooler than an open area without *R. maximum* subcanopy (Clinton and Vose 1996, Clinton 2003). Clinton and Vose (1996) also found that areas shaded by *R. maximum* had temperatures lower than areas covered by shade cloth. The relationship between rhododendron canopy cover and modified azimuth can be attributed to the preferred mesic cove environment of *R. maximum*. It is probable that this shrub has a certain azimuth preference to achieve these conditions, such as a north-facing direction to minimize sun exposure. The relationship with azimuth supports findings by Day and Monk (1974), which concluded that *R. maximum* abundance is affected by the position of mountain slopes. Of all environmental factors assessed, soil organic matter most explained variation in rhododendron canopy cover. High soil organic matter levels are typical of *R. maximum* environments (Elliott et al. 1999) and are likely encourage *R. maximum* growth and spread in terms of canopy cover and therefore biomass, density, LAI, and basal area. The importance of soil organic matter in forest stands as an environmental variable in this study was consistent with the findings of Elliott et al. (1999).

TABLE 1. Stepwise regression analysis of *Rhododendron maximum* canopy cover with associated environmental variables.

Variables	Partial-r^2	Model r^2	F-value	*P*-value
Soil organic matter	0.2422	0.2442	5.82	0.0268
Modified azimuth	0.1891	0.4333	5.67	0.0292
Mean annual temperature	0.1648	0.5982	6.57	0.0209

Conclusions

In this study, the GPS measurement method of evaluating *R. maximum* canopy cover was comparable to the x-y coordinate method of calculating canopy cover. Canopy cover had significant relationships with other abundance measures of *R. maximum* such as LAI, biomass, density, and basal area. However, no significant relationships were found between *R. maximum* canopy cover and overstory tree parameters. This is likely a result of small sample size and the specific surveying method that did not separate trees with *R. maximum* subcanopy and those without a subcanopy. *Rhododendron maximum* canopy cover was also related to various environmental factors, including soil organic matter, modified azimuth, and mean annual temperature.

Using GPS to calculate canopy cover of rhododendron was relatively easy and straightforward when compared to methods for estimating LAI, biomass, density or basal area of *R. maximum*, which are much more difficult and time consuming to measure and calculate. Further research could be conducted using the methods employed in this study to more efficiently estimate these more difficult to measure parameters of *R. maximum.*

Rhododendron and other evergreen understory species play an important role in southern Appalachian ecosystems. Competition between *R. maximum* and canopy tree seedlings for resources often leads to the detriment of the tree seedlings (Clinton and Vose 1996, Nilsen et al. 1999, Nilsen et al. 2001, Beckage et al. 2005, Lei et al. 2006). According to Nilsen et al. (2001) for example, *Quercus rubra* seedling survival was reduced by about 40% in the presence of *R. maximum* when compared to a forested stand without rhododendron in the understory. Light and water availability were the most limiting factors concerning *R. maximum* and canopy tree competition (Nilsen et al. 2001, Lei et al. 2006). Another reason for the study of *R. maximum* was its ability to change the ecosystem though hydrologic processes, nutrient cycling, and primary productivity factors, all of which could be affected by the canopy cover of the shrub. Also, *R. maximum* is believed to be related to landslide initiation (Hales et al. 2009). The associations with neighboring tree species and the ecosystem as a whole illustrate the impact of *R. maximum* in the understory layer of a forest stand, underscoring the importance of understanding *R. maximum* canopy cover.

ACKNOWLEDGEMENTS

Special thanks to Dr. Katherine Elliott, my mentor at Coweeta, for her patience, numerous edits, and extremely helpful advice. Thanks to Patsy Clinton for her hours of help with data collection and for her friendly companionship in the field. I would like to thank Dr. Gary Wein for his advice on GPS techniques and Dr. James Costa, Dr. Anya Hinkle, and Michelle Ruigrok for their edits on the paper.

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WATER QUALITY MONITORING OF THE UPPER CULLASAJA WATERSHED, HIGHLANDS, NORTH CAROLINA

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Abstract. The Upper Cullasaja River watershed is located in the area of Highlands, North Carolina and is composed of four sub-watersheds: the Cullasaja River, Big Creek, Mill Creek, and Monger Creek. In recent years, there have been documented water quality issues in the watershed, emphasizing the need for consistent monitoring. In order to provide an evaluation of the current state of the watershed we conducted a series of water quality assessments at six sites in the watershed. Physical and chemical monitoring were conducted through habitat assessment, Wolman pebble counts, and chemical analyses. Biological monitoring was conducted through an investigation of benthic macroinvertebrates with a focus on EPT data and development of an Index of Biotic Integrity (IBI) as an additional indication of stream health. The results of this study will assist in an update the 2004 Upper Cullasaja Watershed Association (UCWA) Strategy and Action Plan and the 2010 capstone report. Additionally, the present study supports the development of an updated watershed restoration plan for the Upper Cullasaja scheduled to be completed in 2012 through funding from EPA Section 319 and the NC Department of Environment and Natural Resources' (NCDENR) FY2010 Nonpoint Source Pollution Control Grant program.

Key words: biomonitoring; biotic index; Cullasaja River; EPT; habitat assessment; Highlands Plateau; stream chemistry; water quality; watershed plan; Wolman pebble count.

INTRODUCTION

Upper Cullasaja River Watershed

The Upper Cullasaja River watershed is located in the Blue Ridge Mountains of western North Carolina. The Cullasaja River is a tributary to the Little Tennessee River located in southeastern Macon County. The watershed includes the Town of Highlands, a small mountain town with a population of approximately 1000, not including significant tourist and second-home communities. The residential and commercial development associated with these populations contributes to urbanization and associated problems, particularly with respect to water quality. The Upper Cullasaja watershed can be divided into four sub-watersheds associated with the four main tributaries of the Highlands Plateau: Big Creek, Mill Creek, Monger Creek and the Cullasaja River, each of which flow from their headwaters into Lake Sequoyah (Fig. 1).

Land use varies throughout the Upper Cullasaja River watershed, resulting in varying conditions of the streams and sub-watersheds. For example, Mill and Monger Creeks run through downtown Highlands while Big Creek runs through less developed private and public lands, and much of the Cullasaja River drains several golf course communities near Highlands. The drainage area and the total miles of streams in each sub watershed are listed in Table 1 (UCWA 2004a).

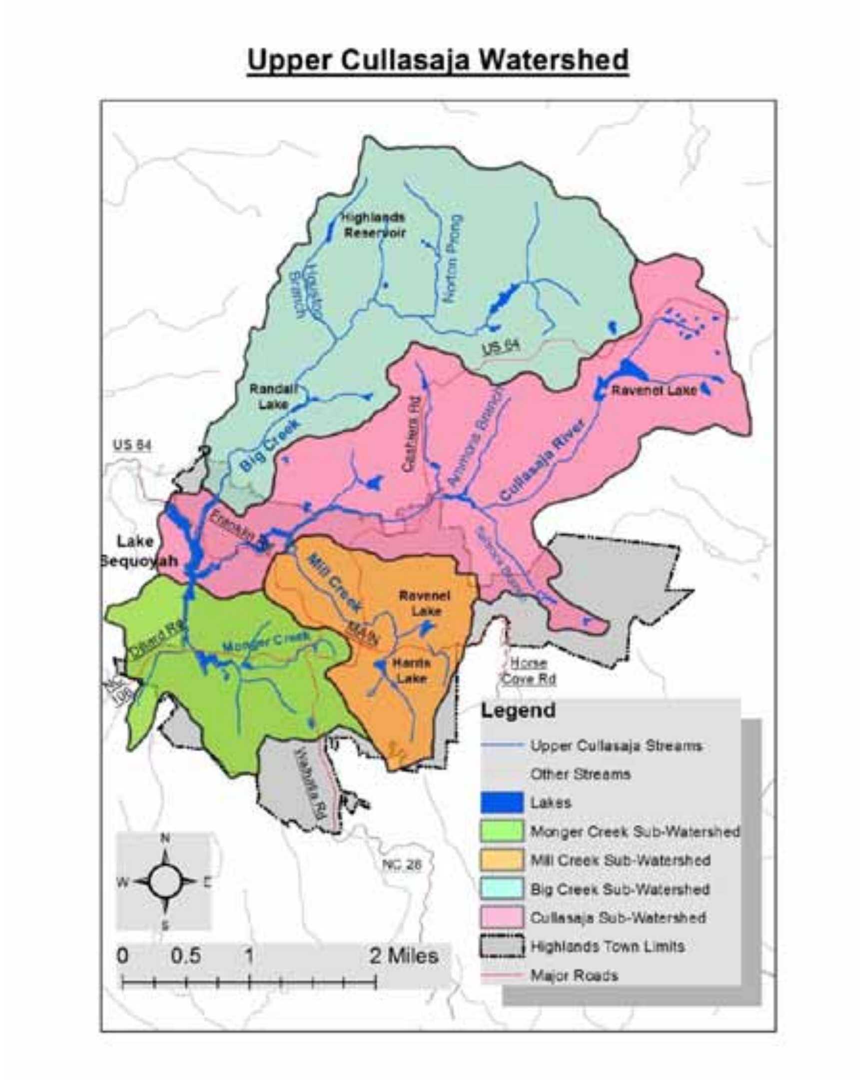

FIG. 1. Map of Upper Cullasaja River watershed with sub-watershed boundaries. Hydrology and road layers have been added for reference.

TABLE 1. Drainage area and total stream mileage of each sub-watershed.

Sub-Watershed	Drainage Area (mi^2)	Stream Mileage
Big Creek	5.3	10.0
Mill Creek	1.7	3.0
Monger Creek	2.0	3.7
Cullasaja River	5.4	10.3
Total	14.4	27.0

Various local and state organizations are involved in projects that monitor and address water quality issues in the Upper Cullasaja River watershed. The North Carolina Division of Water Quality (NCDWQ) is the principal coordinating agency for water quality studies, which include a basin-wide assessment report (NCDWQ 2011), Watershed Assessment and Restoration Projects (WARP) (NCDWQ 2002), and the North Carolina Integrated Report (NCDWQ 2010). The Integrated Report categorizes stream segments on a scale of 1 to 5 based on data from water quality assessments. Category 1 streams attain the appropriate water quality standards and are not considered to be threatened, while impaired streams fall under Category 5. Section 303(d) of the Clean Water Act requires that states develop a list of Category 5 impaired waters requiring the development of a Total Maximum Daily Load (TMDL). The TMDL is then developed to determine the maximum amount of a pollutant or pollution that the subject water body can receive and still attain water quality standards and the actions necessary to reach the targeted load reduction (CWA 1972). Both the Cullasaja River and Mill Creek, from their respective sources to Mirror Lake, are noted as impaired on North Carolina's 303(d) list but have not yet had TMDLs developed (NCDWQ 2010).

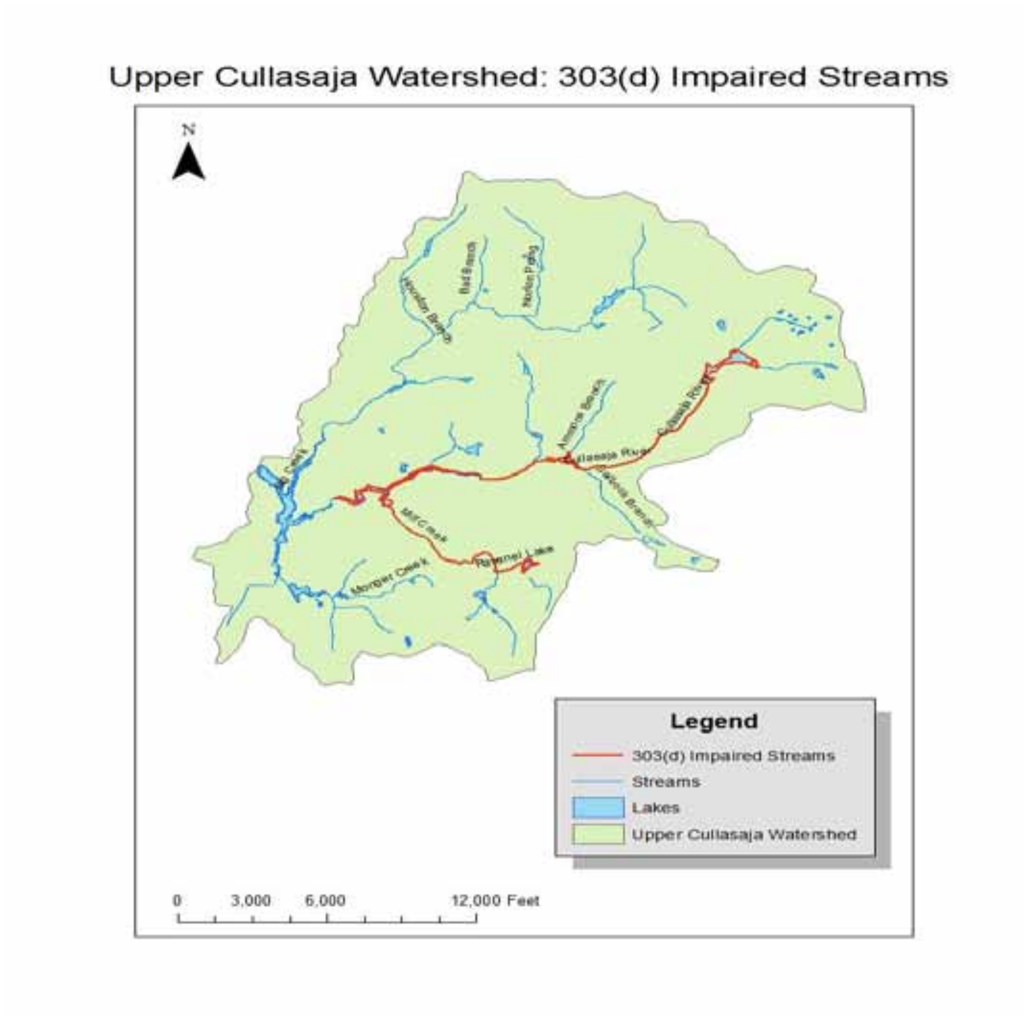

Fig.2 Map of 303(d) listed streams in the Upper Cullasaja Watershed.

In 2004, the Upper Cullasaja Watershed Association (UCWA) published a Strategy and Action Plan for the Upper Cullasaja watershed (UCWA 2004a). In section four of the 2004 plan (the strategy implementation section), the Highlands Biological Station (HBS) and other groups are called upon to implement chemical, physical and biological monitoring initiatives across the watershed. To this end, the current report provides a second year of monitoring data at six sites across the watershed listed in Table 2. Monitoring efforts included water chemistry, physical characterization of stream channels, and measures of benthic invertebrate populations. These data will also be useful for a planned update to the watershed plan slated for 2012.

The updated plan is funded by NC Department of Environment and Natural Resources (NCDENR) through their Section 319 Nonpoint Source Pollution Control Grant for FY2010, a program that administers federal Environmental Protection Agency (EPA) funds for watershed planning and restoration. The grant was awarded to the Little Tennessee Watershed Association (LTWA) in partnership with HBS to develop a nine-element watershed restoration plan for the Upper Cullasaja watershed. Those watersheds that have approved plans in place are eligible for EPA funding to implement practices addressing the water quality concerns identified in the plan. A nine-element plan addresses the nine key issues that EPA considers to be critical in the development of watershed planning efforts, such as identification of causes and sources of pollutants. Several of the elements of nine-element plans involve educational and monitoring components, with which HBS has agreed to provide assistance. In addition to the education and monitoring activities performed during the semester, the current study also provides updated maps, GIS analysis and background information to the 2004 plan that may be used in the proposed plan update.

TABLE 2. Site location and nomenclature used for the six study sites in the Upper Cullasaja watershed.

Site Name	Road Name	Abbreviation	Latitude	Longitude
Monger Creek at Highlands Creek Village	Highway 106	MoC1	35.04946°N	83.20747°W
Cullasaja River at Highway 64	Highway 64	CR1	35.06914°N	83.18779°W
Big Creek at Shortoff Road Bridge	Shortoff Rd.	BC1	35.09062°N	83.19395°W
Big Creek at Town Water Intake	Sequoyah Ridge Rd.	BC2	35.07183°N	83.21633°W
Mill Creek at old Wastewater Plant	Un-named Rd. off Maple St.	MiC1	35.05689°N	83.20043°W
Mill Creek at Brookside Lane	Brookside Ln.	MiC2	35.05916°N	83.20429°W

Hydrology

The Upper Cullasaja watershed includes an area of 14.3 mi^2 and contains the Town of Highlands, NC. Located on the Highlands Plateau and surrounded by the Blue Ridge Mountains, the watershed drains westward away from the eastern continental divide, which forms the watershed's southwestern, southern and eastern boundary. Lake Sequoyah is the principal impoundment of the Upper Cullasaja River. The United States Geological Survey (USGS) has denoted the watershed hydrologic unit No. 06010202 and the North Carolina Department of Water Quality (NCDWQ) Sub-basin Code is 04-04-0. Mill Creek and the Cullasaja River flow into Mirror Lake, which, in turn, drains into Lake Sequoyah; Big Creek and Monger Creek flow directly into Lake Sequoyah. The mainstem of the Cullasaja River then discharges from Lake Sequoyah and flows northwest to its confluence with the Little Tennessee River in Franklin, NC.

USGS low flow estimates for this watershed, as referenced in a recent report by the Upper Cullasaja Watershed Association (UCWA 2004a), predict a 7Q10 (7 days lowest flow average in 10 years) of 2.2 cubic feet per second (cfs) for the upper Cullasaja River with approximately 3.9 mi2 drainage at US 64. Values of 2.9 cfs and 5.4 mi^2 were recorded at Lake Sequoyah after the Cullasaja River confluence with Big Creek, Mill Creek and Monger Creek. 7Q10 for Big Creek was 2.8 cfs (5.2 mi^2) at US 64, while Mill Creek at Brookside Lane and Monger Creek at the Cullasaja confluence had 7Q10 values of 0.8 cfs (1.5 mi^2) and 1.1 cfs (2.0 mi^2), respectively.

Geography and soils

Highlands, North Carolina is located on a mountain plateau near the southern terminus of the Appalachian mountains. The U.S. Forest Service has identified the Highlands Plateau as "Highlands Upland," an area with unique combination of climate, geology, and geography (USFS 2010). Noteworthy ecological features in the vicinity include southern Appalachian bogs, old-growth and second-growth forests with a diverse canopy and subcanopy, and rock outcrop communities. Elevation ranges from 5,000ft on Shortoff and Whiteside Mountains to 3,600ft at Lake Sequoyah. The majority of the Highlands Plateau has a slope between 15 and 50 percent, with some areas exceeding a 60 percent grade (UCWA 2004a).

The Upper Cullasaja River watershed is underlain by gneiss bedrock covered with schist. The area includes prominent granite/gneiss rock outcrops and high elevation domed landscapes set above steep escarpments, such as Whiteside Mountain. The granite/gneiss intrusions make up 60% of the primary bedrock composition, greywacke-schist-amphibolite makes up 20%, and greywacke-schist makes up 19% (UCWA 2004a). The main soils in and around Highlands are stony and fine sandy loam.

Meteorology/Weather

The Upper Cullasaja River watershed is often characterized as a high elevation rain forest due to the characteristic heavy rainfall of the area (UCWA 2004a). The average annual rainfall between 1962 and 2010 was 85.88in, with a range between 58.79in and 115.62in. The average monthly rainfall is 7.13 in, with a minimum of 6.34 in October and a maximum of 8.38in March (Fig. 2). There has been a decreasing trend in rainfall between 1962 and 2010: the 1962-1972 average annual rainfall was 85.67in, while the 2000-2010 average annual rainfall was 79.99in (HBS 2011). Stream flows in this watershed are highly variable because the range of a single month's precipitation between 1962 and 2010 years is 0.04in to 32.37in.

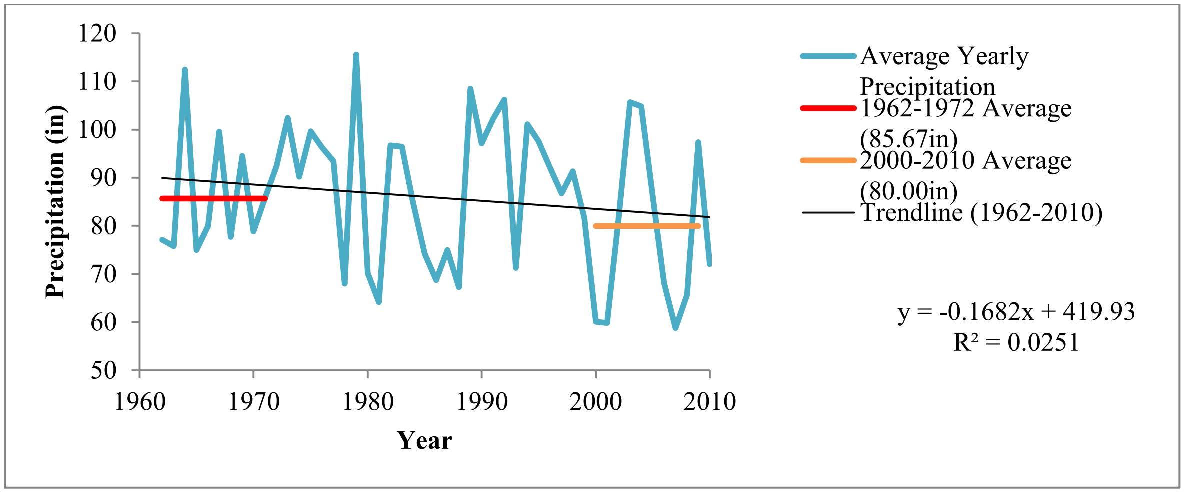

Fig. 2 Average precipitation at the Highlands Biological Station, with 10-year averages for the first and last decade of data

Between 1962 and 2010, the average monthly temperatures in the watershed have ranged from 9.6°F to 84.20°F. The warmest month has usually been July with an average high of 77.65°F, and the coldest month has traditionally been January with an average low of 23.3°F from 1962 to 2010 (Fig. 3). Between 1962 and 2010, average temperature has trended upward, with the annual average high temperature increasing from 60.43°F between 1962-1972 to 62.16°F from 2000-2010. The average annual low temperatures have also trended upward: from 1962-1972 average annual lows were 39.36°F, and from 2000-2010 the average annual lows were 41.79°F (HBS 2011). As average precipitation decreases and temperatures increase, potential evapotranspiration increases. Increased evapotranspiration returns more water to the atmosphere, decreasing the amount available for stream flow (Thornthwaithe 1948).

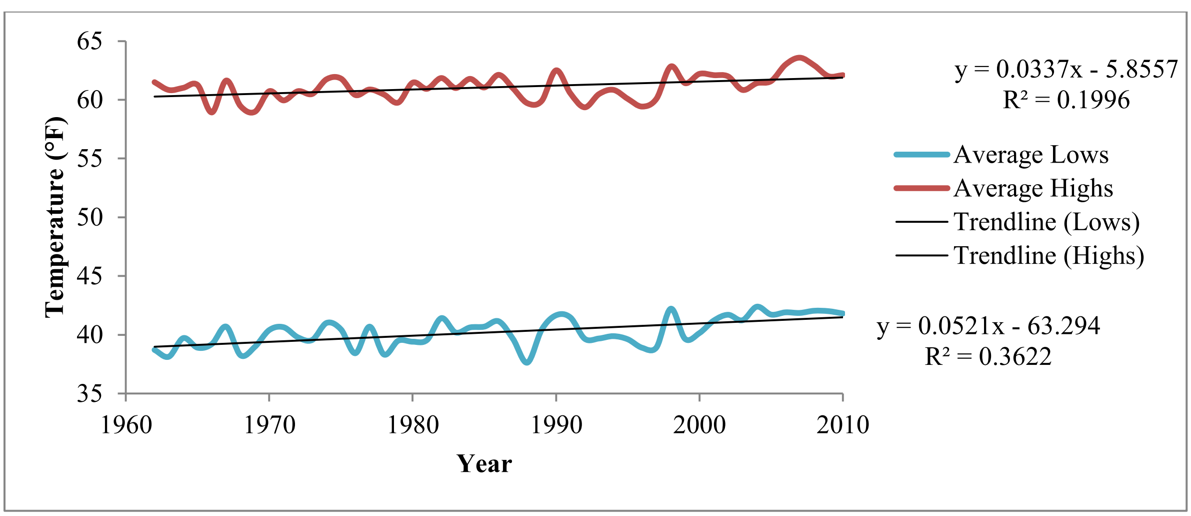

FIG. 3. Yearly average temperatures at Highlands Biological Station.

Land Use

The Highlands Plateau, along with much of western North Carolina, was extensively logged beginning in the late 1800's before being divided into private parcels and National Forest units. The historic Kelsey trail, at one time the only route to Whiteside Mountain that once ran through "primeval forest," fell victim to post-war logging operations and is now preserved only in written accounts (Zahner 1994). The Town of Highlands was incorporated in 1879 as a resort town, promoting itself and the surrounding area as more than just a 'passing attraction' but rather a pleasurable destination capable of restoring ones health (UCWA 2004a).

Though development was initially slow due to a shortage of reliable roads, the construction of roadways in the early 20th century promoted economic growth and further development within the town; Lindenwood Lake, Ravenel Lake, Lake Sequoyah and the Lake Sequoyah hydroelectric dam and Highlands Country Club were all constructed during this era of development. Champion Lumber cleared a large portion of the watershed in the 1940s and, by the 1980s both the Wildcat Cliffs Country Club and Highlands Falls Country Club had been constructed on sites previously covered by old-growth forest. Residential and recreational development in the area coincided with a large number of stream modifications and impoundments over the course of the century (UCWA 2004a).

Based on GIS analysis of a 2006 land cover classification map (http://coweeta.uga.edu), approximately 60% of the watershed is currently forested or undeveloped, while close to 35% is developed to varying degrees of intensity. Land cover classifications for the 2006 land use layer were classified using the National Land Cover Database (NCLD) cover classes for 2001 (MRLC 2010). Further GIS analysis determined that approximately 30% of the watershed flows through the city limits of Highlands (http://gis.highlandsnc.org/), with discharge exposed to a variety of land uses, with various development classes (45.4%) and deciduous forest (41.5%) constituting the largest components.

By comparing the land use coverages in ArcGIS® for the years 1986 and 2006, it is possible to quantify the changes in land use in the Upper Cullasaja watershed between land use classes during this 20-year period in percentages (Table 3, Fig. 4; http://coweeta.uga.edu). The largest increases in proportion of land cover occurred within the developed/open space (+3.28%), deciduous forest (+3.40%) and mixed forest (+3.10%) classes. This is likely due to increased residential development and reductions in logging activity throughout the watershed in recent years. Pasture/hay (-5.40%) and evergreen forest (-3.14%) categories experienced the largest reductions in land cover proportions, likely due to development forest cuts and conversion of old pasture to residential plots. A land use planning effort in 2002-2003 found that 800 parcels, 30% of all parcels within the city limits, remained undeveloped (UCWA 2004a).

TABLE 3. Change in land cover between 1986 and 2006 from Upper Cullasaja Watershed

Land Cover Class	1986 % Land Cover	2006 % Land Cover	% Change
Open Water	0.28	0.46	+ 0.18
Developed, Open Space	27.41	30.69	+ 3.28
Developed, Low Intensity	0.93	2.35	+1.42
Developed, Medium Intensity	0.35	0.65	+ 0.30
Developed, High Intensity	0.03	0.05	+ 0.02
Barren Land/Rock/Sand/Clay	0.10	0.20	+ 0.10
Deciduous Forest	42.40	45.80	+ 3.40
Evergreen Forest	10.70	6.14	-3.14
Mixed Forest	7.35	10.45	+ 3.10
Shrub/Scrub	1.45	1.41	- 0.04
Grassland/Herbaceous	0.00	0.50	+ 0.50
Pasture Hay	6.66	1.23	- 5.43
Cultivated Crops	1.60	0.02	- 1.58
Woody Wetlands	0.66	0.05	- 0.61
Emergent Herbaceous Wetlands	0.01	0.00	- 0.01

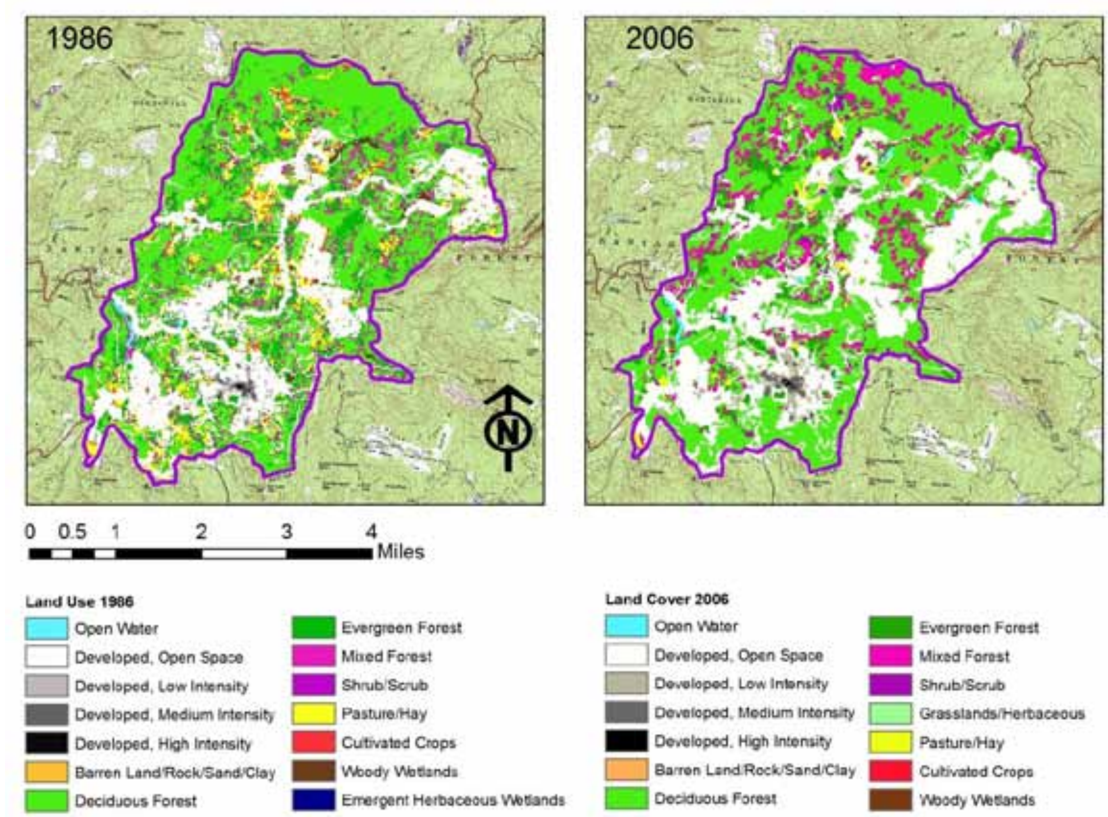

FIG. 4. Land cover raster layers of the Upper Cullasaja Watershed for 1986 and 2006 displaying changes in land use

A large area of the Cullasaja sub-watershed upstream of Mirror Lake, more than half according to UCWA (2004a), is divided among three golf courses and their respective communities. A golf course and both high intensity commercial and residential development are located within the Monger Creek sub-watershed. The Mill Creek sub-watershed is heavily urbanized within downtown Highlands, and flows through mostly residential development above and below the town center. The landowners and land managers in these three sub-watersheds have, over the years, cleared a large proportion of the riparian vegetation, altered stream channels, artificially stabilized banks, added impoundments and routed flow through culverts, all of which have led to current water quality concerns (UCWA 2004a, 2004b). Of all the sub-watersheds, Big Creek is the least developed and contains the largest area of protected/managed lands; 27.9% of the Big Creek sub-watershed is located within the Nantahala National Forest (UCWA 2004a).

Population

Highlands' population is difficult to estimate because the majority of houses serve as seasonal residences and vacation homes. The permanent population of Highlands is estimated to be 924 in the winter and increases to 4,000-5,000 residents in the summer (Census 2010). The local Chamber of Commerce estimates that up to 30,000 occupy the Upper Cullasaja River watershed in the summer; however, this number cannot be substantiated by hard data. Two-thirds of the property tax bills for Highlands are mailed to addresses outside of Macon County, and Macon County sends 50 percent of its county tax bills to owners outside the county (UCWA 2004a). 70.9% of all housing units in Highlands are for seasonal, recreational or occasional use, while only 22% are occupied (Census 2010). The large proportion of remote ownership of property due to seasonal residents adds to the complexity of working jointly with property owners on watershed issues.

Water Supply

Groundwater supplies the majority of private and community well systems throughout the Upper Cullasaja watershed, with the exception of the Town of Highlands, which uses the Big Creek arm of Lake Sequoyah as a source for drinking water in city limits (UCWA 2004a). Unlike coastal North Carolina, the watershed contains no underground aquifers (UCWA 2004a). As of 2011, potable water is provided to 2271 connections throughout the Town from the source of Big Creek (personal communication, Wade Wilson, December 2011).

A new wastewater treatment plant with greater operating capacity than the old facility was completed in 2006, increasing system efficiency and the potential for sewer services throughout the Town, while relocating the outfall from Mill Creek to Lake Sequoyah. Service is provided to 794 commercial and residential connections as of 2011 (personal communication, Alec Templeton, December 2011).

Fisheries

North Carolina Division of Water Quality (NCDWQ) classifies the waters in the Upper Cullasaja River watershed as trout waters. Despite this classification, there are few remaining populations of native trout in the watershed today (UCWA 2004a). The Index of Biological

Integrity (IBI) is a common method used to rate the quality of streams. Only the Big Creek and Cullasaja River sub-watersheds have IBI measures been calculated over the past 21 years. Data from Big Creek in 1999 and 2000 resulted in 102 ratings of "good." The Cullasaja River IBI rating varied between "good", "fair", and "poor" from 1991 to 2007. Three of the last four ratings were "fair" while most of the ratings over this 16-year span have been "good" or "fair" (McLarney 2008).

Stocked trout fisheries are common in the watershed for sport fishing communities, especially in the lakes and ponds of neighborhood communities. Due to high summer temperatures in these lakes, the stocked trout are generally only available during the cooler weather seasons of fall, winter, and spring. Artificially impounded water bodies in the watershed are not suitable for native trout populations and have traditionally been stocked with non-native species, including bass, bluegill, catfish, shiners, carp, and dace (UCWA 2004a).

Stormwater Management

Due to their proximity to the town of Highlands, both Mill and Monger Creeks receive significant levels of urban stormwater runoff. Since peak discharges are not attenuated by stormwater detention, excessive velocity and scour have been noted as significant factors of impairments in Mill Creek (NCDWQ 2002, NCDWQ 2003a, UCWA 2004b). While Mill Creek does appear on the 303(d) list, Monger Creek is not listed although data indicates similar levels of impairment (Ahl 2010, UCWA 2004b).

The town of Highlands developed a stormwater master plan in 2007 (McGill 2007) and has recently implemented at least one stormwater Best Management Practice (BMP) that provides for detention and treatment of stormwater from a portion of the urbanized area. In addition, at least one additional BMP demonstration has been implemented at the Highlands Community Child Development Center by UCWA. This demonstration incorporates pervious pavement and detention as part of the Center's landscape. The stormwater master plan provides recommendations for further detention and treatment of stormwater from a portion of the urbanized area, upgrading existing stormwater collection systems, improving runoff reduction along Main Street, implementation of stormwater treatment facilities at Highlands Recreational Park and Highlands Plaza, implementation of a watershed education program, examination of funding possibilities, and close examination of existing ordinances for opportunities.

Study Watersheds

Cullasaja River

The Cullasaja River sub-watershed (Fig.5) begins on Whiteside Mountain and ends at the dam on Lake Sequoyah. The sub-watershed contains 5.4 mi^2 of drainage area and a total of 10.3mi of stream, making it the largest sub-watershed on the Plateau. The Cullasaja River includes the longest length of stream (6.0mi) in the Upper Cullasaja watershed, with the tributaries of Ammons Branch (0.9mi), Salt Rock Branch (1.0mi) and three unnamed tributaries (0.6, 0.6, and 1.2mi) all contributing to total stream miles. The USGS topographic map for the Highlands area (Highlands quadrangle) shows more than 14 ponds or small lakes within Wildcat Cliffs Country Club property and another nine ponds/ reservoirs downstream of Ravenel Lake. This count does not include the frequent low head dams on many of the tributaries in residents' backyards or along streams in commercial developments. The named lakes in this sub-watershed include Ravenel Lake (at Cullasaja Club), Highlands Falls Country Club Lake, Apple Lake, Mirror Lake, and Lake Sequoyah. The Cullasaja River has been monitored by NCDWQ every five years since 1990, with additional sampling occurring through watershed assessments and restoration projects. The Cullasaja River at US-64 is rated "fair" in bioclassification, which has resulted in listing the Cullasaja River as impaired on North Carolina's 303(d) list of impaired water bodies (NCDWQ 2010).

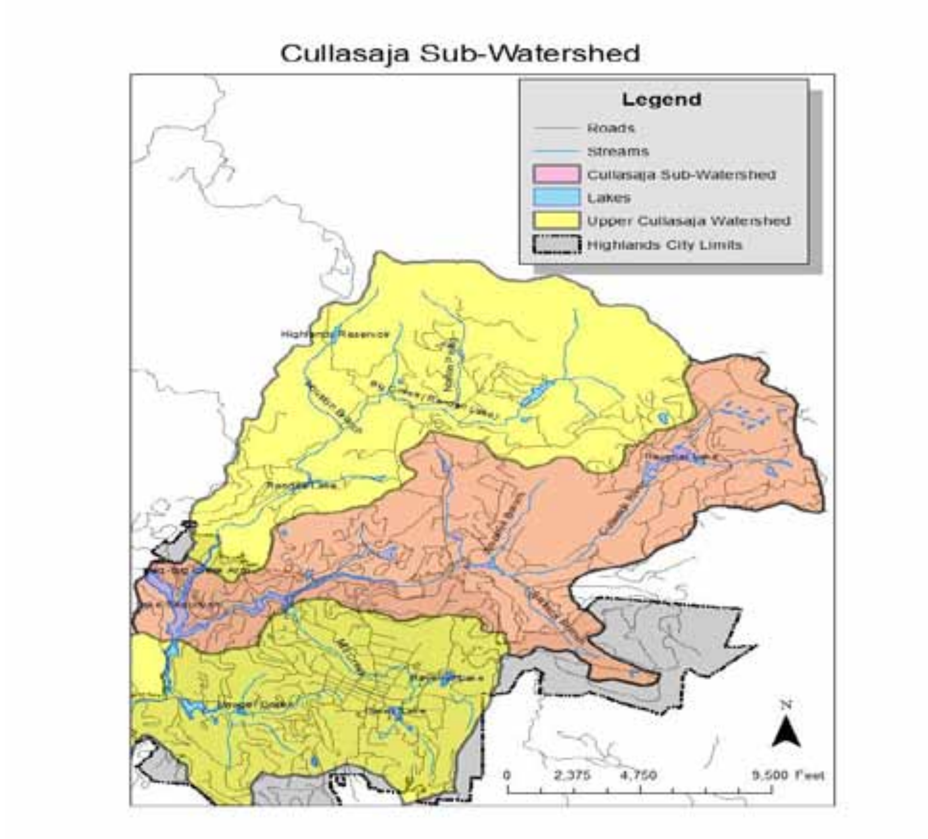

Fig.5. Map of Cullasaja Sub-watershed

Mill Creek

The Mill Creek sub-watershed (Fig.6) begins at Satulah Mountain, Sunset Rock, and the Bear Pen Mountains and flows into Mirror Lake below the Town of Highlands. This watershed includes over half of the drainage for downtown Highlands, with a total of 1.7mi^2 of drainage. Most of the length of Mill Creek is in the main stem (2.0 mi) with the remaining stream length (1.0mi) in Satulah Branch. The USGS topographic map for the 101 area shows at least four impoundments in the watershed, including Lindenwood Lake and Harris Lake. Although preserved in land trusts or low-density residential development on the ridgelines, most of the Mill Creek sub-watershed is urbanized. Mill Creek has been monitored by NCDWQ every five years since 1990, with additional sampling occurring through watershed assessments and restoration projects. Mill Creek was not rated using the bioclassification index due to its small size, but has been placed on North Carolina's 303(d) list of impaired water bodies due to an earlier classification of "impacted" (NCDWQ 2010).

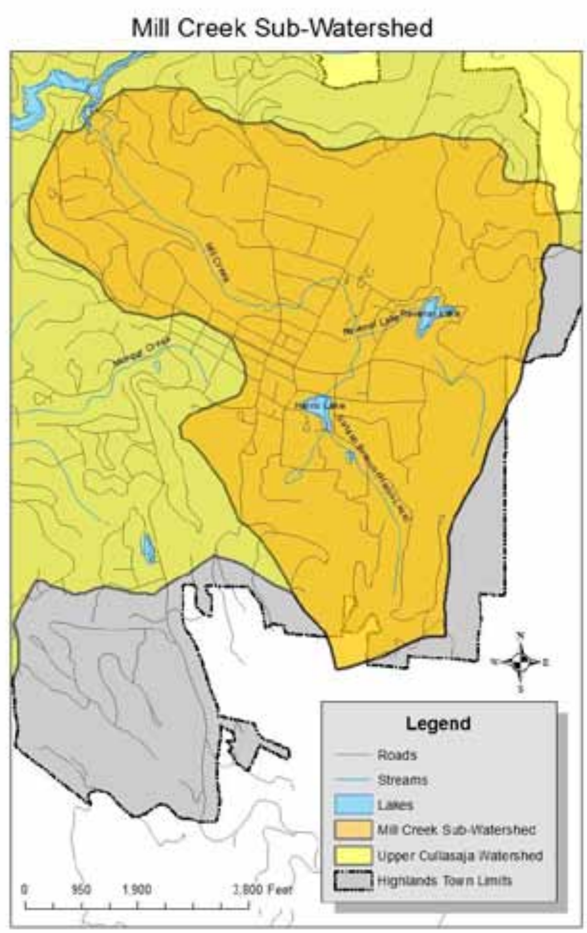

Fig.6. Map of Mill Creek sub-watershed

Monger Creek

The Monger Creek sub-watershed (Fig.7) begins at Sassafras Knob and Little Yellow Mountain and ends at Lake Sequoyah. It contains 2.0mi^2 of drainage area and 3.7mi of stream. The main stem includes 1.7mi of stream with the remainder included in three tributaries. The entire sub-watershed is within the Town of Highlands jurisdiction (UCWA 2004a). Unlike Big Creek and the Cullasaja River, Monger Creek has not been monitored on a regular basis, but the 2002 NCDWQ Assessment Report noted that Monger Creek has similar characteristics as Mill Creek, including stream bank erosion and effects from urban stormwater UCWA 2004b). Monger Creek is considered to be impacted by urban runoff (UCWA 2004a, 2004b).

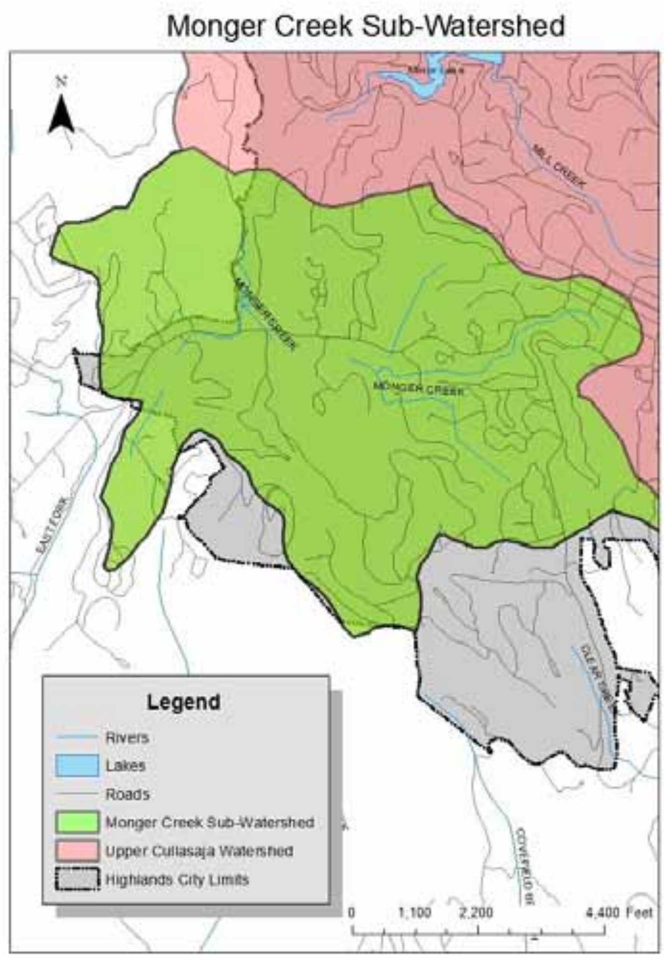

Fig.7. Map of Monger Creek sub-watershed

Big Creek

The Big Creek sub-watershed (Fig.8) begins at Cole and Shortoff Mountains and ends downstream at the US 64W bridge crossing on Lake Sequoyah. Many tributaries of Big Creek flow through the Nantahala National Forest lands and low-density residential areas. The sub-watershed includes Randall Lake and the Big Creek arm of Lake Sequoyah. Almost half of the stream length is included in the main stem of Big Creek, with Houston Branch, Bad Branch, and Big Norton Prong, plus three unnamed tributaries comprising the rest of the stream length. There are 10 impoundments found within the Big Creek sub-watershed, including Randall Lake, Highlands Reservoir, and Cold Springs Lake. The Big Creek sub-basin is the least developed of the four sub-watersheds (UCWA 2004a). Big Creek is classified as "good" (Category 1) by the NC Division of Water Quality on the 2010 combined list. For this reason, sections of Big Creek have been used as reference sampling sites for water quality, storm water and benthic macroinvertebrate population comparisons with the Upper Cullasaja River. Still, Big Creek may be experiencing stresses due to the Randall Lake dam breach and other factors that could jeopardize future water quality (UCWA 2004a).

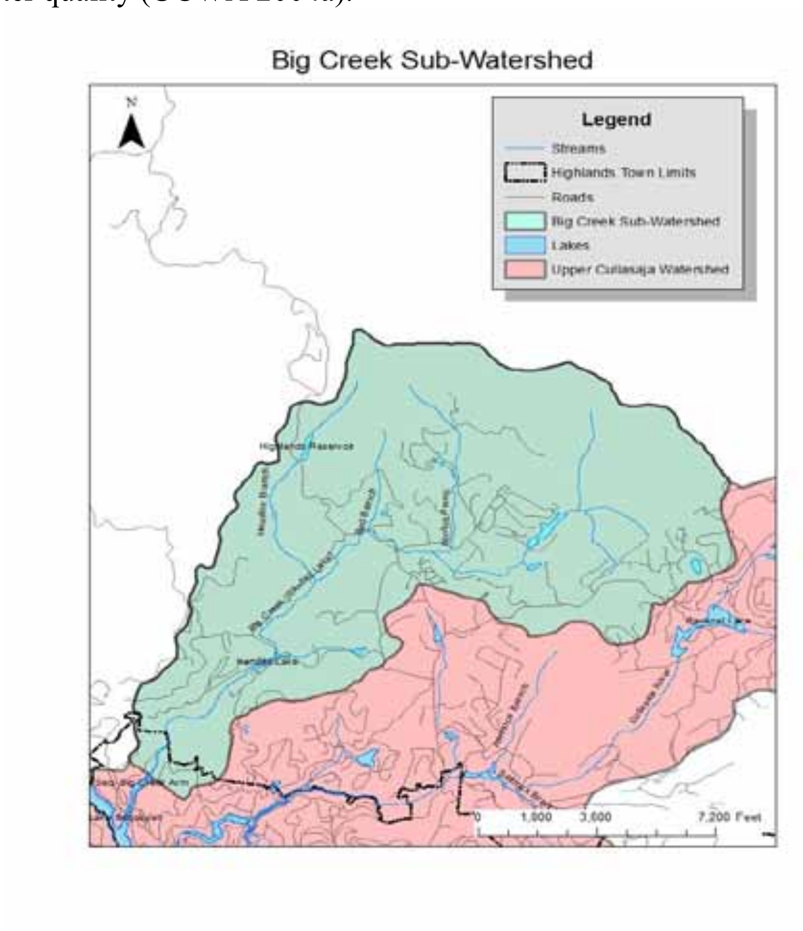

Fig.8. Map of Big Creek sub-watershed

MATERIALS AND METHODS

Aquatic invertebrates study

Aquatic invertebrates were collected at each of the six sites using four different methods: kick net, leaf pack, sweep net, and visual sampling. Our sampling team was comprised of thirteen individuals that were divided into four groups that sampled different reaches of the sampling locations. Each group was responsible for sampling the different aquatic habitats; riffle, bank, and leaf packs, located in their reach of stream. Riffle habitats were sampled using two methods, kick nets and visuals. The kick net method was executed by two individuals holding the kick net downstream of an individual who is shuffles his or her feet and disturbs the streambed. This method allows for aquatic insects that have been uprooted to be caught in the kick net as they float downstream. The visual method was carried out by overturning rocks and other debris within the stream and gathering invertebrates found on those objects. Bank habitat was sampled using both sweep nets and visual methods. Sweep nets were used by an individual who scraped the bottom of banks and roots, which dislodged aquatic invertebrates within those zones. Leaf pack habitats were sampled by collecting leaf packs and placing them into sieve buckets. The leaf packs were then searched for aquatic invertebrates. Once target organisms were found they were removed and placed into a vial with 95% ethanol to preserve them for identification.

After collection, specimens were identified in the laboratory. They were first divided by order and then closely examined under dissecting microscopes. Different families were identified using keys found in "Introduction to Taxonomy and Ecology of EPT" prepared for the NC Department of Environment and Natural Resources- Division of Water Quality.

Only individuals representative of the orders Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) were identified. These specimens were divided into families, which was done due to the varied tolerance to pollutant exhibited by different families making family level identification a good indication of stream health. The Biotic Index (BI) is a number ranging from 0-7 indicating the general health of a stream, with 0 being the least tolerant and 7 being the most tolerant. Through examination of aquatic invertebrate species richness and population size the BIs of the streams could be calculated. The equation used is shown below.

$$BI = \frac{\sum abundance \times BI\ value}{total\ abundance}$$

The EPT data were also used to determine functional feeding groups present at each site by percentages. Each family has one general feeding type, which is described as predator, scraper, shredder, collector, filterer (subcategory of collector), or gatherer (subcategory of collector). Some families were considered to be a mixture of two different feeding groups. These were: collector-shredders, collector-predators, scraper-predators, scraper-collectors, and scraper-shredders.

Physical characteristics

The stream habitat characteristics of the six watershed sites were quantified using the NCDENR Division of Water Quality's Habitat Assessment Field Data Sheet (NCDWQ 2003b). A segment of stream reach ranging from 100 to 200m in length was used to quantify each of the six sites. Data were collected on October 17, 2011 at each site by facing upstream starting at the base location and surveying a 100 to 200m reach. Assessments of Physical Characteristics, Channel Modification, Instream Habitat, Bottom Substrate, Pool Variety, Riffle Habitats, Bank Stability and Vegetation, Light Penetration, and Riparian Vegetative Zone Width were made at each stream reach. Each criterion was scored independently and then summed with all the criteria to yield a total score on a 100-point scale. Other characteristics of stream habitat were also recorded, including: Visible Land Use, Stream Width, Bank Height, Bank Angle, Flow Conditions, Weather Conditions, and Turbidity.

A Wolman pebble count was completed at each site to assess the size and distribution of surface bed material (Wolman 1954). A tape measure was used to measure a 100m stretch of stream reach in which to complete the Wolman pebble count. At ten transects approximately 10m apart, ten particles were selected at random and measured using a ruler. Size was determined by measuring the intermediate axis (the second largest width) with a ruler. Then, using this measurement, each particle was classified based on size. The classes included clay and silt, sand, gravel, cobble, boulder, and bedrock – ranging from finest to coarsest. Each particle was recorded based on its classification. The number of particles in each class was totaled and the percent and cumulative percent of each size class determined. These percentages provide detail on size range, size class distribution and median particle size at each of the locations.

A Bank Erosion Hazard Index (BEHI) (Rosgen 2001) was determined at each site. A cross section of the stream channel at each site was observed to gather the following information: bank height ratio (ft/ft), root depth ratio percentage, root density percentage, bank angle (degrees), and surface protection percentage. The index values for each category ranged from very low to extreme with a numerical value of one to ten respectively. The empirically determined ratios and percents were plotted on graphs showing accepted patterns for BEHI versus the different ratios and percents. Once the empirically determined ratio or percent was plotted the corresponding index value was found (the x-value on the graph). The resulting BEHI values for each criteria studied were then summed to find a numerical total field index value. The maximum Total Field Index (TFI) value was 50. The TFI value was then adjusted based on type of streambank morphology and the presence or lack of stratification, yielding the Adjusted BEHI. Sites with a high amount of bedrock and boulders are adjusted to have a very low or low BEHI respectively. Depending on the percent of sand in a gravel dominated site, the TFI is increased by five to ten points. Sand dominated sites are adjusted by adding ten points to the TFI. Silt and clay dominated areas require no adjustment. Stratification requires an addition of five to ten points depending on the position of unstable layers relative to bankfull stage of the stream.

Chemical characteristics

We visited the six stream reaches with James Aaron of NCDENR Division of Water Quality on November 7, 2011. Using a calibrated YSI Pro Series probe, we measured water temperature, dissolved oxygen, conductivity, and pH. To measure these variables, the probe was placed into running water and held until values stabilized. We also collected water samples to measure turbidity, volatile compounds, fecal coliform, heavy metals, and nutrient levels. When collecting water samples to test levels of volatile compounds, which include gasoline, benzene, and substances that are commonly burned as fuel, it was necessary to perform all collection underwater, as volatile compounds evaporate rapidly. The samples were preserved with 0.5mL of 1:1 HCl. We collected water samples to measure turbidity upstream of all other collections to ensure that we did not collect samples in disturbed areas of the rivers. Nutrient samples were preserved with 2.0mL of a 20% solution of H_2SO_4, and heavy metal samples were preserved with 5.0mL of 1:1 HNO_3. All water samples were sent to the Division of Water Quality lab in Asheville, North Carolina for analysis.

RESULTS

Aquatic invertebrates study

Each site sampled had a wide variety of aquatic invertebrates in both functional feeding groups and family diversity. Monger Creek (MoC) had the lowest abundance, and consisted mostly of Trichoptera. The only other family found at MoC was within the order Ephemeroptera, and only contributed 8% of the sample collected. The aquatic invertebrates found at MoC consisted of two different types of feeding groups: scrapers (8%) and filterers (92%). The filterers were all from the order Trichoptera.

Mill Creek 1 (MiC1) had a total sample size of 73 individuals, all from the orders Trichoptera and Ephemeroptera. The Ephemeroptera from MiC1 were from two different families and were all scrapers (61%). The rest of the aquatic invertebrates from Trichoptera came from two families, which were both filterers (39%).

At Mill Creek 2 (MiC2) 89 aquatic invertebrates were found. The Ephemeroptera found at MiC2 consisted of 27 individuals and were all scrapers (30%). The rest of the sample were Trichoptera and were all filterers (70%).

The Cullasaja River (CR) site had the largest sample size of 153 individuals. Aquatic invertebrates from all three orders were found, however the Plecoptera found consisted of one individual, a predator, and contributed less than one percent to the sample size. All the 31 Ephemeroptera were scrapers (20%), and the rest of the sample size consisted of 121 filterers (79%) from Trichoptera.

Big Creek 1 (BC1) had a sample size of 97, representing all three orders. There were 50 Ephemeroptera, comprised of 46 scrapers, 1 shredder, and 3 gatherers; 10 Plecoptera of which 7 were predators and 3 were shredders; and 37 Trichoptera, with 35 filterers, 1 scraper, and 1 gatherer. There were 5 different feeding groups found at BC1. There total numbers of individuals were: 47 scrapers (48%), 4 gatherers (4%), 35 filterers (36%), 7 predators (7%), and 2 shredders (2%).

Big Creek 2 (BC2) had the largest number of individuals of Plecoptera contributing 50% of the sample size, which were 60 individuals from a total sample size of 114 aquatic invertebrates. The order Ephemeroptera contributed 34 individuals followed by 20 individuals belonging to Trichoptera. The numbers of individuals in each feeding group found at BC2 were: 32 scrapers (28%), 1 gatherer (.8%), 32 shredders (28%), 30 predators (26%), and 17 filterers (15%) The numbers and percentages of individuals from orders and feeding groups, found at each site are shown graphically in figures 9 and 10.

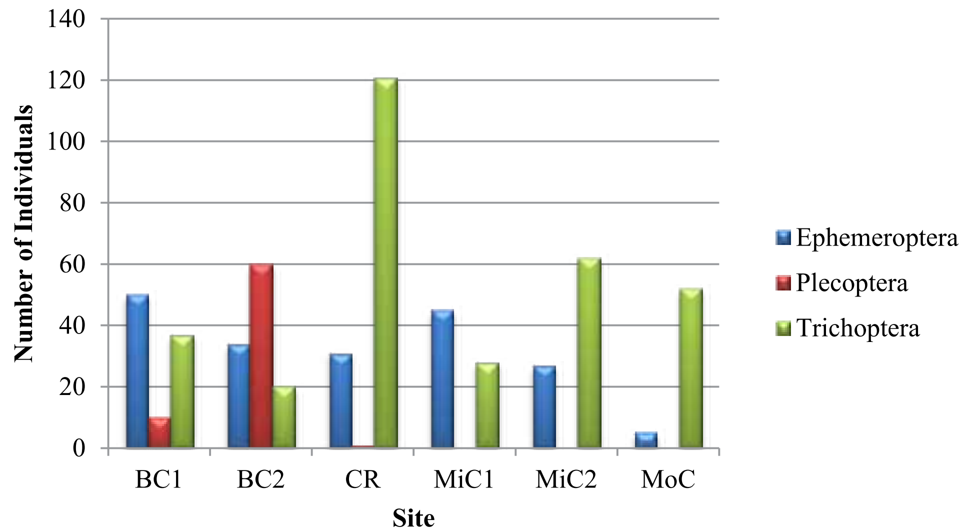

FIG. 9. Number of individuals of each order by site.

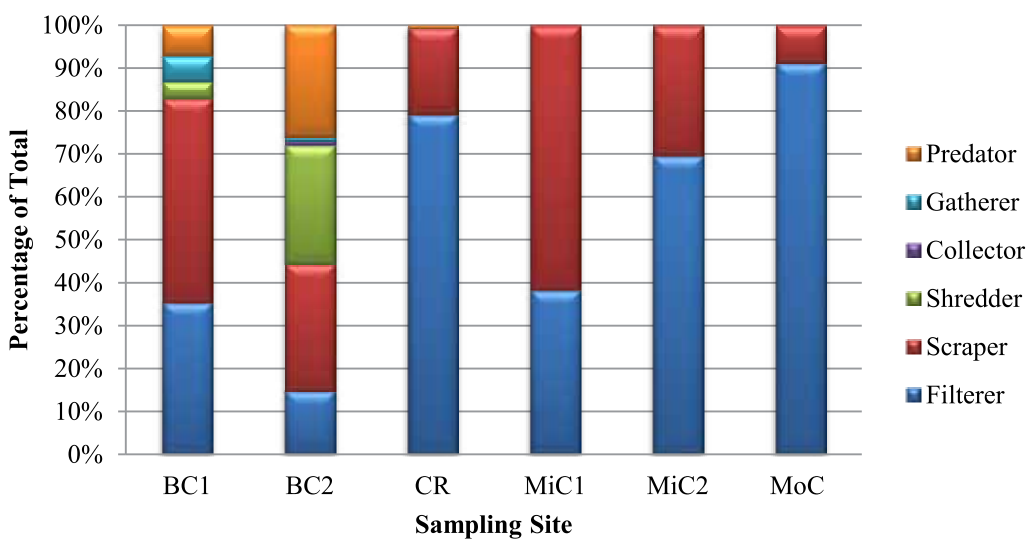

FIG. 10. Percentage of feeding groups by site.

Each site had significant numbers of Hydropsychidae, a family within the order Trichoptera. The smallest number of Hydropsychidae, 8, was found at BC2. This particular family is a filter feeder and its presence in a river indicates elevated particulates, which often indicates a high BI value. Therefore the amount of Hydropsychidae contributes to the BI value of a river (Fig. 10).

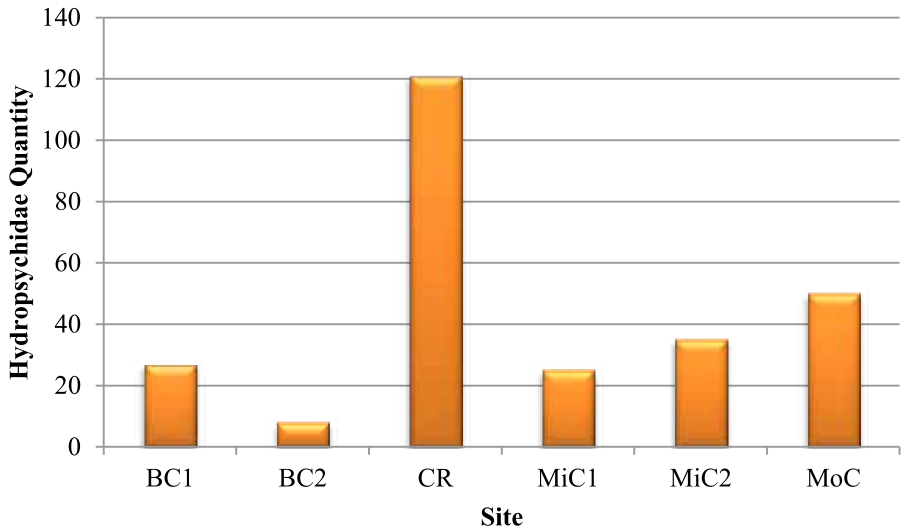

FIG. 11. Number of Hydropsychidae collected at each site.

When assessed for Biotic Index (BI) values, it was found that MiC1 and MoC had the same BI, consisting of 3.96, which makes the streams the least healthy of all the sites. CR had a BI value of 3.83, MiC2 had a BI value of 3.61, and BC1 had a BI value of 3.41. The sample site with the highest water quality was BC2 with a BI value of 2.46 (Fig. 12).

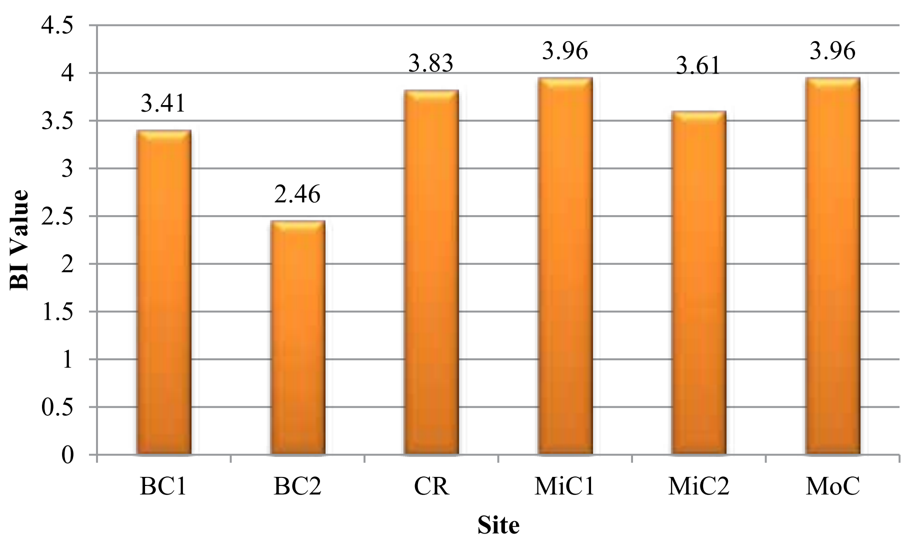

FIG. 12. Biotic Index values by site, found using the equation: $BI = \frac{\sum abundance \times BI\ value}{total\ abundance}$

Physical characteristics

Habitat Assessment

For the habitat assessment methodology used, the maximum score for each of the scored criterion (Table 4) yields a maximum total score of 100. Total scores and individual criterion scores for each stream reach are noted in Figure 13.

TABLE 4. Maximum possible score for each criterion of the habitat assessment.

Subcategory	Channel Modi-fication	Habitat	Substrate	Pool Variety	Riffle Habitat	Bank Stability	Light Penetration	Riparian Zone Width
Maximum Score	5	20	15	10	15	15	10	10

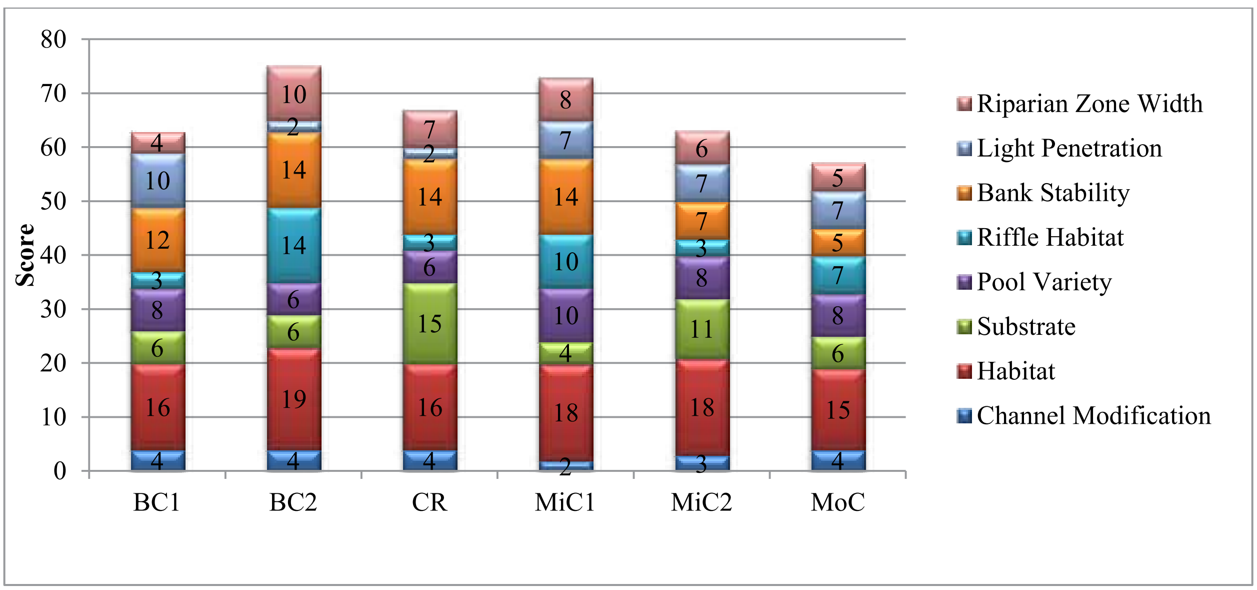

FIG. 13. Total habitat assessment scores and score for each criterion for each site.

The highest ranking site in terms of habitat assessment was BC2 with a total score of 75. The lowest ranking site was MoC with a total score of 57. The total scores ranked in order from highest to lowest are: BC2, MiC1, CR, BC1, MiC2, and MoC. Most sites had good Channel Modification (excluding MiC1 and MiC2) scores, high Pool Variety scores (excluding CR and BC2), and high (good) Bank Stability (excluding MoC and MiC2). All sites had high (good) scores for Habitat. More variability is seen in Substrate, Riffle Habitat, Light Penetration, and Riparian Zone Width. MiC2 and CR received high scores for Substrate, while MoC, BC2, and BC1 received a lower score of 6, and MiC1 received the lowest score of 4 (Fig. 14). BC2 had the highest score (14) for Riffle Habitat, followed by MiC1 and MoC (10 and 7, respectively). MiC2, CR, and BC1 all received the lowest score for this category (3) (Fig. 15). In the light penetration category, the maximum score was 10 at BC1, followed by a score of 7 at MiC1,

Wolman Pebble Count

The results of the Wolman pebble count show the distribution of substrate particles at each site. Overall, the data suggest that at most streams, the majority of the particles are in the gravel and cobble size ranges (Fig. 18). Most sites had a relatively low number of each type of particle class, however, at BC1, there was a definite trend towards fine grained particles and at CR there was a trend towards bedrock.

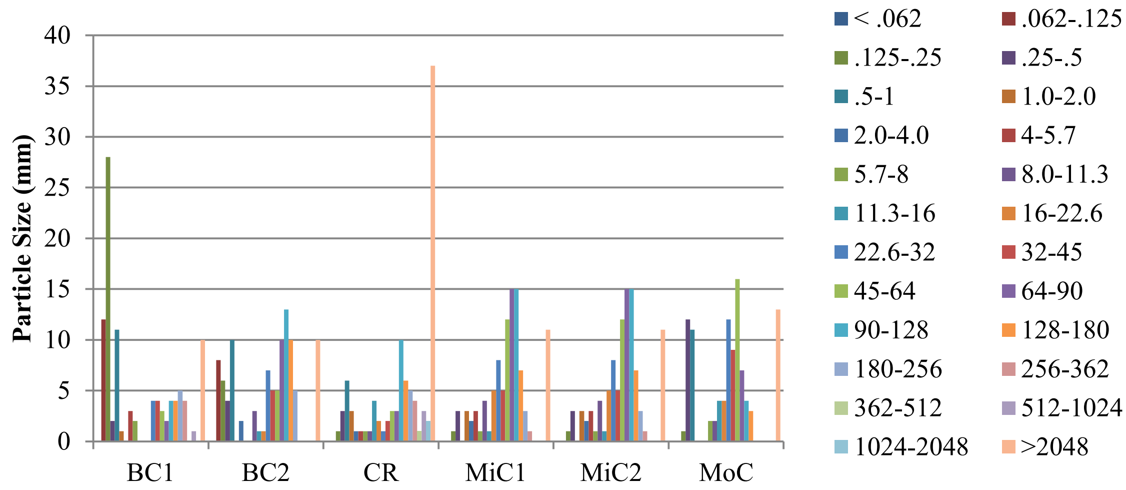

FIG. 18. Frequency of occurrence of each particle type at each site.

The median particle sizes at sites MoC and MiC1 are gravel size particles while the median at BC2 and MiC2 are small gravel. The median particle size at BC1 is significantly smaller and is classified as a coarse sand (.5-1mm) while the median particle size at CR is the largest and is classified as a large cobble (128-180mm) (Fig. 19).

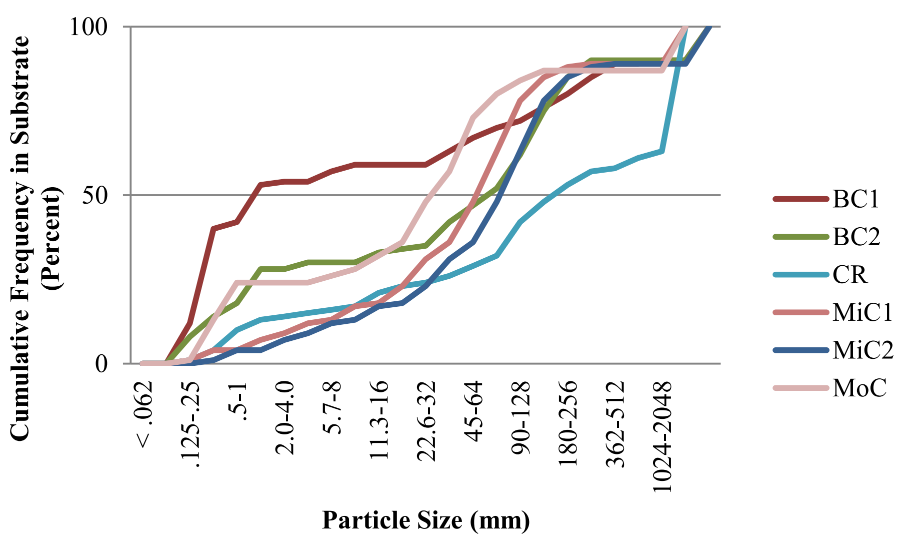

FIG. 19. Cumulative frequency of occurrence of each particle type at each site. The 50% line illustrates the median particle size at each site.

Bank Erosion Hazard Index

The numerical index values for each subcategory and the total index from the BEHI assessment are displayed in Table 5 and Figure 20. BC2 has a significantly lower total index and adjusted BEHI than any other site indicating greater bank stability, most likely a function of the dense woody vegetation at that location.

TABLE 5. Bank Erosion Hazard Index subcategory and total field index scores.

Site	Bank Height Ratio Index	Root Depth Ratio Index	Root Density Index	Bank Angle Index	Surface Protection Index	Total Index	Adjusted BEHI
BC1	9	4	4	3	2	22	27
BC2	1	1.5	2	3	3	10.5	10.5
CR	10	6	2	4	3	25	22
MiC1	5	4	2.5	3.5	3.5	18.5	18.5
MiC2	6	2	6	6	6.5	26.5	31.5
MoC	9	2.5	2.5	3.75	6	23.75	28.75

BC2, MiC1, and MiC2 show the least variability in index values for each subcategory. BC2 and MiC1 have low index values for each site while MiC2 has relatively high index values for each subcategory except Root Depth Ratio. The most variation within one subcategory across different sites occurs in Bank Height Ratio followed by Surface Protection.

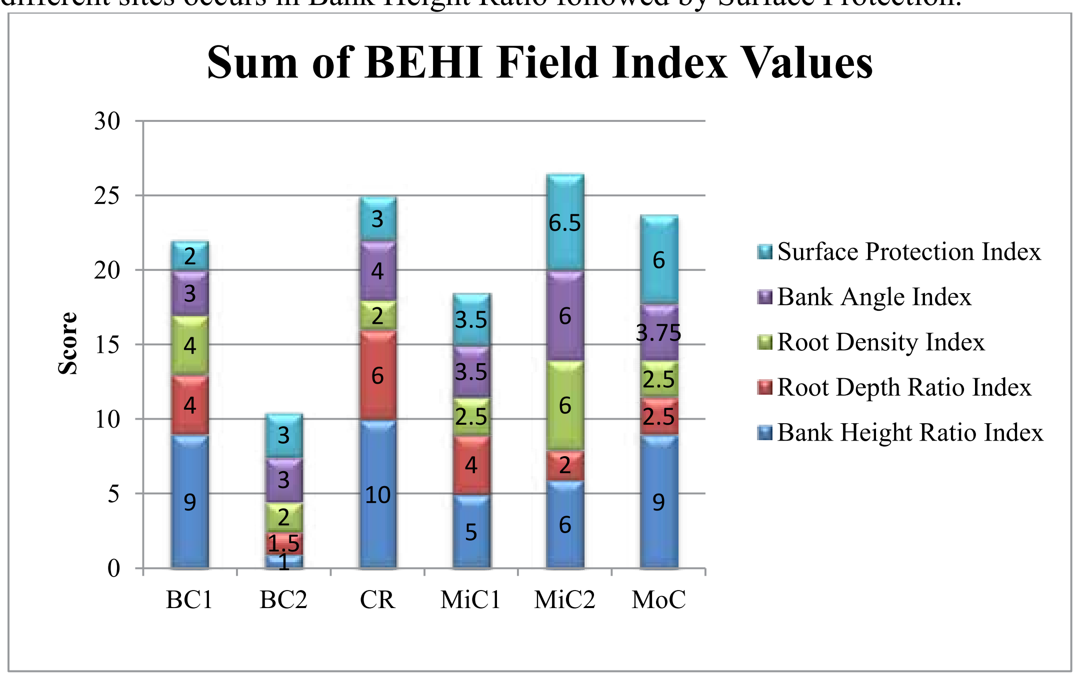

FIG. 20. Total Field Measure by Index of BEHI.

The Adjusted Bank Erosion Hazard Indices for each stream reach are displayed in Figure 21. The TFI at BC1 was adjusted because of the presence of sand in the bank profile. The TFI at BC2 was not adjusted because it was already classified as very low due of the presence of boulders. The TFI at CR was reduced by only 3 points because while there were a lot of boulders which would reduce the TFI, the presence of sand and gravel would increase the TFI. The TFI at MiC1 was not adjusted because it was mainly silt and clay. The TFI at both MiC2 and MoC were increased due to sand.

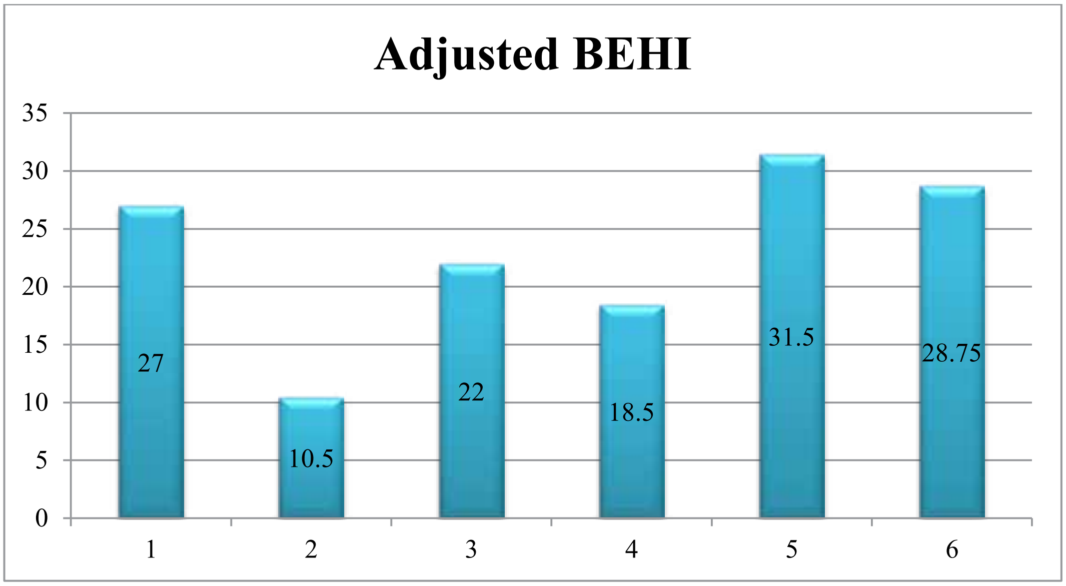

FIG. 21. Adjusted BEHI.

A comparison of Total Field Index and the adjusted BEHI are displayed in Fig. 22.

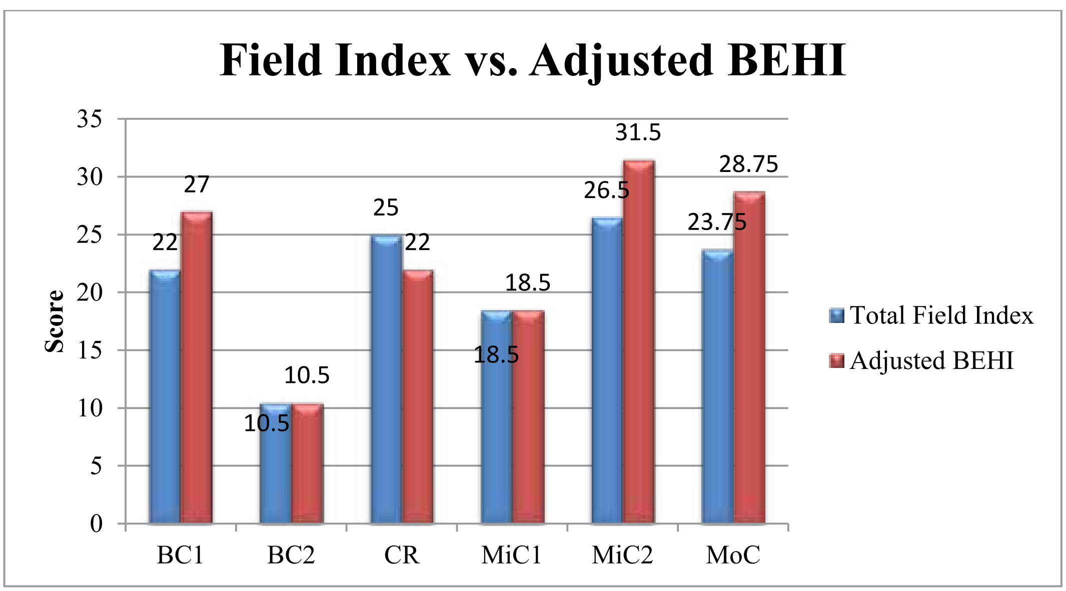

FIG. 22. Comparison of Total Field Index and adjusted BEHI.

Table 6 summarizes the changes between the TFI and the Adjusted BEHI and lists the non-numerical category before and after adjustment. The only site with a category that changed as a result of adjustment was MiC2 whose classification changed from a Moderate to High hazard index. While both BC2 and MiC1 have a BEHI and adjusted BEHI classified as low, the numerical value for BC2 is lower by eight points.

TABLE 6. Comparisons and classifications of TFI and Adjusted BEHI.

Site	Total Field Index	Category	Adjusted BEHI	Category	Numerical Adjustment
BC1	22	Moderate	27	Moderate	+5
BC2	10.5	Low	10.5	Low	+0
CR	25	Moderate	22	Moderate	-3
MiC1	18.5	Low	18.5	Low	+0
MiC2	26.5	Moderate	31.5	High	+5
MoC	23.75	Moderate	28.75	Moderate	+5

Chemical characteristics

Results for pH, temperature, conductivity and dissolved oxygen (Fig.23, Table7) were largely consistent at the sites except for discrepancies in conductivity levels.

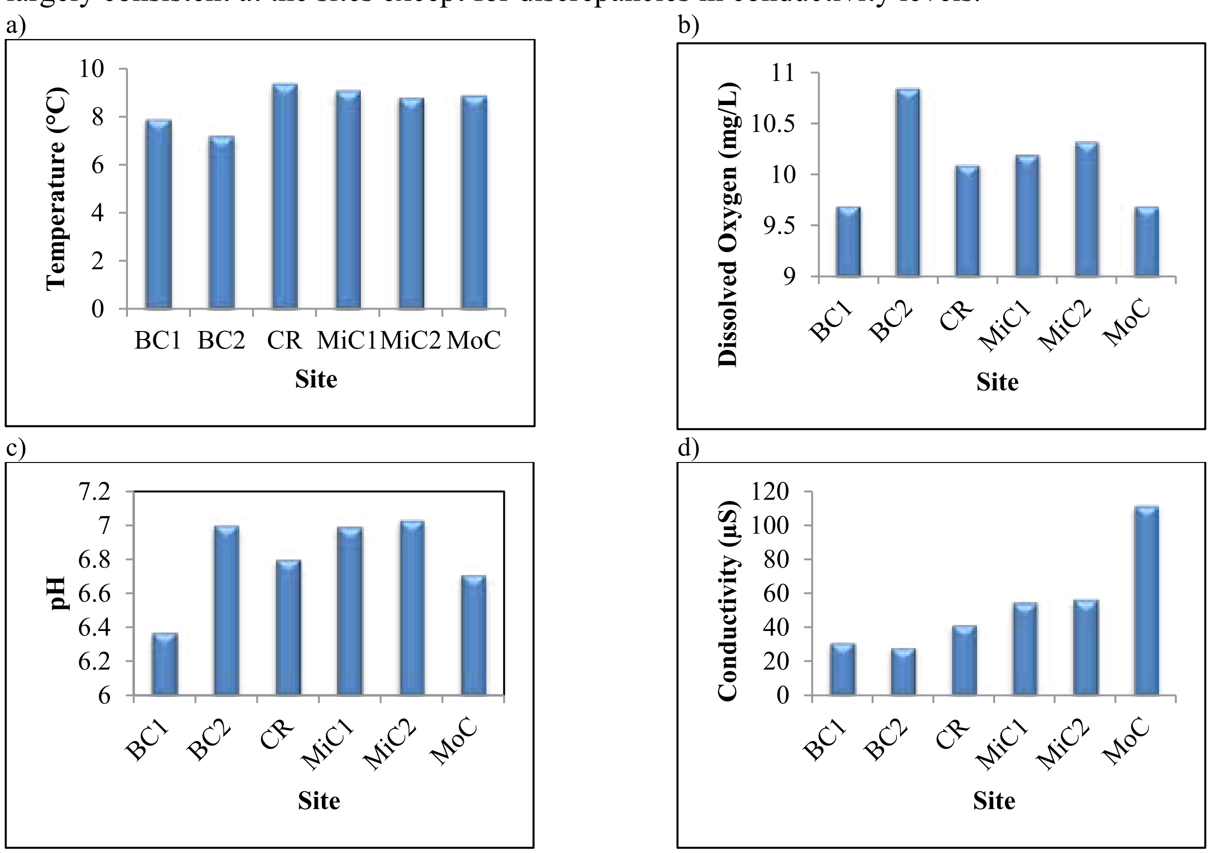

FIG.23. Comparisons of a) temperature, b) dissolved oxygen, c) pH, and d) conductivity by site.

Conductivity at Monger Creek was the greatest at 111.4 µS while Big Creek 1 and Big Creek 2 had the lowest values of 31.2µS and 28.2µS, respectively. Water temperatures ranged from 7.4°C at Big Creek 2 to 9.4°C at Cullasaja River. Big Creek 1 and Monger Creek shared the same dissolved oxygen level of 9.7mg/L. Cullasaja River, Mill Creek 1, and Mill Creek 2 shared similar values ranging from 10.1 to 10.33mg/L while Big Creek 2 had the highest dissolved oxygen level of 10.85mg/L. The lowest pH value of 6.37 was noted at Big Creek 1 and the highest pH value of 7.03 was found at Mill Creek 2. The other four sites had consistent pH ranging from 6.71 to 7.

TABLE 7. Field parameter results for all sites.

Site	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity	pH
BC1	7.9	9.7	31.2	6.4
BC2	7.2	10.9	28.2	7.0
CR	9.4	10.1	41.8	6.8
MiC1	9.1	10.2	54.8	7.0
MiC2	8.8	10.3	56.2	7.0
MoC	8.9	9.7	111.4	6.7

The results for nutrient levels and fecal coliform at all sites were within the acceptable range for ambient water quality standards. Turbidity values were between 1 and 2 Nephelometric Turbidity Units (NTU), which is well within the water quality standard in trout streams. All other tests showed values below the level of detection except for the Cullasaja River sampling site. At this site, Total Kjeldahl Nitrogen (TKN) was 0.26mg/L, and the phosphorous content was 0.02mg/L, possibly due to upstream sources of nutrients from golf courses.

DISCUSSION

Comparison with 2010 results

Aquatic invertebrates

The BI values of each site were consistent with the BI values found in the 2010 study, and the largest difference was only .46 lower at BC2. Furthermore, BC2 was once again the healthiest site evaluated according to BI value and diversity. Consistent with the 2010 data, MoC was the least healthy stream, but unlike the 2010 data MiC1 was tied with MoC. MiC1 also had a dramatic decrease in feeding group diversity, which is reflective of a decrease in stream health.

Physical

The total habitat assessment score shows a change from the results of the study done last year by Ahl et al. (2010). While the streams with the highest and lowest score remained the same, the score for BC2 decreased from 85 to 75, and the score for MoC increased from 49 to 57.) Last year, CR had the second lowest score while this year it has the third highest score.

The results for median particle size are significantly different than the median particle sizes from last year. Last year the median particle sizes for four of the six sites were less than 8mm. This year, all of the median particle sizes are greater than 11mm except for at the CR site (Ahl et al. 2010).

Active stream bank erosion is often a source of sand sized particles deposited within stream reaches. Historical deposition within floodplains will subsequently require the adjustment that causes the TFI to be increased when calculating the adjusted BEHI. Four of the six streams studied in the Upper Cullasaja watershed were adjusted because of the presence of sand sized particles indicating a higher potential for streambank erosion.

The results of the Wolman pebble count may be impacted by error because it was difficult to choose pebbles at random. In addition, most of the physical characteristic tests done were highly qualitative and based on observation more than quantitative tests. This results in room for error to occur because of different individuals collecting data.

Chemical

Compared to the 2010 study, the temperature was lower and the dissolved oxygen was higher. A consistent trend of lower temperatures and higher dissolved oxygen was noted across all sampling sites, which was most likely caused by the difference in timing of analysis between years. Chemical sampling took place on November 7, 2011 for this report, while the sampling for the 2010 report was carried out on September 20. The later sampling time for this report meant that atmospheric temperatures were lower, which likely accounts for a lower water temperature. The lower water temperature would result in a higher dissolved oxygen saturation level. Therefore, the difference between this report's findings and the 2010 report is likely expressing a seasonal change in ambient water conditions.

Big Creek 1

Aquatic invertebrates

BC1 had relatively high diversity of feeding groups and families of aquatic invertebrates. Only collectors were not represented at this site, while filterers and scrapers provided the majority. BC1 also had the highest number of mayflies (Ephemeroptera), which are intolerant to low pH values, but its pH value was only slightly different than the other sites. BC1 had a relatively low BI (good) value compared to the other sites, only BC2 was lower.

Physical

Based on the physical characteristics studied BC1 appears to be a moderately healthy stream when compared to the other sites in this study. The total habitat assessment score, BEHI, and adjusted BEHI ranked in the middle for each of these scores when looking at each site. The median particle size at BC1 was significantly smaller than at any other site. This may be because of sedimentation from streambank erosion, surrounding agricultural fields, and a small riparian zone width (the narrowest of all sites). Recent beaver activity along this section of stream reach has occurred during the study, and there is a possibility that the resulting changes in stream flow will alter stream health.

Chemical

Big Creek 1 showed the lowest measured pH of all the sampling sites, which was consistent with last year's findings, although it is still within ambient water quality standards. The temperature and the conductivity at this site were both the second lowest of all the sites, second only to the other site on Big Creek. This creek runs through a rural setting, and is less affected than other streams by urban runoff and impoundments. This site shared the lowest dissolved oxygen content with the Monger Creek site. The stretch of the stream immediately preceding the sampling site is devoid of riffles and has been impounded by beaver, both likely causes for the low oxygen concentrations.

Big Creek 2

Aquatic invertebrates

Based on an assessment of feeding group and family diversity, BC2 was the healthiest site evaluated. BC2 was the only site where all feeding groups were found, and it had by far the largest quantity of stoneflies (Plecoptera). Stoneflies are the most sensitive to sediment of the three orders examined, which is reflective upon BC2's health. Furthermore, this site had the lowest (good) BI value of all six sites due to the presence of large numbers of Pteronarcydae, a stonefly with a BI value of 0.

Physical

Overall, considering all of the physical characteristics studied, BC2 appears to be the healthiest reach examined. BC2 has the highest habitat assessment score of all six sites. In addition, BC2 has a high variation in substrate types. This variation fosters many types of habitats, as reflected by the high Habitat and Riffle Habitat scores. The high variation in substrate types and the large amounts of vegetative cover also protect stream bank stability. This is reflected by the low TFI and adjusted BEHI for this site. The stream reach monitored here is upstream of the current water intake plant for Highlands. This stream should be preserved first and foremost in order to maintain the current quality of the stream habitats and to protect the town's water source.

Chemical

Big Creek 2 is located upstream of a brick low-head dam and the upstream water supply intake for the town of Highlands. The site demonstrated the highest quality of all six sites with a pH of 7 and the highest dissolved oxygen value of 10.85 mg/L. Compared to the 2010 study, the pH has remained consistent; conductivity and temperature values decreased this year but dissolved oxygen experienced an increase, as expected due to seasonal variation.

Cullasaja River

Aquatic invertebrates

Relative to the other sites, Cullasaja had the third highest diversity in feeding groups represented, but this was only due to the presence of one additional type. In the study carried out in 2010, all feeding groups were represented at CR. Similar to the 2010 study, however, CR was dominated by filter feeders in the Trichopteran family Hydropsychidae. This extreme dominance is a result of the large amounts of algae and fine particulate organic material, likely due to the golf courses through which the river passes. CR had the third highest BI value of the six sites.

Physical

CR had the third highest habitat assessment score. The Substrate and Bank Stability scores at this site were the highest. The Riffle Habitat score at CR is the lowest of all stream sites. This may be because the reach monitored is bedrock dominated. In the pebble count a significant amount of bedrock samples were recorded causing CR to have the largest median particle size of all sites, also impacting the TFI and adjusted BEHI scores for this site. Altogether, the TFI and adjusted BEHI at this site classify this stream as having a moderate erosion risk. This reach of monitored stream is impacted by its proximity to Highway 64 and its sediment characteristics are likely altered as the stream flows through golf courses upstream of the reach examined.

Chemical

The Cullasaja River site is located downstream of golf courses and a number of impoundments which are exposed to direct sunlight. It is likely that this accounts for the higher water temperature, which was the warmest of all sampling sites. Dissolved oxygen was still well above the designated minimum, and the pH was within the appropriate range. TKN and phosphorous content were at elevated levels, although still within water quality standards. These higher values are possibly the result of fertilizer runoff from the golf courses upstream.

Mill Creek 1

Aquatic invertebrates

MiC1 showed relatively low feeding group and family diversity for aquatic invertebrates. The low diversity is evidence of the degradation of the stream. Additionally, MiC1 was tied for the highest BI value along with Monger Creek, and this reflects the poor health of the stream. The poor health is likely due to the large amount of urban runoff associated with the stream.

Physical

The total habitat assessment score was high for MiC1, the median particle size was moderate, and the BEHI was relatively low. MiC1 had the second highest habitat assessment score due to healthy Pool Variety, Riffle Habitat, and Riparian Zone Width. A high habitat assessment score may be the result of minimal human modifications to the stream. The most interesting of these results was the average particle size. The stream reach at MiC1 was noticeably bedrock dominated, but this physical characteristic does not match up with the pebble count results. While the median cumulative frequency in the substrate was not the lowest percentage among the six sites, it was lower than sites BC2 and CR which are sites that had much less bedrock. Ultimately, the particle size results do not seem to match up with the actual physical characteristics of MiC1. This inconsistency may be an indication that the observer does make a difference in the results, and different observers make have different techniques in collecting data. MiC1 has the second lowest TFI and adjusted BEHI and along with BC2 is one of two streams classified as having a low erosion risk. While the reach of this site receives about two-thirds of the town's runoff, has trails and the old wastewater treatment plant, the erosion risk remains low. This is probably because of the intact riparian buffer zone, limited intensity of human activity and bedrock prominence.

Chemical

Mill Creek 1 site is located adjacent to a previously used waste water treatment plant for the town of Highlands. There is a high amount of urban runoff, which, along with seasonality, could account for high temperature. In comparison with the 2010 study, the conductivity level recorded this year was significantly lower. Conductivity measurement noted was 54.8µS while the previous year had a level of 73µS. In 2010, Highlands received 0.73in of precipitation nine days prior to the date of data collection. This may not be a significant factor but may explain the increase in conductivity. The fecal coliform level was at 39, which was much lower than the 2010 value of 380, which was above ambient water quality standards. The change is either a result of temperature differences or seasonality of residential population in the watershed.

Mill Creek 2

Aquatic invertebrates

The data for aquatic invertebrates at MiC2 showed a low diversity in feeding group and family diversity. A majority of the specimens gathered at the site were filter feeders, suggesting an overabundance of fine particulate organic matter in the stream, but the site had the second largest number of stoneflies (Plecoptera), which are sensitive to sediment. The BI value for MiC2 was relatively average.

Physical

The total habitat assessment score for MiC2 is the third lowest of the stream sites. The subcategory scores for the habitat assessment at MiC2 are generally low and similar to the other streams; however, it has the second highest Substrate rating because of the high amounts of embedded gravel and cobble. The Substrate score aligns with the median particle size determined by the pebble count. The Riparian Zone Width subcategory score is moderate, but this measurement is skewed by the large difference between the right and left banks. The river left bank is highly developed while the river right bank has an intact riparian buffer throughout most of this reach. MiC2 has the second highest median particle size and the median can be classified as a large cobble. MiC2 is the only site with adjusted BEHI that is classified as having a high erosion risk. This is thought to be the result of a combination of factors including construction on the stream banks and the removal of most of the riparian zone on river left.

Chemical

The Mill Creek 2 site is located in a residential area close to downtown Highlands. All discrepancies in variables assessed can likely be attributed to seasonality except for conductivity data compared to data from last year. While specific conductance last year was 75µS it was 56.2µS this year. This change in ion levels in the water may have been affected by a precipitation event last year of 0.73in, though this is unlikely to be the main cause, as the precipitation event occurred nine days before testing.

Monger Creek

Aquatic invertebrates

Aquatic invertebrate sampling at MoC revealed that the creek had a BI value of 3.96, which was only .04 lower than the value recorded in 2010 and was tied with MiC1 for the highest (poor) BI value recorded. The high BI value for this creek was no surprise because it had the largest percentage (91%) of Hydropsychidae. Its poor water quality likely comes from the amount of urban runoff and altering of the stream along its entire corridor.

Physical

MoC has the lowest total habitat assessment score of all stream sites. Of the subcategories, MoC ranks the lowest for Habitat and Riffle Habitat and ties for having the second lowest scores for Substrate, Pool Variety, and Light Penetration, and has the second lowest subcategory score for Riparian Zone Width. The median particle size is the second lowest. While MoC has a significant amounts of small particles and bedrock, few particles are categorized as large gravel or cobble classes, reducing available habitat for colonization. MoC has the third highest TFI and second highest adjusted BEHI and both are classified as a moderate erosion risk. The TFI was adjusted at this site because of the amount of smaller gravel mixed with sand. This stream site is immediately behind the Highlands Creek Village Development which has impacted the stream. There was a significant amount of litter found within the stream and modifications by humans were obvious. Modification is the most obvious at the upstream end of the reach monitored.

Chemical

The Monger Creek site receives an abundance of stormwater and urban runoff from downtown Highlands, affecting the chemical variables measured. The specific conductance levels at this site were very high compared to other sites, likely because of urban runoff. The water temperatures at this site, which were slightly higher when compared to the five other sites, can also be attributed to higher temperatures of runoff waters. The low dissolved oxygen levels in Monger Creek indicate the unhealthy effects of polluted runoff input into the creek, possibly affecting biological factors in the river, though the DO values are still well above the 5.0mg/L threshold for freshwater aquatic life. Also, since temperature and dissolved oxygen are known to be inversely related, the waters of Monger Creek have a decreased capacity to hold dissolved oxygen compared to waters with lower temperatures.

Conclusion

Data obtained during the investigation of water quality in the Upper Cullasaja Watershed indicate impairment in many of the stream reaches examined. Most notable and critical are the effects of the discharge of urban stormwater from the Highlands central business district to Mill and Monger Creeks. Further investigation of these and other water quality concerns is warranted as is the inclusion of additional sites in any future study.

While the data obtained are indicative of impairment, there are a number of limitations and potential sources of error associated with the assessment techniques utilized. Some of the error can be resolved by additional training while other aspects can benefit by consistency between observers. Additional information could be obtained by broadening the scope of the study to include stormwater sampling and seasonal baseline water quality monitoring.

Additional benefit could also be gained through the selection of additional stream reaches for evaluation. The reaches examined in the course of this study were selected due to access and to compare against data obtained in 2010. If this study is to be repeated, a close look at the number and location of sites selected would be beneficial.

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