TECHNICAL AND EDUCATIONAL ASPECTS OF STREAM BIOMONITORING PROTOCOLS FOR TEACHERS AND CITIZEN MONITORS IN ALABAMA

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TECHNICAL AND EDUCATIONAL ASPECTS OF STREAM BIOMONITORING PROTOCOLS FOR TEACHERS AND CITIZEN MONITORS IN ALABAMA

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A Thesis

Submitted to

the Graduate Faculty

of Auburn University

in Partial Fulfillment of the

Requirements for the

Degree of

Master of Science

Auburn, Alabama
17 December 2007

TECHNICAL AND EDUCATIONAL ASPECTS OF STREAM

BIOMONITORING PROTOCOLS FOR TEACHERS

AND CITIZEN MONITORS IN ALABAMA

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THESIS ABSTRACT

TECHNICAL AND EDUCATIONAL ASPECTS OF STREAM

BIOMONITORING PROTOCOLS FOR TEACHERS

AND CITIZEN MONITORS IN ALABAMA

Jennifer Lough Fuller

Master of Science, 17 December 2007
(B.S., Columbus State University, 2005)

125 Typed Pages

Directed by William G. Deutsch

Accuracy of the Alabama Water Watch (AWW) Stream Biomonitoring Protocol for citizen monitors was assessed through a desktop study comparing simulated AWW stream quality assessments to known professional bioassessments. Additional citizen methods researched were the Choctawhatchee Riverkeepers, the Georgia Adopt-A-Stream, and the Connecticut Department of Environmental Protection volunteer macroinvertebrate protocols. Simulated protocol accuracy for all four citizen methods compared to professional stream biologists ranged from about 35 to 53%. AWW protocol accuracy was increased from about 35% to 60% through strategic modifications to the AWW Stream Biomonitoring Protocol. All but 5% of inaccurate simulated assessments with the modified AWW protocol were within one stream quality category difference (i.e., categories: excellent, good, fair, poor).

An educational curriculum for secondary (middle and high school) science teachers and their students, based on the AWW Stream Biomonitoring Protocol was developed concurrently, piloted, and implemented to address nonpoint source pollution in Alabama. Science Education students from a local university and AWW volunteer monitoring groups were connected with classrooms for curriculum implementation. The curriculum was piloted in ten classrooms in Alabama over a two-year period. The final curriculum, *Alabama's Living Streams: Stream Biomonitoring* was presented to about 75 educators through four aquatic science workshops held jointly by AWW staff and multiple natural resource educators. Project evaluation suggested the curriculum provided an avenue for overcoming inadequate teacher training in aquatic science and water quality while creating a valuable community support network for educators.

ACKNOWLEDGEMENTS

First and foremost I thank God, the ultimate scientist, for ordaining my path in space and time such that I was able to take part in this research. Secondly, I would like to thank my parents, Rob and Anne Lough, for instilling in me as a child a sense of wonder and awe for creation, and fostering an atmosphere of respect and stewardship for all created things. I would like to thank my committee members for the wisdom, guidance, and patience offered throughout this project. Thank you also to the Alabama Water Watch staff, for bountiful words of encouragement. To Eric Reutebuch and Mark Carpenter for selflessly spending volunteer hours to help with computer programming and statistical analysis, thank you. To my husband Michael, for the many hours spent playing "Mr. Mom" so I could study and write: I couldn't have done this without you rooting for me with practical and emotional support. And last, but in no way least, heart felt gratitude goes to my two boys Eli and Ben, for many interruptions in my work that was instrumental in keeping the big picture before me. This thesis is dedicated to you and your generation, and the many generations to come that will require clean, healthy waters. May the water you drink and the rivers you fish and swim be in better condition than when they were for previous generations and me.

Style manual or journal used: Journal of the North American Benthological Society

Computer software used: Microsoft Word, Microsoft Excel, SAS Program Version 9.1

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INTRODUCTION

"Stewardship is the responsible use (including conservation) of natural resources in a way that takes full and balanced account of the interests of society, future generations, and other species, as well as of private needs, and accepts significant answerability to society" (Worrell and Appleby 2000).

The Clean Water Act (CWA), passed in 1972 by the United States (US) Congress, is the primary legislation protecting water quality in the US. After passage, water quality impairments were largely "remedied" based on specific waterbody segments impacted by point source pollution such as municipal wastewater and industrial discharge. This helped make vast improvements in water quality but has had little affect on nonpoint source (NPS) pollution (USEPA 1991a, USEPA 1996). NPS pollution comes from diffuse sources like urban storm water runoff, or runoff containing sediments and pesticides from agricultural operations (Bennett et al. 2004, Carpenter et al. 1998, Karr 1991, Karr 1999, Novotny 2003, USEPA 1996). This type of pollution was recognized in the original Clean Water Act, but largely overlooked (Karr 1991, Novotny 2003).

Formal federal recognition of the need to address NPS pollution came when the CWA was reauthorized in 1987 (Novotny 2003). The United States Environmental Protection Agency (USEPA) followed with "The Watershed Protection Approach: An Overview" (USEPA 1991a). The USEPA recognized the need for "non-conventional, cost-effective" ways to reduce NPS pollution, as well as methods for locating areas where remediation efforts would have the most impact. The watershed approach suggested that government agencies, private organizations, and citizen stakeholders work in an integrated manner to address water quality conditions in local watersheds. While the USEPA noted in this document that watershed management was not a new concept, it's use at the time was limited (USEPA 1991a). The federal government further called on the states to adopt the watershed approach for continued water quality improvement.

NPS pollution is recognized as the primary cause of existing water quality issues in the US (Carpenter et al. 1998, USEPA 2003, Potter et al. 2004). The nature of NPS pollution makes it difficult to quantify and address, and all citizens are contributors. This suggests citizens should be aware of and involved with local water quality issues as part of the solution. The Watershed Approach Framework (USEPA 1996) explicitly states this idea. The Watershed Approach Framework calls on local, state, and federal agencies in the U.S. to, "…fully engage…users of watershed resources, environmental groups, and the public in the watershed management process to help them better understand the problem, identify and buy into goals, select priorities, and choose and implement solutions" (USEPA 1991a).

The basin approach to water quality management places citizens in a unique role in this new era of stakeholder involvement. In 2007, the USEPA released the "Wadeable Streams Assessment: A Collaborative Survey of the Nation's Streams". The document was the first of it's kind in the US; a "statistically defensible summary of the condition of the nation's streams and small rivers" (Paulsen et al. 2007). It was a multi-year collaborative study between a number of federal and state agencies, universities, and tribes. The biological health of our nation's streams and rivers was assessed using benthic aquatic macroinvertebrates as indicator species in a technique called bioassessment, or stream biomonitoring. Results indicated 42% of our nation's streams and rivers were in poor condition, 25% were in fair condition, and 28% were in good condition (5% not assessed). The two most common stressors observed were excess nutrients, primarily nitrogen and phosphorus, and sediments, (Paulsen et al. 2007).

Stream biomonitoring as a form of evaluating stream health has been around for decades (Hilsenhoff 1977, Hilsenhoff 1987, Firehock and West 1995, Karr 1997, Wilhm and Dorris 1968). A memorandum of final policy on biological assessments came from the USEPA office in 1991 (USEPA 1991b). The USEPA urged states to incorporate biological assessments into state water quality programs. The role of the USEPA was to set national baseline criteria for water quality, but the uniqueness of aquatic ecosystems made it necessary for the states to take a lead role in defining specific standards (USEPA 1991b). The development of ecoregion baselines, or references conditions, followed.

An ecoregion is an area of land exhibiting similar abiotic features such as geology and climate so that biological attributes of that ecoregion, independent of human activity, are expected to be similar (Barbour et al. 1999, Karr 1991, Karr 1999, Novotny 2003, Paulsen et al. 2007). Critical to determining appropriate water quality standards is an understanding of baseline conditions within a given ecoregion (Barbour et al. 1999, Karr 1997, Karr 1999, Paulsen et al. 2007, USEPA 1991b). This allowed states to determine, among other things, realistic expectations for stream quality restoration. Routine bioassessments could then be compared to ecoregional reference conditions and stream quality determined.

The rational for including aquatic macroinvertebrate monitoring in state water quality programs was strong. Biological health is often indicative of ecosystem health (Karr 1999, USEPA 1991b). Macroinvertebrates are affected by not only point source pollution, but habitat degradation and NPS pollution involving multiple stressors (Klemm et al. 2003, USEPA 1991b). Most aquatic macroinvertebrates live the majority of their life cycle within a particular stream segment. They are relatively immobile in that weak locomotive structures confine them to small areas. Unlike fish they cannot move out of a stream reach (a section of stream) if water quality conditions deteriorate, except through current drift. Aquatic macroinvertebrates can be abundant in ecosystems. These organisms behave predictably with defined life cycles and sensitivity to pollution. Therefore the presence or absence of certain groups of macroinvertebrates reflects conditions that have been occurring over months and even years (Barbour et al. 1999, Engel and Voshell 2002, Karr 1999, Klemm et al. 2003, Novotny 2003, Paulsen et al. 2007, USEPA 1991b, Wilhm and Dorris 1968).

The science behind biological water quality assessment using benthic macroinvertebrates has been researched among public and private researchers throughout the last few decades. Journals such as *Freshwater Biology*, *Ecological Applications*, and the *Journal of the North American Benthological Society* have published scores of articles on aquatic macroinvertebrates and bioassessment ranging from classification of taxa to taxa tolerance values to testing methodologies. Early researchers calling for the inclusion of biological criteria and biomonitoring into national water quality assessment guidelines and/or responsible for providing key advancements in the science include Wilhm and Dorris (1968), Hilsenhoff (1977, 1987, 1988), Lenat (1988), and Karr (1991, 1999). Karr's 1991 article, *Biological Integrity: A Long-Neglected Aspect of Water Resource Management*, offers a particularly informative review of the history of biomonitoring and challenges needing to be addressed, many still faced today.

In the US, standard methods used for federal and state water quality programs have been established by the USEPA in the Rapid Bioassessment Protocols (RBP's) for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (Barbour et al. 1999). The consistency in methodology allowed for the Wadeable Streams Assessment to take place nationally and with statistically defensible results. Citizen volunteer water quality monitoring groups in the US have also adopted the RBP's. Groups such as the Isaak Walton League (Firehock and West 1995), the River Network (Dates and Byrne 1997), and Alabama Water Watch (https://aww.auburn.edu/) have promoted a simplified version of the RBP's for citizens wishing to use aquatic macroinvertebrates to monitor water quality in their local watersheds.

Stream biomonitoring offers citizen monitors a low-cost way to monitor watersheds while promoting awareness of the ways citizens contribute to NPS pollution. Alabama Water Watch (AWW), a statewide volunteer monitoring group in Alabama, uses this approach through their AWW Stream Biomonitoring Protocols. Increased use of bioassessment among citizen monitors is noted in the Wadeable Streams Assessment as one of several reasons why the technique was chosen for a nationwide water quality comparison (Paulsen et al. 2007). Nerbonne and Nelson (2004) conducted a survey assessing the structure of volunteer macroinvertebrate monitoring groups and their involvement with local and state governments. Results showed groups vary in size and goals, but primarily existed to track environmental changes in local watersheds. The same study surveyed national and state level leaders, reporting that agencies believed volunteer macroinvertebrate monitors increased the community's interest in local issues and promoted greater participation in government policy. They also reported many government agencies thought citizen data were useful and could be incorporated into local and state databases. The main concern voiced was validity of citizen data; making sure data collected and reported was quality assured (Nerbonne and Nelson 2004).

Citizen involvement is perhaps our greatest ally for combating NPS pollution. Stream biomonitoring for citizens can be a valuable education tool for volunteer monitors and educators alike. The USEPA's Volunteer Stream Monitoring: A Methods Manual (Dohner et al. 1997) describes how to design and implement a stream study, detailing citizen training, data management, and quality assurance. As in other USEPA documents promoting collaboration among stakeholders within watersheds, it encouraged citizen groups to work closely with local and state reporting agencies to maximize quality controlled data collection (Dohner et al. 1997).

Volunteer monitors can provide not only support for state water quality agencies, but also locally relevant, sound science for classrooms in their communities. Two studies in the Journal of Environmental Education (Vaughan et al. 2003, Volk and Cheak 2003) documented the transfer of conservation information from the classroom to the community via children participating in integrated environmental education programs in Costa Rican and Hawaiian communities. Both studies reported an increased awareness for environmental issues leading to behavior changes among community members with children directly involved in the programs (Vaughan et al. 2003, Volk and Cheak 2003). Hawaiian researchers additionally noted an increase in environmental issue awareness among community members without children involved, that was attributed to a community activism component their program (Vaughan et al. 2003).

The incorporation of biological assessments into state monitoring programs coupled with active citizen groups makes stream biomonitoring a potentially useful and powerful technique for changing public behavior in the arena of NPS pollution abatement. Two key components for citizen monitors working with science classrooms would be (1) to ensure valid data and techniques are used and (2) to create an avenue for citizen to classroom interactions that are feasible and useful for the educator. One of two research objectives for this study was to evaluate the frequency with which Alabama Water Watch (AWW) Stream Biomonitoring Protocols for citizen volunteer monitors obtain comparable water quality assessments as that found by stream biologists. Problematic issues with current AWW citizen protocol, such as taxonomic resolution and methodology, were addressed to produce a modified AWW protocol with greater potential to provide accurate data. A second research objective was to evaluate the receptivity and desire among Alabama educators to partner with local AWW citizen monitors in conveying NPS water pollution issues to Alabama youth. The teaching mechanism was an aquatic science curriculum modeled after the AWW Stream Biomonitoring Protocol, coupled with a streamside bioassessment performed by students, teachers, and citizen monitors.

CHAPTER 1

TECHNICAL ASPECTS OF STREAM BIOMONITORING IN ALABAMA

"Properly trained volunteers can extend our knowledge of current stream conditions by sampling more sites than professionals may have resources for. Because they have a personal interest in their local catchments, volunteers are ideal candidates to monitor streams and watch for changes" (Fore et al. 2001).

Introduction

Citizen collected water quality data has become a valuable asset to many state regulatory agencies. Citizens have the ability to collect data on smaller streams where time and resources may not allow for agency sampling. Collected over time, citizen data can demonstrate baseline conditions and identify areas where potential problems exist (Engel and Voshell 2002, Firehock and West 1995, Fore et al. 2001, O'Leary et al. 2004, Penrose and Call 1995). Two general categories of citizen volunteer water quality groups are: (1) those that report data directly to their state's water quality agency, and (2) those that collect data primarily for awareness and environmental education (Nerbonne and Nelson 2004). However, a number of groups, demonstrating a hybrid of the two categories exists, as noted in a national survey of citizen volunteer macroinvertebrate monitoring groups made by Ely (2005).

Alabama Water Watch (AWW), a statewide network of citizen volunteer water quality monitors in existence since 1992, could be considered a hybrid organization. AWW has collected over 49,000 water quality records on over 750 waterbodies using primarily chemical and bacteriological protocols with Environmental Protection Agency (USEPA) and Alabama Department of Environmental Management (ADEM) approved Quality Assurance/Quality Control (QA/QC) plans (Deutsch and Busby 1999, Deutsch and Estridge 2004). Data has been reported and maintained in an extensive public database routinely accessed by ADEM (Lynn Sisk, ADEM Chief of the Water Quality Branch, personal communication, 27 Aug 2007), the Alabama agency responsible for collecting water quality data to implement and enforce the CWA. The AWW database has been described as one of the best in the nation for citizens (Lynn Sisk, ADEM Chief of the Water Quality Branch, personal communication, 27 Aug 2007). Sisk and colleague Fred Leslie, ADEM Chief of Field Operations in Montgomery, note that long-term availability of data through the AWW database is a valuable asset to ADEM. Database information is used by ADEM to corroborate agency data, analyze historical trends in locations of interest, and in the Integrated Water Quality Report, a biennial state water quality report (USEPA 2007).

Biological assessments of aquatic macroinvertebrates, or stream biomonitoring, are commonly used by ADEM as part of a comprehensive water quality assessment plan in addition to chemical and bacteriological monitoring. AWW citizen biomonitoring data is available for use by ADEM, in a limited capacity. AWW biomonitoring protocol lacks a USEPA and ADEM approved QA/QC plan and data are sparse, representing about 275 of over 49,000 AWW data records (https://fp.auburn.edu/icaae/awwstats.aspx, accessed 6

Oct 2007). According to ADEM representatives, the less intensive surveys used by citizen volunteers seldom give a complete picture of stream conditions and what is affecting those conditions (Lynn Sisk, ADEM Chief of the Water Quality Branch, and Fred Leslie, ADEM Chief of Field Operations in Montgomery, personal communication, 27 Aug 2007).

AWW volunteers use a commonly accepted streamside biomonitoring technique similar to the Izaak Walton League of America's Save Our Streams protocol (Firehock and West 1995). Citizens receive a six-hour training workshop split between reviewing the protocol and a field bioassessment. The protocol requires citizens to collect about 100 organisms from a typical stream riffle and note whether taxa were rare, common, or abundant (Figure 1). Taxa are identified primarily to Order and grouped into one of three categories based on pollution tolerance. Group 1 organisms are sensitive to pollution, Group 2 are moderately tolerant, and Group 3 are tolerant of pollution. Weighted index values for each group, designed to give increasing weight to more sensitive organisms, are summed to generate the Cumulative Index Value (CIV). The CIV is then used to make a stream quality assessment of excellent, good, fair, or poor. ADEM uses a multi-habitat, multi-metric index described in the USEPA Rapid Bioassessment Protocols (RBP's) for Use in Wadeable Streams and Rivers (Barbour et al. 1999, ADEM 1992).

Accurate and reliable biological data remains one of the greatest challenges to regulatory use of citizen data by state agencies (Fore et al. 2001, Penrose and Call 1995). One problem is the taxonomic resolution of citizen data compared to agency or professional data (Dr. E. Cliff Webber, retired Research Fellow, Auburn University, personal communication, 28 Aug 2007). Citizen biomonitoring protocols such as that of

AWW typically identify organisms to Order or suborder, with a few taxa identified to Family. In contrast, professional macroinvertebrate surveys involve taxa identification to the lowest taxonomic level possible, usually genus or species.

ALABAMA WATER WATCH
STREAM BIOMONITORING DATA FORM

☐ online

Group Name:____

Collector(s): ____________________ Address:____________________

City:________________ State:______ Zip:______ Phone #: __________

Sample Date:____________ Sample Time:______ AWW Site Code: __________

Watershed: __________ Waterbody:____________ County & State:________

Sampling site location: ____________________________________
(Notify the AWW office about any changes in sampling site location.)

Waterbody condition: ☐ Adequate Depth ☐ Inadequate Depth ☐ Dry ☐ No Access

Tidally influenced streams and rivers: ☐ Rising Tide ☐ Falling Tide ☐ Uncertain

Group I Taxa	Letter Code *	Group II Taxa	Letter Code *	Group III Taxa	Letter Code *
Stonefly		Dragonfly		Midge	
Mayfly		Damselfly		Aquatic Worm	
Caddisfly		Cranefly		Leech	
Riffle Beatle		Blackfly		Pouch Snail***	
Water Penny Beetle		Filtering Caddisfly**			
Snail		Hellgramite			
		Scud			
		Sowbug			
		Crayfish			
		Asiatic Clam			
Number of Taxa= ______		Number of Taxa= ______		Number of Taxa= ______	
Multiply by 3 = ______ (Index Value)		Multiply by 2 = ______ (Index Value)		Multiply by 1 = ______ (Index Value)	

* **Letter Code**: **R** = 0 to 3 (Rare); **C** = 4 to 9 (Common); **A** = 10 or more (Abundant)

** Filtering Caddisflies are in the Family Hydropsychidae (gills on abdomen; common caddisfly)
*** Pouch snails are in the Family Physidae (shell opens to the left; air-breathing snail)

STREAM BIOTIC INDICES		STREAM QUALITY ASSESSMENT (*Check box corresponding to Cumulative Index Value*)			
Total Number of Taxa (*Sum of Number of Taxa in each group*)	☐	**POOR** <11	☐	**FAIR** 11-16	☐
Cumulative Index Value (*Sum of Index Values for each group*)	☐	**GOOD** 17-22	☐	**EXCELLENT** >22	☐

Page 1 of 2

Figure 1. Stream biomonitoring protocol used by Alabama Water Watch, a statewide citizen volunteer monitoring organization in Alabama.

Further discrepancies are complexity of assessment and sampling location within a stream. Citizen protocols are often based on presence or absence or organisms grouped by pollution tolerance sensitive, moderately tolerant, and tolerant. Protocols used by stream biologists generally use numerous metrics, such as taxa richness and % tolerant organisms, that evaluate ecological characteristics of the macroinvertebrate assemblage (Barbour et al. 1999, Karr 1999). Citizens commonly sample in riffle habitat, which tends to have higher biodiversity than other stream habitats such as pools or root wads along undercut banks. Riffles are sections of the stream ecosystem characterized by relatively shallow, turbulent and highly oxygenated waters. Stream biologists typically sample all available habitats according to standard USEPA protocols (Barbour et al. 1999).

A number of studies have addressed the accuracy of citizen biomonitoring protocols, although none in Alabama. Penrose and Call (1995) reported three state studies (North Carolina, Ohio, Connecticut) that compared citizen protocols and professional techniques. A Family-level Biotic Index (FBI) was used in the North Carolina study. The FBI has historically been used as an indicator of organic pollution in waterways (Hilsenhoff 1988) and is a metric detailed in standard methods (Barbour et al. 1999). Using the FBI, citizens were able to obtain similar qualitative assessments as professionals, and consistently underestimated stream health when discrepancies occurred (Penrose and Call 1995). Similar Family level identification results were reported by O'Learhy et al. (2004) and Fore et al. (2001). Citizens in the Ohio study used a protocol like AWW. Agreement between citizens and professionals ranged from 58% to 67%. Only one site was assessed in Connecticut where trained citizens used a multi-metric approach similar to the RBP's (Barbour et al. 1999, Penrose and Call 1995) and were able to reach the same conclusion as professionals. Citizens in these studies received limited training, involving one or several training sessions prior to sampling. All studies had citizens sample in riffles only.

A study that examined Virginia Save Our Streams (SOS) found that volunteer and professional agreements as high as 96% could be obtained with a streamside multi-metric index and qualitative assessment of acceptable or unacceptable water quality (Engel and Voshell 2002). Winn et al. (2005) in Georgia showed moderate agreement between citizen and stream biologist protocols. Both methods detected a similar number of excellent and good sites, but citizens rated a higher number of sites poor than did stream biologists. Multiple habitats were sampled for these studies. Finally, Boward (2005) in a Maryland study conducted with citizen volunteers from Maryland Stream Waders (MSW) demonstrated 83% agreement in water quality assessments between citizens and professionals based on a Family-level Biotic Index (FBI). However state biologists helped with the macroinvertebrate identifications (Boward 2005). All studies worked primarily with citizens historically using volunteer macroinvertebrate protocols to assess stream quality.

Several studies have addressed whether sampling in riffles versus all habitats provided the more accurate water quality assessment. A survey of US mid-Atlantic streams using multiple metrics found higher water quality scores in upland riffle versus upland pools, but little difference in score for lowland riffles versus lowland pools. The study also demonstrated that when sampling only in the dominant habitat, whether it was pool or riffle, consistent discrimination between reference and impaired sites could be achieved (Klemm et al. 2003). Gerth and Herlihy (2006) conducted a mid-Atlantic study and found that although assemblage characteristics differed depending on type of habitat sampled, the overall water quality assessments were consistently similar whether considering riffle only collections or multi-habitat collections. A study in California on 193 macroinvertebrate surveys detected slight differences in assessments made in riffle only versus multi-habitat collections (Rehn et al. 2007). Karr (1999) suggested riffle samples were sufficient to make accurate water quality assessments.

Of particular interest in Alabama is how well citizen protocols perform across the state in terms of ecoregion. Alabama is divided roughly in half by the Fall Line, or the geographic separation between the coastal plain region (Southeastern Plains and Southern Coastal Plains USEPA Level III Ecoregions) and the upper regions (Interior Plateau, Southwestern Appalachians, Ridge and Valley, and Piedmont Ecoregions) (Griffith et al. 2001). The typically slower, low-gradient streams characteristic of coastal plain regions usually lack true rocky-bottom riffles commonly found above the Fall Line. Riffles occur in the coastal plain, but tend to be caused by submerged vegetation and log jams. This raises the question of limiting citizens to riffles in the coastal plain streams.

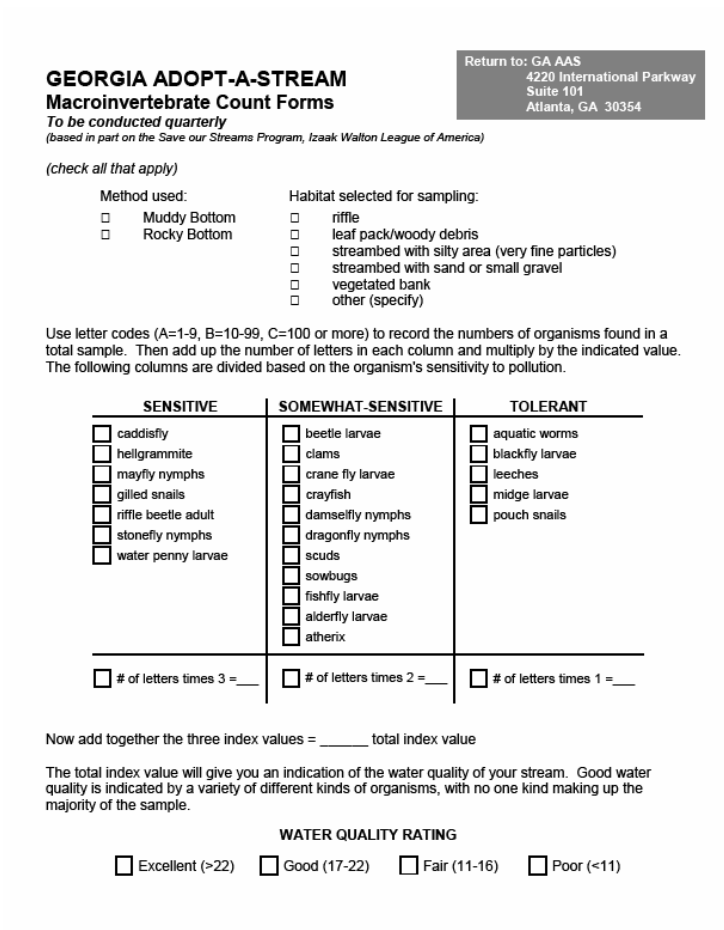
Based on case studies cited earlier, citizen protocols are capable of reaching similar water quality assessments compared with professionals. However protocol differences coupled with confidence in citizen macroinvertebrate identification may still cause skepticism for many state agencies. It was desirable for the AWW Stream Biomonitoring Protocol to carry a USEPA and ADEM approved QA/QC plan. One major focus of this study was to evaluate AWW stream quality assessments compared to professional macroinvertebrate surveys. First, the accuracy of the current AWW protocol was evaluated depending on whether the sample came from a riffle verses all habitats.

Second, the AWW protocol performance was evaluated compared to professional assessments for streams located above and below the fall line. One component of this study also evaluated the feasibility of developing an accurate streamside protocol within the existing AWW framework using higher taxonomic resolution than currently used. A Modified AWW Protocol was then developed based on research conclusions.

Three additional citizen protocols were examined along with the AWW protocol: Choctawhatchee Riverkeepers (CRK) (Collins et al. 2003), Georgia Adopt-A-Stream (GAAS 2006a), and Connecticut Department of Environmental Protection (CDEP 2005) volunteer protocol. CRK, an AWW group located in the coastal plain, made slight modifications to the AWW protocol based on years of field observations in the coastal plain region of Alabama (Table 1). GAAS protocols were of special interest due to common ecoregions shared by Alabama and Georgia. GAAS placed organisms in slightly different pollution tolerance groups than the AWW protocol (Figure 2). Placement variation could provide a closer approximation to stream quality as assessed by stream biologists. CDEP developed a citizen biomonitoring protocols that characterized macroinvertebrates as Most Wanted, Moderately Wanted, Least Wanted, and Others (Figure 3). Aquatic macroinvertebrates chosen as Most Wanted were pollution sensitive, widespread in undisturbed Connecticut streams and readily identified by trained volunteers. Stream quality assessment categories were exceptional, excellent, very good, or needs more data. A similar protocol using pollution-sensitive aquatic macroinvertebrates found in Alabama was developed and evaluated in this study.

Table 1. Alterations made to the Alabama Water Watch Stream Biomonitoring Protocol by Choctawhatchee Riverkeepers, a coastal plain volunteer monitoring group in Alabama. Group 1: pollution sensitive, Group 2: somewhat pollution tolerant.

Alabama Water Watch	Choctawhatchee Riverkeepers
All mayflies (Order Ephemeroptera) in Group 1	All mayflies (Order Ephemeroptera) in Group 2 except for the Family Baetiscidae, which remained in Group 1
Riffle beetles (Family Elmidae) placed in Group 1	Riffle beetles (Family Elmidae) placed in Group 2
Cumulative Index Value scale: > 22 Excellent 17 – 22 Good 11 – 16 Fair < 11 Poor	Cumulative Index Value scale: > 25 Excellent 20 – 25 Good 15 – 19 Fair 8 – 14 Poor < 8 Very Poor



GEORGIA ADOPT-A-STREAM
Macroinvertebrate Count Forms
To be conducted quarterly
(based in part on the Save our Streams Program, Izaak Walton League of America)

Return to: GA AAS
4220 International Parkway
Suite 101
Atlanta, GA 30354

(check all that apply)

Method used:
- ☐ Muddy Bottom
- ☐ Rocky Bottom

Habitat selected for sampling:
- ☐ riffle
- ☐ leaf pack/woody debris
- ☐ streambed with silty area (very fine particles)
- ☐ streambed with sand or small gravel
- ☐ vegetated bank
- ☐ other (specify)

Use letter codes (A=1-9, B=10-99, C=100 or more) to record the numbers of organisms found in a total sample. Then add up the number of letters in each column and multiply by the indicated value. The following columns are divided based on the organism's sensitivity to pollution.

SENSITIVE	SOMEWHAT-SENSITIVE	TOLERANT
☐ caddisfly	☐ beetle larvae	☐ aquatic worms
☐ hellgrammite	☐ clams	☐ blackfly larvae
☐ mayfly nymphs	☐ crane fly larvae	☐ leeches
☐ gilled snails	☐ crayfish	☐ midge larvae
☐ riffle beetle adult	☐ damselfly nymphs	☐ pouch snails
☐ stonefly nymphs	☐ dragonfly nymphs	
☐ water penny larvae	☐ scuds	
	☐ sowbugs	
	☐ fishfly larvae	
	☐ alderfly larvae	
	☐ atherix	
☐ # of letters times 3 =___	☐ # of letters times 2 =___	☐ # of letters times 1 =___

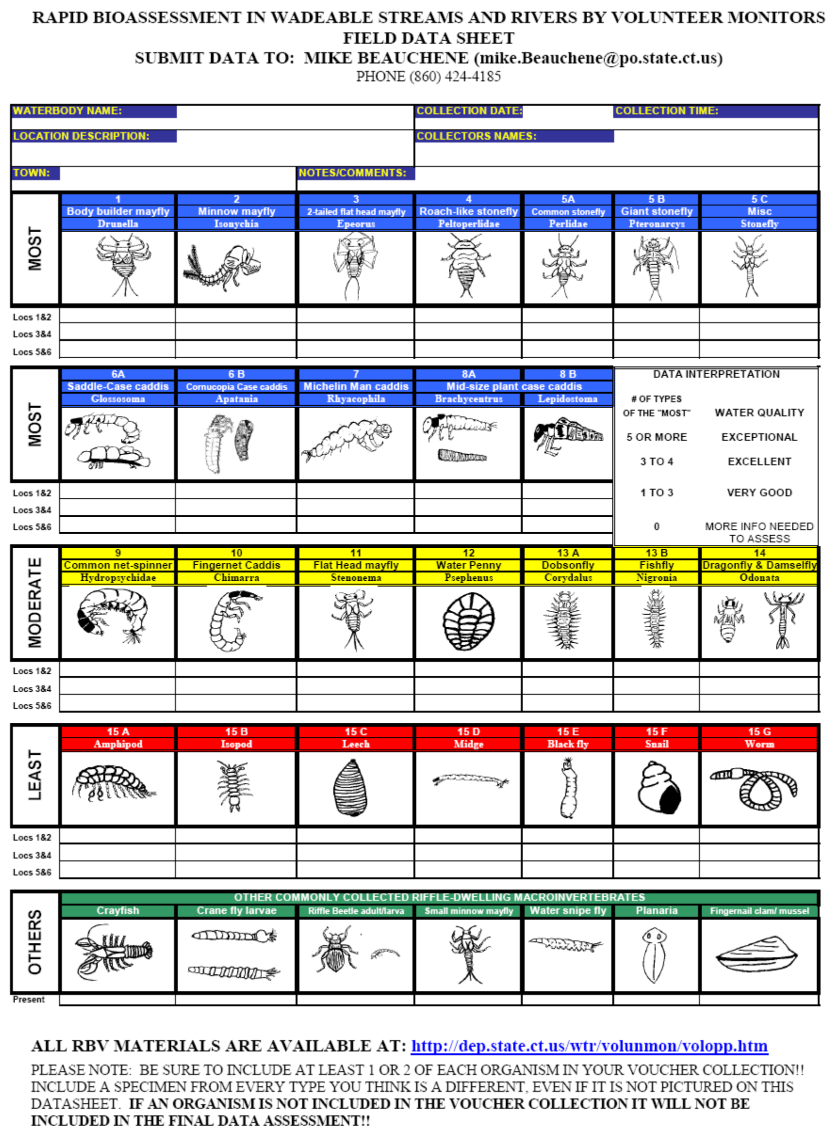
Now add together the three index values = ______ total index value

The total index value will give you an indication of the water quality of your stream. Good water quality is indicated by a variety of different kinds of organisms, with no one kind making up the majority of the sample.

WATER QUALITY RATING

☐ Excellent (>22) ☐ Good (17-22) ☐ Fair (11-16) ☐ Poor (<11)

Figure 2. Stream biomonitoring protocol used by Georgia Adopt-A-Stream, a statewide citizen volunteer monitoring organization in Georgia.


RAPID BIOASSESSMENT IN WADEABLE STREAMS AND RIVERS BY VOLUNTEER MONITORS
FIELD DATA SHEET
SUBMIT DATA TO: MIKE BEAUCHENE (mike.Beauchene@po.state.ct.us)
PHONE (860) 424-4185

WATERBODY NAME: | COLLECTION DATE: | COLLECTION TIME:
LOCATION DESCRIPTION: | COLLECTORS NAMES:
TOWN: | NOTES/COMMENTS:

MOST
1 Body builder mayfly Drunella | 2 Minnow mayfly Isonychia | 3 2-tailed flat head mayfly Epeorus | 4 Roach-like stonefly Peltoperlidae | 5A Common stonefly Perlidae | 5 B Giant stonefly Pteronarcys | 5 C Misc Stonefly
Locs 1&2
Locs 3&4
Locs 5&6

MOST
6A Saddle-Case caddis Glossosoma | 6 B Cornucopia Case caddis Apatania | 7 Michelin Man caddis Rhyacophila | 8A Mid-size plant case caddis Brachycentrus | 8 B Lepidostoma
Locs 1&2
Locs 3&4
Locs 5&6

DATA INTERPRETATION

# OF TYPES OF THE "MOST"	WATER QUALITY
5 OR MORE	EXCEPTIONAL
3 TO 4	EXCELLENT
1 TO 3	VERY GOOD
0	MORE INFO NEEDED TO ASSESS

MODERATE
9 Common net-spinner Hydropsychidae | 10 Fingernet Caddis Chimarra | 11 Flat Head mayfly Stenonema | 12 Water Penny Psephenus | 13 A Dobsonfly Corydalus | 13 B Fishfly Nigronia | 14 Dragonfly & Damselfly Odonata
Locs 1&2
Locs 3&4
Locs 5&6

LEAST
15 A Amphipod | 15 B Isopod | 15 C Leech | 15 D Midge | 15 E Black fly | 15 F Snail | 15 G Worm
Locs 1&2
Locs 3&4
Locs 5&6

OTHERS
OTHER COMMONLY COLLECTED RIFFLE-DWELLING MACROINVERTEBRATES
Crayfish | Crane fly larvae | Riffle Beetle adult/larva | Small minnow mayfly | Water snipe fly | Planaria | Fingernail clam/ mussel
Present

ALL RBV MATERIALS ARE AVAILABLE AT: http://dep.state.ct.us/wtr/volunmon/volopp.htm

PLEASE NOTE: BE SURE TO INCLUDE AT LEAST 1 OR 2 OF EACH ORGANISM IN YOUR VOUCHER COLLECTION!! INCLUDE A SPECIMEN FROM EVERY TYPE YOU THINK IS A DIFFERENT, EVEN IF IT IS NOT PICTURED ON THIS DATASHEET. **IF AN ORGANISM IS NOT INCLUDED IN THE VOUCHER COLLECTION IT WILL NOT BE INCLUDED IN THE FINAL DATA ASSESSMENT!!**

Figure 3. Stream biomonitoring protocol used by volunteer monitors working with the Connecticut Department of Environmental Protection.

Methods and Materials

Aquatic macroinvertebrate survey data were obtained electronically for 206 stream sites in Alabama collected between 1996 and 2004 by (1) Auburn University researchers, (2) Troy University researchers, or (3) Alabama Department of Environmental Management (ADEM) Field Operations biologists. Four of the six USEPA Level III Ecoregions of Alabama were represented (Figure 4): Ecoregion 45

(Piedmont), Ecoregion 67 (Ridge and Valley), Ecoregion 68 (Southwestern Appalachians), and Ecoregion 65 (Southeastern Plains). A detailed listing of sampling locations can be found in Appendix 1-1.

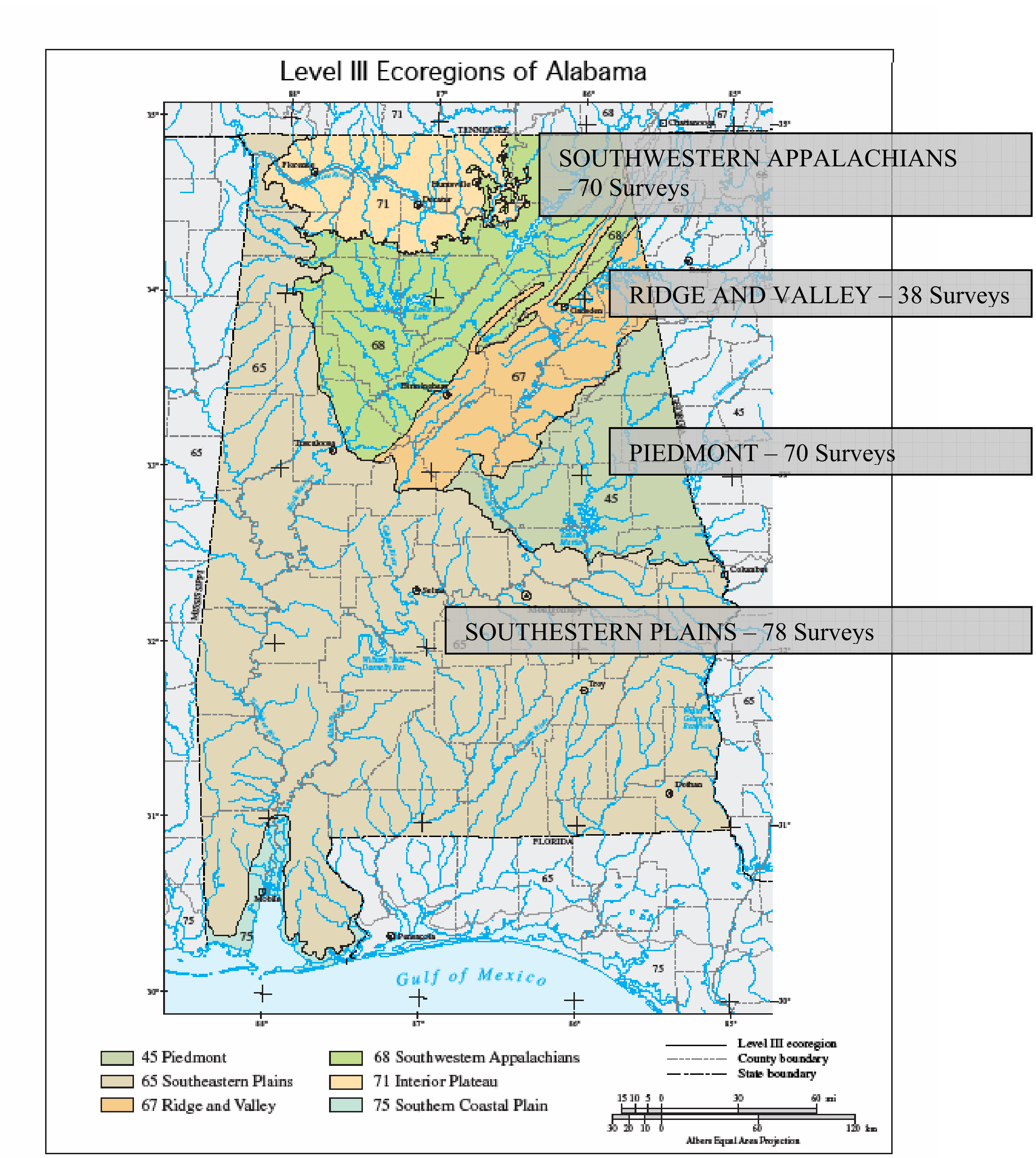


Figure 4. Location of professional macroinvertebrate surveys used for a comparison of citizen volunteer macroinvertebrate protocols and professional (standard) protocols. Surveys were conducted between 1996 and 2004 by the Alabama Department of Environmental Management (ADEM), Troy University researchers (Bennett), and Auburn University researchers (Webber).

All data was collected using a selection of multi-metric indices (Appendix 1-2) described in standard methods (Barbour et al. 1999). Auburn and Troy University data were collected from multiple habitats. Although ADEM also samples multiple habitats in streams, the samples are processed separately. Therefore, ADEM data was from riffle habitat only. Data sets contained macroinvertebrate information for each site including tolerance value, number of individual organisms identified to each taxonomic level, and a stream quality assessment of excellent, good, fair, poor, or very poor. Assessments of very poor were combined with poor sites in order to make stream quality assessment comparisons with the excellent, good, fair, and poor categories used by citizen protocols.

All data were uniformly formatted (Table 2). Individual taxa were assigned one or more habitat location(s) based on descriptions found in Merritt and Cummins (1996). Habitats were coded as: *r* (riffle: lotic erosional), *p* (pool: lotic depositional), *l* (littoral zone), and *n* (neuston). Organisms not identified with a tolerance value in Merritt and Cummins (1996) were coded based on habitat descriptions in Thorp and Covich (2001). Codes were used to analyze organisms theoretically found if sampling in riffle habitat only versus all available habitats.

A desktop study was conducted with the 206 macroinvertebrate survey data sets. Four citizen protocols were simulated: (1) Alabama Water Watch (AWW) (Figure 1), (2) Choctawhatchee Riverkeepers (CRK) (Table 1), (3) Georgia Adopt-A-Stream (GAAS) (Figure 2), and (4) an Alabama version of the Connecticut Department of Environmental Protection "Top 12 Most Wanted Bugs" (TOP9) (Figure 3). For the TOP9 protocol nine taxa were identified with the potential to be found statewide in undisturbed streams and identified by trained citizen volunteers (Table 3). A Cumulative Index Value scale was created to assess stream quality as excellent, good, fair, or poor through the TOP9 protocol (Table 4). The Cumulative Index Value was the sum of the number of TOP9 taxa present in each macroinvertebrate collection.

Table 2. Information included in uniform formatting of 206 professionally collected macroinvertebrate surveys from Auburn and Troy University researchers and Alabama Department of Environmental Protection in Alabama between 1996 and 2004.

1. Month and year of sampling event	7. Whether site was a reference site
2. Location of sampling event	8. Whether organisms was an aquatic insect or other aquatic invertebrate
3. Who collected the data	9. Order, family, genus, and species (if known) for each taxon listed
4. Ecoregional location of site	10. Habitat of each taxa
5. Location of site above or below the Fall Line	11. Total number organisms collected per taxon
6. Stream order or drainage size, if known	12. Tolerance value of each taxon collected

Table 3. Nine taxa chosen for an Alabama version of the Connecticut Department of Environmental Protection's (CDEP) "Top 12 Most Wanted Bugs", a USEPA approved protocol used by volunteer macroinvertebrate monitors in Connecticut.

Family-level taxa	Genus-level taxa	
1. Brachycentridae	4. *Acroneuria sp.*	7. *Isonychia sp*
2. Peltoperlidae	5. *Baetisca sp.*	8. *Pteronarcys sp.*
3. Psephenidae	6. *Chimarra sp.*	9. *Rhyacophila sp*

Table 4. Cumulative Index Value scale created for use with the TOP9 citizen protocol, based on the number of TOP9 taxa present in each macroinvertebrate collection.

Stream Quality Assessment	Cumulative Index Value
Excellent	6 - 9
Good	3 - 5
Fair	1 - 2
Poor	0

Computer programs were written to simulate the four citizen protocols with SAS® statistical software (SAS 9.1, Cody and Smith 2006). Programming generated a Cumulative Index Score and qualitative stream assessment of excellent, good fair, or poor. Specific research questions addressed with SAS® programming were:

1. How often do stream quality assessments using AWW biomonitoring protocols for citizen monitors agree with professional bioassessments?

2. How often do stream quality assessments using the CRK protocol agree with professional bioassessments?

3. How often do stream quality assessments made using the GAAS protocol agree with professional bioassessments?

4. How would a citizen protocol similar to the Connecticut Department of Environmental Protection (CDEP) volunteer protocol work in Alabama?

5. Do any of the four citizen protocols perform better than the others depending on whether sampling location was above or below the fall line?

6. Can a modified AWW protocol using higher taxonomic resolution than the current AWW protocol be developed for a streamside survey?

7. What variation occurs in citizen water quality assessments depending on the months when sampling occurred?

Simulated citizen assessments were grouped by location above and below the Fall Line to see if any of the simulated protocols performed better compared to professional bioassessments in one of the two geographic locations. Simulated citizen assessments were also grouped into two time periods to see if a particular set of months might provide better agreement with professional assessments. Months were grouped roughly in half by number of surveys conducted during 'Cool Weather Months' (September through March; 97 surveys) and 'Warm Weather Months' (April through August; 109 surveys).

Stream quality assessments were imported into SAS® to compare professional and simulated citizen assessments. SAS® generated a 4x4 contingency table summarizing pairwise comparisons between the 206 citizen protocol-professional bioassessment results with each of the four protocols. A simple kappa (κ) statistic for the contingency table results was used to determine the level of agreement between professional and simulated citizen assessments. The simple κ statistic could be a value of 0 to 1, where 0 was no agreement and 1 was high agreement (Cody and Smith 2006, Landis and Koch 1977). Two correlation statistics, Cronbach's alpha (α) and Spearman's correlation (ρ), were used to evaluate trends in citizen assessments compared to professionals (Cody and Smith 2006, Cronbach 1951, Zarr 1972). The Cronbach's α and Spearman's ρ statistics could be a value of –1 to +1, where –1 was high negative correlation, 0 was no correlation, and +1 was high positive correlation

Programming to calculate the average tolerance value of organisms, average number of families, and average Hilsenhoff Biotic Index (HBI) by ecoregions was created using the professional data. Data were calculated for descriptive purposes and to evaluate whether a particular ecoregion had substantially different stream quality based on these variables. The HBI is a family-level biotic used by stream biologists, and originally developed to detect organic pollution in streams (Hilsenhoff 1988).

Results and Discussion

General summary information from professional bioassessments. – Number of surveys, average number of families, average Hilsenhoff Biotic Index (HBI) score, and average tolerance value (TV) of organisms by ecoregion can be found in Table 5. All ecoregions had roughly the same total number of organisms collected except the Southwestern Appalachians, which had about 34,000 individuals.

Biodiversity in terms of the average number of Families collected per site was highest in the Piedmont (28) and Ridge and Valley (21), and lowest in the Southeastern Plains (17) and Southwestern Appalachians (15). In-stream habitats tend to be more diverse above the Fall Line than below because a higher percentage of streams have substrates composed of multiple rock sizes. Below the Fall Line substrate is often composed of sand and silt which creates less habitat diversity. Biodiversity will generally increase with habitat diversity as more niches become available for colonization by macroinvertebrates (Barbour et al. 1999). Therefore the lower average number of Families collected in the Southeastern Plains was possibly a result of natural variation. Streams in the Southwestern Appalachians were expected to have higher substrate diversity and thus a higher average number of Families collected than what was observed (Table 5). Both ecoregions had fewer sites sampled than the Piedmont or Ridge and Valley. Sampling bias could have been introduced if the majority of sites sampled in the Southwestern Appalachians were of lower stream quality. It was not clear which influences resulted in the lower average number of Families collected in the Southwestern Appalachians.

The average HBI and TV varied little by ecoregion. HBI assessments for all four ecoregions were consistent with results from the USEPA Wadeable Streams Assessment (WSA), which indicated 69% (Plains and Lowlands) to 73% (Eastern Highlands) of wadeable streams and rivers were in poor or fair condition. The Southeastern Plains falls in the WSA Plains and Lowlands ecoregion and the Southwestern Appalachians, Ridge and Valley, and Piedmont in the WSA Eastern Highlands ecoregion (Paulsen et al. 2007). Average TV for all ecoregions fell in the intermediate TV range on a scale of one to ten, with one being the least tolerant and ten being the most tolerant (Hilsenhoff 1987).

Table 5. Ecoregional summary information generated by SAS® based on 206 professional bioassessments conducted in USEPA Level III Ecoregion 45, 65, 67, and 68 between 1996 and 2004. Professional data collected by the Alabama Department of Environmental Management (ADEM), Troy University researchers (Bennett), and Auburn University researchers (Webber). HBI = Hilsenhoff Biotic Index, TV = Tolerance Value.

Ecoregion	Number of surveys	Collector	Total number of organisms collected	Average number of families collected	Average HBI score	Average TV
Piedmont (45)	70	Webber	17,635	28	6.05 (Fairly poor)	6.3
Southeastern Plains (65)	78	Webber ADEM Bennett	17,257	17	5.61 (Fair)	6.1
Ridge and Valley (67)	38	Webber ADEM	16,385	21	5.90 (Fairly poor)	6.0
Southwestern Appalachians (68)	20	ADEM	34,680	15	5.64 (Fair)	5.6

Performance of simulated citizen protocols in riffle habitat versus all available habitats. - Few differences in stream quality assessment were found between riffle samples and those from all habitats (Table 6). This was consistent with research findings from Gerth and Herlihy (2006) and Klemm et al. (2003). SAS® contingency tables for habitat simulations can be seen in Appendix 1-4. Results from the Alabama Water Watch (AWW) and the Alabama TOP9 simulated protocols differed most from the professional stream quality assessments. The number of surveys placed in each stream quality (SQ) category by the CRK and GAAS simulated protocols for riffle versus all habitats was nearly identical. Because of the few differences, further protocol simulations were based on all available habitats. This theoretically increased the likelihood of a citizen finding organisms in the professional survey collections that would be used in citizen protocols.

Table 6. Stream quality assessments using simulated citizen bioassessment protocols in riffle versus all habitats based on all 206 professional bioassessments (PROF). Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), the Georgia Adopt-A-Stream (GAAS), and the Alabama TOP9.

SQ Category	PROF	AWW		CRK		GAAS		TOP9	
		Riffle only	All habitats	Riffle only	All habitats	Riffle only	All habitats	Riffle only	All habitats
Excellent	45	129	132	100	103	27	27	0	0
Good	70	37	36	41	41	84	86	0	0
Fair	56	24	29	27	29	58	56	107	113
Poor	35	16	9	38	33	37	37	99	93

The TOP9 protocol was unable to detect streams with a professional assessment of excellent or good (Table 6). Analysis revealed that in the 206 macroinvertebrate assemblages, four or five taxa chosen for the TOP9 protocol were rare (Table 7). Little room for adjusting the Cumulative Index Value was available to create higher agreement between the simulated TOP9 and professional assessments, therefore the protocol was not considered in further analyses. The concept, which identified key sensitive organisms, was incorporated into a modified AWW protocol in later analysis.

Table 7. Taxa chosen for an Alabama TOP9 and the number of times taxa were collected in 206 professionally collected macroinvertebrate assemblages.

Taxon Type	Taxon	Number of organisms	Taxon Type	Taxon	Number of organisms
1. Family	Brachycentridae	14	6. Genus	*Chimarra sp.*	90
2. Family	Peltoperlidae	51	7. Genus	*Isonychia sp.*	106
3. Family	Psephenidae	8	8. Genus	*Pteronarcys sp.*	10
4. Genus	*Acroneuria sp.*	58	9. Genus	*Rhyacophila sp.*	12
5. Genus	*Baetisca sp.*	22			

Performance of simulated citizen protocols versus professional stream quality assessments. – Professional stream quality assessments were distributed in a relatively bell-shaped curve (Figure 5). The percentage of sites rated excellent, good, fair, or poor can be seen in Table 8. Professional analysis rated 22% of sites excellent, 34% of sites good, 27% as fair and 17% poor.

The simulated AWW protocol agreed with professional assessments 35% of the time, while the simulated CRK protocol agreed 42% (Figure 6). The CRK protocol detected a higher number of poor sites (16%) compared to the AWW protocol (4%) (Table 8). Statistical pairwise comparisons between professional assessments and AWW and CRK showed low agreement (simple κ = 0.15 and 0.23 respectively, Appendix 1-4). The AWW and CRK simulated protocols consistently overestimated stream health (63 and 47% of the time, respectively) (Figure 7). AWW overestimations were likely due to the large proportion of Group 2 (somewhat tolerant) organisms, with a weighted multiplier of two (Figure 1), thus inflating the index. Underestimates accounted for only 2% (AWW) and 11% (CRK) of inaccurate assessments. CRK assessments closely followed AWW, but with slightly better agreement with professional bioassessments.

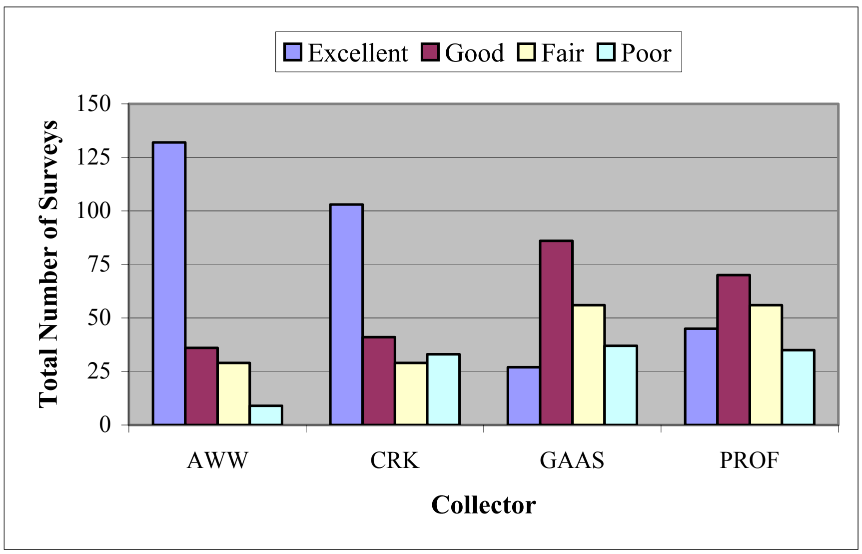


Figure 5. Water quality assessments by collector for 206 professional bioassessments (PROF) and simulated citizen bioassessments in all habitats. Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), and the Georgia Adopt-A-Stream (GAAS).

Table 8. Percentage of simulated citizen bioassessments with stream quality (SQ) of excellent, good, fair, and poor compared to 206 professional bioassessments (PROF). Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), and the Georgia Adopt-A-Stream (GAAS).

SQ	PROF	AWW	CRK	GAAS
Excellent	22	64	50	13
Good	34	18	20	42
Fair	27	14	14	27
Poor	17	4	16	18

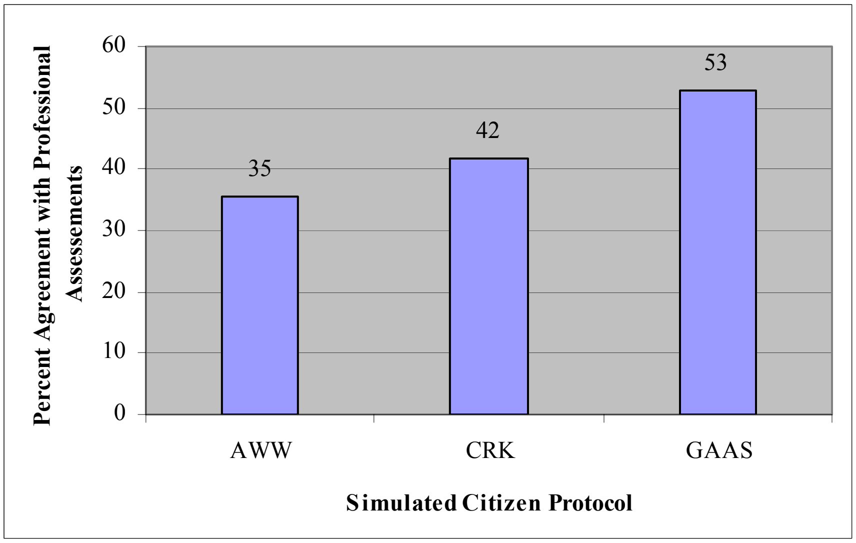


Figure 6. Percent agreement between 206 professional and simulated citizen bioassessments. Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), and the Georgia Adopt-A-Stream (GAAS).

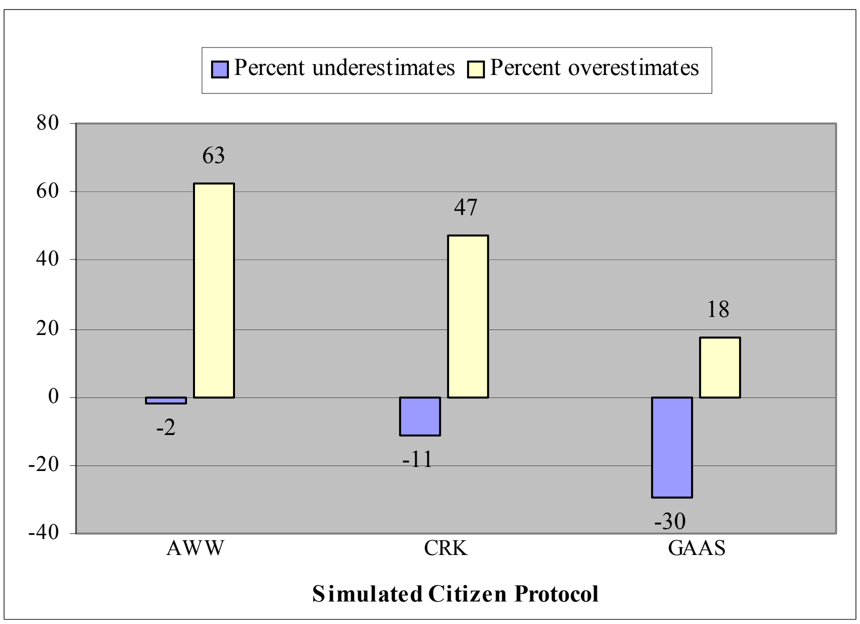


Figure 7. Percent of simulated citizen bioassessments that underestimated and overestimated water quality compared to 206 professional bioassessments. Underestimate percentages shown as negative (-) numbers. Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), and the Georgia Adopt-A-Stream (GAAS).

Low statistical agreement was also seen between the professional and GAAS assessments (simple $\kappa = 0.35$), though GAAS had the highest agreement rate of the citizen protocols (53%) (Figure 6). The simulated GAAS protocol tended to underestimate stream health, accounting for 30% of all assessments (Figure 7). Overestimations of stream health accounted for 18% of assessments. The GAAS protocol used in this study was current until summer 2006. GAAS published a new protocol similar to the first, but with organisms in slightly different groups during the summer of 2006 (GAAS 2006b). Protocol simulations were run with the new protocol. Few differences were observed in simulated GAAS protocol performance compared to professional bioassessments between the two versions. Therefore the original form used in this study (Figure 2, GAAS 2006a) was retained for principle analysis. Overall, GAAS showed the highest accuracy of the three citizen protocols compared to professional assessments. The AWW simulated protocol performed with the least accuracy.

Despite the agreement disparity, statistical analysis detected moderate to moderately high positive correlation between all simulated citizen protocols and professional stream quality assessments (AWW: Cronbach's $\alpha = 0.77$, Spearman's $\rho = 0.64$; GAAS: Cronbach's $\alpha = 0.78$, Spearman's $\rho = 0.64$; CRK: Cronbach's $\alpha = 0.81$, Spearman's $\rho = 0.70$; Appendix 1-4). The majority of inaccurate stream quality assessments for all three protocols occurred within a difference of one stream quality category (AWW 71 - 75%, CRK 81 - 94%, GAAS 75 – 90%) (Table 9). The moderately high correlation with professional assessments seen with the AWW simulated protocol suggested that altering the Cumulative Index Score brackets for stream quality assessment could possibly create higher agreement with professional assessments.

Table 9. Percent of simulated citizen bioassessments that under- and over-estimated stream quality (SQ) by one, two, and three SQ categories compared to 206 professional bioassessments. Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), and the Georgia Adopt-A-Stream (GAAS).

	1 SQ Category Difference		2 SQ Category Difference		3 SQ Category Difference	
	Percent Underestimate	Percent Overestimate	Percent Underestimate	Percent Overestimate	Percent Underestimate	Percent Overestimate
AWW	75	71	25	25	0	4
CRK	91	84	4	14	4	2
GAAS	90	75	10	25	0	0

Performance of simulated citizen protocols above and below the Fall Line versus professional stream quality assessments. – A total of 128 of the professional bioassessments were from streams in ecoregions above the Fall Line and 78 were from streams below the Fall Line. SAS® contingency tables can be seen in Appendix 1-5. Results showed varying performance (Figure 8, Figure 9). Above the Fall Line, the GAAS simulated protocol more closely matched the results of the professional bioassessments (simple $\kappa = 0.39$) than did AWW (simple $\kappa = 0.04$) or CRK protocols (simple $\kappa = 0.14$). The AWW and CRK simulated protocols overestimated stream health (Figure 8). However, moderate to moderately high correlations were detected for all simulated citizen protocols versus the professional bioassessments above the Fall Line (AWW: Cronbach's $\alpha = 0.68$, Spearman's $\rho = 0.52$, CRK: Cronbach's $\alpha = 0.76$, Spearman's $\rho = 0.64$, GAAS: Cronbach's $\alpha = 0.72$, Spearman's $\rho = 0.57$).

All simulated citizen protocols performed better below the Fall Line than above (Figure 8, Figure 9). The CRK simulated protocol more closely matched professional assessments (simple $\kappa = 0.34$) than did AWW (simple $\kappa = 0.33$) or GAAS (simple $\kappa = 0.22$) protocols. AWW tended to overestimated stream health while GAAS tended to underestimate. Moderately high correlations were seen for all simulated citizen protocols (AWW: Cronbach's $\alpha = 0.80$, Spearman's $\rho = 0.69$, CRK: Cronbach's $\alpha = 0.75$, Spearman's $\rho = 0.71$, GAAS: Cronbach's $\alpha = 0.81$, Spearman's $\rho = 0.57$). Results for below the Fall Line stream assessments appeared to justify the modifications made to the AWW protocol by CRK (Table 1). This suggested a modified AWW protocol with higher taxonomic resolution was needed for citizen protocols above the Fall Line for greater agreement with professional bioassessments.

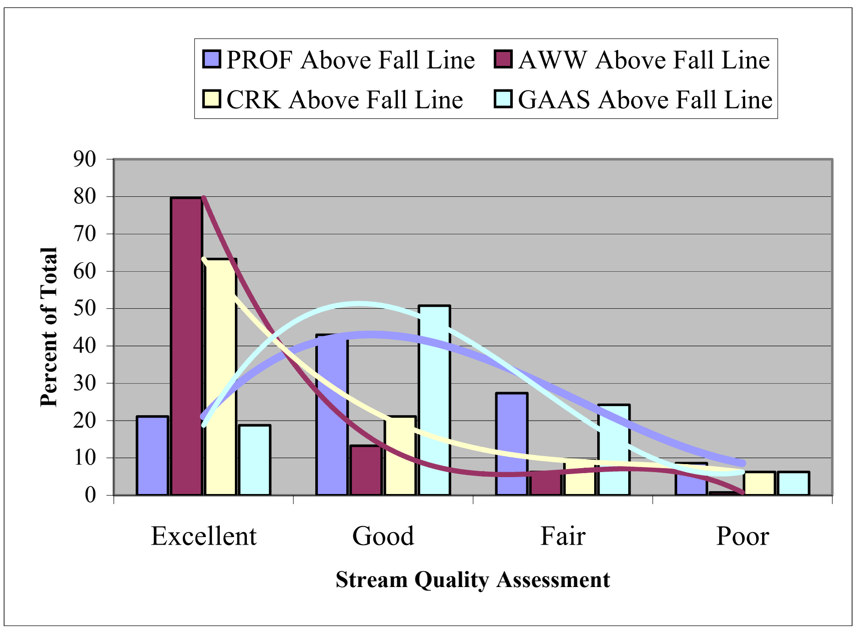


Figure 8. Stream quality trend lines for 128 professional and simulated citizen protocol bioassessments above the Fall Line. Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), and the Georgia Adopt-A-Stream (GAAS).

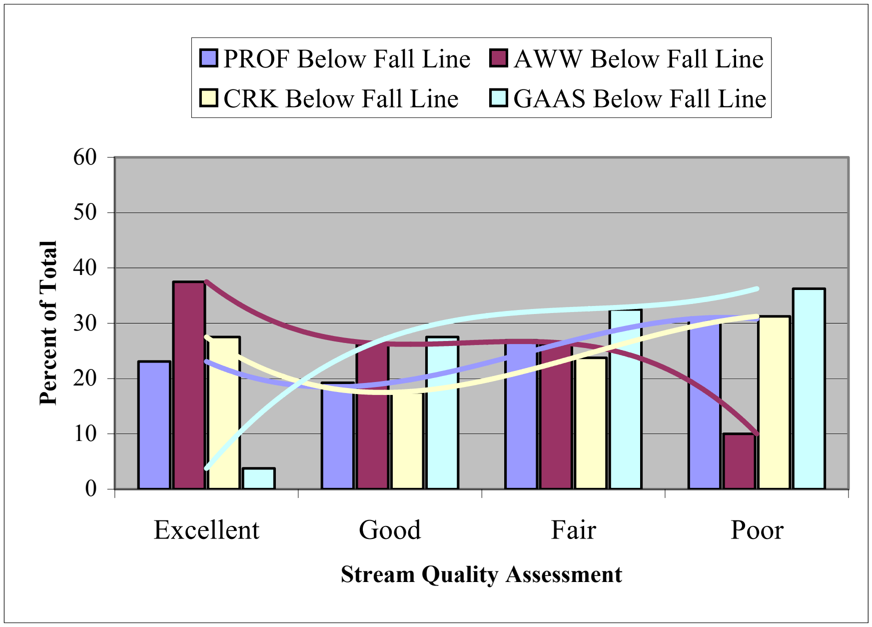


Figure 9. Stream quality trend lines for 78 professional and simulated citizen protocol bioassessments below the Fall Line. Citizen protocols simulated were the Alabama Water Watch (AWW), the Choctawhatchee Riverkeepers (CRK), and the Georgia Adopt-A-Stream (GAAS).

Performance of the AWW simulated protocol during two time periods compared to professional stream quality assessments. – A total of 97 professional bioassessments were conducted between September and March ('Cool Weather Months') by Auburn University (AU). A total of 109 professional bioassessments were conducted between April and August ('Warm Weather Months') and were a combination of ADEM, AU, and Troy University data. During both time periods the AWW simulated protocol consistently overestimated stream health (Table 10). SAS® contingency tables can be seen in Appendix 1-6. 'Cool Weather Months' had slightly higher agreement (40%) than 'Warm Weather Months' (30%). Moderate correlation to professional bioassessments was observed for both time periods ('Warm Weather Months: Cronbach's α = 0.69, Spearman's ρ = 0.50; 'Cool Weather Months: Cronbach's α = 0.70, Spearman's ρ =

0.55). Based on study results, it appeared advantageous for citizens to sample during 'Cool Weather Months' to maximize potential agreement with professional bio assessments. That is stated with caution, however, as field-testing should proceed first to verify study results.

Table 10. Percentage of simulated AWW bioassessment overestimates, underestimates, and agreements during 'Cool Weather Months' (September through March) and 'Warm Weather Months' (April through August) compared with 206 professional stream quality assessments.

Sample Months	Percent underestimates	Percent overestimates	Percent of agreements
'Cool Weather'	0	60	40
'Warm Weather'	4	65	30

Modifications to AWW citizen bioassessment protocol. – The first attempt to resolve inconsistencies between AWW and professional stream quality assessments involved three modifications: (1) altered Cumulative Index Value (CIV) brackets, (2) Group 1 (pollution sensitive) taxa expanded to include Family level identification of mayflies and stoneflies, and (3) mayfly Families Baetidae and Heptageniidae were moved to Group 2 (moderately tolerant) due to higher tolerance values compared with other mayflies. The CIV brackets used by CRK (Table 1) were adopted for initial analysis due to high agreement with professional assessments below the Fall Line. Phenotypically similar Families were placed together in Group 1 to simulate citizen monitor streamside identification capabilities (Table 11).

Table 11. List of phenotypic mayfly (Order Ephemeroptera) and stonefly (Order Plecoptera) groups chosen as identifiable by citizen volunteer monitors streamside; for use as an en expanded taxa list for pollution sensitive (Group 1) macroinvertebrates in a modified AWW protocol.

Mayfly Groups	1	Ephemeridae		
	2	Baetiscidae		
	3	Caenidae	Ephemerellidae	Tricorythidae
	4	Ameletidae	Isonychiidae	Leptophlebiidae
Stonefly Groups	1	Peltoperlidae		
	2	Perlidae		
	3	Pteronarcyidae		
	4	Capniidae	Chloroperlidae	Leuctridae
	5	Nemouridae	Perlodidae	Taeniopterygidae

Bioassessment simulations with a modified AWW protocol based on the three changes resulted in increased accuracy for excellent and poor streams, but performed poorly in the good and fair range based on statistical comparisons (Appendix 1-7).

Additional changes to the CIV brackets to capture higher agreement rates in the good and fair range proved unsuccessful. A large overlap between CIV's generated by the simulated AWW protocol and professional stream quality assessment categories was observed (Figure 10). Increased taxonomic resolution of the mayflies and stoneflies appeared to contribute little to overall performance of the modified AWW protocol. As a result, additional modifications were made to the AWW protocol that simulated citizen identification of three only theoretical 'families' within the two orders. The theoretical 'families' could be any three stonefly families with obvious visual differences that a citizen monitor would be able to recognize the stoneflies as different from each other in a streamside survey. Family level identification requires training, the type of which citizen monitors are unlikely to receive in a typical AWW training workshop.

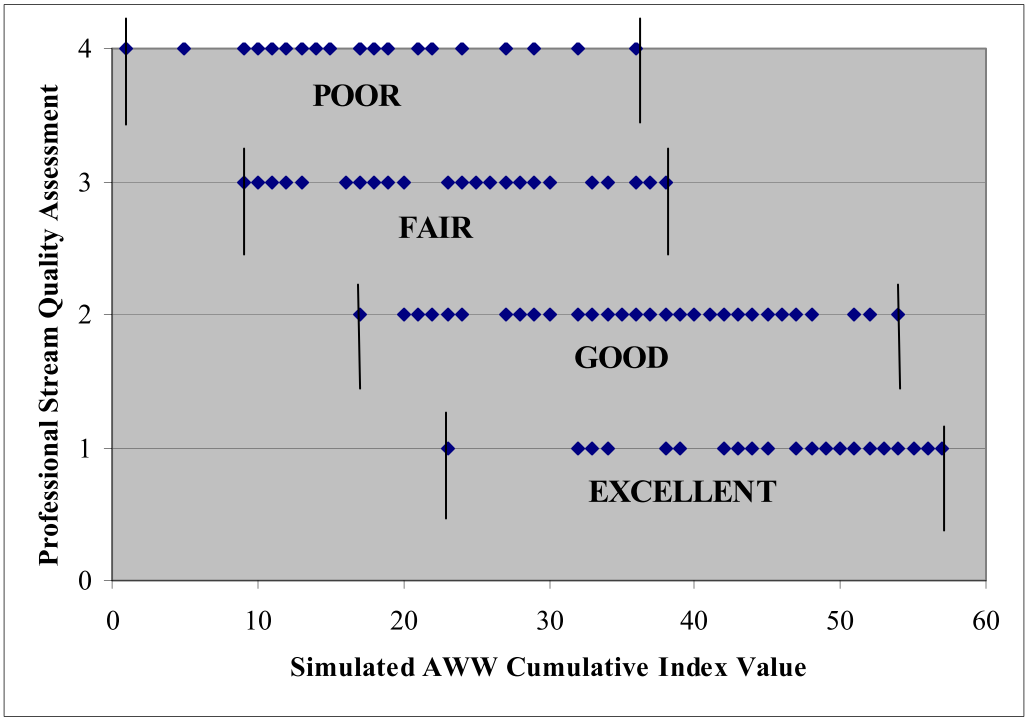


Figure 10. Pairwise comparisons between the Cumulative Index Values generated by the simulated AWW bioassessment protocol after initial modifications, and corresponding professional stream quality assessment. CIV ranges generated with the simulated AWW protocol were: Excellent (23 - 57), Good (17 - 54), Fair (9 - 38) and Poor (1 – 36). Blue diamonds represent individual pairwise comparisons.

This study demonstrated that the GAAS simulated protocol more consistently reached similar stream quality assessments compared to professional bioassessments than did the AWW or the CRK protocol. The GAAS protocol also performed similarly above and below the fall line. The GAAS and the AWW protocols differed only in the placement of a few organisms within pollution tolerance groups. Yet AWW consistently overestimated stream health 60% of the time based on this study. Consideration was given to adopting the GAAS protocol but not chosen because: (1) even though the GAAS protocol performed better than the AWW or the CRK, it only agreed with professional assessments 53% of the time, and (2) when they did not agree, the GAAS protocol tended to underestimate stream health. While neither underestimates nor overestimates are ideal, underestimates have significant consequences. State resources are typically low, and spending time and money to investigate situations inaccurately assessed reflects poorly on citizen involvement in data collection.

Another protocol modification was to use tolerance values (TV) of AWW organisms to identify possible changes to group placement (Table 12). Group 1 gilled snails, riffle beetles and mayflies had average TV higher than expected for pollution-sensitive organisms (6.0, 5.2 and 5.1, respectively). Organisms with a mean TV of 8.0 (sowbug, crayfish, leech, lunged snail) were observed in Group 2 and Group 3. As a result, I tried an AWW protocol with four groups rather than three to better reflect natural tolerance groupings (Table 13). Weighted multipliers used in the original AWW protocol (Figure 1) were retained, with the new group, Group 4, having a multiplier of 0. Group 4 organisms were thus noted in the survey, but did not contribute to the final assessment.

Multiple simulations were conducted varying the placement of organisms with TV falling close to the neighboring stream quality group. An example would be the Mayflies (Group 1) with a TV of 4.6, and Blackflies (Group 2) with a TV of 4.4 (Table 13). Thus, the most accurate Modified AWW Protocol had organisms with some overlap in TV among groups (such as the Mayflies and Blackflies example), a reflection most likely due to the Family and Order TV used in the citizen protocol rather than genus or species TV used in professional bioassessments. The final CIV brackets were also altered to provide more accurate results for the Modified AWW Protocol (Table 14). Trial and error calculations based on the observed CIV overlap between the simulated AWW protocol and professional stream quality assessment (Figure 10) were used to generate the CIV used in the final Modified AWW Protocol.

Table 12. Pollution tolerance values for Group1 (sensitive), Group 2 (somewhat-tolerant) and Group 3 (tolerant) taxa used in AWW citizen volunteer bioassessment protocol.

Group 1 Taxa (sensitive)		Group 2 Taxa (somewhat-tolerant)		Group 3 Taxa (tolerant)	
Common Name	TV	Common Name	TV	Common Name	TV
Stonefly	2.6	Dragonfly	7.1	Non-biting Midge	6.8
Mayfly	5.1	Damselfly	7.1	Aquatic Worm	10.0
Non-filtering Caddisfly	3.5	Cranefly	6.4	Leech	8.0
Riffle Beetle	5.2	Blackfly	4.4	Lunged Snail	8.0
Water Penny Beetle	4.4	Filtering Caddisfly	6.5		
Gilled Snail	6.0	Hellgramite	6.2		
		Scud	6.9		
		Sowbug	8.0		
		Crayfish	8.0		
		Asiatic Clam	6.3		

Table 13. Modified AWW Protocol with four pollution group categories, organisms placed in each group, and corresponding tolerance value.

Group 1 Taxa (sensitive)		Group 2 Taxa (somewhat-sensitive)		Group 3 Taxa (somewhat-tolerant)		Group 4 Taxa (tolerant)	
Common Name	TV	Common Name	TV	Common Name	TV	Common Name	TV
Stonefly 1	2.6	Baetid Mayfly	5.5	Gilled Snail	6.0	Non-biting Midge	6.8
Stonefly 2	2.6	Heptageniid Mayfly	5.5	Filtering Caddisfly	6.5	Aquatic Worm	10.0
Stonefly 3	2.6	Riffle Beetle	5.2	Scud	6.9	Leech	8.0
Mayfly 1	4.6	Blackfly	4.4	Dragonfly	7.1	Lunged Snail	8.0
Mayfly 2	4.6	Water Penny Beetle	4.4	Damselfly	7.1	Sowbug	8.0
Mayfly 3	4.6	Megalopterans	6.2	Cranefly	6.4	Crayfish	8.0
Non-filtering Caddisfly	3.5			Asiatic Clam	6.3		

Table 14. Final Cumulative Index Value brackets chosen for a Modified AWW Protocol after comparative study with 206 professional bioassessments completed in Alabama between 1996 and 2004.

Water Quality Assessment	Cumulative Index Value
Excellent	> 27
Good	17 to 27
Fair	10 to 16
Poor	< 10

Final analysis of the Modified AWW Protocol showed moderate agreement with professional bioassessments (Figure 11). Overall agreement with professional bioassessments increased from about 30% in the original protocol (simple $\kappa = 0.15$) to 60% (simple $\kappa = 0.46$). Overestimations of stream quality decreased from 63 to 23% (Figure 12). Moderately high correlation was observed with the Modified AWW Protocol (Cronbach's $\alpha = 0.89$, Spearman's $\rho = 0.79$). The SAS® contingency table revealed about a 35% chance that a simulated assessment of poor was actually fair compared to the professional bioassessment (Figure 13, Appendix 1-8). The same held true for simulated sites assessed as excellent actually being good. Simulated sites assessed as fair or good held a 20% chance the true stream quality was either one category higher or lower (Figure 13). Additionally, 5% of sites assessed as good by the simulated Modified AWW Protocol were actually in poor condition according to the corresponding professional bioassessment (Figure 13).

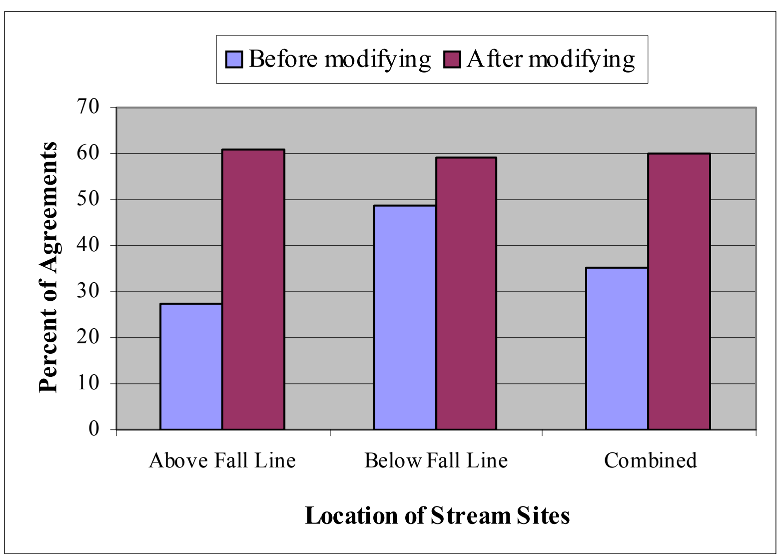


Figure 11. Percent stream quality assessment agreement between 206 professional bioassessments and simulated AWW protocol before (three pollution groups) and after modification (four pollution groups with adjusted Cumulative Index Value).

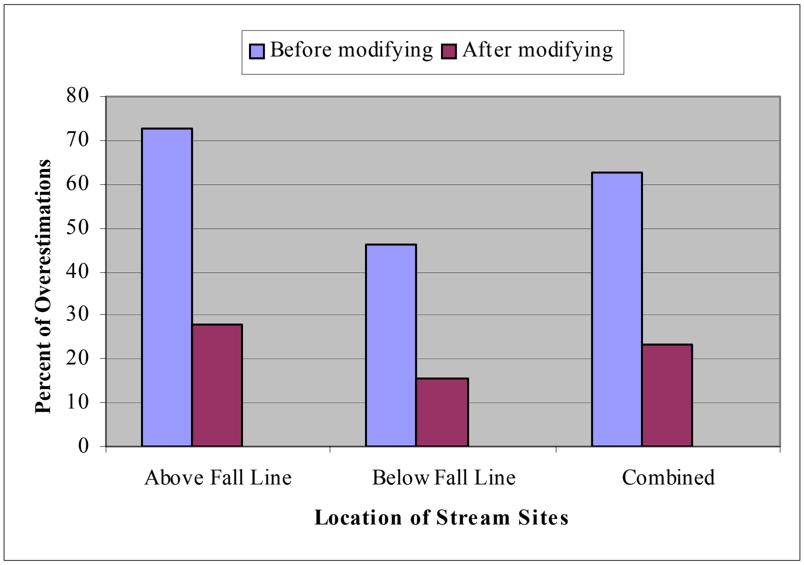


Figure 12. Percent of 206 simulated AWW protocol stream quality assessment overestimations before (three pollution groups) and after modification (four pollution groups with adjusted Cumulative Index Value) compared to 206 professional bioassessments.

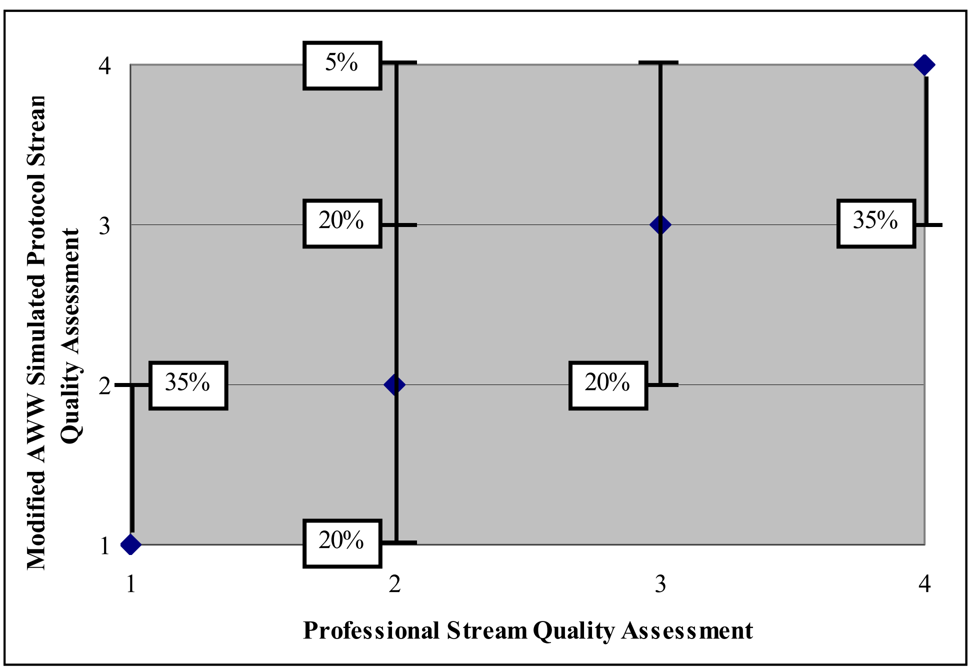


Figure 13. Percent of stream quality assessment error by the simulated Modified AWW Protocol compared to professional bioassessments as revealed in the SAS® contingency table. Blue diamonds represent agreement between simulated and professional assessments. Percentage boxes represents % of sites inaccurately assessed by simulated AWW protocol by one or two water quality categories. Excellent = 1; Good = 2; Fair = 3; Poor = 4.

Analysis demonstrated consistent performance in streams both above and below the Fall Line (Table 15, Appendix 1-8). Pairwise agreement and correlations were similar above (simple κ = 0.43, Cronbach's α = 0.83, Spearman's ρ = 0.72) and below the Fall Line (simple κ = 0.45, Cronbach's α = 0.91, Spearman's ρ = 0.84). There was a slight tendency for a greater degree of overestimation from simulations above the Fall Line. All incorrect stream quality assessments were contained within $^{+}/_{-}$ one stream quality category except for underestimations by two stream quality categories that occurred in 11% of surveys above the Fall Line (Table 15).

Table 15. Percent of simulated Modified AWW Protocol stream quality (SQ) assessments that underestimated and overestimated SQ by one or two SQ categories compared to 206 professional bioassessments. Stream site data are reported collectively and by location of stream site above and below the Fall Line.

	1 SQ Category Difference		2 SQ Category Difference	
Modified AWW Protocol	Percent Underestimate	Percent Overestimate	Percent Underestimate	Percent Overestimate
All Assessments	100	92	0	8
Above Fall Line Assessments	100	89	0	11
Below Fall Line Assessments	100	100	0	0

Study results suggested that the Modified AWW Protocol has the potential to generate scientifically sound data about stream health within a quantifiable margin of error. This simulated study appeared to demonstrate that sampling in riffle versus all available habitats has little effect on the overall stream quality assessment made with citizen protocols. For consistency in protocol procedure it was recommended that citizen volunteers remain in riffles unless sufficient numbers of organisms were not found or no true riffles existed in the sampling location. Further work should be conducted before determining whether citizens should be instructed to sample during a particular time of year. Training citizens will need to be carefully considered. The Modified AWW Protocol developed during this study will definitely require more training time in the workshops for citizen monitors. In order for citizen performance in the field to mimic the results of this study, they must confidently recognize at least three different types of mayfly and stonefly families. Ideally results of this study should be field-tested.

CHAPTER 2

EDUCATIONAL ASPECTS OF STREAM BIOMONITORING IN ALABAMA

"Empowering learners to think critically – to understand the impacts and consequences of the choices they make, to choose the most right course – and to take appropriate action in implementing right choices ought to be the aim of aquatic stewardship in a democratic society" (Siemer 2001).

Introduction

The nature of nonpoint source (NPS) pollution suggests education of citizens, including youth, plays a vital role in water quality improvements in the United States (US). Literature surveys indicated that lack of knowledge about environmental issues remains a primary obstacle to teaching water quality (Bjorkland and Pringle 2001, Ernst 2007, Shepardson et al. 2002). A nationwide survey found that only about 10% of teachers received environmental education training as pre-service teachers (McCrea and deBettencourt 2000). Few chances for professional development in aquatic science also contributed to the lack of water quality awareness in classrooms (Bjorkland and Pringle 2001). And while a plethora of materials and resources are available (Hudson 2001), teachers can often feel intimidated by lack of understanding on how to use and incorporate them into the classroom (Bjorkland and Pringle 2001, Shepardson et al 2002).

Citizens involved in watershed activities help build a sense of community and accountability for local water quality issues (USEPA 1996, Penrose and Call 1995). Local 'citizen scientists' could play a valuable role in bridging the gap between understanding the importance of water quality and educators incorporating aquatic science activities into classrooms. Citizen volunteer monitors connected with classrooms exemplify the watershed approach promoted by the USEPA (1996). A review of nationwide watershed partnerships by Leach and Pelkey (2001) revealed that most partnerships were informal groups of concerned stakeholders, meeting together for the common goal of improving water quality in their communities. The target audience in citizen volunteer-classroom activities is the students; future decision makers and contributing members of the community. Partnerships created through citizen volunteer-classroom interaction are potentially as effective long-term at addressing water quality issues as all-adult groups due to increased understanding of the importance of water quality at a younger age.

Many citizen monitors have moved into the education arena as volunteers with formal and informal learning. These monitors provide valuable time, knowledge and resources for local educators (Ely 1999). A common technique used by citizens to assess water quality is stream biomonitoring. Stream biomonitoring uses the types of aquatic macroinvertebrates collected from a stream to make a stream quality assessment. A national survey of citizen volunteer macroinvertebrate monitoring groups found that about 75% have a primary goal of increasing awareness and public education (Nerbonne and Nelson, 2004). A similar study by Ely and Hamingson (1998) reported that about 46% of surveyed groups were formal classroom educators with students. One such group, New Mexico Watershed Watch, had students involved in water quality monitoring since 1996, and has become an integrated part of the classroom curriculum in 20 regional schools (Fleming 2003).

A number of citizen volunteer groups have developed materials to facilitate classroom connections and/or provide instructional resources for educators. They include IOWATER (iowater.net/educators/IOWATER%20Activities.htm), the Missouri Stream Team (mostreamteam.org/acitivity_guide), University of Vermont Watershed Alliance (uvm.edu/~watershd/?Page=resources.html&SM=submenu_ed.html), and Kentucky Water Watch, (water.ky.gov/ww/volunteer/comed/). In Alabama, citizen volunteers from Lake Watch of Lake Martin (LWLM) have interacted with students for the past 13 years, a project spearheaded by Dick and Mary Ann Bronson. Since 1994, LWLM has hosted more than 3,000 children streamside to show them aquatic macroinvertebrates, where they live in streams, and how they can be used to assess stream quality. In the process, citizen volunteers have shared locally relevant information about their watershed, NPS pollution issues, and how children can help improve water quality in their communities.

The annual field trips have come to be an eagerly anticipated event by children aware of the program, and even a “rite of passage” for schools incorporating the trip into classroom curriculum (Dick Bronson, President LWLM, personal communication 28 Aug 2007). The same reaction was recorded in children with older siblings who had already participated in a conservation education program evaluated by Vaughn et al. (2003). Mr. Bronson notes, “The program is in high demand from local educators who recognize the value of hands-on science education” (Dick Bronson, President LWLM, personal communication, 28 Aug 2007). These results are consistent with literature noting that long-term programs such as this community-classroom partnership produce the most sustainable aquatic stewardship outcomes (Hudson 2001, Siemer 2001).

The long-standing partnership between this citizen group, educators, and children exemplify the power of community involvement in education, particularly watershed science and water quality awareness. With knowledgeable, trained educators, there is great potential for a fully integrated water science curriculum specifically aimed at increasing NPS pollution awareness to have noticeable impacts in Alabama communities.

A wealth of resources exists for educators wishing to incorporate aquatic science into their classrooms. The USEPA Office of Wetlands Oceans and Watersheds has developed a website specifically for school children and teachers that addresses NPS pollution (www.epa.gov/OWOW/nps/kids/), including a game designed to help kids recognize different, designed to help children understand NPS pollution, particularly sediments, and watershed/ecosystem concepts (Allison Jenkins, ACWP Statewide Coordinator, personal communications, 25 Aug 2007). Legacy, Inc., Partners in Education offers the *Water Sourcebook* to Alabama educators; a reference collection of water-related activities for all ages. Legacy, Inc. also offers competitive grants for school projects, particularly those categorized as community-based environmental education (http://www.legacyenved.org).

The Alabama Museum of Natural History has made available to educators an extensive DVD series called *Discovering Alabama* (www.discoveringalabama.org), which documents Alabama natural history and emphasizes conservation education including watersheds and NPS pollution. Also, the Alabama Geologic Survey, the Alabama Cooperative Extension System, and nonprofit groups such as the Sierra Club

Water Sentinels and the Rivers Alliance offer resources of varying type to educators wishing to teach watershed science and water quality. Many of these materials are correlated to the Alabama Course of Study Standards, state-mandated guidelines for teaching content in all Alabama public classrooms from the Alabama Department of Education (ACOS 2005).

Despite the availability of resource materials, limitations exist with teaching aquatic science in the classroom. Constraints commonly faced include lack of funding and time available for "extra curricular" teaching/events, inadequate teacher training, and lack of administrative support (Ernst 2007, Flemming 2003, Orion 1993). This study documented the creation of an aquatic science curriculum for Alabama classrooms based on stream biomonitoring protocols used by Alabama Water Watch (AWW) citizen volunteer monitors. The curriculum, *Alabama's Living Streams: Stream Biomonitoring* was designed to help students understand the effects of NPS pollution and how citizens contribute to water quality degradation in their watershed. Implementation was designed to overcome common constraints to teaching aquatic science in the classroom.

A model for curriculum implementation can be seen in Figure 14. Limitations to teaching aquatic science were addressed in several ways. First, collaboration between AWW and the Auburn University Department of Curriculum and Teaching (AU-DCT) ensured the curriculum addressed concepts mandated for science classrooms by the Alabama State Department of Education. Inadequate teacher training was countered by the AU-DCT incorporating basic aquatic science instruction in their Science Methods course for pre-service teachers. Pre-service teachers were placed in classrooms as interns with educators interested in using the curriculum. Local AWW volunteer monitors assisted interns and teachers by participating in a stream bioassessment with the classrooms. Pre-service teachers and citizen volunteers provided support that might otherwise have been lacking in the school system.

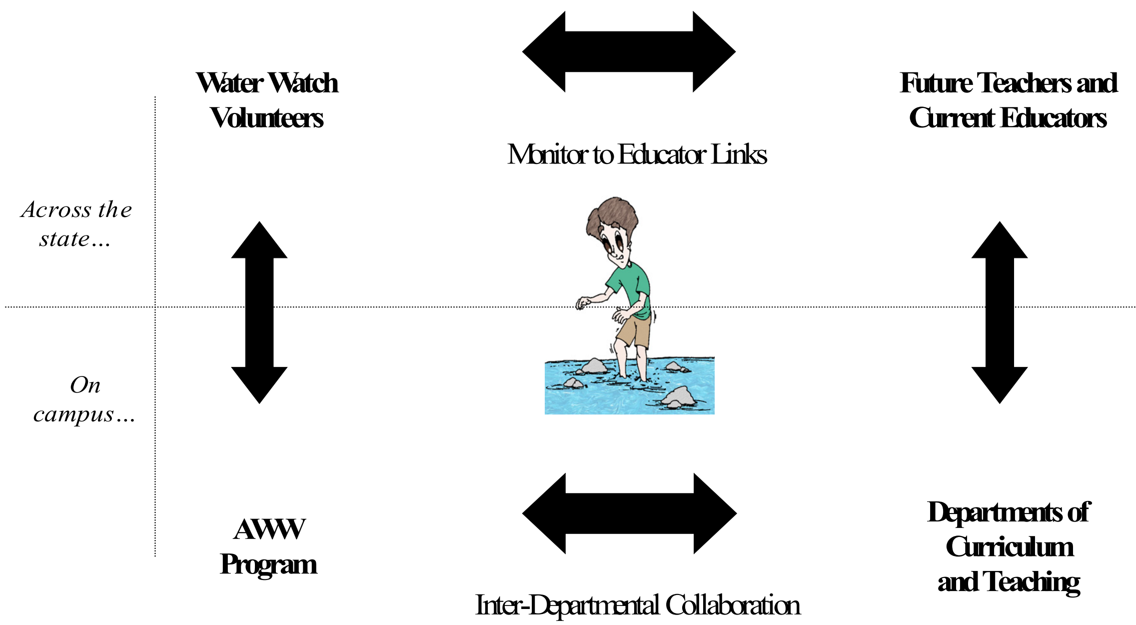


Figure 14. Relationship among Alabama Water Watch, universities, educators, and community volunteers to implement the *Alabama's Living Streams Stream Biomonitoring* curriculum.

Professional development for educators to enhance their understanding of aquatic ecosystems is critical if classrooms are to be a vehicle for conveying water quality issues (Ernst 2007, Shepardson et al. 2002, Siemer 2001). Teacher workshop training was offered for curriculum use. This study evaluated the receptivity by educators to use community partnership and outdoor science exploration as a foundation for teaching aquatic science, watersheds, and NPS pollution concepts in the classroom.

Educators and scientists have noted that community involvement in education was an important component in classrooms for creating aquatic stewardship in children (Bjorkland and Pringle 2001, Ely 1999, Ernst 2007, Hudson 2001, Siemer 2001). This study evaluated the willingness of local watershed groups to become involved in classroom education. National Science Standards place an emphasis on sound science, authentic research and hands-on involvement in outdoor investigative issues (National Research Council 1996). This study also evaluated the scientific accuracy of AWW Stream Biomonitoring protocols simultaneously (see Chapter 1: Technical Aspects of Stream Biomonitoring in Alabama) to ensure sound scientific techniques were being taught to students.

Methods and Materials

Curriculum development and implementation occurred in three major phases: curriculum development and 1st pilot round (Phase 1), curriculum revisions and 2nd pilot round (Phase 2), and final revisions and educator workshops (Phase 3). Methods and materials are included for all three phases. The author's work with the project began by analyzing portions of Phase 1 after curriculum development and 1st pilot round, and continued through Phase 3.

Phase 1: Curriculum development and 1st pilot round. - The Alabama Water Watch (AWW) *Alabama's Living Streams: Stream Biomonitoring* curriculum was developed by Dr. Charles Eick and Jacque Middleton of the Auburn University Department of Curriculum and Teaching, and Dr. William Deutsch and Wendi Hartup of AWW. The curriculum was modeled after AWW Stream Biomonitoring Protocols for

Citizen Monitors, referred to as the Protocols (Eick and Deutsch 2005). Protocol sections were turned into curriculum modules, with language altered to reflect an audience shift from citizen monitors to pre-service teachers. Information from the Protocols used in the modules included basic aquatic science, point and nonpoint source water pollution, introduction to benthic aquatic macroinvertebrates, and stream biomonitoring techniques.

Curriculum modules were structured for teaching one per day. One to two student activities were included with each module to reinforce module topics. A pre- and post-test was developed to determine what students were learning from the curriculum. The weeklong investigation in aquatic science and water quality was to be concluded with a field trip to a local stream to perform a bioassessment with local AWW citizen volunteer monitors. The field trip was designed as a primary component of the curriculum. Citizen volunteers were to serve as additional guidance for the field outing, as well as to provide technical assistance with the bioassessment as "local experts" in their watershed (C. Eick and W. Deutsch, Auburn University, personal communication, October 2005).

During curriculum development, Alabama Water Watch (AWW) and Auburn University (AU) Fisheries staff conducted a series of lectures for Science Methods students in the AU Department of Curriculum and Teaching (course number CTSE 7530), fall semester 2004. These pre-service teachers were certified in AWW Stream Biomonitoring and given the option of piloting the AWW *Exploring Alabama's Living Streams: Stream Biomonitoring* curriculum during a formal classroom internship the following semester. An informational meeting was held with prospective teachers and citizen volunteers to introduce the draft curriculum and recruit classroom teachers for the 2005 spring pilot round (Eick and Deutsch 2005).

Phase 2: Curriculum revisions and 2nd pilot round. – Completed surveys from the 1st pilot round were reviewed and summarized (Middleton 2005), and curriculum revisions made based on comments and suggestions from the surveys. The curriculum was expanded in areas where surveys indicated language was too technical or assuming for the target audience. Additional activities were included totaling three per module, to reach a broader spectrum of learners. Activities chosen were already in use by AWW or being used by organizations such as Legacy, Inc. and the USEPA. Depending on the content of the module, activities were chosen that increased student awareness of their local watershed, issues within their watershed, and government and non-government groups working on behalf of water quality in their watershed and at the state level. A CD-ROM with power point presentations for each module was created to assist educators in conveying information.

AWW staff conducted lectures for Science Methods students in the Auburn University (AU) Department of Curriculum and Teaching (course number CTSE 7530), fall semester 2005, and students recruited to participate in the 2nd pilot round planned for spring semester 2006. Troy University (TU) researchers and educators assisted with the 2nd pilot round by conducting similar training in the TU equivalent to the Science Methods course offered at Auburn University. Teachers accepting pre-service internship students and citizen volunteers in the Auburn and Troy area were approached with the offer to assist in the 2nd pilot round of the curriculum.

Phase 3: Final revisions and educator workshops. – Completed surveys were reviewed after the 2nd pilot round and final revisions made to the curriculum. Revisions included the addition of (1) module activities for a total of four per module, and

(2) resource section with information designed to broaden the educator's knowledge of Alabama freshwater biodiversity and ongoing water quality issues faced in Alabama. Literature was chosen that would serve as enrichment reading for higher grade levels.

Partnership with the Alabama Museum of Natural History (AMNH) allowed for the production of a Discovering Alabama DVD containing five video clips related to module information such as water quality and Alabama watersheds. Video clips were taken from the Alabama Public Television natural history series Discovering Alabama, and correlated to curriculum content. Curriculum material was correlated to Project WET: Water Education For Teachers (Durney 2000), a resource manual with water-related activities for all age groups. All applicable curriculum content was correlated to the Alabama Course of Study Standards (ACOS 2005) for science classrooms in grades 4-7, and high school Biology and Environmental Studies. Correlations were made with guidance from the AU-DCT, ALNH staff, and assistance from AWW staff. Aquatic science workshops were planned for summer 2007 to introduce the curriculum.

Results and Discussion

Curriculum development and 1st pilot round. – Eight Alabama science teachers participated in an AWW Stream Biomonitoring workshop October 2004. Four of those teachers and four pre-service teachers from the Auburn University Science Methods course piloted the curriculum in their classrooms during the 1st pilot round spring semester 2005 (Table 16). Each participant, including the citizen volunteers, agreed to participate in a survey documenting their experience with the curriculum at the end of the pilot project (Appendix 2-1).

Table 16. School, classroom type, location of pre-service teachers and classroom educators, and Alabama Water Watch (AWW) volunteer monitoring groups participating in the 2nd pilot round of the AWW *Exploring Alabama's Living Streams: Stream Biomonitoring* curriculum spring 2005.

Time	School	Classroom	City	County	AWW Volunteer Group
Spring 2005 Pilot Round	Drake Middle	6th grade Earth and Space Science	Auburn	Lee	Save Our Saugahatchee
	Auburn High	Environmental Science	Auburn	Lee	None
	Opelika High	Environmental Science	Opelika	Lee	None
	Benjamin Russell High	Environmental Science	Alexander City	Tallapoosa	Lake Watch Lake Martin

Curriculum content feedback showed high school classrooms completed the curriculum in about one week while middle school classrooms took close to two weeks. All classrooms ideally needed more than one week to cover the material in depth. Curriculum content was considered too technical for middle school children. Both middle and high school teachers remarked that pre- and post-tests proved difficult for students. It was suggested that much of the curriculum could be adapted into a broader spectrum of key subject areas addressed in the Alabama Course of Study (ACOS) standards for Alabama science classrooms, such as photosynthesis and food chains. Survey feedback also indicated a need for illustrations to help students understand curriculum content. In spite of the shortcomings, all teachers indicated they would like to use the curriculum again (Middleton 2005).

Community involvement feedback indicated AWW citizen monitors played a key role in students understanding of watersheds and watershed protection concepts, though some students were unable to interact with a citizen monitor. Teachers structured the stream biomonitoring field trip differently. Two teachers took all students to the stream, one teacher took a select few as extracurricular, and one teacher collected macroinvertebrate samples and brought them into the classroom. For students able to participate in the stream bioassessment first hand, it was noted the trip helped to fully comprehend the lessons of the previous week. AWW citizen monitors from Save Our Saugahatchee and Lake Watch Lake Martin that interacted with students and teachers streamside gave high reviews of the field trip, and noted the desire to pursue similar connections in the future (Middleton 2005).

Curriculum development and 2nd pilot round. – Three teachers and three pre-service teachers completed AWW workshop training and piloted the curriculum in their classrooms during the 2nd pilot round spring semester 2006 (Table 17). All participants agreed to complete a survey at the end of the pilot project (Appendix 2-1).

Table 17. School, classroom type, location of pre-service teachers and classroom educators, and AWW citizen groups participating in the 2nd pilot round of the AWW *Exploring Alabama's Living Streams: Stream Biomonitoring* curriculum spring 2006.

Time	School	Classroom	City	County	AWW Volunteer Group
Spring 2006 Pilot Round	Drake Middle	7th grade Life Science	Auburn	Lee	Save Our Saugahatchee
	Benjamin Russell High	Environmental Science	Alexander City	Tallapoosa	Lake Watch Lake Martin
	McKenzie High	Environmental Science	McKenzie	Butler	Choctawhatchee Riverkeepers

Surveys from the 2nd pilot round were reviewed and summarized as part of this document. Feedback suggested students gained a better understanding of point and nonpoint source water pollution and how it affects their communities' water resources as a result of the curriculum. Power point lessons accompanying the curriculum were received favorably. Teachers indicated a primary limitation to full curriculum use would be resources available for the field trip. It was also noted that correlating curriculum content to ACOS standards would increase feasibility for classroom use.

Citizen volunteer surveys indicated citizens believed community partnership enhanced the learning experience for students. Not all students were able to interact with a citizen monitor. Heavy rains prevented one class from accessing their local stream. A second classroom took a select group of students based on attitude, interest, and class average. Students in the third classroom examined a macroinvertebrate stream sample brought in by a local AWW citizen monitor. This option might be feasible in situations where limited resources prevent a stream visit. However, it is most desirable to have students outside the classroom for hands-on learning in the local environment.
Surveys indicated the connection with students and teachers was a positive experience for all involved. Citizen survey response recommended that AWW help classrooms connect not only with AWW citizen monitors but with Alabama Clean Water Partnership (ACWP) groups as well. While AWW is a statewide organization, it does not have groups in every county. Therefore connecting with an ACWP group could be a useful alternative in the absence of an AWW group. A number of ACWP volunteers perform stream bioassessments in their watersheds.

Final revisions and educator workshops – Final curriculum changes and sponsors can be seen in Table 18. Four educator workshops were conducted summer 2007 with the *Alabama's Living Streams: Stream Biomonitoring* curriculum. Locations were chosen where active AWW groups were established (Table 19). Workshop partnerships were established to provide resource material for participants and to model community cooperation. Partners were the Alabama Chapter of the Sierra Club Water Sentinels, Alabama Wildlife Federation, *Discovering Alabama*, World Wildlife Fund, Alabama Cooperative Extension System, and Alabama Department of Conservation and Natural Resources (AL DCNR).

Sponsors provided workshop participants with basic biomonitoring equipment including kick seines, sorting trays and forceps, and hand-held magnification lenses. Sponsors were Soil and Water Conservation Districts of Lee, Calhoun, and Baldwin counties, Kroger, Cleveland Brothers of Auburn, Alabama, Camp McDowell, and the University of West Alabama. The AL DCNR provided Project WET (Durney 2000) certification, to increase curriculum flexibility by offering a larger variety of water-related activities to suite individual educator needs.

Workshop attendees represented 45 formal and informal educational facilities or classrooms (Table 20, Table 21). Multiple educators from a single facility were common. Educational facility information was not obtained from three participants, and not included in the final count. Three citizen volunteer groups were represented, one being a Tennessee resident affiliated with AWW.

Table 18. Improvements made to the *Alabama's Living Streams: Stream Biomonitoring* after two pilot projects and a summer workshop series.

Original curriculum	Final curriculum
No correlation to Alabama Course of Study standards	Correlation to Alabama Course of Study standards: Alabama science classrooms for grades 4-12.
Few graphics incorporated in curriculum	Graphics incorporated in each module as series of power point lessons on CD-ROM
One activity per module	Four activities per module:
Resource material: Three sections on (1) selecting a stream sample site and (2) adaptations commonly seen in aquatic macroinvertebrates, and (3) common macroinvertebrates	Resource material: Addition of (1) two professional journal articles related to Alabama water (2) four, 5-minute *Discovering Alabama* lotic systems, (3) section on curriculum use in lotic systems, (4) current list of interactive and informational websites, and (5) correlation to Project WET activities
One Project sponsor: Auburn University Environmental Institute	Five Project sponsors: Auburn University Environmental Institute Auburn University Truman Pierce Institute Tallapoosa Watershed Project Legacy, Inc. Partners in Environmental Education *Discovering Alabama*

Table 19. Number of participants in four Alabama educator workshops conducted summer of 2007 to introduce the *Alabama's Living Streams: Stream Biomonitoring* curriculum and how to implement aquatic science in the classroom.

Location of Workshop	Number of Participants
Auburn, Alabama	16
Nauvoo, Alabama	19
Millbrook, Alabama	30
Livingston, Alabama	14

Table 20. Summary information for four aquatic science workshops held across Alabama summer 2007 through cooperation between Alabama Water Watch, the Alabama Wildlife Federation, the Alabama Chapter of the Sierra Club Water Sentinels, *Discovering Alabama*, and World Wildlife Fund.

Number of Educational Facilities Represented[1]	45
Number of K-12 and Higher Education Schools Represented[2]	34
Number of Alabama Counties Represented[3]	20
Average Number of Student Interactions/Yr Based on Workshop Survey Responses[4]	> 12,000

[1] Formal and informal (includes two churches and multiple environmental education facilities)

[2] Primary, Secondary, and Collegiate, formal classrooms only

[3] Out of 67 counties in Alabama; 3 participants were from out of state (GA, TN, TX)

[4] Best estimate; data incomplete from Lanark workshop

Survey data showed attendees represented educational facilities in 20 of Alabama's 67 counties (Figure 15). The estimated total number of student interactions per year was over 12,000 (Table 20). Data was incomplete for 25 participants. At informal educational facilities such as an environmental education center, multiple workshop participants worked with the same group of students. To avoid duplication, the number of student interactions per year reported by informal educators from the same facility were averaged and included as one count.

Table 21. Educational facilities, number of attendees, and education type for participants in the aquatic science workshops conducted in Alabama June and July 2007 with the AWW *Alabama's Living Streams: Stream Biomonitoring* curriculum.

Educational Facility	Number of People	Education Type[1]	Educational Facility	Number of People	Education Type[1]
Alabama A&M University	2	P	Montgomery Academy	1	R
AU Davis Arboretum	3	I	New Horizon Alternative School	1	P
AU Environmental Institute	2	I	North Sumter Jr High	1	P
AU Louise Kreher Forest Ecology Preserve	4	I	North Sumter Jr High Campus of Discovery	1	I
Blossomwood Elementary	2	P	Oak Mountain State Park	1	I
Chambers Academy	2	R	Phil Campbell Elementary	1	P
Charles R Drew Middle School	2	P	Popham Elementary (DelValle, TX)	1	P
Chelsea Middle School	1	P	Ragland High School	1	P
Coosa Valley Elementary	2	P	Randolph School	2	R
Country Day School	1	P	Ridgecrest Elementary	1	P
Crossville Elementary	2	P	Smiths Station High School	1	P
Dade County High School (Trenton, GA)			Springwood School	1	R
Eclectic Child Development	1	P	St. James Academy	1	R
Environmental Education Association of Alabama	1	I	Sumiton Christian	4	R
Episcipol Church	1	O	Sumter Co SWCD	1	I
Escambia County Middle School	1	P	Tombigbee RC&D	1	I
Eutaw Primary School	1	P	Trinity Christian School	3	R
Faith Church	1	O	Tuscaloosa Academy	1	R
Fort Payne High School	1	P	University of West Alabama	1	P
Franklin Co RC&D	1	I	Valley Intermediate	4	P
Holbrook Field Studies/Bob Jones High School	1	P	Volunteer Monitor (Chattahoochee Middle River Stewards)	1	O
Huntsville High School	1	P	Volunteer Monitor (Elk River Water Watch)	1	O
Locust Fork High School	1	P	Volunteer Monitor (Save our Saugahatchee)	1	O
Lowndes Academy	6	R			
Macon East Montgomery Academy	1	R	Walter M Kennedy Elementary	2	P

[1]Public School (P), Private School (R), Informal Classroom (I), or Other (O)

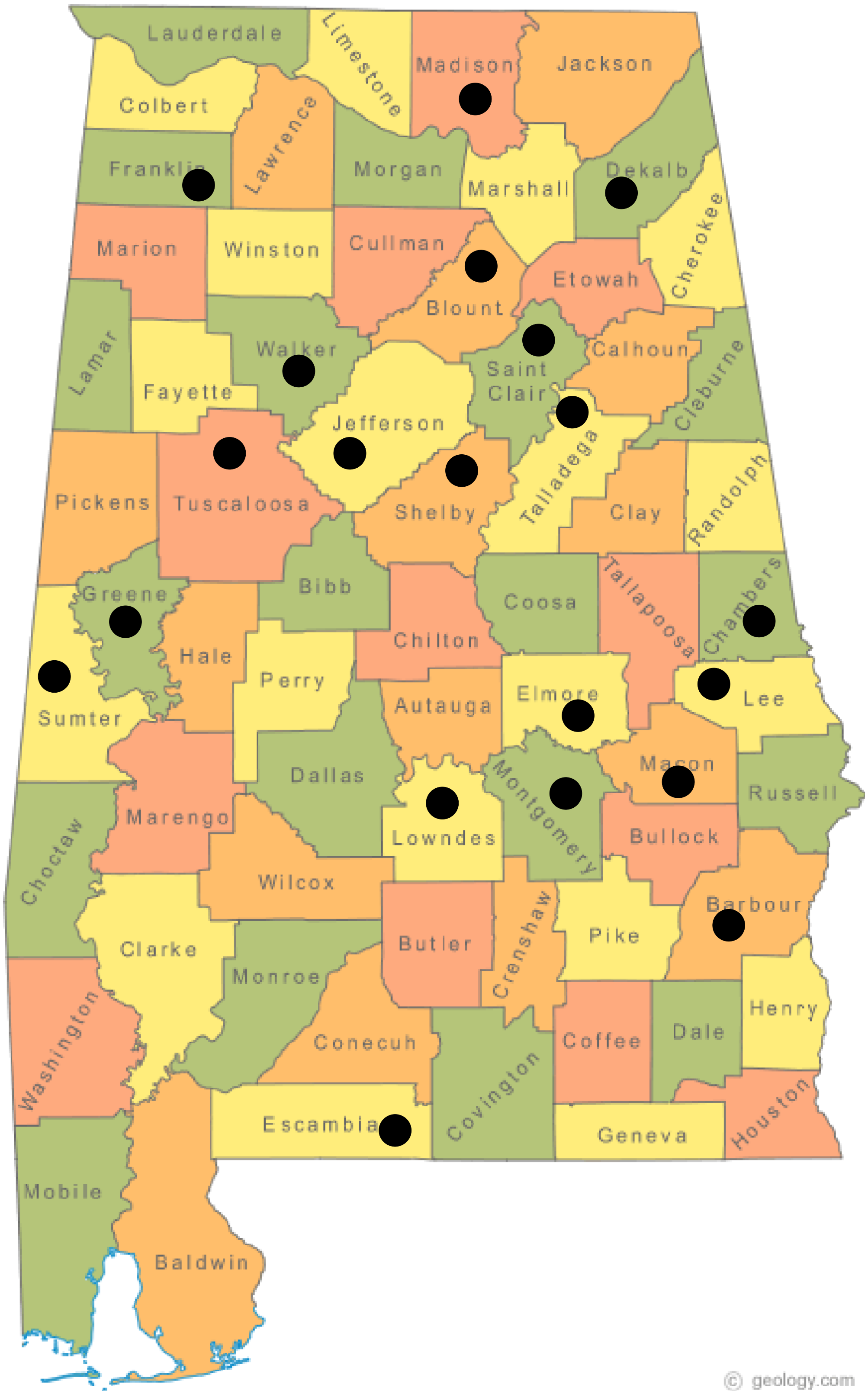


Figure 15. Twenty Alabama counties, shown with black dots, were represented by educators during four aquatic science workshops held across Alabama summer 2007.

Educators working with kindergarten through 8th grade students were the most common participants, totaling 70 of 89 survey responses (Table 22). Early elementary educators indicated the curriculum would need modification for their age group but expressed intent to use the curriculum. Most educators were comfortable working in and around water prior to the workshops. One respondent indicated they were uncomfortable getting in streams beforehand, but that participation in workshop activities helped gain confidence.

Table 22. Grade levels most often represented (including adults) by workshop participants in four aquatic science workshops held across Alabama summer 2007 through cooperation between Alabama Water Watch, the Alabama Wildlife Federation, the Alabama Chapter of the Sierra Club Water Sentinels, *Discovering Alabama*, and World Wildlife Fund.

	Number of Workshop Participants Representing Designated Grade Levels				
Grade Level	Auburn	Nauvoo	Millbrook	Livingston	Totals
Kindergarten thru 4th	6	5	19	8	38
5th thru 8th	8	4	11	9	32
9th thru 12th	5	3	0	4	12
Adult	1	2	0	4	7

Survey respondents were able to identify at least one pond, stream/creek, lake, or river in their local community that was potentially accessible for implementing the field trip portion of the AWW *Alabama's Living Streams: Stream Biomonitoring* curriculum (Table 23). Many participants had access to multiple waterbodies in the form of a school pond plus other local stream/creek, river, or lake. Ways to adapt the curriculum to waterbodies other than a stream were discussed to accommodate educators without stream access.

Table 23. Types of waterbodies local to educators attending one of four aquatic science workshops held across Alabama summer 2007.

Type of waterbody local to educational facility	Number of survey responses
School Pond	17
Off-campus Pond	14
Stream/Creek	25
Lake	5
River	23

Workshop agendas were designed to provide sufficient background knowledge on aquatic systems, nonpoint source pollution and water quality to help educators feel comfortable teaching these concepts. Participants noted the instructional background material was informative and enriching, and that cooperation among workshop presenters strengthened the impact. Multiple hands-on activities were included in the workshop including a stream bioassessment. Survey responses consistently rated hands-on activities and background material presentation as workshop strengths that increased the likelihood of curriculum implementation in their educational facility.

Many partners and sponsors made it possible for educators to attend workshops with little personal expense. Participants were supplied with necessary resources to implement the curriculum including field equipment. Surveys indicate resources supplied, whether lodging, meals, curriculum material, or equipment, was worth more than the actual dollar figures. The addition of teaching resources appeared to enhance likelihood of curriculum use, though no follow up study has been conducted to date.

CONCLUSIONS

The overall goal of this study was to evaluate the ability for citizens to interact effectively with educators as part of the Environmental Protection Agency's (USEPA) watershed approach to water quality improvements in the United States for the 21st century. This revolved around two things: (1) the ability for citizen volunteer water quality monitors to collect valid data through a scientifically sound stream biomonitoring protocol, and (2) the ability of those volunteers to become 'citizen scientists' in schools for locally relevant science learning and increased awareness for nonpoint source (NPS) pollution.

The mechanism developed to make the connection between local volunteers and the classroom was the Alabama Water Watch (AWW) educational curriculum *Alabama's Living Streams: Stream Biomonitoring*. The curriculum was based on the AWW Stream Biomonitoring Protocols for citizen volunteer monitors, which is a commonly accepted method for assessing stream health using aquatic macroinvertebrates as biological indicators of stream quality. It is necessary for aquatic science curricula to be based on sound science, therefore a desktop study evaluating the performance of AWW stream biomonitoring protocols compared to professional bioassessments through computer simulations took place simultaneously with curriculum development and implementation.

Results from the evaluation of the simulated AWW Stream Biomonitoring Protocols compared to professional bioassessments demonstrated only a 35% accuracy rate for the AWW protocol. Overestimations of stream health made up about 60% of the inaccuracy. After consideration of similar citizen protocols (primarily Georgia Adopt-A-Stream and Choctawhatchee Riverkeepers, an AWW coastal plain group) modifications were made to the original AWW protocol that increased accuracy to about 60% $^{+}/_{-}$ 20% for poor and fair stream quality assessments, and 63% $^{+}/_{-}$ 35% for excellent and poor stream quality assessments. The increased accuracy of the Modified AWW Protocol was obtained by altering three aspects of the original protocol based on study analysis. The modifications were: (1) a fourth pollution tolerance group was created with no weighted value, (2) organisms were shifted into different groups based on known tolerance values, and (3) the Cumulative Index Value brackets used to make the final stream quality assessment of excellent, good, fair, or poor water quality were shifted.

A secondary goal of the desktop study was to produce an AWW protocol scientifically rigorous enough to develop a Quality Assurance/Quality Control (QA/QC) plan to submit to the USEPA and ADEM for approval. The simulated Modified AWW Protocol was capable of producing consistent results to justify the development of a QA/QC plan. However it is recommended the study be continued further. This study modified existing AWW protocol within the framework of presence/absence of particular organisms to create a more accurate citizen protocol. Further work with the study database simulating metrics similar to the Engel and Voshell study (2002) could produce significantly higher agreement than the Modified AWW Protocol.

Accuracy obtained with the Modified AWW Protocol validated the use of the AWW *Alabama's Living Streams: Stream Biomonitoring* curriculum as a scientifically sound vehicle for incorporating aquatic science into the classroom. The curriculum's inherent abilities to increase NPS pollution awareness while developing an ethos of aquatic stewardship, as documented in surveys from the *Living Streams* pilot projects and summer workshop evaluations, could be enhanced with broader partnerships. For example, consistent integration of the Alabama Clean Water Partnerships *What's In Your Water?* 5th grade curriculum followed by aquatic science in subsequent grades through the *Alabama's Living Streams: Stream Biomonitoring* curriculum has the potential to not only develop stronger community partnerships, but increase student exposure to NPS pollution issues in their local watersheds.

Survey responses from summer workshop evaluations indicated educators were enthusiastic and eager to gain a better understanding of aquatic science and water quality issues in their communities. Responses suggested a genuine need exists for educator opportunities to gain first-hand experience with water quality issues and how to convey concepts to students. Teacher training, therefore, is a critical component of the *Alabama's Living Streams: Stream Biomonitoring* implementation process. Future efforts for resource agencies and community groups should be directed towards a cooperative approach to teacher training using locally relevant, scientifically sound curricula. Results of this study suggested working with the educational system in such a manner has the potential to produce effective, long-term advances in NPS pollution abatement for Alabama.

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APPENDICES

APPENDIX 1-1

Macroinvertebrate survey information for 208 sites collected in wadeable streams in Alabama by Alabama Department of Environmental Management (ADEM), Auburn University researchers (Webber), or Troy University researchers (Bennett) between 1996 and 2004. ADEM sites 68 and 69 were in database but not used in simulations due to unknown professional water quality assessment.

Collector	Site Number (s)
Bennett	1 through 49
ADEM	50-83, 102-104
Webber	84-101, 105-208

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
1	17	2001	Apr	Deer Branch	Bullock Co; trib. of Johnson Crk, 3.1 km north of Midway at CR 47
2	129	2001	Apr	Hurricane Crk	Barbour Co; 13.9 km north of Louisville at Hwy 238
3	148	2001	Apr	Persimmon Branch	Pike Co; 4.4 km north of Troy at TSU Golf Course
4	162	2001	Apr	Richland Crk Trib	Pike Co; 15.4 km east of Troy at Hwy 29
5	172	2001	Apr	Buckhorn Crk	Pike Co; 19.1 km east of Troy at Hwy 29
6	182	2001	Apr	Pea Crk	Barbour Co; 28.4 km east of Troy at CR 9
7	213	2001	Apr	Dorril Branch	Pike Co; off Richland creek, 15.7 km east of Troy between CR 26 and CR 69
8	256	2001	Apr	Mims Crk	Pike Co; 5.2 km southwest of Brundidge at CR 59
9	271	2001	Apr	Big Crk	Barbour Co; 11.9 km east of Brundidge at Hwy 10
10	272	2001	Apr	Thompson Crk	Barbour Co; 14.5 km east of Brundidge at Hwy 10
11	302	2001	Apr	Indian Crk	Pike Co; 13.6 km southwest of Brundidge at CR 331
12	308	2001	Apr	Whitewater Crk	Coffee Co; 18.8 km southwest of Brundidge at Hwy 167

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
13	316	2001	Apr	Clearwater Crk Trib	Coffee Co; 12.7 km west of Ariton at CR 110
14	372	2001	Apr	Bluff Crk Trib	Coffee Co; 16.5 km east of Brantley at CR 331
15	377	2001	Apr	Cowpen Crk	Coffee Co; 21.4 km east of Brantley at CR 324
16	378	2001	Apr	Whitewater Crk	Coffee Co; 6.3 km southwest of Lowry Mill at CR 224
17	394	2001	Apr	Clearwater Crk	Coffee Co; 11.6 km west of Ariton at CR 105
18	433	2001	Apr	Pauls Crk	Barbour Co; 6.1 km southwest of Clayton at Hwy 51
19	454	2001	Apr	McSwain Crk	Barbour Co; 11.3 km southeast of Clayton at McSwain Crk Rd
20	455	2001	Apr	Pauls Crk	Barbour Co; 13.9 km south of Clayton at CR 20
21	479	2001	Apr	Wallace Crk	Barbour Co; 5.8 km southwest of Texasville at Mavis Barroll Rd
22	480	2001	Apr	Dear Crk	Barbour Co; 5.8 km south of Texasville at Mavis Barroll Rd
23	571	2001	Apr	Bucks Mill Crk	Coffee Co; 6.1 km southeast of Elba at CR 518
24	583	2001	Apr	Little Hayes Crk	Coffee Co; 11.3 km southwest of Elba at CR 420
25	586	2001	Apr	Pages Crk	Coffee Co; 9.9 km east of Opp at CR 440
26	691	2001	Apr	Panther Crk	Geneva Co; 10.4 km west of Samson
27	701	2001	Apr	Corner Crk	Geneva Co; 12.2 km southwest of Samson at CR 54
28	760	2001	Apr	Sandy Crk	Geneva Co; 6.4 km south of Samson at Johnson Rd
29	898	2001	Apr	Cowpen Crk	Coffee Co; 4.6 km east of Enterprise at Hwy 84
30	917	2001	Apr	Choctawhatchee River Trib	Dale Co; 3.2 km west of Midland City at Hwy 231
31	944	2001	Apr	Double Bridges Crk	Coffee Co; 15.1 km southwest of Enterprise at CR 655
32	969	2001	Apr	Gilley Mill Crk	Houston Co; 13.3 km north of Slocomb at CR 2

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
33	975	2001	Apr	Little Choctawhatchee River Trib	Dale Co; 16.8 km northwest of Dothan at CR 63
34	1038	2001	Apr	Pates Crk	Geneva Co; 8.1 km north of Slocomb at Hwy 123
35	1078	2001	Apr	Boggy Branch	Geneva Co; 7.3 km northwest of Geneva at CR 8
36	1102	2001	Apr	Negro Church Branch	Coffee Co; 10.7 km northeast of Geneva at Hwy 52
37	1106	2001	Apr	Justice Mill Crk	Geneva Co; 4.1 km southwest of Hartford at CR 16
38	1147	2001	Apr	Little Sandy Crk	Geneva Co; 9.0 km west of Geneva at CR 16
39	1168	2001	Apr	Spring Crk	Geneva Co; 6.7 km east of Geneva at CR 6
40	1172	2001	Apr	Spring Crk	Geneva Co; 11.6 km east of Geneva at CR 55
41	1201	2001	Apr	Wrights Crk Trib	Geneva Co; 7.8 km south of Slocomb at CR 91
42	1216	2001	Apr	Holmes Crk	Geneva Co; 7.5 km southeast of Slocomb at CR 48
43	1250	2001	Apr	Pea River	Pike Co; 9.1 km west of Ariton at Hwy 231
44	1251	2001	Apr	Whitewater Crk	Coffee Co; in Lowry Mill at CR 224
45	1500	2001	Apr	Rock Crk	Houston Co; next to TGI Fridays in Dothan at Westgate Pky
46	1501	2001	Apr	Klondike Crk	Dale Co; 7.0 km south of Ozark at Arnold Farm
47	1503	2001	Apr	East Fork Choctawhatchee River	Barbour Co; 7.5 km east of Texasville at CR 75
48	1506	2001	Apr	Hurricane Crk	Dale Co; 7.8 km south of Ozark at Arnold Farm
49	1507	2001	Apr	Choctawhatchee River Trib	Dale Co; 11.0 km southeast of Ozark, at Hwy 231
50	SPD 001	2002	Apr	Soapstone Crk	Dallas Co; upstream of US 80, east of Selma
51	SPD 002 q	2002	Apr	Soapstone Crk	Dallas Co; upstream of US 80, east of Selma

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
52	SWFC 001	2002	May	Swift Crk	Chilton Co; at CR 24 near Billingsly
53	WASP 001	2002	May	Washington Crk	Perry Co; upstream of Hwy 183 bridge SW of Marion
54	CAFC 001	2002	May	Caffee Crk	Bibb Co; Caffee Crk at Co Hwy 24
55	FRMB 008	2002	May	Fourmile Crk	Bibb Co; CR 10 northwest of Brierfield Trib to Little Cahaba
56	FRMS 009	2002	May	Fourmile Crk	Shelby Co; at CR 61
57	HNMB 004	2002	May	Hendrick Mill Branch	Blount Co;
58	MAYB 001	2002	May	Mayberry Crk	Bibb Co; unnamed Bibb CR (may be 24) off of Bibb CR 10
59	PA 001	2002	May	Patton Crk	Jefferson Co; Hwy 150
60	WLFS 009	2002	May	Wolf Crk	St. Clair Co; unnamed St. Clair CR ~ 1 mile north of Wolf Crk
61	DRYB 011	2002	May	Dry Crk	Blout Co; at Phillips Rd
62	GRVB 004	2002	May	Graves Crk	Blount Co; at Martis Mill Rd
63	MUDJ 002	2002	May	Mud Crk	Jefferson Co; at Groundhog Rd
64	NORF 028 c	2002	May	North R	Fayette Co; at unnamed Fayette CR near Berry
65	VA 001	2002	May	Valley Crk	Jefferson Co; at Jefferson CR 36 (CM 32.3)
66	VLGJ 004	2002	May	Village Crk	Jefferson Co; at Avenue F in Ensley
67	CLKM 004	2002	May	Clark Crk	Marion Co; at CR 35 near Fulton Bridge
68	CTML 006	2002	May	Cantrell Mill Crk	NOT USED IN ANALYSIS DUE TO LACK OF DATA
69	TLNF 009	2002	May	Tollison Crk	NOT USED IN ANALYSIS DUE TO LACK OF DATA
70	DRYC 002	2002	May	Dry Crk	Calhoun Co; at Calhoun CR 55 (Rabbittown Rd) in Talladega Nat'l Forest near Burns
71	DRYT 009	2002	May	Dry Crk	Talladega Co; at CR 234 (Forest Service Rd) off CR 302 in the Talladega Natl. Forest

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
72	LCNE 001	2002	May	Little Canoe Crk	Etowah Co; at unnamed CR off of AL Hwy 7
73	BWCUA 001	2002	Jun	Blackwater Crk	Walker Co; at AL Hwy 257
74	BERD 009	2002	Jun	Bear Crk	Dekalb Co; Bear Adamsburg Rd off Dekalb CR 127 near Ft Payne and Dog Town
75	BINC 190	2002	Jun	Brindley Crk	Cullman Co; at Cullman CR prior to confluence with Eightmile Ck
76	BLVC 001	2002	Jun	Blevens Crk	Cullman Co; at unnamed Cullman CR west of CR 31
77	BRSL 003	2002	Jun	Brushy Crk	Lawrence Co; upstream of North Loop of CR 73 (east of CR 70) in Bankhead Nat'l Forest
78	EMIC 073a	2002	Jun	Eightmile Crk	Cullman Co; at Mount View
79	HGUJ 160	2002	Jun	Hogue Crk	Jackson Co; at AL Hwy 117
80	INMW 001	2002	Jun	Inman Crk	Winston Co; at unnamed Forest Service Rd in Bankhead Nat'l Forest
81	MUDC 002	2002	Jun	Mud Crk	Cullman Co; at AL Hwy 31
82	RYNC 001	2002	Jun	Ryan Crk	Cullman Co; about 1/4 mile south of CR 438/18, below mouth of Bavar Ck
83	TPSL 001	2002	Jun	Thompson Crk	Lawrence Co; at US Forest Service Rd 208 in Bankhead Nat'l Forest
84	CB-1	2004	Jun	Chewacla Crk	Lee Co; at AL 51, upstream of bridge about 100 m
85	CB-2	2004	Jun	Robinson Crk	Lee Co; Chewacla Ck tributary; at CR 146, 50 m upstream of bridge
86	CB-3	2004	Jun	Chewacla Crk	Lee Co; 100 m above bridge on CR 27
87	CB-4	2004	Jun	Nash Crk	Lee Co; Chewacla Ck tributary, just upstream of confluence with Chewacla Ck
88	CB-5	2004	Jun	Chewacla Crk	Lee Co; downstream of dam on Lake Ogletree about 600 m
89	CB-5A	2004	Jun	Chewacla Crk	Lee Co; just above the "pretty hole" near quarry
90	CB-5B	2004	Jun	Chewacla Crk	Lee Co; about 600 m downstream of "pretty hole" in middle of sinkhole reach
91	CB-6	2004	Jun	Chewacla Crk	Lee Co; downstream of MM quarry, above Chewacla Lake effluent and Moores Mill Crk

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
92	CB-7	2004	Jun	Chewacla Crk	Lee Co; just downstream from confluence of Town Crk and Chewacla
93	CB-8	2004	Jun	Chewacla Crk	Lee Co; about 600 m downstream of Parkerson Mill Crk
94	PB-1	2004	Jun	Parkerson Mill Crk	Lee Co; at end of Lake St about 0.5 mi north of I-85
95	PB-2	2004	Jun	Parkerson Mill Crk	Lee Co; at CR 10 just below bridge; above discharge of Southside Sewage Treatment Plant
96	PB-3	2004	Jun	Parkerson Mill Crk	Lee Co; about 200 m downstream of discharge from Southside Sewage Treatment Plant on CR 10
97	RB-1	2004	Jun	Cane Crk	Lee Co; 3rd-order reference stream at CR 217
98	RB-2	2004	Jun	Ropes Crk Tributary	Lee Co; 2nd-order reference stream in the Saugahatchee Ck watershed off CR 65
99	RB-4	2004	Jun	Hatchet Crk	Coosa Co; 4th-order reference stream in the Coosa drainage at CR 44
100	CB-9	2004	Jun	Chewacla Crk	Macon Co; at US 80, upstream of bridge
101	RB-5	2004	Jun	East Fork Choctawhatchee River	Barbour Co; 4th-order reference stream at CR 75south of Baker Hill
102	FMCJ 004	2002	Jun	Fivemile Crk	CR 67 (Republic Rd)
103	LFKB 002	2002	Jun	Locust Fork	Blount Co; at Vaughns Bridge
104	LFKB 002 q	2002	Jun	Locust Fork	Blount Co; at Vaughns Bridge
105	BC1	1999	Jun	East Fork Choctawhatchee River	Barbour Co;
106	BC2	1999	Jun	Pea River	Barbour Co; Bridge crossing at AL Hwy 10 West of Clio
107	BC3	1999	Jul	West Fork Choctawhatchee River	Barbour Co; Bridge crossing at AL Hwy 131
108	BC4	1999	Jul	Pauls Crk	Barbour Co; Bridge crossing at CR 20
109	BC5	1999	Jul	Leak Crk	Barbour Co; Bridge crossing at CR 79 West of Eufaula

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
110	BC6	1999	Aug	Lindsey Crk	Barbour Co; Bridge crossing at CR 41 West of Texasville
111	BC7	1999	Aug	Whitewater Crk	Barbour Co; Bridge crossing at CR 215 West of Victoria
112	RB-3	1999	Aug	Whitewater Crk	Coffee Co; 4th-order reference stream at CR 215
113	CH2	1996	Aug	Choccoloco Crk	Site description unknown
114	CH3	1996	Aug	Choccoloco Crk	Site description unknown
115	CH4	1996	Aug	Choccoloco Crk	Site description unknown
116	CH5	1996	Oct	Choccoloco Crk	Site description unknown
117	CH6	1996	Oct	Choccoloco Crk	Site description unknown
118	CH7	1996	Oct	Choccoloco Crk	Site description unknown
119	CH8	1996	Oct	Choccoloco Crk	Site description unknown
120	SN10	1996	Oct	Snow Crk	Site description unknown
121	SN11	1996	Oct	Snow Crk	Site description unknown
122	SN12	1996	Oct	Snow Crk	Site description unknown
123	SN13	1996	Oct	Snow Crk	Site description unknown
124	TC14	1996	Oct	Terrapin Crk	Site description unknown
125	CH15	1996	Oct	Choccoloco Crk	Site description unknown
126	SF16	1996	Oct	South Fork Terrapin Crk	Site description unknown
127	CB-1	1999	Oct	Chewacla Crk	Lee Co; at AL 51, upstream of bridge about 100 m
128	CB-2	1999	Oct	Robinson Crk	Lee Co; Chewacla Ck tributary; at CR 146, 50 m upstream of bridge
129	CB-3	1999	Oct	Chewacla Crk	Lee Co; 100 m above bridge on CR 27

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
130	CB-4	1999	Oct	Nash Crk	Lee Co; Chewacla Ck tributary, just upstream of confluence with Chewacla Ck
131	CB-5	1999	Oct	Chewacla Crk	Lee Co; downstream of dam on Lake Ogletree about 600 m
132	CH2	1996	Oct	Choccoloco Crk	Site description unknown
133	CH3	1996	Oct	Choccoloco Crk	Site description unknown
134	CH4	1996	Oct	Choccoloco Crk	Site description unknown
135	CH5	1996	Oct	Choccoloco Crk	Site description unknown
136	CH6	1996	Nov	Choccoloco Crk	Site description unknown
137	CH7	1996	Nov	Choccoloco Crk	Site description unknown
138	CH8	1996	Nov	Choccoloco Crk	Site description unknown
139	SN10	1996	Nov	Snow Crk	Site description unknown
140	SN11	1996	Nov	Snow Crk	Site description unknown
141	SN12	1996	Nov	Snow Crk	Site description unknown
142	SN13	1996	Nov	Snow Crk	Site description unknown
143	TC14	1996	Nov	Terrapin Crk	Site description unknown
144	CH15	1996	Nov	Choccoloco Crk	Site description unknown
145	SF16	1996	Nov	South Fork Terrapin Crk	Site description unknown
146	CB-6	1999	Nov	Chewacla Crk	Lee Co; downstream of MM quarry, above Chewacla Lake effluent and Moores Mill Crk
147	CB-7	1999	Nov	Chewacla Crk	Lee Co; just downstream from confluence of Town Crk and Chewacla
148	CB-8	1999	Nov	Chewacla Crk	Lee Co; about 600 m downstream of Parkerson Mill Crk
149	PB-1	1999	Nov	Parkerson Mill Crk	Lee Co; at end of Lake St about 0.5 mi north of I-85

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
150	PB-2	1999	Nov	Parkerson Mill Crk	Lee Co; at CR 10 just below bridge; above discharge of Southside Sewage Treatment Plant
151	PB-3	1999	Nov	Parkerson Mill Crk	Lee Co; about 200 m downstream of discharge from Southside Sewage Treatment Plant on CR 10
152	RB-1	1999	Nov	Cane Crk	Lee Co; 3rd-order reference stream at CR 217
153	RB-2	1999	Nov	Ropes Crk Tributary	Lee Co; 2nd-order reference stream in the Saugahatchee Ck watershed off CR 65
154	CB-9	1999	Nov	Chewacla Crk	Macon Co; at US 80, upstream of bridge
155	BC1	2003	Nov	East Fork Choctawhatchee River	Barbour Co;
156	BC2	2003	Nov	Pea River	Barbour Co; Bridge crossing at AL Hwy 10 West of Clio
157	BC3	2003	Nov	West Fork Choctawhatchee River	Barbour Co; Bridge crossing at AL Hwy 131
158	BC4	2003	Nov	Pauls Crk	Barbour Co; Bridge crossing at CR 20
159	BC5	2003	Nov	Leak Crk	Barbour Co; Bridge crossing at CR 79 West of Eufaula
160	BC6	2003	Nov	Lindsey Crk	Barbour Co; Bridge crossing at CR 41 West of Texasville
161	BC7	2003	Nov	Whitewater Crk	Barbour Co; Bridge crossing at CR 215 West of Victoria
162	RB-1	2000	Nov	Cane Crk	Lee Co; 3rd-order reference stream at CR 217
163	RB-2	2000	Nov	Ropes Crk Tributary	Lee Co; 2nd-order reference stream in the Saugahatchee Ck watershed off CR 65
164	CB-1	2000	Nov	Chewacla Crk	Lee Co; at AL 51, upstream of bridge about 100 m
165	CB-2	2000	Nov	Robinson Crk	Lee Co; Chewacla Ck tributary; at CR 146, 50 m upstream of bridge
166	CB-3	2000	Nov	Chewacla Crk	Lee Co; 100 m above bridge on CR 27
167	CB-4	2000	Dec	Nash Crk	Lee Co; Chewacla Ck tributary, just upstream of confluence with Chewacla Ck
168	CB-6	2000	Dec	Chewacla Crk	Lee Co; downstream of MM quarry, above Chewacla Lake effluent and Moores Mill Crk

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
169	CB-7	2000	Dec	Chewacla Crk	Lee Co; just downstream from confluence of Town Crk and Chewacla
170	CB-8	2000	Dec	Chewacla Crk	Lee Co; about 600 m downstream of Parkerson Mill Crk
171	PB-1	2000	Dec	Parkerson Mill Crk	Lee Co; at end of Lake St about 0.5 mi north of I-85
172	PB-2	2000	Dec	Parkerson Mill Crk	Lee Co; at CR 10 just below bridge; above discharge of Southside Sewage Treatment Plant
173	PB-3	2000	Dec	Parkerson Mill Crk	Lee Co; about 200 m downstream of discharge from Southside Sewage Treatment Plant on CR 10
174	RB-3	2000	Dec	Whitewater Crk	Coffee Co; 4th-order reference stream at CR 215
175	CB-9	2000	Dec	Chewacla Crk	Macon Co; at US 80, upstream of bridge
176	CB-1	2001	Dec	Chewacla Crk	Lee Co; at AL 51, upstream of bridge about 100 m
177	CB-2	2001	Dec	Robinson Crk	Lee Co; Chewacla Ck tributary; at CR 146, 50 m upstream of bridge
178	CB-3	2001	Dec	Chewacla Crk	Lee Co; 100 m above bridge on CR 27
179	CB-4	2001	Dec	Nash Crk	Lee Co; Chewacla Ck tributary, just upstream of confluence with Chewacla Ck
180	CB-5A	2001	Dec	Chewacla Crk	Lee Co; just above the "pretty hole" near quarry
181	CB-5B	2001	Dec	Chewacla Crk	Lee Co; about 600 m downstream of "pretty hole" in middle of sinkhole reach
182	CB-6	2001	Dec	Chewacla Crk	Lee Co; downstream of MM quarry, above Chewacla Lake effluent and Moores Mill Crk
183	CB-7	2001	Dec	Chewacla Crk	Lee Co; just downstream from confluence of Town Crk and Chewacla
184	CB-8	2001	Dec	Chewacla Crk	Lee Co; about 600 m downstream of Parkerson Mill Crk
185	PB-1	2001	Dec	Parkerson Mill Crk	Lee Co; at end of Lake St about 0.5 mi north of I-85
186	PB-2	2001	Dec	Parkerson Mill Crk	Lee Co; at CR 10 just below bridge; above discharge of Southside Sewage Treatment Plant
187	PB-3	2001	Dec	Parkerson Mill Crk	Lee Co; about 200 m downstream of discharge from Southside Sewage Treatment Plant on CR 10

APPENDIX 1-1, continued

Site #	Site Code	Sample Year	Sample Month	Stream Name	Site Description
188	RB-2	2001	Dec	Ropes Crk Tributary	Lee Co; 2nd-order reference stream in the Saugahatchee Ck watershed off CR 65
189	RB-1	2001	Dec	Cane Crk	Lee Co; 3rd-order reference stream at CR 217
190	CB-9	2001	Dec	Chewacla Crk	Macon Co; at US 80, upstream of bridge
191	RB-5	2001	Dec	East Fork Choctawhatchee River	Barbour Co; 4th-order reference stream at CR 75south of Baker Hill
192	CB-1	2002	Dec	Chewacla Crk	Lee Co; at AL 51, upstream of bridge about 100 m
193	CB-3	2002	Dec	Chewacla Crk	Lee Co; 100 m above bridge on CR 27
194	CB-2	2002	Dec	Robinson Crk	Lee Co; Chewacla Ck tributary; at CR 146, 50 m upstream of bridge
195	CB-4	2002	Dec	Nash Crk	Lee Co; Chewacla Ck tributary, just upstream of confluence with Chewacla Ck
196	CB-5	2002	Dec	Chewacla Crk	Lee Co; downstream of dam on Lake Ogletree about 600 m
197	CB-5A	2002	Dec	Chewacla Crk	Lee Co; just above the "pretty hole" near quarry
198	CB-6	2002	Dec	Chewacla Crk	Lee Co; downstream of MM quarry, above Chewacla Lake effluent and Moores Mill Crk
199	CB-7	2002	Dec	Chewacla Crk	Lee Co; just downstream from confluence of Town Crk and Chewacla
200	CB-8	2002	Dec	Chewacla Crk	Lee Co; about 600 m downstream of Parkerson Mill Crk
201	PB-1	2002	Dec	Parkerson Mill Crk	Lee Co; at end of Lake St about 0.5 mi north of I-85
202	PB-2	2002	Dec	Parkerson Mill Crk	Lee Co; at CR 10 just below bridge; above discharge of Southside Sewage Treatment Plant
203	PB-3	2002	Dec	Parkerson Mill Crk	Lee Co; about 200 m downstream of discharge from Southside Sewage Treatment Plant on CR 10
204	RB-2	2002	Dec	Ropes Crk Tributary	Lee Co; 2nd-order reference stream in the Saugahatchee Ck watershed off CR 65
205	RB-1	2002	Dec	Cane Crk	Lee Co; 3rd-order reference stream at CR 217
206	RB-4	2002	Dec	Hatchet Crk	Coosa Co; 4th-order reference stream in the Coosa drainage at CR 44
207	CB-9	2002	Dec	Chewacla Crk	Macon Co; at US 80, upstream of bridge
208	RB-5	2002	Dec	East Fork Choctawhatchee River	Barbour Co; 4th-order reference stream at CR 75south of Baker Hill

APPENDIX 1-2

Example of metrics used by Alabama Department of Environmental Protection (ADEM), Auburn University researchers (Webber), and Troy University researchers (Bennett) for making water quality assessments using aquatic macroinvertebrates.

Alabama Department of Environmental Management (ADEM):

	BERD-9	BERD-9	BLVC-1	BLVC-1	DRYC-2	DRYC-2	BRSL-3	BRSL-3
Subecoregion	68d		68d		68d		68e	
Drainage area (mi^2)		Fair	9	Fair		Good		Good
Date (yymmdd)	020625	13	020618	13	020625	17	020612	17
Total taxa richness (gener	56	3	63	3	48	1	58	3
EPT taxa richness (genera	13	3	13	3	15	3	17	5
NCBI	5.73	1.00	5.33	1.00	4.24	5.00	5.18	3.00
% Dominant Taxon	10.9	5.0	31.5	1.0	16.2	3.0	13.4	3.0
# EPT	51		993		556		433	
# organisms collected	212		1745		935		1524	
% EPT Organisms	24	1	57	5	59	5	28	3
# EPT families	10	Good	9	Fair	10	Good	14	Good

Auburn University researchers (Webber):

	Metric Value							
	2nd Order Stream Sites				Bioassessment Scores			
	RB-2	CB-1	CB-2	CB-4	RB-2	CB-1	CB-2	CB-4
Richness[1]	44	39	44	36	6	6	6	6
EPT Index[1]	13	6	12	8	6	0	6	0
HBI[2]	4.73	6.47	6.00	5.16	6	4	4	6
SC/FC Ratio[1]	0.71	1.07	1.43	0.32	6	6	6	4
%Contrib.Dom[3]	17	9	18	32	6	6	6	2
EPT/Chir Ratio[1]	4.4	1.6	4.1	5.4	6	2	6	6
SH/Total Ratio[1]	0.8	0.05	0.00	0.02	6	6	0	2
				Total Score	42	30	34	26
				Biological Condition	Non	SL	SL	SL

[1]Metric values compared as ratio of study site to reference site x 100.
[2]Metric values compared as ratio of reference site to study site x 100.
[3]Metric values evaluated not percent comparability.

Non = Not Impaired
SL = Slightly Impaired

APPENDIX 1-2, continued

Troy University researchers (Bennett):

Choctawhatchee-Pea Watershed Macroinvertebrate Metrics

Site Number: 17 Catchment Area (km^2): 0.61
Site Name: Deer Branch
Location: Bullock County, AL; CR 47
Lat: 32°06'50" Long: 85°31'07"

Metric	Actual Observation	Index Score
1. Number of EPT Taxa	0	0
2. Number of Trichoptera Taxa	0	0
3. Number of Crustacea and Mollusca Taxa	1	2
4. Number of Diptera Taxa	2	6
5. Percent Dominant Taxa	45%	4
6. Percent Ephemeroptera Individuals	0%	0
7. Percent Diptera Individuals	46%	6
8. Percent Chironominae to Chironomidae	97%	6
9. Percent Shredder Individuals	0%	0
10. Family Biotic Index (FBI)	7.68	4
	Total Index Score:	28
	Descriptive Score:	P

APPENDIX 1-3

Example of SAS® codes used to generate simulated citizen volunteer stream quality assessments and comparisons between citizen and professional assessments.

```
/*  Riffle-AWW.SAS-PROGRAM to calc AWW riffle only score for macroinvertebrate collections */ options linesize=80 pagesize=500;
FILENAME BUG1 'C:\Documents and Settings\FULLEJ3\Desktop\Thesis Material\Data\SAS\Input\Master Data for SAS Input.csv';
DATA DS1; INFILE BUG1 DLM=',' n=30000 LRECL=250;
informat order  $ 16.;
informat family $ 16.;
INPUT site  yr  mth $ collectr $ s_code $ s_order $ d_size ecoregn falline $ ref $ type $ order $ family $ taxon $ habitat $ TV  number;

if habitat = 'p'  then return;
if habitat = 'ln'  then return;
if habitat = 'pl'  then return;
if habitat = 'l'  then return;
if habitat = 'n'  then return;

/* Group 1 taxa */
if family = 'Hydropsychidae' then  order='Trichoptera2';
if order = 'Trichoptera' then  AWW_taxa=1;
if order = 'Ephemeroptera' then  AWW_taxa=2;
if family = 'Elmidae' then  AWW_taxa=3;
if family = 'Physidae' then  order='Gastropoda2';
if order = 'Gastropoda' then  AWW_taxa=4;
if order = 'Plecoptera' then  AWW_taxa=5;
if family = 'Psephenidae' then  AWW_taxa=6;

/* Group 2 taxa */
if family = 'Simuliidae' then AWW_taxa=10;
if family = 'Tipulidae' then AWW_taxa=11;
if order = 'Decapoda' then  AWW_taxa=12;
if family = 'Aeshnidae' or family = 'Cordulegastridae' or family = 'Corduliidae' or family = 'Gomphidae' or family = 'Libellulidae' or family = 'Macromiidae' then  AWW_taxa=13;
if family = 'Calopterygidae' or family = 'Coenagrionidae' or family = 'Lestidae' then AWW_taxa=14;
if family = 'Hydropsychidae' then AWW_taxa=15;
if order = 'Megaloptera' then  AWW_taxa=16;
if order = 'Amphipoda' then  AWW_taxa=17;
if family = 'Athericidae' then AWW_taxa=18;
if order = 'Isopoda' then  AWW_taxa=19;
if family = 'Corbiculidae' then AWW_taxa=20;
```

```
/* Group 3 taxa */
if order = 'Oligochaeta' then  AWW_taxa=21;
if family = 'Chironomidae' then AWW_taxa=22;
if family = 'Physidae' then AWW_taxa=23;
if order = 'Hirudinea' then  AWW_taxa=24;

if AWW_taxa < 7 then AWW_g=1;
if 9 < AWW_taxa < 21 then AWW_g=2;
if AWW_taxa > 20 then AWW_g=3;

if AWW_taxa ge 1 then count=1;
output; return; RUN;

DATA ds2; set ds1;
if count ne 1 then return;
output; return; RUN;

PROC SORT; BY site yr mth collectr s_code s_order d_size ecoregn falline ref
AWW_g AWW_taxa; RUN;

PROC MEANS NOPRINT; BY site yr mth collectr s_code s_order d_size ecoregn
falline ref AWW_g AWW_taxa;
VAR count;
OUTPUT OUT=DS3 MEAN=count2; RUN;

PROC SORT; BY site yr mth collectr s_code s_order d_size ecoregn falline ref
AWW_g; RUN;

PROC MEANS NOPRINT; BY site yr mth collectr s_code s_order d_size ecoregn
falline ref AWW_g;
VAR count2;
OUTPUT OUT=DS4 Sum=index_v1; RUN;

DATA ds5; set ds4;
if AWW_g=1 then index_v2=index_v1*3;
if AWW_g=2 then index_v2=index_v1*2;
if AWW_g=3 then index_v2=index_v1*1;
output; return; RUN;

PROC SORT; BY site yr mth collectr s_code s_order d_size ecoregn falline ref; RUN;
```

```
PROC MEANS NOPRINT; BY site yr mth collectr s_code s_order d_size ecoregn
falline ref;
VAR index_v2;
OUTPUT OUT=ds6 Sum=Cum_IV; RUN;

DATAds7; set ds6;
If Cum_IV < 11 then AWW = 4;
If 10 < Cum_IV < 17 then AWW = 3;
If 16 < Cum_IV < 23 then AWW = 2;
If Cum_IV > 22 then AWW = 1; RUN;

PROC SORT; By site yr mth collectr s_code s_order d_size ecoregn falline ref; RUN;

FILENAME profdat 'C:\Documents and Settings\FULLEJ3\Desktop\Thesis
Material\Data\SAS\Input\PROF.csv';
DATA DS8; INFILE profdat DLM=',' n=30000 LRECL=250;
INPUT site PROF;
output; return; RUN;

DATA DS9; merge ds7 ds8; by site;
output; return; RUN;

PROC SORT; By site yr mth collectr s_code s_order d_size ecoregn falline ref; RUN;

PROC FREQ data=ds9;
tables AWW PROF
AWW*PROF / AGREE ; RUN;

PROC CORR data=ds9 nomiss alpha spearman;
  var aww prof; RUN;

PROC PRINT; RUN;
```

APPENDIX 1-4

SAS® 4x4 contingency table with statistics from comparison of 206 simulated citizen stream bioassessments in riffles and all habitats to known professional stream quality assessments. Professional bioassessments conducted by Alabama Department of Environmental Management, Auburn University and Troy University researchers between 1996 and 2004. Water quality key: excellent (1), good (2), fair (3) and poor (4).

Simulated Alabama Water Watch (AWW), RIFFLE Habitat

Table of AWW by PROF for RIFFLES

AWW \ PROF	1	2	3	4	Total
1	43 20.9 33.3 95.6	60 29.1 46.5 85.7	22 10.7 17.1 39.3	4 1.9 3.1 11.4	129 62.6
2	1 0.5 2.7 2.2	9 4.4 24.3 12.9	20 9.7 54.1 35.7	7 3.4 18.9 20.0	37 18.0
3	1 0.5 4.2 2.2	1 0.5 4.2 1.4	9 4.4 37.5 16.1	13 6.3 54.2 37.1	24 11.7
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 2.4 31.3 8.9	11 5.3 68.8 31.4	16 7.8
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa κ

Statistic	Value	ASE	95% Confidence	
Simple	0.1411	0.0362	0.0701	0.2120
Weighted	0.3356	0.0379	0.2613	0.4099

Cronbach Coefficient α

Variables	Alpha
Raw	0.7865
Standardize	0.7869

Spearman Correlation Coefficients ρ

Prob > |r| under H0:

	AWW	PROF	
AWW	1.0000	0.6602	<.0001
PROF	0.6602	1.0000	<.0001

APPENDIX 1-4, continued

Simulated Alabama Water Watch (AWW), ALL AVAILABLE Habitats

Table of AWW by PROF for ALL HABITATS

AWW	PROF 1	2	3	4	Total
1	43 20.9 32.6 95.6	60 29.1 45.5 85.7	24 11.7 18.2 42.9	5 2.4 3.8 14.3	132 64.1
2	1 0.5 2.8 2.2	9 4.4 25.0 12.9	18 8.7 50.0 32.1	8 3.9 22.2 22.9	36 17.5
3	1 0.5 3.5 2.2	1 0.5 3.5 1.4	13 6.3 44.8 23.2	14 6.8 48.3 40.0	29 14.1
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.5 11.1 1.8	8 3.9 88.9 22.9	9 4.4
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.144	0.036	0.074	0.215
Weighted Kappa	0.311	0.037	0.237	0.385

Cronbach Coefficient α

Variables	Alpha
Raw	0.771
Standardized	0.775

Spearman Correlation Coefficients ρ

Prob > |r| under H0: Rho=0

	AWW	PROF	
AWW	1.000	0.635	<.000
PROF	0.635	1.000	<.000

APPENDIX 1-4, continued

Simulated Choctawhatchee River Keepers (CRK), RIFFLE Habitats

Table of CRK by PROF for RIFFLES

CRK	PROF: 1	2	3	4	Total
1	40 19.4 40.0 88.9	50 24.3 50.0 71.4	8 3.9 8.0 14.3	2 1.0 2.0 5.7	100 48.5
2	3 1.5 7.3 6.7	13 6.3 31.7 18.6	20 9.7 48.8 35.7	5 2.4 12.2 14.3	41 19.9
3	1 0.5 3.7 2.2	6 2.9 22.2 8.6	15 7.3 55.6 26.8	5 2.4 18.5 14.3	27 13.1
4	1 0.5 2.6 2.2	1 0.5 2.6 1.4	13 6.3 34.2 23.2	23 11.2 60.5 65.7	38 18.5
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.264	0.042	0.181	0.348
Weighted Kappa	0.476	0.040	0.398	0.555

Cronbach Coefficient α

Variables	Alpha
Raw	0.812
Standardized	0.817

Spearman Correlation Coefficients ρ

Prob > |r| under H0: Rho=0

	CRK	PROF	
CRK	1.000	0.703	<.000
PROF	0.703	1.000	<.000

APPENDIX 1-4, continued

Simulated Choctawhatchee River Keepers (CRK), ALL AVAILABLE Habitats

Table of CRK by PROF for ALL HABITATS

CRK	PROF 1	2	3	4	Total
1	41 19.9 39.8 91.1	51 24.8 49.5 72.9	9 4.4 8.7 16.1	2 1.0 1.9 5.7	103 50.0
2	3 1.5 7.3 6.7	12 5.8 29.3 17.1	21 10.2 51.2 37.5	5 2.4 12.2 14.3	41 19.9
3	0 0.0 0.0 0.0	6 2.9 20.7 8.6	14 6.8 48.3 25.0	9 4.4 31.0 25.7	29 14.1
4	1 0.5 3.0 2.2	1 0.5 3.0 1.4	12 5.8 36.4 21.4	19 9.2 57.6 54.3	33 16.0
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.231	0.041	0.149	0.313
Weighted Kappa	0.453	0.039	0.376	0.530

Cronbach Coefficient α

Variables	Alpha
Raw	0.810
Standardized	0.813

Spearman Correlation Coefficients ρ

Prob > |r| under H0: Rho=0

	CRK	PROF	
CRK	1.000	0.704	<.000
PROF	0.704	1.000	<.000

Simulated Georgia Adopt-A-Stream (GAAS), RIFFLE Habitats

Table of GAAS by PROF for RIFFLES

GAAS \ PROF	1	2	3	4	Total
1	16 7.8 59.3 35.6	8 3.9 29.6 11.4	3 1.5 11.1 5.4	0 0.0 0.0 0.0	27 13.1
2	25 12.1 29.8 55.6	42 20.4 50.0 60.0	12 5.8 14.3 21.4	5 2.4 6.0 14.3	84 40.8
3	4 1.9 6.9 8.9	18 8.7 31.0 25.7	28 13.6 48.3 50.0	8 3.9 13.8 22.9	58 28.2
4	0 0.0 0.0 0.0	2 1.0 5.4 2.9	13 6.3 35.1 23.2	22 10.7 59.5 62.9	37 18.0
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.344	0.048	0.250	0.438
Weighted Kappa	0.494	0.042	0.411	0.578

Cronbach Coefficient α

Variables	Alpha
Raw	0.785
Standardized	0.787

Spearman Correlation Coefficients ρ

Prob > \|r\| under H0: Rho=0

	GAAS	PROF	
GAAS	1.000	0.646	<.000
PROF	0.646	1.000	<.000

APPENDIX 1-4, continued

Simulated Georgia Adopt-A-Stream (GAAS), ALL AVAILABLE Habitats

Table of GAAS by PROF for ALL HABITATS

GAAS	PROF 1	2	3	4	Total
1	16 7.8 59.3 35.6	8 3.9 29.6 11.4	3 1.5 11.1 5.4	0 0.0 0.0 0.0	27 13.1
2	25 12.1 29.1 55.6	43 20.9 50.0 61.4	12 5.8 14.0 21.4	6 2.9 7.0 17.1	86 41.8
3	4 1.9 7.1 8.9	17 8.3 30.4 24.3	28 13.6 50.0 50.0	7 3.4 12.5 20.0	56 27.2
4	0 0.0 0.0 0.0	2 1.0 5.4 2.9	13 6.3 35.1 23.2	22 10.7 59.5 62.9	37 18.0
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.350	0.048	0.256	0.444
Weighted Kappa	0.494	0.043	0.409	0.578

Cronbach Coefficient α

Variables	Alpha
Raw	0.781
Standardized	0.782

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	GAAS	PROF	
GAAS	1.000	0.638	<.000
PROF	0.638	1.000	<.000

Simulated Alabama "Top 9 Most Wanted Bugs" (TOP9), RIFFLE Habitat

Table of TOP9 by PROF for RIFFLES

TOP9 \ PROF	1	2	3	4	Total
1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0
2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0
3	33 16.0 30.8 73.3	48 23.3 44.9 68.6	21 10.2 19.6 37.5	5 2.4 4.7 14.3	107 51.9
4	12 5.8 12.1 26.7	22 10.7 22.2 31.4	35 17.0 35.4 62.5	30 14.6 30.3 85.7	99 48.1
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

UNABLE TO CALCULATE

Cronbach Coefficient α

Variables	Alpha
Raw	0.5055
Standardized	0.5965

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	TOP9	PROF	
TOP9	1.0000	0.4234	<.0001
PROF	0.4234	1.0000	<.0001

Simulated Alabama "Top 9 Most Wanted Bugs" (TOP9), ALL AVAILABLE Habitat

Table of TOP9 by PROF for ALL HABITATS

TOP9 \ PROF	1	2	3	4	Total
1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0
2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0
3	38 18.5 33.6 84.4	49 23.8 43.4 70.0	21 10.2 18.6 37.5	5 2.4 4.4 14.3	113 54.9
4	7 3.4 7.5 15.6	21 10.2 22.6 30.0	35 17.0 37.6 62.5	30 14.6 32.3 85.7	93 45.2
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ
UNABLE TO CALCULATE

Cronbach Coefficient α

Variables	Alpha
Raw	0.566
Standardized	0.664

Spearman Correlation Coefficient ρ
Prob > \|r\| under H0: Rho=0

	TOP9	PROF	
TOP9	1.000	0.497	<.000
PROF	0.497	1.000	<.000

APPENDIX 1-5

SAS® 4x4 contingency table with statistics from comparison of 206 simulated citizen stream bioassessments in all habitats, above and below the Fall Line, to known professional stream quality assessments. Professional bioassessments conducted by Alabama Department of Environmental Management, Auburn University and Troy University researchers between 1996 and 2004. Water quality key: excellent (1), good (2), fair (3) and poor (4).

Simulated Alabama Water Watch (AWW), ABOVE Fall Line

Table of AWW by PROF for ALL HABITATS, ABOVE FALL LINE

AWW	PROF 1	PROF 2	PROF 3	PROF 4	Total
1	27 21.1 26.5 100.0	51 39.8 50.0 92.7	20 15.6 19.6 57.1	4 3.1 3.9 36.4	102 79.7
2	0 0.0 0.0 0.0	4 3.1 23.5 7.3	12 9.4 70.6 34.3	1 0.8 5.9 9.1	17 13.3
3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 2.3 37.5 8.6	5 3.9 62.5 45.5	8 6.3
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.8 100.0 9.1	1 0.8
Total	27 21.1	55 43.0	35 27.3	11 8.6	128 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.0403	0.0303	-0.0192	0.0998
Weighted Kappa	0.1663	0.0374	0.0930	0.2395

Cronbach Coefficient α

Variables	Alpha
Raw	0.6769
Standardized	0.7061

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	AWW	PROF	
AWW	1.0000	0.5171	<.0001
PROF	0.5171	1.0000	<.0001

APPENDIX 1-5, continued

Simulated Alabama Water Watch (AWW), BELOW Fall Line

Table of AWW by PROF for ALL HABITATS, BELOW FALL LINE

AWW \ PROF	1	2	3	4	Total
1	16 20.5 53.3 88.9	9 11.5 30.0 60.0	4 5.1 13.3 19.1	1 1.3 3.3 4.2	30 38.5
2	1 1.3 5.3 5.6	5 6.4 26.3 33.3	6 7.7 31.6 28.6	7 9.0 36.8 29.2	19 24.4
3	1 1.3 4.8 5.6	1 1.3 4.8 6.7	10 12.8 47.6 47.6	9 11.5 42.9 37.5	21 26.9
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 1.3 12.5 4.8	7 9.0 87.5 29.2	8 10.3
Total	18 23.1	15 19.2	21 26.9	24 30.8	78 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.325	0.069	0.189	0.462
Weighted Kappa	0.469	0.064	0.342	0.595

Cronbach Coefficient α

Variables	Alpha
Raw	0.808
Standardized	0.811

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	AWW	PROF	
AWW	1.000	0.692	<.000
PROF	0.692	1.000	<.000

Simulated Choctawhatchee River Keepers (CRK), ABOVE Fall Line

Table of CRK by PROF for ALL HABITATS, ABOVE FALL LINE

CRK \ PROF		1	2	3	4	Total
1	Frequency	26	45	8	2	81
	Percent	20.3	35.2	6.3	1.6	63.3
	Row Percent	32.1	55.6	9.9	2.5	
	Column Percent	96.3	81.8	22.9	18.2	
2	Frequency	1	7	16	3	27
	Percent	0.8	5.5	12.5	2.3	21.1
	Row Percent	3.7	25.9	59.3	11.1	
	Column Percent	3.7	12.7	45.7	27.3	
3	Frequency	0	3	8	1	12
	Percent	0.0	2.3	6.3	0.8	9.4
	Row Percent	0.0	25.0	66.7	8.3	
	Column Percent	0.0	5.5	22.9	9.1	
4	Frequency	0	0	3	5	8
	Percent	0.0	0.0	2.3	3.9	6.3
	Row Percent	0.0	0.0	37.5	62.5	
	Column Percent	0.0	0.0	8.6	45.5	
Total	Frequency	27	55	35	11	128
	Percent	21.1	43.0	27.3	8.6	100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.140	0.049	0.043	0.236
Weighted Kappa	0.322	0.051	0.220	0.423

Cronbach Coefficient α

Variables	Alpha
Raw	0.763
Standardized	0.764

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	CRK	PROF	
CRK	1.000	0.637	<.000
PROF	0.637	1.000	<.000

Simulated Choctawhatchee River Keepers (CRK), BELOW Fall Line

Table of CRK by PROF for ALL HABITATS, BELOW FALL LINE

CRK	PROF 1	2	3	4	Total
1	15 19.2 68.2 83.3	6 7.7 27.3 40.0	1 1.3 4.6 4.8	0 0.0 0.0 0.0	22 28.2
2	2 2.6 14.3 11.1	5 6.4 35.7 33.3	5 6.4 35.7 23.8	2 2.6 14.3 8.3	14 18.0
3	0 0.0 0.0 0.0	3 3.9 17.7 20.0	6 7.7 35.3 28.6	8 10.3 47.1 33.3	17 21.8
4	1 1.3 4.0 5.6	1 1.3 4.0 6.7	9 11.5 36.0 42.9	14 18.0 56.0 58.3	25 32.1
Total	18 23.1	15 19.2	21 26.9	24 30.8	78 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.344	0.074	0.198	0.490
Weighted Kappa	0.568	0.062	0.446	0.690

Cronbach Coefficient α

Variables	Alpha
Raw	0.845
Standardized	0.846

Spearman Correlation Coefficient ρ

Prob > |r| under H0: Rho=0

	CRK	PROF	
CRK	1.000	0.715	<.000
PROF	0.715	1.000	<.000

Simulated Georgia Adopt-A-Stream (GAAS), ABOVE Fall Line

Table of GAAS by PROF for ALL HABITATS, ABOVE FALL LINE

GAAS \ PROF	1	2	3	4	Total
1	14 10.9 58.3 51.9	7 5.5 29.2 12.7	3 2.3 12.5 8.6	0 0.0 0.0 0.0	24 18.8
2	12 9.4 18.5 44.4	39 30.5 60.0 70.9	10 7.8 15.4 28.6	4 3.1 6.2 36.4	65 50.8
3	1 0.8 3.2 3.7	8 6.3 25.8 14.6	19 14.8 61.3 54.3	3 2.3 9.7 27.3	31 24.2
4	0 0.0 0.0 0.0	1 0.8 12.5 1.8	3 2.3 37.5 8.6	4 3.1 50.0 36.4	8 6.3
Total	27 21.1	55 43.0	35 27.3	11 8.6	128 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.394	0.064	0.268	0.519
Weighted Kappa	0.471	0.061	0.351	0.591

Cronbach Coefficient α

Variables	Alpha
Raw	0.724
Standardized	0.726

Spearman Correlation Coefficient ρ

Prob > |r| under H0: Rho=0

	GAAS	PROF	
GAAS	1.000	0.571	<.000
PROF	0.571	1.000	<.000

Simulated Georgia Adopt-A-Stream (GAAS), BELOW Fall Line

Table of GAAS by PROF for ALL HABITATS, BELOW FALL LINE

GAAS \ PROF	1	2	3	4	Total
1	2 2.6 66.7 11.1	1 1.3 33.3 6.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 3.9
2	13 16.7 61.9 72.2	4 5.1 19.1 26.7	2 2.6 9.5 9.5	2 2.6 9.5 8.3	21 26.9
3	3 3.9 12.0 16.7	9 11.5 36.0 60.0	9 11.5 36.0 42.9	4 5.1 16.0 16.7	25 32.1
4	0 0.0 0.0 0.0	1 1.3 3.5 6.7	10 12.8 34.5 47.6	18 23.1 62.1 75.0	29 37.2
Total	18 23.1	15 19.2	21 26.9	24 30.8	78 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.219	0.069	0.082	0.355
Weighted Kappa	0.442	0.059	0.326	0.558

Cronbach Coefficient α

Variables	Alpha
Raw	0.810
Standardized	0.824

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	GAAS	PROF	
GAAS	1.000	0.700	<.000
PROF	0.700	1.000	<.000

APPENDIX 1-6

SAS® 4x4 contingency tables with statistics from comparison of 206 simulated Alabama Water Watch stream biomonitoring protocols in all habitats during 'Cool Weather Months' (September through April) and 'Warm Weather Months' (March through August) to known professional stream quality assessments. Professional bioassessments conducted by Alabama Department of Environmental Management, Auburn University and Troy University researchers between 1996 and 2004. Water quality key: excellent (1), good (2), fair (3) and poor (4).

Table of AWW by PROF for COOL WEATHER MONTHS

AWW	PROF 1	PROF 2	PROF 3	PROF 4	Total
1	34 35.1 40.0 100.0	40 41.2 47.1 95.2	11 11.3 12.9 61.1	0 0.0 0.0 0.0	85 87.6
2	0 0.0 0.0 0.0	2 2.1 33.3 4.8	4 4.1 66.7 22.2	0 0.0 0.0 0.0	6 6.2
3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 3.1 50.0 16.7	3 3.1 50.0 100.0	6 6.2
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0
Total	34 35.1	42 43.3	18 18.6	3 3.1	97 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

UNABLE TO CALCULATE

Cronbach Coefficient α

Variables	Alpha
Raw	0.694
Standardized	0.736

Spearman Correlation Coefficient ρ

Prob > |r| under H0: Rho=0

	AWW	PROF	
AWW	1.000	0.496	<.000
PROF	0.496	1.000	<.000

Table of AWW by PROF for WARM WEATHER MONTHS

AWW \ PROF	1	2	3	4	Total
1	9 8.3 19.2 81.8	20 18.4 42.6 71.4	13 11.9 27.7 34.2	5 4.6 10.6 15.6	47 43.1
2	1 0.9 3.3 9.1	7 6.4 23.3 25.0	14 12.8 46.7 36.8	8 7.3 26.7 25.0	30 27.5
3	1 0.9 4.4 9.1	1 0.9 4.4 3.6	10 9.2 43.5 26.3	11 10.1 47.8 34.4	23 21.1
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.9 11.1 2.6	8 7.3 88.9 25.0	9 8.3
Total	11 10.1	28 25.7	38 34.9	32 29.4	109 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.126	0.051	0.025	0.227
Weighted Kappa	0.262	0.049	0.165	0.359

Cronbach Coefficient α

Variables	Alpha
Raw	0.702
Standardized	0.703

Spearman Correlation Coefficient ρ

Prob > |r| under H0: Rho=0

	AWW	PROF	
AWW	1.000	0.553	<.000
PROF	0.553	1.000	<.000

APPENDIX 1-7

SAS® 4x4 contingency table with statistics from simulated modified AWW protocol (expanded taxa list and Cumulative Index Value brackets from Choctawhatchee Riverkeepers protocol) stream quality assessments compared with professional bioassessments. Professional bioassessments conducted by Alabama Department of Environmental Management, Auburn University and Troy University researchers between 1996 and 2004. Water quality key: excellent (1), good (2), fair (3) and poor (4).

Table of AWW by PROF for Modified Biotic Index Value with CRK and Expanded Taxa List

CRK		PROF 1	PROF 2	PROF 3	PROF 4	Total
1	Frequency	44	63	22	4	133
	Percent	21.4	30.6	10.7	1.9	64.6
	Row Percent	33.1	47.4	16.5	3.0	
	Column Percent	97.8	90.0	39.3	11.4	
2	Frequency	1	6	17	5	29
	Percent	0.5	2.9	8.3	2.4	14.1
	Row Percent	3.5	20.7	58.6	17.2	
	Column Percent	2.2	8.6	30.4	14.3	
3	Frequency	0	1	9	7	17
	Percent	0.0	0.5	4.4	3.4	8.3
	Row Percent	0.0	5.9	52.9	41.2	
	Column Percent	0.0	1.4	16.1	20.0	
4	Frequency	0	0	8	19	27
	Percent	0.0	0.0	3.9	9.2	13.1
	Row Percent	0.0	0.0	29.6	70.4	
	Column Percent	0.0	0.0	14.3	54.3	
Total	Frequency	45	70	56	35	206
	Percent	21.8	34.0	27.2	17.0	100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.1893	0.0365	0.1178	0.2607
Weighted Kappa	0.3937	0.0389	0.3175	0.4699

Cronbach Coefficient α

Variables	Alpha
Raw	0.8123
Standardized	0.8134

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	AWW	PROF	
AWW	1.0000	0.6855	<.0001
PROF	0.6855	1.0000	<.0001

APPENDIX 1-8

SAS® 4x4 contingency table with statistics from simulated Final Modified AWW Protocol (4 groups) stream quality assessments compared with professional assessments. Professional bioassessments conducted by Alabama Department of Environmental Management, Auburn University and Troy University researchers between 1996 and 2004. Water quality key: excellent (1), good (2), fair (3) and poor (4).

Table of Final Modified AWW (4 groups) by PROF for ALL HABITATS

AWW \ PROF	1	2	3	4	Total
1	31 15.1 63.3 68.9	18 8.7 36.7 25.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	49 23.8
2	14 6.8 17.1 31.1	45 21.8 54.9 64.3	19 9.2 23.2 33.9	4 1.9 4.9 11.4	82 39.8
3	0 0.0 0.0 0.0	7 3.4 18.4 10.0	24 11.7 63.2 42.9	7 3.4 18.4 20.0	38 18.5
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	13 6.3 35.1 23.2	24 11.7 64.9 68.6	37 18.0
Total	45 21.8	70 34.0	56 27.2	35 17.0	206 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.456	0.047	0.364	0.548
Weighted Kappa	0.628	0.035	0.558	0.699

Cronbach Coefficient α

Variables	Alpha
Raw	0.878
Standardized	0.878

Spearman Correlation Coefficient ρ

Prob > |r| under H0: Rho=0

	AWW	PROF	
AWW	1.000	0.785	<.000
PROF	0.785	1.000	<.000

Table of Final Modified AWW (4 groups) by PROF for ALL HABITATS, ABOVE FALL LINE

AWW	PROF 1	PROF 2	PROF 3	PROF 4	Total
1	21 16.4 58.3 77.8	15 11.7 41.7 27.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	36 28.1
2	6 4.7 9.7 22.2	37 28.9 59.7 67.3	15 11.7 24.2 42.9	4 3.1 6.5 36.4	62 48.4
3	0 0.0 0.0 0.0	3 2.3 15.0 5.5	15 11.7 75.0 42.9	2 1.6 10.0 18.2	20 15.6
4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 3.9 50.0 14.3	5 3.9 50.0 45.5	10 7.8
Total	27 21.1	55 43.0	35 27.3	11 8.6	128 100

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.428	0.062	0.304	0.551
Weighted Kappa	0.555	0.053	0.451	0.659

Cronbach Coefficient α

Variables	Alpha
Raw	0.829
Standardized	0.829

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	AWW	PROF	
AWW	1.000	0.724	<.000
PROF	0.724	1.000	<.000

Table of Final Modified AWW (4 groups) by PROF for ALL HABITATS, BELOW FALL LINE

PROF

AWW		1	2	3	4	Total
	1	10 12.8 76.9 55.6	3 3.9 23.1 20.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	13 16.7
	2	8 10.3 40.0 44.4	8 10.3 40.0 53.3	4 5.1 20.0 19.1	0 0.0 0.0 0.0	20 25.6
	3	0 0.0 0.0 0.0	4 5.1 22.2 26.7	9 11.5 50.0 42.9	5 6.4 27.8 20.8	18 23.1
	4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	8 10.3 29.6 38.1	19 24.4 70.4 79.2	27 34.6
	Total	18 23.1	15 19.2	21 26.9	24 30.8	78 100.0

ROW KEY:
Frequency
Percent
Row Percent
Column Percent

Kappa Statistic κ

Statistic	Value	ASE	95% Confidence Limits	
Simple Kappa	0.448	0.073	0.304	0.592
Weighted Kappa	0.671	0.048	0.576	0.767

Cronbach Coefficient α

Variables	Alpha
Raw	0.913
Standardized	0.913

Spearman Correlation Coefficient ρ

Prob > \|r\| under H0: Rho=0

	AWW	PROF	
AWW	1.000	0.836	<.000
PROF	0.836	1.000	<.000

APPENDIX 2-1

Sample surveys from the first and second pilot project and following aquatic science workshops for the Alabama Water Watch *Alabama's Living Streams – Stream Biomonitoring* aquatic science curriculum.

Teacher survey from the 1st pilot round, spring semester 2005, Lee and Tallapoosa Counties, Alabama:

Teacher Survey

Likert Scale: 5= Strongly Agree; 4 = Agree; 3 = Neither Agree or Disagree; 2 = Disagree; 1 = Strongly Disagree

_____ 1. I found the support from my citizen group volunteer(s) to be very helpful in being able to implement this program with my students.

_____ 2. My citizen group volunteer(s) were most helpful in setting up this project with my students.

_____ 3. My citizen group volunteer(s) were most helpful in implementing the field trip with my students.

_____ 4. My citizen group volunteer(s) were most helpful in interpreting results from the field trip with my students.

_____ 5. My citizen group volunteers(s) were most helpful in classroom follow-up exercises and meetings with my students.

_____ 6. I found the support from my assigned student teacher to be very helpful in being able to implement this program with my students.

_____ 7. My student teacher was most helpful in setting up this project with my students.

_____ 8. My student teacher was most helpful in implementing the field trip with my students.

_____ 9. My student teacher was most helpful in interpreting results from the field trip with my students.

_____ 10. My student teacher was most helpful in classroom follow-up exercises and teachings with my students.

_____ 11. I found the education manual and daily lessons easy to use in my classroom.

_____ 12. I found the additional content in the education manuals to be very useful.

_____ 13. I found the protocols for bioassessment in the education manuals to be very useful.

_____ 14. I found the additional lessons and activities in the education manual to be very useful.

_____ 15. I found the layout and design of the education manual to be teacher-friendly.

APPENDIX 2-1, continued

Citizen volunteer monitor survey from the 2nd pilot round, spring semester 2006, Lee, Tallapoosa, and Butler Counties Alabama:

***Living Streams* Citizen Volunteer Survey (front)**

We would like to evaluate how effective the partnership is between teacher, intern, and community volunteer in terms of implementing *Living Streams*. Please take a moment to consider the following questions, and answer with **Y** (yes), **N** (no), **UD** (undecided), or **NA** (not applicable). If undecided, please explain in the Comments and Suggestions section. Thank you.

________I found the support from the classroom teacher to be very helpful in being able to implement this program with the students.

________The classroom teacher was helpful in setting up this project with the students.

________The classroom teacher was helpful in implementing the field trip with the students.

________The classroom teacher was helpful in interpreting results from the field trip with the students streamside.

________The classroom teacher was helpful in classroom follow-up exercises and meetings with the students.

________I found the support from the assigned intern to be very helpful in being able to implement this program with the students.

________The intern was helpful in setting up this project with the students.

________The intern was helpful in implementing the field trip with the students.

________The intern was helpful in interpreting results from the field trip with the students.

________The intern was helpful in classroom follow-up exercises and teachings with the students.

________I feel the students benefited from having an intern and community volunteer work collaboratively in the classroom.

________I feel the students benefited from engaging in activities related to local water quality concepts and issues.

________I feel the students benefited from exploring agencies who help determine the outcome of water quality issues and regulations in Alabama.

________I feel the students have a better understanding of Alabama's unique water resources because of the curriculum.

________I feel the students have a better understanding of nonpoint source pollution and how each citizen contributes to it because of the curriculum.

________This curriculum helps fulfill the educational objectives of our AWW group.

***Living Streams* Citizen Volunteer Survey (back)**

Comments and Suggestions

Who participated in the streamside biomonitoring? (check all that apply)
____Citizen Monitor ____Intern ____Teacher ____All Students ____Select Students
If Select Students, how was it determined who would go and who would not? ___________________

Do you believe bringing AWW citizen monitors into the classroom significantly enhanced the effectiveness of *Living Streams*? If not, why?

Do you believe *Living Streams* holds the capacity to be implemented statewide as an effective curriculum for teaching basic aquatic science in terms of the protection and restoration of water resources in Alabama? If not, why?

Do you believe *Living Streams* holds the capacity to be implemented statewide as an effective curriculum for teaching the need for community partnerships to combat nonpoint source pollution in Alabama? If not, why?

How do you feel *Living Streams* could be strengthened to increase its impact and effectiveness?

Additional Feedback:

APPENDIX 2-1, continued

Participant survey from the summer workshops (2007) conducted for the *Alabama's Living Streams: Stream Biomonitoring* curriculum (front):

Discovering *Alabama's Living Streams* Post Workshop Survey

Name ____________________

Address ____________________

Telephone __________ **Email** __________

Member:
Alabama Water Watch Monitor O Y O N

Alabama Water Watch Association Member O Y O N

Are you interested in attending an Alabama Water Watch Stream Biomonitoring certification workshop? O Y O N
If yes, would you like to be contacted when the next workshop date in announced? O Y O N

Questions:
1 What is the name and location of the school or workplace that you will be using the Living Streams curriculum?
Name of School/ Workplace __________

Location __________

2 What water resource(s) are local to your school?
O School Pond O Off Campus Pond O Stream (Name) ______
O Creek (Name) ______ O River (Name) ______
O Bay (Name) ______ O Gulf of Mexico

3 Of the above water resources local to your school, which are accessible for biomonitoring?

____

4 Do you plan on using the MacroMania game in your educational facility? O Y O N
If yes, where? O In-class use only O In-class and at waterbody O At water body only

5 Have you taught an outdoor classroom before? O Y O N
If yes, then please explain __________

APPENDIX 2-1, continued

Participant survey from the summer workshops (2007) conducted for the *Alabama's Living Streams: Stream Biomonitoring* curriculum (back):

6 Do you plan on using this curriculum? O Y O N If yes, then :

Where? ______

When? ______

How Often? ______

What grade(s) or age group? ______

7 What timeframe will you use with the curriculum?

O 1 to 2 weeks O 1 month O 1 to 2 months O 2 to 3 months O 4 months or more

8 What format will you be using with the curriculum (What order will you present the modules)?

______

9 Will you use the handouts/ resources, and activities supplied with the curriculum? O Y O N

Which do you feel are the most useful? ______

______

______

10 Where you comfortable getting in the water prior to this workshop? O Y O N

If no, did that change after participating in this workshop? O Y O N

Please explain ______

______

11 What do you feel was a strongpoint for this workshop? ______

______

______

12 What could be done differently to enhance this workshop? ______

______

______