ROCKY RIVER WATERSHED BASED CURRICULUM GUIDE PROJECT

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This is to certify that the following professors have examined this project by
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ABSTRACT

Environmental education has the ability to increase cognitive ability, have a positive impact on group work skills, attitudes and self-efficacy, and increase student performance. Due to Federal "No Child Left Behind Act" legislation, increased standardized testing has resulted in the disenfranchisement of students from formal learning. The purpose of this project was to develop a curriculum guide based on the Rocky River watershed so teachers could use the Rocky River watershed as a means to satisfy the objectives of the NC Standard Course of Study and at the same time increase student environmental awareness, classroom engagement, sense of place and scores on the NC Earth/Environmental Final Exams. The project was developed to correlate with the newly revised North Carolina Standard Course of Study for Earth/Environmental Science. The curriculum guide was developed by utilizing the best practices suggested by scientific literature, the NC Standard Course of Study for Earth/Environmental Science, the North American Association for Environmental Education and the National Education Association.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1.

INTRODUCTION

The Rocky River Heritage Foundation calls the Rocky River "Chatham County's Own River" (Rocky River Heritage Foundation) due to the fact that the majority of the Rocky River watershed lies within Chatham County. The Rocky River provides an opportunity for Chatham County teachers to engage their earth/environmental science students in a place-based environmental education pedagogy based in and around the River.

This paper describes the development of a new environmental education program for high school Earth/Environmental science students currently enrolled in the Chatham County, NC School system based on the current best practices in environmental education. The Literature Review (Chapter 2) provides an overview of the educational theories that support the development of a nonformal environmental education program based on opportunities that can be found in the Rocky River watershed. Chapter 3 describes the methodology for the development of the activities for a watershed based environmental education curriculum. North Carolina Science Standards (Appendix A), nationally recognized best-practices for environmental education from the North American Association for Environmental Education and the National Education Association, and David Kolb's Learning Cycle (Kolb, 1984) are discussed to justify the rationale for choosing the topics, activities and environmental education framework for the curriculum development. The development of the Activities in the Curriculum Guide integrate the best-practices of current environmental education, experiential learning, place-based education and the NC Standard Course of Study for Earth/Environmental

Science. The process of the literature review and the basis for the development of the entire curriculum guide is discussed in the methodology section. There is also feedback from classroom teachers who reviewed the Curriculum Guide and look forward to using the lessons in their classrooms and along the Rocky River.

Need for the Curriculum Guide

At the present time, every state park and recreation area in North Carolina has an "Environmental Education Learning Experience" (EELE) written about their location (North Carolina State Parks, 2015). Teachers may use local EELE's to expand their curriculum outside of the classroom by using the materials provided by the EELE and a visit to the park or natural area from which the EELE originates. EELE's are correlated with the North Carolina Standard Course of Study (NC SCOS) for the core curricula of math, science, social studies and English (North Carolina State Parks, 2015) which make the park or natural area an invaluable tool when environmental education is utilized as a form of pedagogy in the classroom. Numerous studies (Certo, Cauley, & Chafin, 2003; Cooley, Cumming, & Burns, 2013; Flanagan, 2006; Porter, King, Goodkin, & Chan, 2012; Yunker, 2010) have shown that environmental education has the ability to increase cognitive ability, have a positive impact on group work skills, attitudes and self-efficacy, and increase student performance.

The current North Carolina State Standards for Earth/Environmental classes were rewritten and implemented in 2013 (North Carolina Public Schools, 2015). Through a review of the new Standard Course of Study (SCOS) to teach Earth/Environmental Science in Chatham County, it was determined that almost 50% of the Essential Standards (North Carolina Public Schools 2015) could be addressed by activities covered

in a Rocky River "EELE" type curriculum. The students of teachers currently using the environment to teach Earth/Environmental Science have higher scores on the North Carolina final exams in Earth/Environmental Science when compared to teachers not using the environment in their curriculum by a 10 to 15 % margin at one Chatham County school (D. Raymond personal communication, June 10, 2015).

In order to better serve the educational needs of the students enrolled in the Earth/Environmental science classes of Chatham County, the Rocky River watershed provides an excellent source of nonformal education activities. The river, the man-made structures (current and historical), the surrounding uplands of fields and forest can all provide opportunities to accomplish mastery of the NC SCOS in a full bodied learning experience as an alternative to virtual public school activities and textbook activities commonly used in the Earth/Environmental classrooms at this time.

This project met the goal of developing a curriculum guide that includes an EELE-like set of SCOS correlated environmental educational activities, labs and site visits to assist Earth/Environmental Science teachers in achieving an increase in student environmental awareness, classroom engagement and sense of place. In addition, the goal of the curriculum is for the students learning earth/environmental science with this environmental education pedagogy to increase scores on the NC Earth/Environmental Final Exams.

The Rocky River Heritage Foundation, a local non-profit organization that supports the Rocky River, has become involved with nonformal education of students in the Rocky River Watershed over the last 6 years by conducting biannual Education Festivals at the river. Because this new education curriculum project will increase the

awareness of the river in the County, the Rocky River Heritage Foundation has encouraged the development of a curriculum guide for the local school system (K. Hundley personal communication, April 30, 2014) in order to reach a greater number of students each year.

Definitions

Authentic Learning - A wide variety of educational and instructional techniques focused on connecting what students are taught in school to real-world issues, problems, and applications. The basic idea is that students are more likely to be interested in what they are learning, more motivated to learn new concepts and skills, and better prepared to succeed in college, careers, and adulthood if what they are learning mirrors real-life contexts, equips them with practical and useful skills, and addresses topics that are relevant and applicable to their lives outside of school (Authentic Learning, 2013).

Earth/Environmental Science Course - This course is the study of geology, meteorology, oceanography, and astronomy. Within these areas of earth science, students explore ecological principles including ecosystems, pollution, climate change, and natural resource conservation. Throughout this course students are asked to critically examine environmental issues from local and global perspectives. Students participate in labs, fieldwork, and projects throughout the semester. Earth/Environmental Science Honors is a rigorous curriculum designed to allow highly motivated students to conduct an in-depth study of the Earth/Environmental Sciences. In Earth/Environmental Science Honors students are expected to work independently on a variety of assignments and accept greater responsibility for their learning. In order to develop a greater understanding of the processes that shape our everyday lives, the curriculum will integrate inquiry

investigations and a variety of technologies with the study of earth as a system. The impacts of human activities on earth systems will also be a focus. The results of student investigations should be communicated through presentations and formal laboratory reports (Chatham County Schools, 2015a).

Environmental Education - Teaches children and adults how to learn about and investigate their environment, and to make intelligent, informed decisions about how they can take care of it (North American Association for Environmental Education, 2015).

Experiential Learning – "A process where knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). "Experiential education is a philosophy that informs many methodologies in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, clarify values, and develop people's capacity to contribute to their communities. It is often utilized in many disciplines and settings: Non-formal education, Place-based education, Project-based education, Global education, Environmental education, Student-centered education, Informal education, Active learning, Service learning, Cooperative learning and Expeditionary learning" (Association for Experiential Education, 2015, p. 1). "Experiential learning is also referred to as learning through action, learning by doing, learning through experience, and learning through discovery and exploration" (Northern Illinois University, 2015, p. 1).

Formal Education: A publicly approved system in which participants are required to learn and demonstrate certain competencies. This type of education takes place in public and private preschools, elementary schools, middle schools, secondary schools, colleges and

universities. Home schools are also under the umbrella of formal education (North Carolina Office of Environmental Education, 2008).

Nonformal Environmental Education – "Education about the environment that takes place in nonformal settings such as parks, zoos, nature centers, community centers, youth camps, etc., rather than in a classroom or school" (North Carolina Office of Environmental Education, 2008, p. 11).

North Carolina Standard Course of Study – "The appropriate content standards for each grade level and each high school course to provide a uniform set of learning standards for every public school in North Carolina. Based on a philosophy of teaching and learning that is consistent with current research, exemplary practices, and national standards. The goal of these standards is to prepare all students to become career and college ready. Classroom instruction is a partnership between the state, which sets content standards in the *Standard Course of Study*, and local educators who determine which curriculum materials they will use to deliver instruction to reach the standards" (North Carolina Public Schools, 2015, p.1).

Place-based Education "…is learning that is rooted in what is local - the unique history, environment, culture, economy, literature, and art of a particular place. The community provides the context for learning, student work focuses on community needs and interests, and community members serve as resources and partners in every aspect of teaching and learning" (Bartholomaeus, 2006, p. 482).

CHAPTER 2.

LITERATURE REVIEW

Introduction

In reviewing the literature for this environmental education curriculum development project, formal and nonformal education resources, curriculum development guidelines, learning styles and national and local educational guidelines were explored to provide a foundation for the concepts of educational pedagogy and how it could relate to the development of an environmental education curriculum. As a result, the literature review is organized into a review of the origins of environmental education, a review of the formal education in schools and concludes with a review of educational alternatives to current formal education pedagogy found in the public schools.

Origins of Environmental Education

The North American Association for Environmental Education (North American Association for Environmental Education [NAAEE], 2015) states that the goal of environmental education is for people to learn about the environment and to make intelligent, informed decisions about how they can take care of it. Environmental education can be taught in traditional classrooms or a variety of nonformal settings. Learning about the environment involves knowledge and skills from many disciplines and works best when it is taught in an organized sequence reflecting national and local standards (NAAEE, 2015). The NAAEE (2010) bases their goal of environmental education on the groundbreaking work done to develop the Belgrade Charter in 1975.

The Belgrade Charter states the goal of environmental education is:

> To develop a world population that is aware of, and concerned about, the environment and its associated problems, and which has the knowledge, skills, attitudes, motivations and commitment to work individually and collectively toward solutions of current problems and the prevention of new ones (p. 1).

Just three years later, the Tbilisi Declaration (Federal Interagency Committee on Education, W. D., & Department of Health, E. D., 1978) resolved that the goals of environmental education should be:

> To foster clear awareness of, and concern about, economic, social, political and ecological interdependence in urban and rural areas;
>
> To provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment;
>
> To create new patterns of behavior of individuals, groups and society as a whole towards the environment (p. 17).

Even though the definition of environmental education has continued to evolve over the years, the North American Association for Environmental Education (2010) states that the aim of environmental education is the idea that environmental literacy is needed in order to form "a democratic society in which effective, environmentally literate citizens participate with creativity and responsibility" (p. 2).

Formal Environmental Education in the Public Schools

Smith and Sobel (2010) have noted that up to 60 percent of students in the formal classroom are engaged in learning which may indicate that formal education is no longer consistently reaching all of the students in the classroom (p. 39). Smith (2002) further states that overall, formal education is becoming increasingly disconnected from the student's lives which ends up making the students feel that their learning is a chore rather than an opportunity to enjoy their learning. According to a study of rural Australian students by Bartholomaeus (2006), there is a "disengagement of a significant proportion of students, particularly from mainstream education" (p. 481). Bartholomaeus (2006) goes on to point out the detachment of students from their learning as a result of using textbooks to learn about the world rather than going out and actually experiencing how their world works. In a study of high school students by Certo et al., (2003) it was determined that the students were more engaged in classes with authentic learning rather than classes which utilized note taking and worksheets as the predominant educational tools. In the same study, the students were of the opinion that experiential learning would assist in having the material "stick" with them once they were out of the class.

An increased emphasis on standardized testing resulting from the passage of the "No Child Left Behind" Act has created an atmosphere where authentic learning is no longer encouraged and uniformity is required. Gruenwald (2003a) states that the isolation of students in their schooling "is exacerbated in many countries by the standardized curriculum, testing, emphasis on high scores…and a reliance on textbooks produced to serve a wide range of students" (as cited in Bartholomaeus, 2006, p. 481). During the fall of the 2010-2011 school year, benchmark tests and a lock-step curriculum

have been instituted in 60% of the science courses being taught in Chatham County Schools, NC (D. Jordan, personal communication, August 17, 2010). Darling-Hammond (1994) points out that high stakes testing and standardized curricula has substantial data that indicates the standardized test "have not had the effect of 'motivating' students or schools into greater learning" (p. 485). Studies show that even the vaunted New York State Reagents Tests are "educationally counterproductive" (p. 486) to student performance, teaching quality and the creation of a challenging curriculum. In researching Virginia's standardized end of course testing, called the Standards of Learning (SOL), Certo, et al. (2003) found that there was less authentic learning and more "seatwork/worksheet-type instruction because of the emphasis on the SOL" (p. 712). Gruenewald (2003a) sums it up succinctly when he states that the purpose of education today has been "reduced to preparing workers to compete in the 'global economy'" (p. 629).

Environmental Education Alternatives to Current Formal Pedagogy

NAAEE (2004) states that environmental education begins "close to home encouraging learners to understand and forge connections with their immediate surroundings" (p. 2). Unfortunately, as students are prepared for the global economy employing standardized curricula and evaluation by standardized tests, education is missing the framework of a child's life experience with which to build a student's knowledge (Lim & Calabrese Barton, 2006, p. 112). A study of student responses on standardized achievement tests by Nuthall and Alton-Lee (1995) revealed that "students who learned more in classrooms may perform better on achievement tests, not because they have learned more answers, but because they have more alternative parallel ways of

solving problems" (p. 220). Nuthall and Alton-Lee (1995) went further and stated that students learned more because they connected their learning to their existing base of knowledge (p. 220). Lew (2010) describes this type of learning as "constructivism," a learning theory where students "construct their own learning based on their past experiences" (p. 10). According to Schulte (1996), constructivists believe that actual learning takes place through accommodation, which occurs when students change their existing ideas in response to new information. So when given a new situation to understand, students that bring views based on their everyday experiences into the classroom will have a greater learning potential because they have a basis to reflect upon what they learn. Dewey believed that each new experience was shaped by what has happened before in the student's life (as cited in Rampp & Guffey, 2000). Yunker (2010) stated that students made substantial gains in their achievement when connecting the real world, in the form of field trips to local sites, which helped by fostering connections and coherence between the classroom and their daily experience.

Gruenwald (2003a) explains that over time environmental education has been referred to as place-based education, nonformal education, experiential education, context-based learning, outdoor education, critical pedagogy, service learning, native science, and community based education. For the purposes of this research, the phrase environmental education will be used unless a specific type of environmental education is discussed. Many papers (Gruenewald, 2002; Smith, 2002; Sobel, 2008) trace the roots of environmental education to the writings of Dewey and Thoreau who both promoted the involvement of the whole child in an education that had its roots in the outdoors and the community. In 1938, Dewey said "from the standpoint of the child, the great waste in

the school comes from his inability to utilize the experiences he gets outside the school in any complete and free way within the school itself…" (as cited in Bartholomaeus, 2006, p. 481).

Numerous studies (Bartholomaeus, 2006; Gruenewald, 2003b; Lewicki, 2000; Lieberman & Hoody, 1998; Lim & Calabrese Barton, 2006; Powers, 2004) have researched how the use of environmental education can contribute to student learning. The results of these studies show that environmental education does well in increasing scores and participation in school and community. Leiberman and Hoody (1998) found that using the "Environment as an Integrating Context for Learning" increased student performance in reading, writing and math significantly. Scores in language increased 93%, math 85%, thinking 94% and science rose 99% (p. 4). In Emekauwa's (2004) study of a predominately African American school system, the implementation of a Place-based Curriculum decreased the unsatisfactory scoring levels of math and science students 13.4 points, from 32.3% to 18.9% while the state percentage dropped by only 3.7 points in the same year. Bartholomaeus (2006) concluded from her study of rural communities in Australia, that "place-based education can both enable students to gain higher academic achievements and learn to live well and better appreciate the place where they live" (p. 487). With encouraging data from studies around the world, place-based and other forms of environmental education seem to be viable alternatives to standardized curriculum and testing in the formal classroom.

Nonformal environmental education is another form of environmental education that the NAAEE (2009) describes as taking place outside the formal education system in nonformal settings such as parks, zoos, nature centers, community centers, and youth

camps, rather than in a classroom or school. Much like place-based environmental education, nonformal environmental education uses local environmental sites to connect the student's classroom learning with their community and personal experience. Flanagan (2006) relates several school success stories that are based on environmental education pedagogy that utilized the experience of the students and the outdoors to learn the standardized curriculum. Successes include Clay County, Kentucky where the students built an outdoor classroom, restored wetlands, and constructed a nature trail that focused upon native plant conservation. Flanagan (2006) notes that after the students completed their learning projects, the school's Biology teacher remarked that the students now had pride in their school and no longer considered it a "prison" (p. 12). Florida provided another example of environmental education with the success of the Gove School. According to the principal of The Gove School, which developed an interdisciplinary environmental education program, "an important element of making education work is making it interesting and relevant to our students" (as cited in Flanagan 2006). Flanagan (2006) reported that the process of engaging the students with the environment resulted in the students "making significant improvement in their writing and language arts skills" (p. 8), so much improvement that the school was removed from the list of state critical schools. These studies suggest that environmental education could be the best educational practice that connects environmental education and the 21st Century Learners in today's standardized classroom.

In order to prepare students for the global economy of today, The National Education Association (NEA, 2015) has become vocal proponents in developing the 21st Century Learner program. A 21st Century Learner is defined by McCoog (2008) as a

learner of skills: global awareness and scientific literacy, higher order thinking, planning and managing, collaboration, using technology in the context of learning, E-communication, and creativity, ethics, and creating products. As part of developing a 21st Century Learner, the NEA (2015) encourages all educators, when planning or implementing curriculum, to use Critical thinking, Communication, Collaboration, and Creativity or, the "Four C's" to create an effective educational experience (p. 3). Collaboration skills of students when conducting group work was studied by Cooley et al., (2013) and they determined that outdoor education had considerable positive impact on group work skills when the participants had participated in outdoor education (p. 34). NAAEE has developed voluntary guidelines for environmental education in order to guide formal and nonformal educators in planning environmental education curricula. One of the core principles that the NAAEE has in their guidelines is the recognition that "learners forge connections with, explore, and understand their immediate surroundings" (p. 3). The other core principles align with the guidelines by suggesting that learners learn through direct experience, understanding the systems around them and how humans are interdependent with those systems. The core principles are further developed when the guidelines are broken down into 4 Strands of learning for different levels of education.

NAAEE 4 Strands:

Strand 1— Questioning, Analysis and Interpretation Skills

Strand 2— Knowledge of Environmental Processes and Systems

Strand 3— Skills for Understanding and Addressing Environmental Issues

Strand 4— Personal and Civic Responsibility (NAAEE, 2015)

The NAAEE Guidelines breakdown their "4 Strands" (2015) into guidelines that present specific learning objectives for 9 – 12 grade students which are based upon the original Tbilisi Declaration Environmental Education Objectives (Federal Interagency Committee on Education, W. D., & Department of Health, E. D., 1978):

> Awareness—to help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems.
>
> Knowledge—to help social groups and individuals gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems.
>
> Attitudes—to help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.
>
> Skills—to help social groups and individuals acquire the skills for identifying and solving environmental problems.
>
> Participation—to provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems.

NAAEE (2010) notes that these objectives have been modified over time and have resulted in numerous environmental education programs and curricula that have been widely used in formal education nationwide. Programs such as Project WILD, Project Learning Tree, Project Wet, Wisconsin Center for Environmental Education at the University of Wisconsin, Steven's Point, and the World Wildlife Fund have

developed program frameworks based upon these NAAEE Guidelines (NAAEE, 2010, pp. 91 - 112).

These core principles and strands, when applied to formal education via an environmental education model of learning, provide students the opportunity to learn by exploring the out-of-doors, conducting hands-on activities and having these experiences near where they live so they can relate their daily lives to the activity. The practice of the environmental education should also include the use of the "4 C's" that the NEA recommends (p. 2) as part of the learning experience. In their Nonformal Environmental Education Programs: Guideline for Excellence, the NAAEE (2009) states that environmental education should be engaged in local, direct experiences that promote higher order thinking skills and provide a basis for making connections with the rest of the world so they can participate in a democratic society.

CHAPTER 3.

METHODOLOGY

In order to develop a Rocky River Watershed Based Curriculum Guide (from this point forward referred to as *The Guide*) the North Carolina Department of Public Instruction Standard Course of Study (SCOS) for Earth/Environmental Science was reviewed to determine the relevance of the various clarifying objectives to sites within the Rocky River watershed. The Methodology section covers four main areas: 1) the SCOS for Earth/Environmental Science courses, 2) how the topics for the guide reflect the priorities of that SCOS, 3) a discussion of the best practices for environmental education to explain the basis for formatting *The Guide* and its activities, and 4) the process undertaken to develop the curriculum guide including how the lessons were reviewed and rewritten for improvement.

Standard Course of Study for Earth/Environmental Science

The SCOS for Earth/Environmental Science is divided into nine Essential Standards for the entire Earth/Environmental Science course (North Carolina Public Schools, 2012). Within each of these nine Essential Standards are numerous Clarifying Objectives that guide the science teachers in planning their Earth/Environmental course. The Objectives (North Carolina Public Schools, 2012) cover topics that vary from the water cycle (EEn.2.3.2) to alternative energy (EEn.2.8.1) so there are numerous topics that lend themselves to environmental education within the watershed. In following Dewey's notion (as cited in Ord & Leather, 2011) that students need a framework of experience to learn effectively, only Clarifying Objectives that could be addressed by using locations and experiences within the Rocky River Watershed were considered for

use when planning *The Guide*. In order to correlate the Objectives with possible experiential learning sites within the Rocky River Watershed, a selected group of four Chatham County Earth/Environmental Science teachers compared the topics of the Clarifying Objectives with sites located within the watershed that they had visited during a teacher training workshop earlier in the year. During that comparison, the teachers determined that almost 50% of the Earth/Environmental Science Clarifying Objectives could be taught by using the variety sites within the Rocky River watershed (North Carolina Public Schools, 2015) (see Appendix A).

Curriculum Guide Topic Selection Method

In order to select the topics for *The Guide* activities the released Earth/Environmental science final exams, or Measures of Student Learning (MSL) from the 2013 and 2014 school years (North Carolina Public Schools, 2014) were evaluated by test question data from the North Carolina State Department of Public Instruction (NCDPI). Each school receives feedback after each MSL administration that is broken down by Clarifying Objectives and the number of MSL questions that are drawn from that Objective. The NCDPI (2014) publishes the specific weights of each of the Clarifying Objectives (Table 1) that are represented by questions on the MSL. This data provided an excellent source of quantifiable data on which to base the development of *The Guide*.

Table 1.

Test Specification Weights for the Earth/Environmental Science NC Final Exam

Standards	Essential Standard	Percent of Total Score Points
EEn.2.7	Explain how the lithosphere, hydrosphere and atmosphere individually and collectively affect the biosphere.	14%-19%
EEn.2.1	Explain how processes and forces affect the lithosphere.	11% to 17%
EEn.2.2	Understand how human influences impact the lithosphere.	11% to 17%
EEn.1.1	Explain the earth's role as a body in Space.	11% to 16%
EEn.2.8	Evaluate human behaviors in terms of how likely they are to ensure the ability to live sustainably on Earth.	9%-14%
EEn.2.4	Evaluate how humans use water.	7% to 12%
EEn.2.6	Analyze patterns of global climate change over time.	7% to 10%
EEn.2.3	Explain the structure and processes within the hydrosphere.	4% to 10%
EEn.2.5	Understand the structure and processes within our atmosphere.	4% to 10%
Total		100%

Note. From (North Carolina Public Schools, 2014, p. 2)

Based upon the Test Specification Weights for Earth/Environmental Science NC Final Exam data (North Carolina Public Schools [NCPS], 2014), the Standards were ranked from most weighted to least weighted. The most weighted Standard is EEn.2.7 which is "Explain how the lithosphere, hydrosphere, and atmosphere individually and collectively affect the biosphere (NCPS, 2012, p. 11). This Standard provided the basis for developing an experiential environmental education program for the Rocky River Watershed because it had the greatest number of relevant topics in the Rocky River watershed. Standard EEn.2.7 contained ecological topics that addressed biodiversity, biotic and abiotic factors in the environment, invasive species and human impact on the

environment. The next two most weighted Standards were EEn.2.1 "Explain how processes and forces affect the lithosphere" and EEn.2.2 "Understand how human influences impact the lithosphere" (NCPS, 2012, pp. 4 - 5). These two standards primarily focused on mining and the geologic processes of the lithosphere so did not provide an adequate number of topics to develop into activities. EEn.2.1 and 2.2 did provide two topics that could be addressed by an experiential environmental education program: soil particles and erosion by human activities and water. The next two most weighted Standards were EEn.1.1 "Explain the Earth's role as a body in space" and EEn.2.8 "Evaluate human behaviors in terms of how likely they are to ensure the ability to live sustainably on Earth" (NCPS, 2012, p. 4 & p. 12). EEn.1.1 was not a viable choice for a place-based experiential curriculum guide because it is space oriented. Standard EEn.2.8 had some ecological topics that that could be considered for use in *The Guide* that addressed carrying capacity and the impacts of a growing population on the natural resources. The next most weighted Standard was EEn.2.4, "Evaluate how humans use water" (NCPS, 2012, p. 7). Standard EEn.2.4 contains surface water pollution, water quality of streams, non-point source pollution and population growth. These topics are excellent sources of activities for this watershed place-based experiential curriculum guide. Standard EEn.2.6, "Analyze patterns of global climate change over time" (NCPS, 2012, p. 10) was the next most weighted of the Standards. Due to the nature of this Standard being focused upon long term atmospheric events, Standard EEn.2.6 was not considered to be useful for this place-based experiential curriculum guide. The final two Standards, EEn.2.3 and EEn.2.5, were split on their usefulness for this place-based experiential curriculum guide. EEn.2.5 covered the topics of cyclonic

storms, atmospheric composition and weather systems which did not provide useful topics for this guide. However, EEn.2.3 provided some topics that could possibly be addressed by sites in the watershed. Floods, river systems and the hydrologic cycle are all included in this Standard, but they are intertwined with the movement of groundwater through the hydrosphere.

By looking at the Standards and the relative weights of their topics in relation to the Earth/Environmental Science Final Exam, a better picture of what topics could and should be covered by *The Guide* was developed. As described above, some of the standards were not included in the planning for the curriculum guide because their topics were not appropriate for place-based experiential environmental education. The next step in developing *The Guide* was to take the topics that could be utilized in the Rocky River watershed and develop them into useful activities for the classroom educator based on the best practices in environmental education.

Best Practices for Environmental Education

For many years the North Carolina State Parks have developed an environmental education experience for each park and natural area within the State Park system (North Carolina State Parks, 2015). These learning experiences are called Environmental Education Learning Experiences or EELE's (North Carolina State Parks, 2015). The park system has modified the EELE's over the years to better reflect teacher needs but are still being used by the Parks to educate school students in a variety of ways (S. Higgins, personal communication June 2015). The standard format for each EELE has an introduction to the Park, a correlation guide, Pre-Visit activities, On-Site Activities, and Post-Visit Activities (North Carolina State Parks, 2015). This format is encouraged

by many environmental education programs (Bitgood, 2011; Meredith et al. 2000; Preston 2004) because it effectively educates students by utilizing experiential learning. This was an important consideration when developing this curriculum guide.

Experiential learning has its roots in work of Dewey, Piaget, and Kolb. All three researchers explored the effects of experience on learning, and Kolb (1984) summarizes their research on learning as a "process that is based upon experience" (p. 28). Kolb's research led him to develop a learning "cycle" (Figure 1) that would describe how a learner accommodates new knowledge. Healey and Jenkins (2000) describe Kolb's cycle as having four stages that includes a concrete experience followed by reflective observation followed by abstract conceptualization followed by testing in new situations or active experimentation. This cycle can repeat many times until the learner has accommodated the new experience into their knowledge base. Kolb (1984) defined experiential learning as a "process whereby knowledge is created through the transformation of experience" (p. 38).

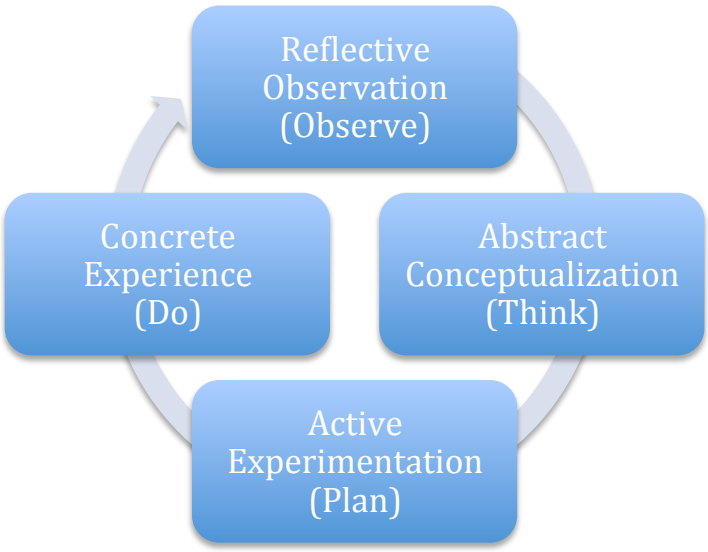

Figure 1. Kolb's experiential learning cycle (based on Healey & Jenkins, 2000)

Lieberman and Hoody (1998) extend the concept of experiential education by encouraging educators to go outdoors and use the "environment as an integrating context" (p. 1). Their research showed that the students in classes that utilize the environment as a part of their pedagogy engage their students in a variety of learning styles. When teachers use the environment as an educational focus, according to Lieberman and Hoody (1998), they engage their students using a broader range "of learning modalities" (p. 13) that address the varied learning styles of the students which increases their achievement in school.

Sobel (2008) promotes place-based education as a way to increase student achievement by "emphasizing hands-on, real-world learning experiences" (p. 131) when using the local community and environment as a starting point for teaching science and other curricula. The benefits of place-based education on student achievement have been documented by many studies (Bartholomaeus, 2006; Emekauwa, 2004; Gruenewald, 2003b; Lewicki, 2000; Lieberman & Hoody, 1998; Lim & Calabrese Barton, 2006; Powers, 2004) which provided guidance for planning this curriculum guide. The EELE's use the resources found in the State Park or Natural Area for which the activities were written and are, by definition, place-based education (Bartholomaeus, 2006). Using the local Rocky River watershed as a focus for this place-based guide is key to making the *The Guide* relevant to the students in order to increase the student interest and engagement in their Earth/Environmental Science course. When students are engaged in their subject matter their achievement increases (Bartholomaeus, 2006). Sobel (2008) also notes that place-based education is an excellent form of pedagogy to instill a sense of community that leads to students becoming active citizens within the community.

The National Education Association (NEA) encourages the use of "Critical Thinking, Communication, Collaboration and Creativity" (NEA, 2015, p. 3), or the "4 C's" in order to promote the development of 21st century skills. In the NEA Guide to the "4 C's" (2015), Critical Thinking is broadly defined as having the students analyze the parts of a whole, evaluate evidence, arguments, claims and beliefs as well as making connections between information and arguments and interpreting information to draw conclusions from their learning experiences. Clear communication skills were encouraged in the NEA Guide (NEA, 2015) in both "articulating thoughts and ideas effectively using oral, written and nonverbal…skills" and being able to "listen effectively to decipher meaning" (p. 14). In their "reflections on communication" section (NEA, 2015, p. 16) the NEA encourages teachers to find a variety of methods to promote the development of communication skills in their students in both the classroom and the community. "Due to globalization and the rise of technology" (NEA, 2015, p. 19) the NEA promotes Collaboration as a necessary skill that students need to master. The NEA (2015) views Collaboration as students being able to work effectively and respectively with others, being flexible, showing the ability to compromise and share responsibility for the work being done by the group. When the students work collaboratively the NEA states that they can "generate more knowledge" (p. 20) and be more successful in today's society. Creativity is considered to be an individual skill as well as a group trait in the NEA's Guide to the "4 C's" (2015). For the individual, brainstorming skills, developing original ideas in both incremental and radical steps and maximizing creative efforts are all parts of the Creativity "C". In groups, the NEA (2015) encourages the individual to be "open and responsive to new and diverse perspectives…view failure as an opportunity

to learn…and to…act on creative ideas" (p. 25) in order to have personal and professional success in today's world.

The NAAEE, in their *Environmental Education Materials: Guidelines for Excellence* (NAAEE, 2004) provide guidelines for educators that "aim to help developers of activity guides…produce high quality products" (p. 1). The six "Key Characteristics" (2004, p. 4) that educators should follow when developing environmental education materials are as follows: #1 – Fairness and Accuracy, #2 - Depth, #3 – Emphasis on Skills Building, #4 – Action Orientation, #5 – Instructional Soundness, and #6 – Usability (p. 4). These Key Characteristics provide the curriculum developer concrete guidance for each activity they develop. When developing an activity, Key Characteristic #1 (2004) states that the basis of any activity should use data or examples that are fair, accurate and diverse when describing the environmental issue. Depth, Key Characteristic #2 (NAAEE, 2004), guides the educator towards environmental issues that are developmentally appropriate, focus on themes not just facts, include ecological, social and economic aspects and may reflect different scales (local, regional or global). NAAEE Key Characteristic #3, Emphasis on Skills Building, corresponds with three of the NEA's "4 C's" because it encourages critical and creative thinking skills as well as collaboration skills. NAAEE Key Characteristic #3 and #4 (2004) are reflected in the belief of David Sobel (2008) that any activity should include an action component to so that the learner can develop a feeling of responsibility that may manifest itself in civic action. NAAEE Key Characteristic #4 (2004) also stresses the role that the individual has in their life and in the life of the community to resolve environmental issues. NAAEE Key Characteristic #5 (2004) is an extension of Kolb because it promotes

learning by building on the learner's previous knowledge. The focus of NAAEE Key Characteristic #5 (2004), Instructional Soundness, also encourages educators to develop activities that are relevant to the learner's everyday life by using materials that include local issues or reflect age, cultural and gender differences. The NAAEE Guidelines also encourage educators to remember there are a variety of learning styles and an educational curriculum should promote the creation of activities that utilize those styles. NAAEE Key Characteristic #5 (2004) encourages "learner centered instruction" (p. 14). The final NAAEE Key Characteristic, #6 – Usability (2004), informs the educator that the activity should be clear, logical, easy to use and have a long life not limited to one use. It also encourages the training of teachers to use the activity and the correlation of the activity with State curricula so that it can be easily integrated into the teacher's curriculum.

The best practices for environmental education were determined by reviewing Kolb's model of experiential education, the NAAEE Guidelines for Excellence and the NEA's "4 C's". These sources provided numerous similar examples of the beneficial educational practices that environmental education can provide to public education. In addition, information gleaned from the NC Department of Public Instruction Earth/Environmental Science SCOS and the data supplied by the NC final exam for Earth/Environmental Science provided clear weighted guidelines to use in the development of *The Guide*.

Development of the Curriculum Guide

Once the topics for the activities were determined, the actual writing of *The Guide* began. In developing an effective curriculum guide, it was necessary to integrate the constructivist views of Dewey (as cited in Wojcikiewicz & Mural, 2010), Piaget (as cited

in Athman & Monroe, 2001) and Kolb's "Learning Cycle" (Kolb, 1984, Healey & Jenkins, 2000) as well as the NAAEE Core Principles and 4 Strands, plus the NEA's "4 C's" pedagogy. Kolb's Learning Cycle (Healey & Jenkins, 2000) provided the framework for the entire *Guide* and the EELE model for environmental education provided an acceptable overall format for *The Guide*. The format of the EELE mirrors Kolb's experiential learning cycle with a pre-visit activity to introduce the student with a concrete experience, then reinforces the experience with a site-visit to observe it in real-life and then a reflection on the process with a post-visit reflection. In *The Guide*, the Pre-Visit Activities are the "Abstract Concept", the River Activities are the "Active Experimentation" and "Concrete Experience" and the Post-Visit Activities are the "Reflective Observation" (p. 187). Within each activity, Kolb's Learning Cycle (Healey & Jenkins, 2000) is utilized as the activity introduces a concept, leads the student through the activity and then concludes with reflection on the concept experienced during the activity. In their *Excellence in Environmental Education—Guidelines for Learning (K–12)*, the NAAEE (2010) supports environmental education efforts by setting grade appropriate achievement expectations and suggesting an effective framework for the curricula so it will meet state disciplines. For the purposes of this project, the NAAEE Guidelines for grades 9 – 12 were utilized because the Earth/Environmental course is generally taught as a 9th grade course (Chatham County Schools, 2015a).

Mastery of the Clarifying Objective will be achieved by using a pedagogy of place-based education in the Rocky River watershed and was addressed by developing an Activity to satisfy the Objective. The typical EELE has nine activities (North Carolina State Parks, 2015) and for *The Guide* nine activities were developed**.** Following the best

practices of the NAAEE (4 Strands and Key Characteristics) and the NEA ("4 C's"), the majority of the activities are hands-on, inquiry-based, collaborative and address environmental issues as appropriate for the concept being taught. Each activity was developed as a place-based experiential learning experience reflecting sites and concepts present in the Rocky River Watershed. For example, the Pre-Visit and River Activities followed NAAEE (2004) Strand 1 guidelines to encourage "collecting" and "organizing information" (pp. 51 – 52) and "drawing conclusions" (p. 52). Other NAAEE Strands were used as guidance when developing the Activities. NAAEE Strand 2 (2004) was easily applied in the development of Activities because it focused on "Knowledge of Environmental Processes and Systems" (pp. 54 - 62) which covered organisms, populations and communities, systems and connections, individuals and groups, political and economic systems, human/environment interactions and places. Due to the fact that *The Guide* has a place-based theme of the Rocky River watershed, Strand 2 was a useful guide in developing the Activities. The activities in *The Guide* were developed based on the availability of a site in the watershed which could support the lesson in its entirety as well as successfully addressing the concept required by the SCOS.

To illustrate the development of one of the Activities, the following reviews the process that resulted in Pre-Visit Activity #1:

> 1. Chose the Clarifying Objective: The Clarifying Objective 2.7 "Explain how the lithosphere, hydrosphere, and atmosphere individually and collectively affect the biosphere" (NCPS, 2014, p. 11) was the most heavily weighted Clarifying Objective when a review of the Test

Specification Weights for the Earth/Environmental NC Final Exam was conducted.

2. Chose a Topic that is Relevant To the Clarifying Objective: In making a choice for a topic to illustrate the Clarifying Objective, the Unpacked Standards were reviewed and a topic chosen from the Standards. Of the Unpacked Standards, "EEn.2.7.2 Explain why biodiversity is important to the biosphere and EEn.2.7.3 Explain how human activities impact the biosphere" (NCPS, 2014, p. 12) were chosen because of the biodiversity in the Rocky River. Two other Unpacked Standards (2014), EEn.2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments and EEn.2.8.3 Explain the effects of uncontrolled population growth on earth's resources were included in the planning of the Activity because they were also relevant to the topic.

3. Determined the Focus of the Activity: Once the focus of the topic was determined, the focus of the Activity had to determined. The decline in freshwater mussel populations in the river (p. 1) is the most significant biodiversity issue discussed in Alderman and Alderman's report (2010) on the Rocky River. In order to illustrate the issues of biodiversity, invasive species and the effects of humans on water quality and resources, freshwater mussels were chosen as the organism to study in the Activity. The development of the Activity was further guided by reflecting on the NEA's "4 C's" and the NAAEE Key Characteristics.

4. Determined the Teaching Methodology: The Activity was developed to incorporate hands-on experiential environmental education by using a dichotomous key to identify freshwater species found in the Rocky River by having small groups of students work together to identify the organisms. This style of learning requires critical thinking, collaboration, and communication to determine the species of mussel within the Activity. The subject of freshwater mussels from the Rocky River provides an organism for the student to learn more about their local surroundings and inquire as to why non-native species are in a local river. The students also have an opportunity for action in their home, neighborhood and town to make a difference in water quality and biodiversity based on the knowledge that they gained from this Activity.

5. Developed the Assessment Plan for the Activity: Determining the student mastery of the concept set forth in the Clarifying Objectives was the next step in the development of the Activity. In Pre-Visit Activity #1, there were two types of assessment; the first being a correct use of the dichotomous key to identify the mussels and the second being four questions that required written answers based on the student observations during the lab and extrapolating their lab results into a real world application. All the Activities have a variety of assessment techniques that reflect the material learned and the type activity that the students used to learn the material. All of the assessments are based on the NEA's "4 C's" and involve a combination of creativity, critical thinking, collaboration

and communication between group members to achieve the objectives for the Activity.

6. Reviewed and Refined the Activity: The refinement of the Activity was assisted by the feedback from local teachers since they had the opportunity to review the Activity and provide feedback. After the activities were completed they were reviewed by a group of local earth/environmental science teachers who are active participants in teacher training and curriculum writing. The teachers read over *The Guide* activities and provided constructive feedback so the activities could be as useful as possible for the classroom teacher. The benefits and drawbacks for each of the activities were reviewed and edited based on the feedback from the earth/environmental science teachers. For example, the reviewers agreed that the downloadable Dichotomous Key for the Freshwater Mussels of NC was too difficult for the students to read and the students would stop reading and be unable to complete the activity. As a result of the feedback, a simplified Dichotomous Key for the Mussels of the Rocky River was created based on the mussels commonly found in the river. The reviewers also pointed out the need for a simplification of student directions in some of the activities. They provided written examples of what they would like to see for directions and those directions were modified to make *The Guide* more accessible to a wider range of student abilities. Comments from two of the Northwood High School reviewers expressed hope that the activities from *The Guide* would be “an

> opportunity for our Professional Learning Community to learn more about the river" in the future (Personal Communication, August 28th 2015). The reviewers were also excited to learn that the Rocky River Heritage Foundation intends to assist the teachers with visits to the Rocky River and provide materials to the classroom. One teacher from SAGE Academy stated she was "glad they could help out because my school is short on useful river materials and I could use an extra set of hands when we visit the river" (Personal Communication, August 28th 2015).

The NAAEE (2004) encourages the support and training of educators by conducting teacher-training workshops to support any curriculum produced. While *The Guide* was being written, the Rocky River Heritage Foundation (RRHF) was approached about the implementation of *The Guide.* The Board of the RRHF suggested utilizing *The Guide* during the summer of 2016 during a week-long teacher institute on the Rocky River sponsored by the RRHF. This training will develop a "network of practitioners" (NAAEE, 2004, p. 26) who can provide support for the educators when using the curriculum. The training can also develop a network of river experts working in partnership with the Rocky River Heritage Foundation for the educators to utilize in the classroom and field.

Conclusion

The Rocky River Watershed Curriculum Guide was developed based on the need for a more engaging curriculum for earth/environmental science classes in Chatham County, NC high schools. It also satisfies the desires of a local non-profit river organization to engage more students in river education. The educational framework for

The Guide was based upon Kolb's Learning Cycle and the design of the North Carolina State Parks Environmental Education Learning Experience's. Kolb's (1984) Learning Cycle of concept introduction, active experimentation, concrete experience and reflection on what the student just experienced challenges the student to modify their previous knowledge to accommodate what they just experienced. *The Guide* follows the style of the Learning Cycle by beginning with a Pre-Visit Activity to introduce a potentially abstract concept to the student. After mastering that concept the student engages in a place-based, experiential education activity at the Rocky River that extends the concept that was introduced in the Pre-Visit Activity. Once the student returns to the school they participate in a Post-Visit Activity to reflect upon the previous activities. Current best practices in environmental education from the NAAEE and sound instructional practices by the NEA also guided the development of the Curriculum Guide. The 4 Strands from the NAAEE Guidelines for Excellence provided guidance for the development of the teaching style of each Activity. Each Activity uses engagement, questioning, collection of data, analyzing of data, and thought provoking discussion to cover the topic being studied. The topics for the Activities in *The Guide* are based on the current North Carolina Earth/Environmental Science Standard Course of Study. The literature (Meredith et al., 2000; NAAEE, 2004; NEA, 2015; North Carolina Office of Environmental Education, 2008; Yunker, 2010) strongly encouraged basing the Activities on current standards so that it would be useful to the formal education teacher and they would see the relevance to their curriculum and utilize *The Guide* in class. The NAAEE (2004) further suggests that any environmental education curriculum should be

interdisciplinary, if at all possible, as it is integrated into local, state and national guidelines.

The resulting product may be used as a unit using the Rocky River Watershed as place-based experiential education or the activities may be used individually to augment a classroom or riverside activity. In the future, *The Guide* will no doubt be augmented by new Activities as teachers become involved in environmental education that uses the Rocky River as a focal point. The goal would be to have teachers either develop curriculum to add to *The Guide* or make suggestions to the Rocky River Heritage Foundation for further teacher training.

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APPENDIX A

CLARIFYING OBJECTIVES OF THE NC SCOS THAT CAN BE ADDRESSED WITHIN THE ROCKY RIVER WATERSHED

EEn.2.1.1

- Explain the rock cycle in enough detail to relate the cycling of materials - formation and destruction of the three major rock types to the forces responsible: physical and chemical weathering, heat and pressure, deposition, foliation and bedding. The forms of energy that drive the rock cycle include heat and mechanical (gravitational potential) energy.
- Explain how various mechanisms (mantle convection, ridge push, gravity pull) drive movement of the lithospheric plates.
- Infer the relationship between the type of plate boundary and the locations of various features such as ocean trenches, mountain ranges and mid-ocean ridges. (Relate to the development of the theory of plate tectonics and geologic time.)
- Compare magma and lava. Locate volcanoes and relate back to plate boundaries. Explain volcanic effects on the lithosphere and relate back to plate boundaries (convergent, divergent, transform) including lahar (mud) flows and ash in the atmosphere.
- Describe the anatomy of an earthquake. Locate earthquakes – epicenter and focal point – and relate to different types of plate boundaries. Explain how the release of energy of various types of earthquakes relates to magnitude, and P and S waves.
- Summarize the major events in the geologic history of North Carolina and the southeastern United States. Explain how current geologic landforms developed such as Appalachian Mountains, fall zone, shorelines, barrier islands, valleys, river basins, etc. using the geologic time scale.

EEn.2.1.3

- Recall that soil is the result of weathering of rocks and includes weathered particles: sand, silt and clay.
- Explain differences in chemical and physical weathering and how weathering rates are affected by a variety of factors including climate, topography and rock composition.
- Compare erosion by water, wind, ice, and gravity and the effect on various landforms.

EEn.2.1.4

- Conclude the best location for various types of development to reduce impacts by geohazards and protect property.
- Explain precautions that can be made to protect life from various geohazards and include meteorological hazards. Some examples include landslides, earthquakes, tsunamis, sinkholes, groundwater pollution, and flooding.

EEn.2.2.1

- Explain the need for and consequences of various types of land use such as urbanization, deforestation and agriculture.
- Explain ways to mitigate detrimental human impacts on the lithosphere and maximize sustainable use of natural resources.
- Explain the effects of human activity on shorelines, especially in development and artificial stabilization efforts.

- Explain the effects of human activity on mountainsides, especially in development and artificial stabilization efforts.

EEn.2.3.2

- Illustrate the water cycle to explain the connection between groundwater and surface water, detailing how groundwater moves through the lithosphere. (Emphasize the processes of evaporation and infiltration in the conceptual diagram of the hydrologic cycle.)
- Explain river systems including NC river basins, aquifers, and watersheds.
- Explain how flood events might be affected by groundwater levels.

EEn.2.4.1

- Explain various water uses by humans and evaluate for benefits and consequences of use (ex. wells, aquifer depletion, dams and dam removal, agriculture, recreation).
- Explain consequences of aquifer depletion including subsidence and salt-water intrusion on the coast.
- Evaluate the effects of population growth on potable water resources. Infer future effects.
- Explain how pollutants might flow through a watershed and affect inhabitants that share the same watershed.

EEn.2.4.2

- Evaluate issues of ground and surface water pollution, wetland and estuary degradation, and salt water intrusion.
- Analyze how drinking water and wastewater treatment systems impact quantity and quality of potable water.
- Evaluate water quality of NC streams (chemical, physical properties, biotic index).
- Analyze non-point source pollution and effects on water quality (sedimentation, stormwater runoff, naturally and human induced occurrences of arsenic in groundwater).
- Evaluate conservation measures to maximize quality and quantity of available freshwater resources.

EEn.2.7.2

- Define the biosphere as all life on Earth.
- Explain biodiversity as including genetic variation within populations and variation of populations within ecosystems that makeup the biosphere.
- Infer the relationship between environmental conditions and plants and animals that makeup live within various biomes that comprise the biosphere.
- Explain the global impact of loss of biodiversity.

EEn.2.7.3

- Explain effects of human population growth, habitat alteration, introduction of invasive species, pollution and overharvesting on various plant and animal species in NC.
- Explain effects of invasive nonnative species (plant or animal) on an NC ecosystem.
- Summarize ways to mitigate human impact on the biosphere.

EEn.2.8.1

- Critique the benefits, costs and environmental impact of various alternative sources of energy for North Carolina (solar, wind, biofuels, nuclear fusion, fuel cells, wave power, geothermal).
- Evaluate which sources of alternative energy may work best in different parts of the state and why.
- Extension: Examine for region, country, continent, hemisphere, and world.

EEn.2.8.2

- Critique the advantages and disadvantages of traditional agriculture/aquaculture techniques and compare with sustainable agriculture/aquaculture techniques. Include the economics and environmental impacts in this comparison.
- Judge potential impact of sustainable techniques on environmental quality (include magnitude, duration, frequency).

EEn.2.8.3

- Explain carrying capacity.
- Infer limiting factors to human population growth.
- Summarize the impacts of a growing population on the natural resources in North Carolina

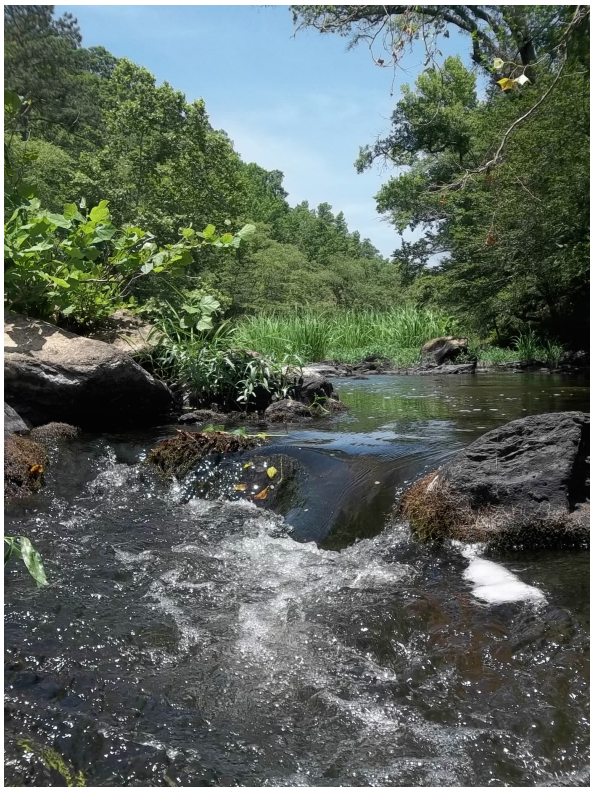
EEn.2.8.4

- Explain how ecological footprints exist at the personal level and extend to larger scales.
- Evaluate personal choices in terms of impacts on availability of natural resources and environmental quality; relate this to ecological footprints on various scales.
- Evaluate the impact of implementing change that adheres to the "reduce, reuse, recycle" philosophy (e.g. through case studies, data collection/analysis, model development, etc.) (North Carolina Public Schools, 2015, pp. 4 - 13).

APPENDIX B

ROCKY RIVER WATERSHED CURRICULUM GUIDE

Rocky River Watershed Curriculum Guide



By Phillip Cox
In conjunction with the Rocky River Heritage Foundation
Chatham County, NC
2015

Table of Contents

Introduction

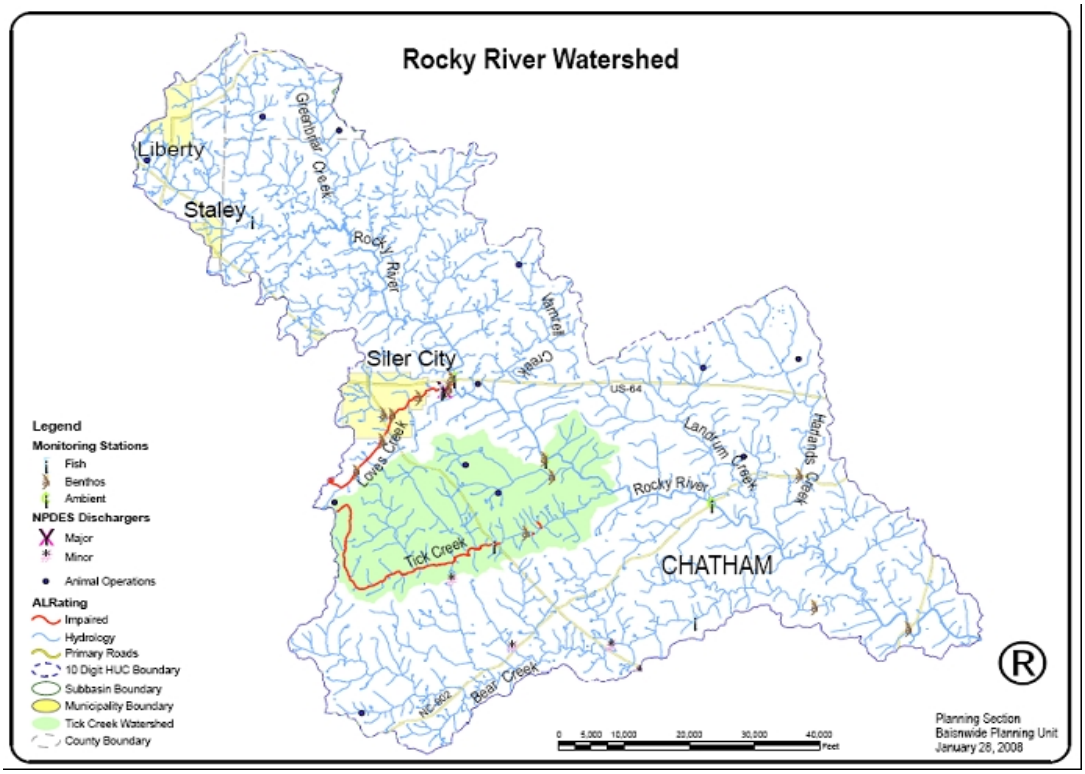
The Rocky River is part of the Cape Fear river basin and is one of the three rivers that form the headwaters of the Cape Fear River. The Cape Fear river basin is the largest basin entirely within the state. Within the headwaters of that basin the Rocky River flows through Chatham County and meeting the Deep River which then joins the Haw River at Mermaid Point, just south of Pittsboro, NC, forming the Cape Fear River. The Cape Fear river is 200 miles long from its beginnings in Chatham County to its mouth just past Wilmington in the Atlantic Ocean.

The Rocky River is 37 miles of pools, riffles, and rocks at times resembling a mountain stream. Of those 37 miles of river, 88% of the river is within Chatham County. This has led the Rocky River Heritage Foundation, a local non-profit river preservation group, to call the Rocky River "Chatham's Own River".

The Rocky River watershed is the home of 10 natural heritage areas identified by the NC Natural Heritage Program. Locations named Dragonfly Riffles, 902 Laurel Bluffs and Mussel Beds, Wood's Mill Bend and the Basalt Bluffs and Levees are all recognized as significant in the natural heritage of the Rocky River. The Nature Conservancy has also identified the watershed as one of the top watersheds to be protected in the United States ranking it in the top 15% of the 327 watersheds in the country. It also is the water supply for Siler City.

A 2010 survey of the river showed that the Rocky River is home to 9 species of freshwater mussels (down from their historically known 16 species), eight species of snails, four species of crayfish and 24 species of fish. The Rocky River is home to the Federally Listed Endangered Cape Fear Shiner (*Notropis mekistocholas*), all nine species of mussels are State listed as Endangered and of Special Concern by the US Fish and Wildlife Service.

The Rocky River has had over 15 dams and reservoirs constructed along its length in the last 150 years. Many of those dams have been breached and fallen into disrepair. Presently there are 4 dams and reservoirs located on the river and the river flow is still affected by a few of the old breached dams. Historically dams were placed on the river to make mill ponds for grist mills and only one of those dams remains today just east of Siler City at the Hackney Mill. Of the other three reservoirs on the river, two have been built to provide water for the town of Siler City as City Lake (or Upper Reservoir built in 1934) and the Turner Reservoir (the Lower Reservoir built in 1965). The third dam, Hoosier dam, was built in the 1920's for water and to generate electricity much further downstream near US Highway 15/501. The dams have generally impaired the water quality of the river due to low oxygen and high algae content. The construction of any dam on the river changes the flow of the river and also changes the biodiversity due to the change in flow regime. There is talk at this time about removing the old Hoosier Dam in order to increase the spawning habitat for the Federally Endangered Cape Fear Shiner (*Notropis mekistocholas*) that occurs above and below the reservoir created by the Hoosier Dam.


Rocky River Watershed
Liberty
Staley
Siler City
CHATHAM
Greenhill Creek
Rocky River
Tick Creek
Loves Creek
Bear Creek
Landrum Creek
Hadrills Creek
US-64
NC 902
Legend
Monitoring Stations
Fish
Benthos
Ambient
NPDES Dischargers
Major
Minor
Animal Operations
ALRating
Impaired
Hydrology
Primary Roads
10 Digit HUC Boundary
Subbasin Boundary
Municipality Boundary
Tick Creek Watershed
County Boundary
0 5,000 10,000 20,000 30,000 40,000
Feet
Planning Section
Basinwide Planning Unit
January 28, 2008

Alien Invaders

Educator Information for Pre-Visit Activity #1

Curriculum Objectives:
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.7.2 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.
EEn. 2.8.3 Explain the effects of uncontrolled population growth on earth's resources

Location: Classroom

Group Size: 30 students in pairs or foursomes.

Estimated Time: 40 minutes

Appropriate Season: Any

Materials Needed:
1 Dichotomous key to the freshwater mussels of NC per group
Pictures of 5 Freshwater Mussels per group (or real freshwater mussel shells)
Pencil per person

Note: Use the simplified key for this lab or download a copy of *The Workbook and Key to the Freshwater Bivalves of North Carolina* by Arthur E. Bogan of the NC Museum of Natural Science (http://naturalsciences.org/staff/arthur-bogan)

Major Concepts:
• Biodiversity
• Populations
• Native and nonnative species
• Impact of invasive species

Objectives:
- Differentiate between a variety of native freshwater mussels and invasive clams.
- Analyze morphological differences between freshwater mussels.
- Master the use of a dichotomous key.
- Understand the ecological services of a freshwater mussel.
- Explain the impact of invasive species on the population of native species.

Educator Information:
Invasive species are becoming a bigger problem as commerce brings a variety of new organisms to the County. Invasive species are a threat to native species because they out-compete the natives for resources. In this activity the students will be identifying a variety of mussels that are found in the Rocky River. The Asian clam, *Corbicula fluminea*, is a very common freshwater mussel that arrived in the U.S. from Asia almost 100 years ago. It has spread from the West Coast to NC and is found in almost every river in between. Freshwater mussels improve water quality in the river by filtering pollutants, algae and bacteria. They also provide a source of food for other river life. The greater the biodiversity of mussel populations in the river, the better the long-term health of the river. Asian clams threaten this biodiversity by outcompeting the native mussels for food and habitat due to their ability to live in a variety of river habitats.

This activity can be done with the photos provided, however, having the actual mussel shells would be ideal to prepare the students for the Site Visit Activity. Sets of mussels from the Rocky River can be borrowed from the Rocky River Heritage Foundation by contacting them at: rockyriverheritageinfo@gmail.com.

Teachers will need to introduce the use of a dichotomous key as a way to identify mussels. The example on the student information sheet may be used to explain how the dichotomous key works or either of the dichotomous keys available for this activity.
It may also be wise for teachers to also review the "Parts of a Mussel" so that the students are familiar with the words used to describe a mussel's shape on the dichotomous key.
Next, depending on the number of mussel sets and students, divide the students into pairs or groups of four and allow the students to practice identifying the mussels.
Once the students have finished identifying the mussels, have them complete the questions at the end of the activity.

The correct names of the mussels in this lab:

Mussel #1 – ***Elliptio producta*** (Atlantic Spike)
Mussel #2 - ***Elliptio complanata*** (Eastern Elliptio)
Mussel #3 - ***Villosa delumbis*** (Eastern Creekshell)
Mussel #4 - ***Pyganodon cataracta*** (Eastern Floater)
Mussel #5 – ***Villosa constricta*** (Notched Rainbow)
Mussel #6 – ***Corbicula fluminea*** (Asian Clam)

Alien Invaders

Student Information for Pre-Visit Activity #1

There's more life in the Rocky River than just fish and crayfish. One important animal that is quietly hidden in the river is the Freshwater Mussel.

Freshwater Mussels?
Freshwater mussels are **bivalve** mollusks that live in the riffles and pools of the Rocky River. They are similar to the clams and oysters that people see at the coast except they live in the Rocky River.
Freshwater mussels are filter feeders that live in the sand and gravels that comprise the bottom of the river. They siphon water, algae, sediment, bacteria and pollutants through their bodies, digest the food and spit out the waste. They are very important for maintaining good water quality in the river. In fact, they are often used as water quality indicator species. If the water is too dirty, mussel populations decrease.

Benefits of Mussels
Mussels can filter more than 18 gallons (70 liters) of water each day that improves water quality in the river. They are also a valuable source of food for animals like crayfish, otters, raccoons and muskrats. People have also used the native mussels, sometimes for food (they don't taste good) and for firing pottery, making spoons, hoes and for making pearls in oysters. In the late 1800's mussel shells were used as buttons! The shells looked like pearls on the inside so they were valued in the clothing until plastic buttons came out in the 1950's. But by that time many of the mussel species in the southeast were greatly reduced or eliminated altogether.

Lifecycle
Mussels live on the bottom of a river, don't move very fast or far, can't see or hear but they do just fine with reproduction. How?!? There are male and female mussels and when they become adults the males release sperm into the water and the females siphon water and sperm into their bodies to fertilize the eggs. Larval mussels, or **glochidia**, attach to a host fish's blood rich gills, metamorphose in a juvenile and then drop off to the **substrate**.

Biodiversity
In the Rocky River there are over 7 different species of freshwater mussels. The Eastern Creekshell, Florida Pondhorn, Notched Rainbow, Atlantic Pigtoe, Eastern Floater, Carolina Lance and the Creeper or Strange Floater are some of the colorful names given to these interesting animals. The problem these days is the lack of mussels in the river. When **biodiversity** decreases in the river the health of the river is threatened. Fewer mussels means poor water quality, fewer animals up the food pyramid and a larger amount of algae in the river. So fewer mussels means fewer otters and other animals!
The loss of mussel diversity also makes it possible for the river to lose all mussels if a change in the environment takes place.

Threats to Mussels
The two major concerns to the mussel population in the Rocky River: People and invasive species. People change the water flow and chemistry and add pollutants and sediments to the water. All of these cause the slow **extirpation** of native species.
The most common invasive species in the river affecting the mussel population is the Asian Clam or *Corbicula fluminea.* This freshwater mussel was brought to the west coast of the U.S. in the 1920's for food or in the ballast water of ships from Asia. From there is has spread across the country and is now found in the Rocky River. They have a variety of ways that they affect native mussel populations; eat food, eat larval mussels, add nitrogen and phosphorous to the water (increasing algae and lowering dissolved oxygen) and disrupting the substrate of the river dislodging native mussels.

In order to take care of the river and its inhabitants, it is important to know the population of the mussels. To know what mussels live in the river, **taxonomists** have created a dichotomous key of the freshwater mussels found in NC…..

Alien Invaders — Pre-Visit Activity #1

In this Pre-Visit Activity you will be working in groups to identify some common freshwater mussels from the Rocky River.
In order to identify the mussels, you will need to use a dichotomous key. A dichotomous key is an organized table that separates the many characteristics of an organism into different levels that usually have two choices. In the example below, this is level 4 that you reached by answering yes to question (2b). In level 4 you can choose from the basin location for your mussel shell. Which basin did it come from? If it is from the Atlantic Ocean drainage, go to level 5. If it is from the Mississippi, then go to level 31.

Example:

4. (2b) a. origin of shell is from rivers or lakes draining into the Atlantic Ocean 5

b. origin of shell is from rivers or lakes draining into the Mississippi River Basin..... 31

So, by answering yes or no to the characteristics of your mussel shell at each level, you will work your way through the dichotomous key to the name of your mussel!

Objectives:
- Understand the concept of a freshwater mussel.
- Master the use of a dichotomous key.
- Differentiate between a variety of freshwater mussels.
- Analyze morphological differences between freshwater mussels

Materials Needed:
-1 Dichotomous key to the freshwater mussels of NC per group
-Pictures of 6 Freshwater Mussels per group (or real freshwater mussel shells)
-Hand lens
-Pencil per person

Procedure:
-Get into a group of 4 students.
-Download your copy of *The Workbook and Key to the Freshwater Bivalves of North Carolina* from http://naturalsciences.org/staff/arthur-bogan or get a copy from your instructor.
-Take a look at the labeled sketches on pages 1 – 3 of the *Workbook and Key*. Familiarize yourself with these sketches so that you can refer to them to identify the parts of the shell.
-Using the dichotomous key complete the table below and identify the 6 mussel shells.

Mussel Shell Number	Characteristics	Mussel Name
1.		
2.		
3.		
4.		
5.		
6.		

Questions: Please complete these questions by discussing them with your group.
1. Which one of these shells is the invasive species? How can you determine this?
2. What are three physical characteristics that you could use to differentiate between native mussels and invasive mussels?
3. Are there any features of the Asian clam that gives it an advantage over the native mussels? Explain

Mussel Identification Page

Mussel #1

Mussel #2

Mussel #3

Interior

Exterior

Mussel #4

Mussel #5

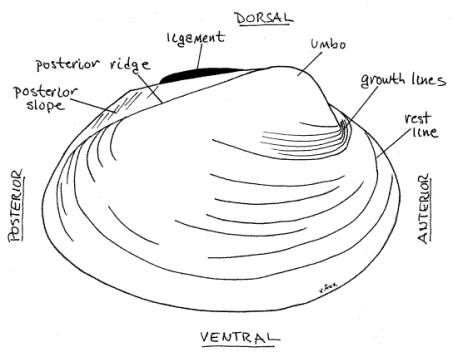
Interior

Exterior

Mussel #6

Dichotomous Key for the Mussels of the Rocky River

Parts of a Mussel….



↑Height

←Length

Dichotomous Key

1a Is the shell longer than it is tall? ……Go to 2
1b Are the length and height of the shell almost equal (an almost round shell)…….Go to 5

2a. (1a) Is the shell over 2x longer than it is high?.....Go to 3
2b. (2a) Is the shell less than 2x longer than it is high? ……Go to 4

3a. (2a) Is the shell thin, lightweight and is very iridescent (rainbow/pearly)
Your mussel is a ***Pyganodon cataracta*** (Eastern Floater)
3b. (3a) The shell has a thin shell but is chalky and white on the inside.
Your mussel is an ***Elliptio producta*** (Atlantic Spike)

4a (2b) Heavy, thick shell, usually dark brown in color. Your mussel is an ***Elliptio complanata***.
4b (4a) Medium thick shell. There are dark lines, rays, running from hinge to front edge of shell.
Your mussel is a ***Villosa delumbis*** (Eastern Creekshell)
4c (4b) Medium thick shell. There are no rays, running from hinge to front edge of shell.
Your mussel is a ***Villosa constricta*** (Notched Rainbow)

5a (1b) Shell is round or teardrop shaped with thick growth rings.
Your mussel is a ***Corbicula fluminea*** (Asian Clam)
5b (5a) Shell is very small (less than 1cm) and has thin growth rings.
Your mussel is a ***Sphaerium striatinum*** (Striated Fingernail Clam)

Estimating Populations

Educator Information for Pre-Visit Activity #2

Curriculum Objectives:
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.72 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.
EEn. 2.8.3 Explain the effects of uncontrolled population growth on earth's resources

Location: Classroom

Group Size: 30 students in groups of three.

Estimated Time: 20 minutes

Appropriate Season: Any

Materials Needed:
•1 - Quarter sized washer per pair
•1 - River mussel population paper per group
• Ruler per group
•Pencil
•1 - Activity sheet per person

Major Concepts:
• Biodiversity
• Populations
• Native and nonnative species

Objectives:
-Understand methods of estimating populations.
-Utilize the quadrat method for determining a population.
-Accurately estimate a population of mussels
-Analyze the reasons for errors in estimating populations.
-Analyze the effects varied populations have on biodiversity.

Educator Information
How many mussels are in a mile of river? How many fish are swimming in two pools in the river? Ecologists are often tasked with determining the number of organisms in an assigned area in order to determine the health of a river and the organisms in that river. They save themselves a large amount of effort and time they estimate the population of organisms. Ecologists aren't lazy, they often times face populations that may number in the thousands or millions! There are a variety of techniques used to estimate populations, but in this activity we will be using the **quadrat** method of population estimation. This is done by randomly selecting a location in the study area, placing the quadrat, and then counting the organisms within the quadrat.

The quadrat method makes the following assumptions:
•The number of individuals in each quadrat is counted.
•The size of the quadrat is known.
•The quadrat samples are representative of the study area as a whole.

Using this method of estimating populations, large numbers of organisms can be counted. In counting people, we call this a census and the quadrats are towns or city blocks!
The students will also be introduced to the concept of error and sample size.

To begin this activity, divide the class into groups of three. Depending on the level of class that you are teaching, it may be necessary to review the math for calculating area and comparing two different population totals.

After obtaining the materials for the activity each group will…
…randomly count three quadrats and determine the number of mussels on the page from their data and calculations.
…will share their Estimated Population of the River with the entire room.
…will determine the average population of the "river".
…will answer the post activity questions.

When completing this portion of the activity, the students may express wonder at why some groups have numbers that are so different from theirs. A good discussion may ensue about sample size and the accuracy of estimating populations!

This activity is the second activity in the curriculum guide so that the students could learn how to identify native and non-native species in the river before completing this activity. After completing the Extension the students should discover that there are more invasive clams in the river than native mussels. A classroom discussion on how the mussels arrived in NC as well as the impact of their arrival on the native populations could be conducted.

Guiding questions for post activity discussion:
-Why are there so many non-native species in the river?
-Why would the non-native species be brought to the US?
-How did freshwater clams migrate across the country?
-What could happen to the number of native species in the river as a result of the non-native invasion?

Further research online could be conducted into the impact that the loss of biodiversity has on an ecosystem, origins of Asian Clams (*Corbicula*) in the US, other invasive species that are found in NC and their impact on the State, the unique methods of mussel reproduction.

Estimating Populations

Student Information for Pre-Visit Activity #2

How many mussels are in a kilometer of river? How many fish are swimming in two pools in the river? How many fish are in the entire river?

Ecologists are often asked to determine the number of organisms in an assigned area in order to determine the health of a river and the organisms in that river. They can save themselves a large amount of effort and time they estimate the population of organisms. Ecologists aren't lazy, they often times face populations that may number in the thousands or millions!
Just think about counting the number of beans in a jar…what would you do if there were many more animals and the jar was several kilometers long?

There are a variety of techniques used to estimate populations, but in this activity we will be using the **quadrat** method of population estimation. The quadrat method is done by randomly selecting a location in the study area, placing the quadrat, and then counting the organisms within the quadrat.
Quadrats, or quads, are usually square or circular shaped. Quads are easily made from PVC pipe and can be any size you need to count the population. If you are counting trees, your quad might be very large, if you are counting grasses, it might be less than a meter square.
But what if your sample moves? The quadrat method is good for slow or non-moving populations, but for fish? Maybe we should use another method of estimating the population!

The quadrat method makes the following assumptions:

- The number of individuals in each quadrat is counted.
- The size of the quadrat is known.
- The quadrat samples are representative of the study area as a whole.

Using this method of estimating populations, large numbers of organisms can be counted. When counting people, we call this type of sampling a census and the quadrats are towns or city blocks!

Something to think about…. Is an estimation always accurate?

Estimating Populations Pre-Visit Activity #2

In this activity you will be determining the population of mussels in the "Rocky River" by using the quadrat method of estimating populations. In this activity the quadrat is a washer and you will use the washer to randomly select three different areas on the "river". From your data you will be able to determine the number of mussels on the entire "river" page. You will be working with a small group but sharing your estimated population data with the entire classroom at the end of your measuring and calculations. Wait to answer the questions until you get the entire class's data!

Objectives:
-Understand methods of estimating populations.
-Utilize the quadrat method for determining a population.
-Analyze the reasons for errors in estimating populations.

Materials Needed:
•1 - Washer per pair
•1 - River with a population of mussels. 1 page per pair
• Ruler per group
•Pencil
•1 - Activity sheet per person

Procedure:
1. Choose a partner to work with.
2. Get your materials for the activity.
3. Measure the diameter of the washer in cm. Divide the diameter of the washer by 2 to get the radius of the washer. Record the radius of the washer. **Radius** = _____

4. Calculate the area of the washer by using the formula $A = \pi r^2$ (or $3.14 \times r^2$)
Area of washer = _____
5. Take the washer and flip it onto the "river" then use your pencil to draw a circle around the outer edge of the washer.
6. Remove the washer and count the number of mussels in the circle.
Record the number of mussels that are partially or completely inside the circle.
Number of Mussels in Circle _____
7. Repeat steps 5 and 6 two more times
Number of Mussels in Circle _____

Number of Mussels in Circle _____

8. Total up the number of mussels and determine the average number of mussels that you counted inside the circles.
Total Number of Mussels in the Three Circles _____

9. Determine the average number of mussels of the three circles. (Total/3=Avg.)
Average Number of Mussels per Circle _____

10. Calculate the number of mussels on the entire page! Find the area of the page in cm^2 and then compare it to the area of your washer. This is your estimated population for the river!

Estimated Population of the River_____

11. Share your data for the **Estimated Population of the River** with the other groups in class.

Group 1 Estimated Population _____

Group 2 Estimated Population _____

Group 3 Estimated Population _____

Group 4 Estimated Population _____

Group 5 Estimated Population _____

Group 6 Estimated Population _____

Group 7 Estimated Population _____

Group 8 Estimated Population _____

Group 9 Estimated Population _____

Group 10 Estimated Population _____

Average Estimated Population _____

Post Activity Questions:

1. How did the class average for the populations of mussels in the river compare to your average?

2. Why do you think that the class' average mussel population was different from your average?

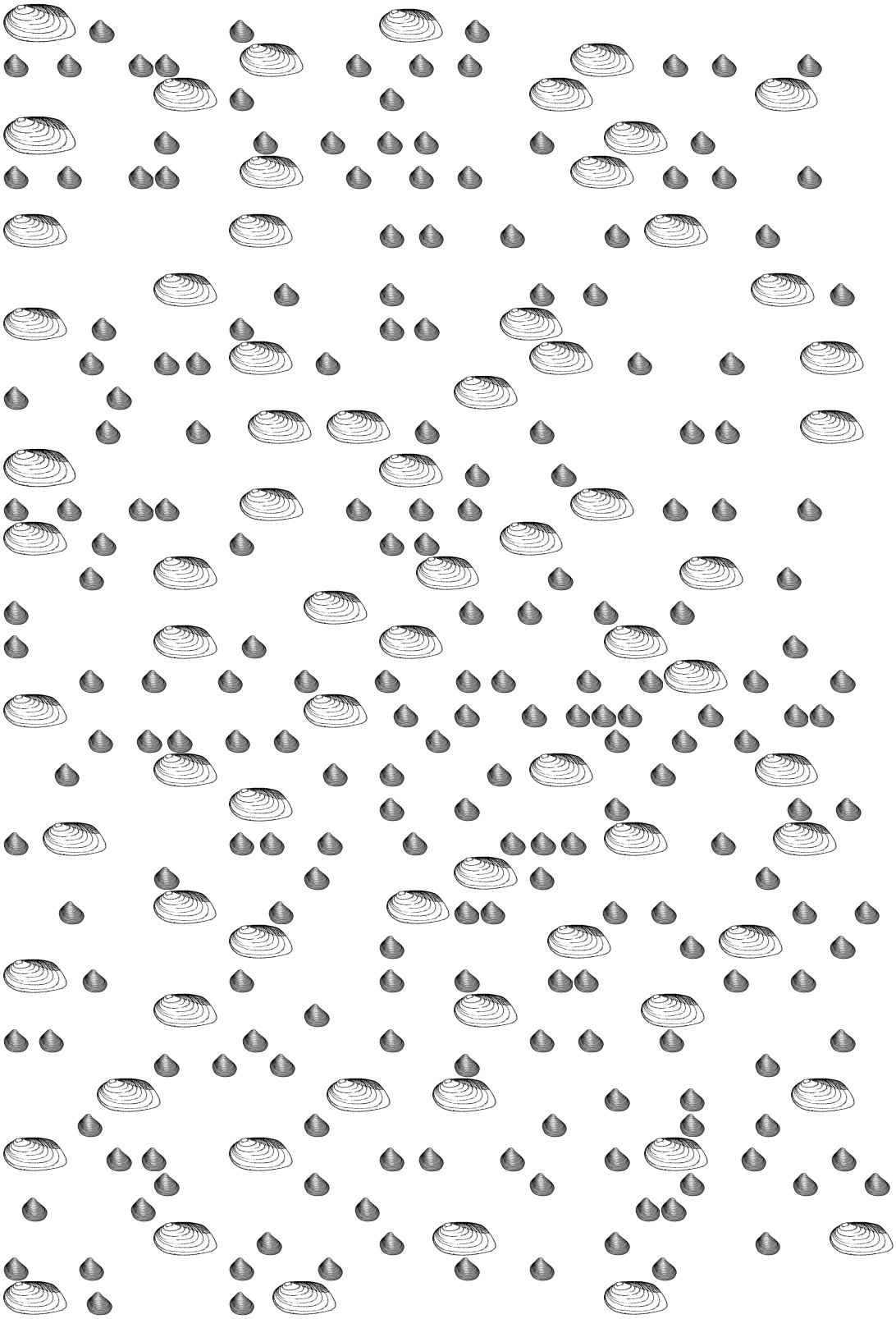
3. Is this an accurate way to estimate populations? Explain your answer.

4. Explain two sources of error for this activity.

5. Explain how you could do this method of population estimation in the actual Rocky River if you were asked to determine the population of native and invasive mussels found in the river.

Extension: What is the population of invasive species compared to the population of native mussels in this "river"? How could you calculate the difference in populations? Design a methodology to determine the difference and then go ahead and discover if there is a difference in native and non-native populations!

Rocky River "Estimating Populations" Activity Mussel Page



Rocky Dams

Educator Information for Pre-Visit Activity #3

Curriculum Objectives:
EEn.2.4.1 Evaluate human influences on freshwater availability.
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.7.2 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.
EEn. 2.8.4 Evaluate personal choices in terms of impacts on the availability of natural resources and environmental quality; relate this to ecological footprints on various scales.

Location: Classroom

Group Size: 30 students in foursomes or pairs.

Estimated Time: 40 minutes for research, 15 minutes for presentation.

Appropriate Season: Any

Materials Needed:
-3 Partners to work with
-Map of Chatham County (1870 Ramsey Map)
-Computer
-Internet Access
-Pencil
-Activity Sheet
-Sheet of poster paper
-Markers or colored pencils

Major Concepts:
• Reservoirs and alternative energy
• Effects of Dams on Rivers
• Water Quality and Dams

Objectives:
- Describe three effects of reservoir construction on water quality.
- Practice map skills.
- Analyze morphological and water quality differences between reservoirs and rivers.
- Understand three effects of water flow on biodiversity.

Educator Information:
The Rocky River has had over 15 dams and reservoirs constructed along its length in the last 150 years. Many of those dams have been breached and fallen into disrepair. Presently there are 4 dams and reservoirs located on the river and the river flow is still affected by a few of the old breached dams. Historically dams were placed on the river to make mill ponds for grist mills and only one of those dams remains today just east of Siler City at the Hackney Mill. Of the other three reservoirs on the river, two have been built to provide water for the town of Siler City as City Lake (or Upper Reservoir built in 1934) and the Turner Reservoir (the Lower Reservoir built in 1965). The third dam, Hoosier dam, was built in the 1920's for water and to generate electricity much further downstream near US Highway 15/501. The dams have generally impaired water quality due to low oxygen and high algae content. The construction of any dam on the river changes the flow of the river and also changes the biodiversity due to the change in flow regime. There is talk at this time about removing the old Hoosier Dam in order to increase the spawning habitat for the Federally Endangered Cape Fear Shiner (*Notropis mekistocholas*) that occurs above and below the reservoir created by the Hoosier Dam.

In this Activity the students will be utilizing the internet to determine the impact that reservoirs and millponds have on the river environment and the animals and plants that live there.

They will be researching the differences between millponds/reservoirs and rivers. Make sure they focus on the Piedmont of NC for the animals and plants. They will be working in pairs or ideally groups of 4 to research their assigned topic. The research topics are on the cards and more than one group may have the same topic making it appropriate for pairs to research.

After the groups research their topic and create a poster, conduct a "Gallery Walk" of the posters so the students can share their research. Following the Gallery Walk, discuss the findings of the student research with the students so they understand the effects of dam construction on the river.

Rocky Dams

Student Information Pre-Visit Activity #3

The Rocky River has had numerous dams and reservoirs constructed along its length in the last 150 years. Many of those dams have been breached and fallen into disrepair. The Rocky River was dammed in the 1800's in many places so that grist mills could be constructed to grind grains. Upstream from each mill was a millpond that provided water storage for the waterwheels that turned the grinding stones in the mill. Most of those dams and mill ponds were washed out during storms in the last 100 years. However, the river's flow is still affected by a few of the old breached dams. Only one grist mill and dam remains today, the Hackney Mill, just east of Siler City where Highway 64 crosses the Rocky River.

There are three dams and reservoirs on the river at this time, two have been built in the last 50 years to provide water for the town of Siler City and one for making hydroelectric power. City Lake (or Upper Reservoir) and the Turner Reservoir (the Lower Reservoir) were built for water storage. The third dam, Hoosier dam, was built in the 1920's for water and to generate electricity much further downstream near US Highway 15/501. The construction of any dam on the river changes the flow of the river and also changes the biodiversity due to the change in the amount of the water flowing downriver.

There is a discussion going on at this time about removing the old Hoosier Dam in order to increase the spawning habitat for the Federally Endangered Cape Fear Shiner (*Notropis mekistocholas*) that occurs above and below the reservoir created by the dam.

In this Activity you will be exploring the reasons dams are constructed and their effects on the flow of water downstream. You will also be looking at the effects of dam/reservoir construction on the organisms that live in the river, both upstream and downstream from the dam.

Rocky Dams Pre-Visit Activity #3

In this Activity you will be working with a partner to determine the effects of dams and reservoirs on the animals and plants that live in the river.

Objectives:
- Describe three effects of reservoir construction on water quality.
- Practice map skills.
- Analyze morphological and water quality differences between reservoirs and rivers.
- Understand three effects of water flow on biodiversity.

Materials Needed:
-A group of 4 students
-Map of Chatham County (1870 Ramsey Map)
-Computer
-Internet Access
-Pencil
-Activity Sheet
-Sheet of poster paper
-Markers or colored pencils

Procedure:
In this section you will be working with three partners to determine the differences between reservoirs and rivers.
You will need your computer and a copy of the 1870 Ramsey Map of Chatham County that shows the location of the mills along the Rocky River.
You will be researching one of the Rocky Dams Activity Cards topics (concerning water quality, different species of animals and plants, and water flow) that your teacher provides to your group.
When you have completed researching the topic from the card, your group will create a poster illustrating the information about the Activity Card topic.
The poster will present: Title, information about your topic, a sketch of three of the common organisms from your research, or if applicable, sketch the topic itself - river or millpond to illustrate the physical characteristics of the topic.
Then, your group will present your research findings to the other groups using the "Gallery Walk" method described by your instructor.

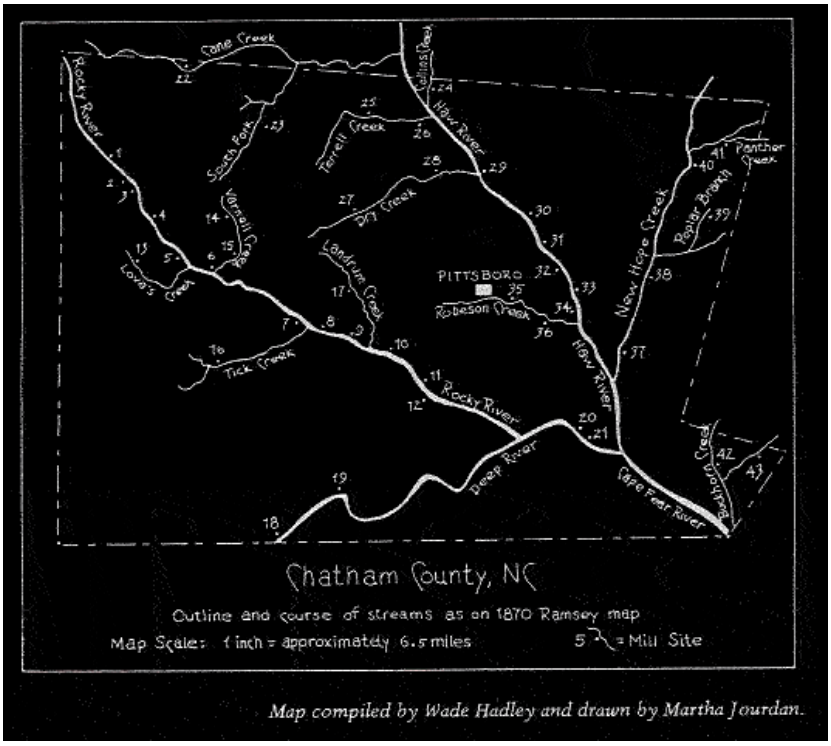
Pre-Research Questions:

1. How many dams and mills were located along the Rocky River in 1870?
2. What were the uses for those dams constructed along the Rocky River in 1870?
3. What do you think was the impact of those dams to the river and the animals that live there?

Post Research Questions:
After each group has completed their research and posted their poster in the "Gallery", go by each poster and take notes on the major ideas of the poster topic. Then answer the questions below. If you need to, go back up and take a look at each poster as needed.

1. How does a dam affect the river that it is built across?
2. Do dams change the plants and animals that live in the river? Explain your observations.
3. In what ways is a dam able to affect the plants and animals that live there?
4. What might have been the effects of all the dams and reservoirs on the Rocky River in 1870?
5. What might happen to the river and the life in the river if a dam was removed from the river after many years?

Ramsey Map from 1870



Rocky Dams Activity Cards

Cut out the cards and pass one out to each of the groups so they may research the information for their poster. Some groups may have the same research card due to class size.

Water Quality in Millponds Research the data for this month's water: Temperature Dissolved oxygen Rate of water flow	**Water Quality in Rivers** Research the data for this month's water: Temperature Dissolved oxygen Rate of water flow
Animals in Millponds Research what species are found in millponds and reservoirs in the Piedmont of NC	**Animals in Rivers** Research what species are found in millponds and reservoirs in the Piedmont of NC
Plants in Millponds Research what species are found in millponds and reservoirs in the Piedmont of NC	**Plants in Rivers** Research what species are found in millponds and reservoirs in the Piedmont of NC

River Activity #1

Curriculum Objectives:
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.72 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.
EEn. 2.8.3 Explain the effects of uncontrolled population growth on earth's resources

Location: Rocky River, Chatham County, NC. Consult with the Rocky River Heritage Foundation for the accessing the best sites along the river.

Group Size: 30 students in foursomes.

Estimated Time: 30 minutes

Appropriate Season: Fall or mid spring

Materials Needed:
•1 Laminated Key to the Freshwater Mussels of the Rocky River per group.
•1 meter^2 quadrat* per group
•A gallon Ziploc bag or small rubbermaid container to hold mussels
•Pencil per person
•Boots or shoes to get wet in the river
Note: Make a class set of laminated Key to the Freshwater Mussels of the Rocky River page that follows these Educator Information Pages.

Educator Information for Show Me Your Mussels!

Major Concepts:
• Biodiversity
• Estimating Populations
• Native and nonnative species
• Impact of invasive species

Objectives:
- Understand the concept of a freshwater mussel.
- Practice the identification of freshwater mussels.
- Determine the population of mussels in a portion of the Rocky River.
-Determine the biodiversity of the Rocky River mussel population

Educator Information:
Invasive species are becoming a bigger problem as commerce brings a variety of new organisms to the County. Invasive species are a threat to native species because they out-compete the natives for resources. In this activity the students will be identifying a variety of mussels that they find in the Rocky River. The Asian clam, *Corbicula fluminea*, is a very common freshwater mussel that arrived in the U.S. from Asia almost 100 years ago. It has spread from the West Coast to NC and is found in almost every river in between. Freshwater mussels improve water quality in the river by filtering pollutants, algae and bacteria. They also provide a source of food for other river life. The greater the biodiversity of mussel populations in the river, the better the long-term health of the river. Asian clams threaten this biodiversity by out competing the native mussels for food and habitat due to their ability to live in a variety of river habitats.
Besides the invasive *Corbicula* living in the river, *Elliptio complanata* and *Villosia delumbis* may also be easily collected in the river.
The students will be applying the knowledge that they gained from the two Pre-Visit Activities that they completed at the school in order to count and identify the mussels in the river. Each group will have a meter^2 quadrat* to count the mussels in the **substrate** of the river.

Safety Concerns:
This activity takes place in the Rocky River so safety is a concern. Make sure the students work in groups of four so they may assist each other with the activity. Rocks in the river and the riverbank can be slippery so stress the importance of the students taking their time in walking about and have the students always face upstream when walking in the river so they can walk more easily.
The activity works best in shallow riffles and pools so it is best to preview the site before the students visit in order to determine the best location for the activity and the location of any safety concerns.
Remember to point out poison ivy leaves and vines so the students don't walk through or grab a loose vine!

Procedure:
Upon arriving at the river, demonstrate the appropriate method for randomly selecting a site in the river (which would be standing in the river and dropping the quadrat over your shoulder or tossing it gently into a riffle or pool without looking.)

Also, go over the safety rules about slippery banks and rocks in the river. Be sure everyone has sturdy footwear on before entering the river. No sandals or bare feet!

Divide the students into groups and assign the groups either a riffle location in the river or a pool location. Pass out the quadrats and walk carefully to the river.

Before starting, you will most likely need to demonstrate the tactile method of finding mussels (stick your hands into the gravels and get a handful of sediments and mussels) or the visual method (find a mussel with the siphons visible and show the students or show them the mussels siphons on the Mussel Key.)
Have the students spread out into the river to their assigned location in either the riffle or the pool and begin to collect data. After completing one site, each group will need to randomly select another site in the river and repeat the data collection.

Once all the groups are done with data collection, you will need to complete the lab back at school and save the data for later so the students can complete the data analysis in the classroom or for homework.

Collect the quads and lead a short discussion about the data they collected and any difficulties they had in collecting the data.

Note: If you are planning on doing **River Activity # 2 - Nature's Filters** remind each group that they will need to carefully save two *Elliptio* and four *Corbicula* for that Activity. This can be done by placing them in a plastic Ziploc bag or just holding them in their hand.

***Quadrats** can be easily constructed with ½" PVC pipe and 4 PVC 90° elbows per quad from a local hardware store. A class set may be borrowed from the Rocky River Heritage Foundation by contacting them via: rockyriverheritageinfo@gmail.com

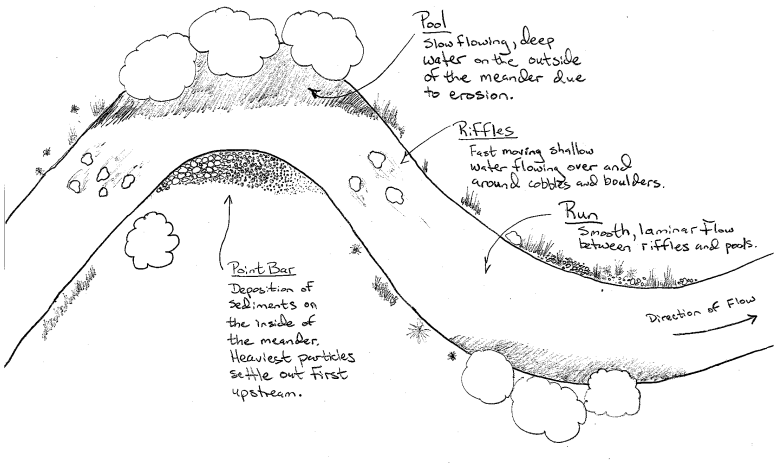


Diagram of the Riffles and Pools in a river.

Visual Key to the Freshwater Mussels of the Rocky River

Elliptio producta (Atlantic Spike)

Elliptio complanata (Eastern Elliptio)

Villosa delumbis (Eastern Creekshell)

Pyganodon cataracta (Eastern Floater)

Villosa constricta (Notched Rainbow)

Corbicula fluminea (Asian Clam)

An *Elliptio* on the bottom of the river. Look for the “figure 8” siphons!

Show Me Your Mussels!

How many mussels are in the Rocky River?

Today you will be visiting the Rocky River here in Chatham County to determine the population of freshwater mussels in a section of the river.

Safety First!
When you are working at the river please stay with your teacher and listen to their directions.
Remember:
•The rocks in the river are slippery.
•Always face upstream when walking in the river.
•The mud on the riverbanks may be slippery.
•There may be poison ivy to avoid.
Please stay together with your group and no wandering off.

Mussel Populations
Ecologists are often asked to determine the number of organisms in an assigned area in order to determine the health of a river and the organisms in that river. They can save themselves a large amount of effort and time they estimate the population of organisms. Ecologists aren't lazy, they often times face populations that may number in the thousands or millions!
Just think about counting the number of beans in a jar…what would you do if there were many more animals and the jar was several kilometers long?

Today you will practice methods ecologists use to estimate populations with this River Activity!

There are a variety of techniques used to estimate populations, but in this activity we will be using the **quadrat** method of population estimation. The quadrat method is done by randomly selecting a location in the study area, placing the quadrat, and then counting the organisms within the quadrat.
The quadrats, or quads, are square shaped in this activity and are made from PVC pipe.
The quadrat method is good for slow or non-moving populations like freshwater mussels.
Remember: the quadrat method makes the following assumptions:
•The number of individuals in each quadrat is counted.
•The size of the quadrat is known.
•The quadrat samples are representative of the study area as a whole.

Using this method of estimating populations, large numbers of organisms can be counted. When counting people, we call this type of sampling a census and the quadrats are towns or city blocks!

Student Information

Sampling Techniques
To find mussels in your quad, there are two sure-fire methods; visually and tactile.
The visual method can be used to locate *Elliptio.* They can be found by looking for a white or grey "figure 8" in gravelly areas of the **substrate**. The "figure 8" is made of the two siphons that allow the mussel to pass water through its body. One is the incurrent siphon, the other, the excurrent siphon. Look carefully! (For an example of how they look, look at the Mussel Key for a photo of a mussel in its habitat).
The tactile method is much easier for the novice mussel hunter. Just take your fingers and dig down into the sand and gravel about 2 inches and grab a handful of substrate. Let the water wash the sand and small rocks out of your fingers and then look for mussels left behind with the larger gravels.
Place the mussels in the bucket and allow the gravel to settle back to the bottom of the river. Easy!

Take care of the mussels! They are living animals and deserve the respect as an important part of the balanced river system. Don't try to force the mussels open, they close up to avoid suffocation and predation. Place them gently back in the river when you are finished with them. Thanks!

Show Me Your Mussels! River Activity #1

In this activity you will be determining the population of mussels in a portion of the Rocky River by using the quadrat method of estimating populations. In this activity the quadrat is a meter^2 and you will use the quad to randomly select three different areas in shallow riffles or pools in the river. From the class data you will be able to determine the number of mussels in the entire river. You will be working with a small group but sharing your estimated population data with the entire class at the end of the field trip. Wait to answer the questions until you get the entire class's data when you return to school!

Objectives:

- Understand the concept of a freshwater mussel.
- Practice the identification of freshwater mussels.
- Determine the population of mussels in a portion of the Rocky River.
- Determine the biodiversity of the Rocky River mussel population

Materials Needed:

- 1 Laminated Key to the Freshwater Mussels of the Rocky River per group.
- 1 meter^2 quadrat* per group
- A gallon Ziploc bag or small rubbermaid container to hold mussels
- Pencil and activity sheet per person
- Boots or shoes to get wet in the river

Procedure:

1. Team up with three other students to complete the activity.
2. Get your materials for the activity and record the location of the site on the river.
3. Record the area of the quad in m^2. **Area of quad** = _____
4. Take the quad and drop it into the river in a shallow water area (no more than .5m deep).
5. At this point, one person needs to hold the quad down on the river bottom. Two people will need to look for mussels, and the fourth person will be collecting the mussels in a container. After collecting all the mussels from the quad, the entire group will collaborate on identifying the mussels and counting the number of each type of mussel.
6. Identify and record the number of live mussels that are partially or completely inside the quad.

	Location #1	**Location #2**
Number of *Elliptio sp*. in Quad	_____	_____
Number of *Villosia sp*. in Quad	_____	_____
Number of *Corbicula* in Quad	_____	_____

7. Once you have counted and identified all the mussels in your bucket, place all the mussels back in the center of the quad so they can carry on with their lives in the river.

8. Repeat steps 4 through 7 one more time and switch jobs of the 4 members in the group.

9 . Total up the number of mussels and determine the average number of mussels that you counted inside the quad.

Total Number of Mussels in the two quads _____

10. Determine the average number of mussels of the two quads. (Total/2=Avg.)

Average Number of Mussels per quad _____

11. Calculate the number of mussels in one km^2 of the Rocky River (that would be an area of river 20m wide and 50,000m long)! Now compare it to the area in the river that you were working. This is your estimated population for the river!

Estimated Population for the River_____

11. Share your data with the other groups in class.

Group 1 Estimated Population_____

Group 2 Estimated Population _____

Group 3 Estimated Population _____

Group 4 Estimated Population _____

Group 5 Estimated Population _____

Group 6 Estimated Population _____

Group 7 Estimated Population _____

Group 8 Estimated Population _____

Group 9 Estimated Population _____

Group 10 Estimated Population _____

Average Estimated Population _____

Questions:

1. How did the class average for the populations of mussels in the river compare to your average?

2. Why do you think that the class' average mussel population was different from your average?

3. Describe three changes in the river might change the numbers of mussels in the river?

4. Which mussel was the most common? What could explain the difference in populations?

5. Does the Rocky River have a diverse group of mussels in the area you studied? Explain your answer based on your data.

6. Do you think there is an issue with invasive species in the Rocky River? If so, list and explain any issues that might face the river as a result of an invasion.

Nature's Filters

Educator Information for River Activity #2

Curriculum Objectives:
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.72 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.

Location: Rocky River, Chatham County, NC. Consult with the Rocky River Heritage Foundation for the accessing the best sites along the river via: http://rockyriverheritagefoundation.wordpress.com

Group Size: 30 students in foursomes.

Estimated Time: 30 minutes

Appropriate Season: Fall or mid spring

Materials Needed:
•6 freshwater mussels of NC per group. Three *Elliptio* and three *Corbicula*
•4 clear plastic container or cups per group
•Sediment (pebbles or gravels) from the river to place in cups.
•A spoonful or two of mud from the river per cup
•1 Timer per group
•Pencil and activity sheet per person
•Boots or shoes to get wet in the river

Major Concepts:
• Biodiversity
• Native and nonnative species
• Impact of invasive species on the biosphere
• Effects of human population growth on animal species in NC
•Summarize ways to mitigate human impacts on the biosphere
• The effects of invasive nonnative species on a NC ecosystem.

Objectives:
- Understand the concept of a freshwater mussel siphoning water.
- Analyze the differences in native and invasive mussels and their ability to siphon water.
- Determine the impact of a change in the population of mussels in the Rocky River would have on the water quality in the river.

Educator Information:
Mussels are nature's filters in an aquatic ecosystem siphoning upwards of 18 gallons of river water per day! The ability of a mussel to filter so much water per day means that they can clean a large amount of sediment, algae, and man-made waste out of the water. This river activity will illustrate the abilities of the mussels to filter the water by clearing the water of sediment in a cup full of river water. The activity will also strive to show the difference between native and invasive mussels and their abilities to filter the water.

Procedure:
After completing River Activity #1 each group will need to have saved 6 mussels from their Activity. On a flat spot above the river, have the materials for this Activity ready for each group. Each group will use four clear cups or containers to hold equal amounts of water in each cup. Please draw lines on the cups at the same level on each cup so the students know how much water and sediment (pebbles or gravels) to add to the cups before the Activity begins. The students will vary the species and number of mussels in the cups to compare and contrast the siphoning ability of mussels. Suggested parings would be one *Elliptio* in the first cup, two in the second cup, one *Corbicula* in the third cup and 2 *Corbicula* in the fourth cup. Allow the students time to talk about how they will plan the set-up for the lab and then to set the lab up. The time it takes for the mussels to clear the water will depend on the mussels, the amount of sediment place in the cup and the number of mussels. *Note* This activity can be easily completed after the groups have completed River Activity #1 and while doing River Activity #3.

Nature's Filters

River Activity #2

Student Information

Today you will be visiting the Rocky River here in Chatham County to determine the effect of freshwater mussels have on the amount of sediment suspended in river water.

Safety First!
When you are working at the river please stay with your teacher and listen to their directions.
Remember:
•The rocks in the river are slippery.
•Always face upstream when walking in the river.
•The mud on the riverbanks may be slippery.
•There may be poison ivy to avoid.
Please stay together with your group and no wandering off.

Sedimentation
The number one pollutant in NC rivers is sediment. You can easily see the effects of sediment on the Rocky River when there is a heavy rain or a quick melt of snow because the river changes from its normally clear or **tannin** stained water to a muddy butterscotch or caramel colored body of fast moving water. Where does the sediment come from? Sediment is the silts, clays, and sands that are washed into the Rocky River by water erosion during a rain. The harder the rainfall, the greater the erosion and the more sediment discolors the river. When the water gets filled with sediments, ecologists say that the river has high **turbidity** and the water is not clear enough to see through. Low turbidity is desired because it is better for the life in the river.

The color of the river is not the only problem with sediments in the river. Sediments make it more difficult for those animals with gills to breathe, they decrease the amount of dissolved oxygen in the river and they can increase the temperature of the river water. If the water is too turbid, the light cannot reach the submerged plants in the river and they will not grow as well and produce oxygen as they could in clear water. Once the river begins to slow its flow after the rain stops, the sediments can no longer be supported by the water and begin to settle to the bottom of the river. When this happens, the organisms that live in or on the substrate can be buried under a layer of sediments.

Many fish also need clean gravels on which to **spawn**. If there is too much sedimentation they can no longer reproduce or the eggs that they laid may suffocate and die.

Some organisms see the sediment as a benefit. With the flow of sediment, the river also brings more nutrients to those filter feeders on the bottom of the river. Mussels are one of those organisms that filters the food and sediment from the river and they can be very good at filtering. In this Activity your group will be looking at just how effective mussels can be at filtering the river water. You have the opportunity to compare different species and numbers of mussels to see the effectiveness of mussels at clearing the water of sediments.

Nature's Filters River Activity #2

In this activity you will be determining the effects that freshwater mussels have on the water quality of the Rocky River.

Objectives:
- Understand the concept of a freshwater mussel siphoning water.
- Analyze the differences in native and invasive mussels and their ability to siphon water
- Determine the impact of a population of mussels in the Rocky River would have on the water quality in the river.

Materials Needed:
•6 freshwater mussels of NC per group. Three *Elliptio* and three *Corbicula*
•4 clear plastic container or cups per group
•Sediment (pebbles or gravels) from the river to place in cups
•A spoonful or two of mud from the river per cup
•1 Timer per group
•Pencil and activity sheet per person

Procedure:
In this Activity you will be observing the siphoning ability of freshwater mussels and determining if different species of freshwater mussels have differing effects on the siphoning rate of sediments in the water. To set up the lab you will need some of the mussels from the first Activity, three (3) *Elliptio* and three (3) *Corbicula.* **Handle them gently** so they will open up quickly in the cup of water.

1. Fill the four cups with river water to the upper line on the cup.
2. Add fine sediments (sand , pebbles or gravels) to the lower line on the cup so the mussels have something familiar to sit upon.
3. Add mussels and mud to the cups and start the timer. (You might ask your co-workers about how many mussels and what species of mussels you will place in the cup at this point. Come to an agreement on what you would like to measure and then add the mussels!)
4. Record the time that that it takes for the water to clear enough to read the lab sheet through the cup of water. (Note* - This may be different for each cup, so don't stop the timer until <u>all</u> the cups have cleared enough to read through!)
5. Once you have finished timing, gently return water, sediments and mussels back to the river. Recycle the cups as your teacher requests.
6. Graph your data below and then answer the questions.

Mussel Siphoning Graph

Questions:

1. What happened to the water in the cup? How did this happen?

2. What sort of arrangement did your group have for the mussels in the cups? Why did you choose that grouping of mussels in each cup?

3. Describe the effect mussels would have on the amount of sediments in the waters of the Rocky River. (Think back to River Activity #1)

4. Which species of mussel was the most efficient at removing the sediments from the water? Why do you think that was true?

5. What effects do invasive mussels have on the Rocky River? Are those effects positive or negative? Explain.

6. How have humans influenced the quality of the water in the Rocky River? What role do the mussels play in the changes to the water quality? Explain your answer based on this activity and the previous activity.

Go with the Flow!

Educator Information for River Activity #3

Curriculum Objectives:
EEn.2.3.2 Explain river systems including NC river basins, aquifers, and watersheds.
EEn.2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn.2.7.1 Explain how abiotic and biotic factors interact to create the various biomes in North Carolina.

Location: Rocky River, Chatham County, NC. Consult with the Rocky River Heritage Foundation for the accessing the best sites along the river.

Group Size: 30 students in foursomes.

Estimated Time: 15 minutes

Appropriate Season: Fall or mid spring

Materials Needed:
•Groups of 4 students
•Timer
•50m Measuring Tape
•A floating object that is easily seen
•1 Timer per group
•Pencil and activity sheet per person
•Lamotte Dissolved Oxygen kit

Major Concepts:
Water Quality
Physical properties of water
Flood events
Biodiversity

Objectives:
-To evaluate water quality of NC streams by measuring the flow of the river.
-Explain the movement of sediments through a watershed and the effect that river flow might have on the inhabitants that share the same watershed.
-Explain two ways that abiotic factors in the river affect the biota in the river to create the various biomes in a North Carolina river.
-Explain how human activities impact the biosphere.

Educator Information:
Flow is the amount of water that is moving in a river. The flow of water in a river is important to the type and amount of life in the river. If there is a large amount of water flowing downriver, we might call it a flood. If there is too little water running downstream, we call that a disaster. The proper flow in a river at a particular time allows animals and plants to survive, increasing biodiversity. If the river slows many animals may die or they could be replaced by more tolerant species. Clean gravels for spawning, enough dissolved oxygen to breathe, lower levels of algae and the constant movement are a few of the reasons that river flow is important.

In this Activity the students will be learning how to measure the velocity of the water (river flow) of the Rocky River. Anything may be used as a floating object. Just be sure, if it is plastic the students must get it before it floats off. Usually an old, dry stick is the best choice for a floating object to measure the flow.

Procedure:
To begin this Activity, ask the students to note the riffles and pools in the river and then engage them in a discussion of the physical characteristics of the river in each spot. The students will no doubt mention the amount of flow in the river, slower in the pools and faster in the riffles. Ask them to justify their observations, make it quantifiable! Pose the question on how to find a number for the flow rate and then how to determine this in the river. Now have them break into groups and find out the difference in flow from one spot in the river to another using the materials provided.
After the students have finished determining the flow of the river, have them check the dissolved oxygen (DO) in the pool and the riffles. The students can compare the flow to the DO in each of the two tested locations to see if flow rate affects the amount of DO in the water in turn affecting the water quality.

Go with the Flow! River Activity #3

Student Information
Today you will be visiting the Rocky River here in Chatham County to determine the river flow of the pools and riffles of the Rocky River.

Safety First!
When you are working at the river please stay with your teacher and listen to their directions. Remember:
•The rocks in the river are slippery.
•Always face upstream when walking in the river.
•The mud on the riverbanks may be slippery.
•There may be poison ivy to avoid.
•Please stay together with your group and no wandering off.

Objectives:
-To evaluate water quality of NC streams by measuring the flow of the river.
-Explain the movement of sediments through a watershed and the effect that river flow might have on the inhabitants that share the same watershed.
-Explain two ways that abiotic factors in the river affect the biota in the river to create the various biomes in a North Carolina river.
-Explain how human activities impact the biosphere.

River Flow
Flow is the amount of water that is moving in a river. The flow of water in a river is important to the type and amount of life in the river. If there is a large amount of water flowing downriver, we might call it a flood. If there is too little water running downstream, we call that a disaster. The proper flow in a river at a particular time allows animals and plants to survive, increasing biodiversity. If the river slows many animals may die or they could be replaced by more tolerant species. Clean gravels for spawning, enough dissolved oxygen to breathe, lower levels of algae and the constant movement are a few of the reasons that river flow is important.

Materials Needed:
•Group of 4 students
•Timer
•50m Measuring Tape
•A floating object that is easily seen
•1 Timer per group
•Pencil and activity sheet per person
•Boots or shoes to get wet in the river

Procedure:
1. With your group, determine the roles for each of your partners. You will need someone to time, two people to measure the distance of 10 meters, and one person to release the floating object down the river.
2. Measure 10m of river length **at an area of riffles** (this can be done from the bank or in the water).
3. Have one person stand by the end of the 10m at the downriver part of the measuring tape with the timer and one person go upriver to the start of the 10m with the floating object.
4. Coordinate with the person who is timing to begin timing as the floating object starts moving downriver within the 10m portion of the river. Yell “start” back to the timer so they may start the timer.

5. When the floating object passes by the end of the 10m, stop timing and record the time it took for the floating object to travel the 10m. Record your time on the data table.
6. Repeat steps 4 and 5 two more times to get accurate flow times.
7. Once you have finished determining the velocity of the riffle section of the river, go to the **pools** section of the river and repeat steps 2 - 6.

Flow Data

	Riffles	**Pools**
Trial	**Time (in seconds)**	**Time (in seconds)**
1st		
2nd		
3rd		

Calculate the average velocity of the river (Distance/Time = Velocity) for the riffle section and the pool section.

Average velocity for Riffles _____ **Average velocity for the Pools _____**

Now to answer some questions….

Questions:

1. Which area of the river had the fastest flow? What are two reasons why that section is the fastest section of the two river sections? Would the flow be greater in a millpond or river? Explain your answer.

2. Describe the physical appearance of the river in the riffle section. Describe the pool section.

3. Which area might have the greatest amount of dissolved oxygen in the water? What are some reasons for your answer? Check your answer by using the Lamotte kit for determining D.O..

4. Did you see any green algae in either of the two areas (it may look like green hair or flat green mats on the bottom of the river)? Why do you think that the algae is there (or not there)?

5. Look for sediments covering the rocks or gravel in the riffles and pools. Which area had the most sediments covering the bottom of the river? Why? Does the amount of flow have any affect on the amount of sediments? Explain…

6. What do you think would happen to the flow rate if there is a large amount of rainfall upriver from where you are located? Would that be an improvement to the river or not? Explain.

7. How does the flow rate correlate with the amount of dissolved oxygen in the river? How would that correlation affect the amount of life in the river? Explain your answer with observed facts.

Follow the Yellow Brick Road Educator Information for River Activity #4

Curriculum Objectives
EEn.2.1.3 Explain how natural actions such as weathering, erosion (wind, water and gravity), and soil formation affect Earth's surface.
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.72 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.

Location: Rocky River, Chatham County, NC. Consult with the Rocky River Heritage Foundation for the accessing the best sites along the river via: http://rockyriverheritagefoundation.wordpress.com

Group Size: 30 students in one group, or two groups of 15

Estimated Time: 15 minutes

Appropriate Season: Fall or mid spring

Materials Needed:
Lab Sheet
Wentworth Scale
Ruler
Pencil
Boots or shoes to wade in the river

Major Concepts:
-Biodiversity
-Water Quality measurement
-Effects of Sedimentation
-How humans can affect biodiversity

Objectives:
-Understand the differences in sediment size.
-Measure the amount of embeddedness of pools and riffles.
-Explain the relationship between flow and sedimentation.
-Analyze a river for the reproductive success of fish.

Educator Information
Just like Dorothy had a yellow brick road to take her to the Emerald City, fish in the Rocky River need a clear path for them to reproduce successfully. Darters, chubs, and some shiners all need clean areas of gravel in order to lay their eggs. Suspended sediments in the water due to **erosion** and **deposition** due to low flow prevent fish from spawning because they deposit their eggs on gravel or in between the pieces of gravel on the river bottom. **Embeddedness** refers to the percentage of the rocks and gravels on the bottom of the river are surrounded, covered or sunken into the mud or sand. Looking at the embeddedness of a river bottom can provide a good idea of how many aquatic plants or animals can live in the river. As a general rule, as rocks become more embedded, the fewer places there are for **macroinvertebrates** to live and for fish to live, spawn and rear young. There is an inverse relationship between embeddedness and the amount of life in the river. Less embeddedness means more life in the river because the life is not being buried by sediments. So, embeddedness can be utilized as a water quality indicator!

Procedure:
In this activity, the class will work together to determine the embeddedness of the **pools** and **riffles** of the Rocky River. The class can complete this Activity as one large group measuring both riffles and pools at the same time, or you may divide the class in half and have one group measure the riffles and one measure the pools. To begin the activity, review the Wentworth Scale so that the students are reminded about the size of sediments in the river and know how to choose cobbles instead of larger boulders or smaller pebbles. Another point of procedure is to remind the students that they need to replace the cobble back where they found it in the same spot they found it. A short discussion could review the points that these cobbles are home for plants and animals and the cobbles need to be placed as they were found so the organisms have the same conditions to live as they had before the students arrived.

To collect the embeddedness data, have the students form a line across the river, facing upstream at arms length away from each other. The students will need to pick up one cobble sized rock found in the river at their feet. As the student lifts the cobble, make sure they note how deeply the rock was buried in the sediment as a percentage. Record that number on their data sheet. Be sure to remind them that they will need to use only 0%, 25%, 50% and 75% as their percentages. Estimate! After they lift each cobble, have them walk one step upstream for a new collection point. Once they have collected data for 10 cobbles, they can either go to the next part of the river or leave the river and trade data with the other students. The students can graph flow rate vs embeddedness to see if there is a relationship between flow and embeddedness once they get back to class.

After the Activity data has been collected, discuss the water quality of both riffles and pools based on embeddedness data using the Embeddedness rating table for gravel, rubble, and boulder particles found on the last page of this Activity. Discuss the connections between the concept of embeddedness and water quality with millponds and flowing rivers.

Extension: Before leaving the river or before the students begin picking up cobbles, ask the students to look underneath each cobble they pick up and see if there are any small animals scurrying across the bottom of the cobble. Have them keep a mental note about which level of embeddedness has the most and least number of small animals beneath the cobble.

Follow the Yellow Brick Road Student Information for River Activity #4

Student Information

Today you will be visiting the Rocky River here in Chatham County to determine the embeddedness of the pools and riffles of the Rocky River.

Safety First!
When you are working at the river please stay with your teacher and listen to their directions.
Remember:
•The rocks in the river are slippery.
•Always face upstream when walking in the river.
•The mud on the riverbanks may be slippery.
•There may be poison ivy to avoid.
Please stay together with your group and no wandering off.

Embeddedness
Just like Dorothy had a yellow brick road to take her to the Emerald City, fish in the Rocky River need a clear path for them to reproduce successfully. Darters, chubs, and some shiners all need clean areas of gravel in order to lay their eggs. Suspended sediments in the water due to **erosion** and **deposition** due to low flow prevent fish from spawning because they deposit their eggs on gravel or in between the pieces of gravel on the river bottom. **Embeddedness** refers to the percentage of the rocks and gravels on the bottom of the river are surrounded, covered or sunken into the mud or sand. In other words, embeddedness is a measure of how deep the rock is buried in the mud in the bottom of a river!

Looking at the embeddedness of a river bottom can provide a good idea of how many aquatic plants or animals can live in the river. As a general rule, as rocks become more embedded, the fewer places there are for **macroinvertebrates** to live and for fish to live, spawn and rear young. There is an inverse relationship between embeddedness and the amount of life in the river. Less embeddedness means more life in the river because the life is not being buried by sediments. So, embeddedness can be utilized as a water quality indicator!

In this activity, the class will work together to determine the embeddedness of the **pools** and **riffles** of the Rocky River.

Photo of the embeddedness of pebbles in the Rocky River.

Follow the Yellow Brick Road River Activity #4

Objectives:
Understand the differences in sediment size.
Determine the amount of embeddedness of pools and riffles.
Understand the relationship between flow and sedimentation.
Analyze a river for the reproductive success of fish.

Materials Needed:
•Lab Sheet
•Ruler
•Pencil
•Boots or shoes to wade in the river

Procedure:
In this Activity you will be comparing the Average Embeddedness of cobble sized rocks on the bottom of pools and riffles in the Rocky River.
First, follow your teacher's instructions to see if you are doing this as an entire class or just doing either the riffles or the pool.
Once you are assigned your area of measurement, follow the following procedure:
1. Move to your assigned section of river and stand facing upriver. Make sure the spot you choose is shallow enough that you can touch the bottom with your hand and reach a rock without getting your shirt wet!
2. Pick up a cobble sized rock (2 – 10 inches wide) from the bottom of the river. Determine how much of the cobble is buried in mud or sand. Estimate the amount of the cobble being buried as a percentage. Was the cobble not buried at all (0%), somewhat buried (25%)or was it half buried (50%) or mostly buried (75%). If it is totally buried in mud or sand that would be 100% (but how did you see the rock?).
3. Take a step or two upstream and repeat with another cobble. Repeat step 2 and 3 until you have 10 measurements.
4. Calculate the average embeddedness for your section and then collect data from the other groups so you can have the measurement for a total of 100 cobbles. Find the Average Embededdness for this section of the river.
5. Move to another section of the river and repeat this procedure or get the data from the other groups that did the alternative portion of the river (if you did riffles, get the pools data).

Embeddedness Data Table

Cobble #1 _____ Cobble #2 _____

Cobble #3 _____ Cobble #4 _____

Cobble #5 _____ Cobble #6 _____

Cobble #7 _____ Cobble #8 _____

Cobble #9 _____ Cobble #10 _____

Your Average Embeddedness _____

Average Embeddedness for the entire class **Pools:** _____ **Riffles:** _____

Now, graph the data for the Average Embeddedness for the entire class and answer the questions.

Embeddedness of the Rocky River

Questions:

1. Which section of the river had the greatest amount of embeddedness? Pools or Riffles?

2. How would explain the reason why that section has the greatest amount of embeddedness?

3. Based on your data, which part of the river would have the greatest biodiversity, pools or riffles? Explain your answer.

4. If you had to compare the embeddedness of a millpond and a river, which do you think would have the greater amount of embeddedness? Why?

5. In a good paragraph, please summarize the relationship between river flow, embeddedness, water quality and biodiversity.

WENTWORTH SCALE OF ROCK PARTICLE SIZES

Classification	Particle size (diameter)
Boulder	Above 256 mm
Cobble	64–256 mm
Pebble	4–64 mm
Gravel (or Granule)	2–4 mm
Very coarse sand	1–2 mm
Coarse sand	0.5–1 mm
Medium sand	0.25–0.5 mm
Fine sand	0.125–0.25 mm
Very fine sand	0.062–0.125 mm
Silt	0.004–0.062 mm
Clay	Less than 0.004 mm

From http://www.riverhabitatsurvey.org/manual/images/

Embeddedness rating for gravel, rubble, and boulder particles

RATING	RATING DESCRIPTION
5	< 5 percent of surface covered by fine sediment
4	5 to 25 percent of surface covered by fine sediment
3	25 to 50 percent of surface covered by fine sediment
2	50 to 75 percent of their surface covered by fine sediment
1	> 75 percent of surface covered by fine sediment

From Platts, Megahan, and Minshall 1983

Dam Removal

Curriculum Objectives:
EEn.2.4.1 Evaluate human influences on freshwater availability.
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.7.2 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.
EEn. 2.8.1 Evaluate alternative energy technologies for use in North Carolina.
EEn. 2.8.4 Evaluate personal choices in terms of impacts on the availability of natural resources and environmental quality; relate this to ecological footprints on various scales.

Location: Classroom

Group Size: 30 students in pairs.

Estimated Time: 45 minutes

Appropriate Season: Any

Educator Information for Post Visit Activity #1

Materials Needed:
-Computer
-Internet Access
-Pencil
-Colored Pencils or markers
-Activity Sheet

Major Concepts:
• Reservoirs and alternative energy
• Effects of Dams on Rivers
• Water Quality and Dams

Objectives:
- Understand the concept of reservoirs.
- Practice communication skills.
- Analyze morphological and water quality differences between reservoirs and rivers.
- Participate in real world simulation of an environmental issue.

Educator Information
This is an opportunity for the students to apply the knowledge from the river to a real life situation that may arise in the near future. The Hoosier Dam has been talked about being removed and it will change many things about the river. More spawning area for the Cape Fear Shiner, possible polluted sediments released downstream into Cape Fear Shiner habitat, no more reservoir/lake, better flow and dissolved oxygen in the river, opportunities for different types of recreation, and more.

What will the student's position be on the removal of the dam? The "bumper stickers" will provide insight into what they have learned and how they feel about the effects of dam removal.

Procedure:
After completing the activities about the river, use this as a reflection on the knowledge that the students have learned along this river unit. To prepare for this Activity, get some 11"x17" paper an use a paper cutter to cut 11"x 4" slices of paper for the "bumper stickers". Then make sure that the students have access to colored pencils or markers to make the bumper sticker. For research, they can use their notes and lab work as well as the internet to research the Hoosier Dam Removal Plan. Once they have completed their research they may create their bumper sticker. When they have completed both, paper clip them together and turn them both in together.

Note* If you wish, you may have the students construct a "bumper sticker" online and either print it out for you on the colored printer or email it to you in living color! This may make the artistically impaired feel more comfortable about their work and do better research.

Dam Removal — Post-Visit Activity #1

Using the internet, search for: *Hoosier Dam, Chatham County NC* or *Hoosier Dam, Chatham County NC Removal.*

Once you have found a good website or three, answer the following questions about the dam on a separate piece of paper to turn in with your bumper sticker:

-History of the dam (why it was built and uses)
-How the river changed after the dam was built
-Why the dam may be removed
-Changes in the river after the dam is removed
-Pros and cons of the removal
-The species that are affected by the dam's removal
-Also, include a discussion of endangered species and anadromous fish found in the Rocky River

Use at least three sources to get your information, and be sure to write down the sources of the information from your websearch. Ex. www.naturalsciences .org

Then, get a piece of paper from your teacher and create a "bumper sticker" that reflects your view of the possible Hoosier Dam removal. This is a bumper sticker so it will not have a lot of words on it. Be sure to write/sketch accurately and factually based in a way to get your point across to the general public. They don't know about this issue, so make sure they know or want to know more about it. Good Thinking!

Post Visit Activity #2

Yes! No! Well, Maybe….

Curriculum Objectives:
EEn.2.4.1 Evaluate human influences on freshwater availability.
EEn. 2.4.2 Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments.
EEn. 2.7.2 Explain why biodiversity is important to the biosphere.
EEn. 2.7.3 Explain how human activities impact the biosphere.
EEn. 2.8.1 Evaluate alternative energy technologies for use in North Carolina.
EEn. 2.8.4 Evaluate personal choices in terms of impacts on the availability of natural resources and environmental quality; relate this to ecological footprints on various scales.

Location: Classroom

Group Size: 30 students in groups of 3 or 4.

Estimated Time: 40 minutes

Appropriate Season: Any

Materials Needed:
- 2 or 3 partners to work with
-Computer
-Internet Access
-Pencil
-Role Card

Major Concepts:
• Reservoirs and alternative energy
• Effects of Dams on Rivers
• Water Quality and Dams
• Biodiversity

Objectives:
- Understand the concept of reservoir construction.
- Analyze morphological and water quality differences between reservoirs and rivers.
- Enable students to participate in a debate format that mimics real life
- Understand other peoples viewpoints

Educator Information:
You have studied the river with your students and they will now have the opportunity to reflect upon what they have learned in the classroom and at the river. This is a possible assessment of the students' knowledge of the benefits and drawbacks of dams along the Rocky River. Mastery of many of the concepts that they have covered in the Pre-Visit Activities and the Activities at the river can be observed by their participation in this debate.
You will need to be the moderator for this debate and make sure that they are polite and stick to their roles and time constraints. Look for accuracy in their facts and enjoy their presentation.
Please have the students divide into groups of 3 or 4 and then pass out the Role Cards, one per group. Allow the students some time to discuss their Role and a little bit of time to research any terms that they are unfamiliar with.
This could also be done as a "fish bowl" discussion. For more information on leading a "fish bowl" discussion, visit: http://www.learner.org/workshops/tml/workshop3/teaching2.html

Role Cards for Yes! No! Well, Maybe…. Debate (Cut out and pass out one per group)

Property Owner Along the Reservoir	**Dam Owner**
As a property owner along the reservoir, the lake has always been there. Your family has had lakefront property since your grandfather bought the land at the lake in 1928. It is a joy in your life to fish and boat around on the lake as you have done all your life. Now you hear that there is plan underway to remove the dam from the river and the lake will be drained to become just a river. **What will you do?**	You just bought this dam and found out that the hydroelectric production is just not worth the hassle. The regulations are strict, the river flow has to be kept going, but, during droughts no power can be made because of low water. You just found out that Mitigation Banking credits for removing the dam could make you lots of money in the future. **What will you do?**
US Fish and Wildlife Service	**Fisherman**
As a government employee who has been studying the slow decline of the endangered Cape Fear Shiner, you hear that there is a plan to remove the dam and drain the lake returning the lake back to river. Could this be the opportunity that you have been waiting for? But there is a good population of Shiners just downstream from the dam, could there be any problem with removing the dam? **What will you do?**	You are a lake fishing addict. You just love going out on the lake and trying to catch whatever bites. There is nothing more enjoyable than going out and competing with your buddies to see who can catch the largest bass. Unless it is those late nights trying to catch the largest catfish. And now you hear there is a plan to drain the lake and remove the dam. **What will you do?**
Elliptio Mussel	**Cape Fear Shiner**
You are a stout mussel that lives in the river just downstream from the dam and lake. For you, filter feeding is the name of the game. However, a chatty snail came by and told you that the dam and lake upstream from your cozy bed of rocks is about to be drained and the dam removed. **What will you do?**	You are a small, endangered species of fish and only live in a small portion of this river and a little bit of the river at the mouth of this river. A snail told you the other day that the dam might be removed from just upstream from your spawning beds. Is this a good thing or a bad thing? **What will you do?**
Environmentalist	**Tax Payer**
You just heard that there is a plan going around detailing the process of dam removal and lake draining in the river that you have always had high hopes of making a healthier river. You have always wanted for the river to be designated a "wild and scenic" river. Could this be your opportunity? **What will you do?**	Yeah, you don't live on the river and have never even set foot in the river, but now you hear that the dam and reservoir in the river might be removed. Is this a good thing or a bad thing? You pay your taxes for the government to take care of these sorts of things for you. **What will you do?**

End Notes

Want to Know More?

Freshwater Mussels - NC Wildlife Resources Commission
http://www.ncwildlife.org/LinkClick.aspx?fileticket=sw9ZQA0Y5-8%3D&tabid=2061&portalid=0&mid=5934

Mollusk Lifecycle - Freshwater Mollusk Conservation Society
http://molluskconservation.org/MUSSELS/Reproduction.html

Mussel Taxonomist -Art Bogan (The Mussel Man!)
http://naturalsciences.org/staff/arthur-bogan

Overlooked Gems: The Benefits of Freshwater Mussels - Al Smith and Sarina Jepsen
http://www.xerces.org/ wp-content/uploads/2009/01/mussel_article.pdf

Glossary:

Biodiversity – Biodiversity is the full range of species that live in an area.

Bivalve – Part of Phylum Mollusca. Their body is made up of two shells attached by a ligament and hinge then held together by two large adductor muscles. Related to clams, oysters, scallops and even snails and squid!

Deposition – The laying down, or depositing, of sediments when wind or water slow down in velocity.

Embeddedness - The degree to which fine sediments surround coarse substrates on the surface of a streambed. Embeddedness measures have now been used to assess fish spawning and macroinvertebrate habitat, as well as substrate mobility. Embeddedness continues to be used as an indicator of water quality.

Erosion - The movement or removal of soils due to water or wind.

Extirpation – When a population of animals is completely removed from their native habitat.

Glochidia - Mussel larvae that look like a toothed "pac-man." Attach to host fish for food to develop and then drop off when after metamorphosis to juvenile stage of life.

Macroinvertebrate – An aquatic invertebrate that is large enough to be seen without magnification. From macro (meaning large) and invertebrate (without a backbone).

Pool – Deep, quiet spot in the river with low velocity water flow.

Quadrat - A quadrat is usually a four-sided figure which delineates the boundaries of a sample plot. The quadrat may also be circular and other shapes.

Riffle – A shallow area in the river where the water flows across gravel and rock to disturb the water's surface. Sometimes mistakenly called "rapids".

Spawning – The process of egg laying in many aquatic animals.

Substrate – The bottom, or floor, of a river. The river floor sediments may be mud, sand, gravel or rock.

Tannin – A chemical substance that can be leached out of decomposing plant leaves and color a river or lake making it look like tea.

Taxonomist - Scientists that describe, identify, name, and classify organisms.

Turbidity - The measure of relative clarity of a liquid. Turbidity can make water cloudy or opaque.

References:

American Rivers - Learn About Rivers
www.american**rivers**.org/**rivers**/about/

Freshwater Mollusk Conservation Society - Mollusk Lifecycle
http://molluskconservation.org/MUSSELS/Reproduction.html

Lander University –Freshwater Unionid Mussels
http://lanwebs.lander.edu/faculty/rsfox/invertebrates/actinonaias.html

National Wildlife Federation - Biodiversity https://www.nwf.org/Wildlife/Wildlife-Conservation/Biodiversity.aspx

Rocky River Subbasin Aquatic Taxa Surveys - Alderman, J. M., & Alderman, J.D. (2010) Alderman Environmental Services, Inc.

University of Toronto – Counting Populations
http://bio150.chass.utoronto.ca/sampling/book/sampling.html

USGS – Turbidity - http://water.usgs.gov/edu/turbidity.html

US Army Corps of Engineers – Techniques for Measuring Substrate Embeddedness -
http://el.erdc.usace.army.mil/elpubs/pdf/sr36.pdf

US EPA - Mitigation Banking **http://water.epa.gov/lawsregs/guidance/wetlands/mitbanking.cfmUS**

Water Encyclopedia – Bivalves http://www.waterencyclopedia.com/Bi-Ca/Bivalves.html
http://www.fao.org/docrep/w2598e/w2598e05.htm

Photos and Illustrations:

http://raven.islandwood.org/kids/stream_health/macros/freshwater_mussel.html
https://pubs.ext.vt.edu/420/420-014/BivalveMollusks.html
http://www.ncwildlife.org/Learning/Species/Mollusks/NotchedRainbow.aspx
http://www.jaxshells.org/baym.htm
http://www.ncwildlife.org/Learning/Species/Mollusks/EasternCreekshell.aspx
https://www.dnr.sc.gov/fish/species/shellfish/assets/eastern-floaterlg.jpg
http://dnr.wi.gov/topic/EndangeredResources/Animals.asp http://mkohl1.net/Corbiculidae.html
http://www.eenorthcarolina.org/riverbasins.html http://www.eenorthcarolina.org/riverbasins-gis-map.asp http://www.ces.ncsu.edu/depts/agecon/WECO/rocky/
http://www.rockyriverchatham.org/files/RRPost_Mar3_2013.pdf