ABSTRACT

LAIRD, SHELBY GULL. A Volunteer Educational Approach to Interactive Research-based Watershed Assessment. (Under the direction of Stacy Nelson).

This research examined the use of volunteers and volunteer monitoring organizations (VMOs) in watershed studies in order to more accurately assess the optimal inclusion of public participation in watershed assessments. Literature provides a comprehensive review of watershed assessments and the need to include citizen scientists or volunteer monitors. Research on the Black Creek Watershed project indicates the need for specific and purposeful cooperation between researchers, managers, and public participants to optimize experiences for all involved. This research includes a watershed assessment completed for the Black Creek Watershed Association (BCWA), including complete geodatabase development and volunteer involvement through stream habitat and pollution inventory data collection. Public participation was also encouraged through regular BCWA meetings, expanding opportunities for public participation. The research continues through the completion of a survey instrument to assess the current status of volunteer monitoring organizations in North Carolina and the rest of the United States. Data were collected by online survey to further understand volunteer water quality monitoring programs, including organizational structures, data collection procedures and data use. Results indicate much data collected by water quality VMOs in the United States and particularly North Carolina goes largely unnoticed with the notable exception of specific examples where community involvement or government cooperation created an environment for change and extensive testing for data validity has been conducted, such as lake water quality monitoring programs. This research defines volunteer data as a useful and underutilized resource for researchers and government agencies. Results from this research indicate the need for cooperation and
strong partnerships in data collection and use in water quality analysis in North Carolina and beyond.
A Volunteer Educational Approach to Interactive Research-based Watershed Assessment

by
Shelby Gull Laird

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APPROVED BY:

______________________________
Stacy A.C. Nelson, PhD
Committee Chair

______________________________
James Gregory, PhD

______________________________
April James, PhD

______________________________
Harriett Stubbs, PhD
DEDICATION

To my beautiful husband and brilliant baby girl.
BIOGRAPHY

Shelby Gull Laird is from Raleigh, North Carolina, but has lived across the state in Salisbury, Troy and Durham. She attended the North Carolina School of Science and Mathematics in Durham graduating in 1997 with a high school diploma. Following family tradition of her mother and father, she attended North Carolina State University. She began her studies in education as a North Carolina Teaching Fellow. She received a BS in Science Education with a concentration in Earth Science in 2001, attending the UNC system geology field camp that summer. After teaching for four years at Garner Magnet High School, Shelby continued her schooling with a Masters of Education in Science Education with a Geographic Information Science minor in 2006. She continued to study natural resources, enrolling in the PhD program in Forestry the following year. Shelby married Malcolm Laird in 2004. On December 30, 2008, Shelby and Malcolm expanded their family with the birth of their daughter, Patricia Maryn Laird.
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# TABLE OF CONTENTS

List of Tables ........................................................................................................................... ix

List of Figures ........................................................................................................................... x

Chapter 1: Introduction ............................................................................................................. 1

Objectives of the Research .................................................................................................... 3

Purpose of the Research ........................................................................................................ 4

Significance of Study ............................................................................................................ 4

Dissertation Organization ..................................................................................................... 5

Chapter 2: Literature Review .................................................................................................... 6

Historical Context of Watershed Assessment .................................................................... 6

Importance of Volunteer Involvement in Watershed Assessment ...................................... 12

Volunteer Monitors as Citizen Scientists ............................................................................ 16

Including Volunteer Monitors in Research Studies ............................................................ 17

Volunteer Monitors Participation in Watershed-based Research ....................................... 19

Translating Scientific Watershed Research into Useable Data ........................................... 23

References ........................................................................................................................... 27

Chapter 3: A comprehensive assessment of the Black Creek Watershed Monitoring Project:
Engaging community members to develop a comprehensive watershed assessment for
managers and researchers ....................................................................................................... 33

Introduction ........................................................................................................................... 36
Study Area ............................................................................................................................................... 42
Case Study Analysis ............................................................................................................................. 43
Water Quality Data Collection ............................................................................................................. 43
Geodatabase Creation .......................................................................................................................... 46
Community Engagement ...................................................................................................................... 47
Discussion ............................................................................................................................................. 50
Conclusion ............................................................................................................................................. 54
References ............................................................................................................................................ 58

Chapter 4: A Survey of Volunteer Monitoring Organizations (VMOs) in NC and the US:
Organizational structures and data use ............................................................................................. 72
Introduction ........................................................................................................................................ 75
Purpose and Data Use ......................................................................................................................... 78
Methods .............................................................................................................................................. 83
Results .................................................................................................................................................. 85
Leadership Structure ......................................................................................................................... 86
Data Collection Procedures .............................................................................................................. 88
Data Use ............................................................................................................................................ 89
Discussion .......................................................................................................................................... 90
Leadership Structure ......................................................................................................................... 91
Data Collection Procedures and Data Use ........................................................................................ 93
Conclusion ........................................................................................................................................... 96
LIST OF TABLES

Table 1: Community based monitoring (CBM) scale of community involvement. .......................... 68
Table 2: Local influencing factors on the Black Creek watershed area. ............................................. 69
Table 3: Relevant GIS layers for the Black Creek watershed assessment. ........................................ 70
Table 4: Survey link distribution via various listservs. ........................................................................ 106
Table 5: Top-down versus bottom-up volunteer water quality monitoring organizations. ...... 107
Table 6: Historical organization leadership style of volunteer monitoring organizations. .............. 108
Table 7: Professional scientist associations of volunteer monitoring groups .................................. 109
Table 8: Years each volunteer organization has been completing monitoring activities at their oldest site. ......................................................................................................................... 110
Table 9: Training required of volunteers. .......................................................................................... 111
Table 10: Does a Quality Assurance / Quality Control (QA/QC) plan exist for this monitoring site? ................................................. ......................................................................................................................... 112
Table 11: Are data collected by volunteers used for any of these watershed management purposes? ........................................................................................................................................ 113
Table 12: Has volunteer collected data been published for research? .............................................. 114
Table 13: Leadership Structure versus Training Requirements: Is Training Required? .................. 115
Table 14: Publication of Data versus Professional Scientist Association .......................................... 116
Table 15: Table of Statistical Results, including odds ratios and p-values. ...................................... 117
LIST OF FIGURES

Figure 1: Location of Black Creek watershed in North Carolina. ........................................... 63
Figure 2: Black Creek watershed boundary with orthophotography, 2005. ............................ 64
Figure 3: Temporal extent of various monitoring agencies and groups. ............................... 65
Figure 4: Spatial extent of various monitoring agencies. .................................................. 66
Figure 5: Organizational chart for the comprehensive watershed assessment by reviewing
  various participants in the watershed association. .......................................................... 67
Figure 6: Geographic Distribution of Survey Responders.................................................... 118
Figure 7: Self-selected organization type, where each organization was allowed to choose
  more than one response.................................................................................................. 119
CHAPTER 1: INTRODUCTION

Maintaining high water quality in freshwater streams, lakes and rivers is a major challenge facing humanity in the Twenty-first century (Malmqvist and Rundle, 2002; Zimmerman and others, 2008). Maintaining or improving the quality of the water in the surrounding environment while still using as much as possible for a growing human population is the priority management objective of government agencies in charge of water resources (Perry and Vanderklein, 1996). But how do we know what the quality of the water really is? This question has been and will continue to be answered during the next several decades not only by dedicated scientists and government agencies, but also by non-profit environmental groups and even concerned community members acting out of their own concern for this precious resource. Because of the great logistical challenge of monitoring every single body of water in the world, it makes sense to use volunteers who live near the water to collect water quality data and act as local experts. With hundreds if not thousands of volunteers and volunteer groups collecting water quality data across the United States (Nerbonne and Nelson, 2008), it is important the scientific community be able to use this data to their advantage. Instead, many scientists are extremely cautious of the idea of engaging volunteer data for scientific studies due to the sometimes questionable quality (Nerbonne and Vondracek, 2003; Penrose and Call, 1995).

The goal of this study is to understand the dynamics of water quality volunteer monitoring organizations (VMOs) in the United States, specifically North Carolina, as well
as to provide an example of how closely monitored volunteer data could be used in any type of watershed assessment study with community members or students.

The main research question for this study was how can volunteer data be collected at a resolution and in such a way that data are useful to research scientists and government managers? Currently, very little data collected by citizen scientists or volunteer monitors are used by research scientists (Ely 2008a; Nerbonne and Nelson, 2004). Volunteers from across the country have been collecting water quality data for decades (US EPA, 1998), and their information could be an important gauge for water quality health particularly where no other water quality data has ever been collected. Looking more closely at data collected and used by a research study conducted at Black Creek Watershed in Cary, North Carolina, this study examines the basic minimum GIS data requirements for management purposes as well as provides an example for volunteer involvement in data collection. Analysis of various water quality monitoring groups across North Carolina and the United States are compared to determine how they relate and which strategies for involvement of community members are optimal for quality data return. Can volunteer data be used for watershed assessment for research purposes? If so, at what scale can volunteer data be collected and how does it compare to data collected by researchers and governments for study and management purposes?
Objectives of the Research

The objectives of this research were to:

1. Examine how water quality and GIS data collection can incorporate volunteers from the community in an urbanizing watersheds,

2. Evaluate the baseline community engagement compared to more traditional research methods and other CBM efforts, and

3. Suggest methods for increasing community member participation in watershed assessment, including the creation of a community-led watershed association in concert with university-based research.

4. Determine the existing leadership structure of volunteer monitoring organizations, comparing North Carolina to the rest of the United States.

5. Evaluate the data collection procedures which improve water quality data for volunteer monitoring organizations, comparing North Carolina and the rest of the United States?

6. Examine how volunteer monitoring data are currently used by volunteer monitoring organizations, managers and researchers, comparing North Carolina and the rest of the United States?
Purpose of the Research

This research investigated simplification of volunteer data collection for watershed assessment studies. It identified specific training recommendations for engaging volunteers in watershed studies where researchers will use volunteer or even students to complete some data collection. The research developed a geodatabase baseline for use with future studies of the watershed. In addition, community members collected data for various aspects of the Black Creek Watershed monitoring project and their participation value analyzed. Also, this research evaluated the status of volunteer water quality monitoring across North Carolina and the United States. Various groups were compared to determine best practices and compliance with positive performance measures to determine recommendations for best practices.

Significance of Study

This research was significant for several reasons. First, it studies a sample of volunteer monitoring organizations (VMOs) from both North Carolina and across the United States. This information about organizational structure, data collection procedures and data uses existed in only one prior study, with variations on questioning and responses. Secondly, no prior research information exists on VMOs specific to North Carolina.
Thirdly, this research contributed to the field of knowledge by developing recommendations for VMOs, research scientists and municipal governments to work together in an effective way so that each can benefit from the work of the other. This model includes an example of existing partnerships and encourages these agencies to work together so that all types of data collected for both volunteer groups and research can ultimately be used to influence management decisions of the local, state, and national government agencies.

Lastly, this research utilized a mixed methods research design, with watershed assessment field research and an internet survey with quantitative and qualitative response analysis.

**Dissertation Organization**

The remaining chapters of this dissertation are organized into three major chapters. Chapter 2 explores literature in watershed assessment, volunteer monitors and involvement of volunteer monitoring organizations in watershed assessments. Chapter 3 examines the Black Creek watershed assessment in manuscript format for submission to the journal *Society and Natural Resources*. Chapter 4 discusses survey results of water quality volunteer monitoring organizations in North Carolina and compares results to the rest of the United States in manuscript format for submission to the journal *Environmental Management*. Chapter 5 provides a summary to the dissertation and results of the research questions.
CHAPTER 2: LITERATURE REVIEW

Many scientists realize the difficulties of seeing research results integrated into policy and management actions that can affect change in the world. This is true in many fields, but is becoming more important to watershed management as the world’s population grows and waters supplies become more scarce and important (Malmqvist and Rundle, 2002; Richter, and others, 1996). Public involvement through volunteer monitoring organizations may hold part of the solution to this problem. Volunteer monitoring occurs on a daily basis across the United States, but these volunteer collected data go largely unnoticed and unused by watershed researchers and municipal policy makers alike (Ely, 2008a). Through volunteer monitoring and participatory geographic information science (GIS) integration, watershed researchers can make their studies have a greater impact on communities and management of watersheds.

Historical Context of Watershed Assessment

The history of watershed research in the Southern United States spans as far back as the first half of the Twentieth Century. Research watersheds, variable in size, were created at different locations for the purpose of supporting hydrology research (Swank and others, 2001). These research-based studies were completed at the watershed or catchment scale. It
is understood that a watershed or catchment, drainage area or river basin is the area of land contributing runoff to a given point on a body of water (Ward and Trimble, 2004). Watersheds are delineated, or defined, based on tracing the topography back from the chosen output point along the highest ridges that border the water body, in order to find the entire area that drains to the watershed output point. These early studies used predefined watersheds, usually in smaller forested areas where they could be manipulated and highly controlled experiments could be conducted.

These types of research-based studies vary greatly from the watershed assessments conducted today. A watershed assessment is defined by DeBarry (2004) as “a detailed evaluation of the specific processes, influences, and problems in a watershed so that a plan of action to preserve the watershed can be developed. The watershed management plan should be a systematic approach to preserve or restore the watershed and its hydrologic regime or to correct problems based on the comprehensive assessment.” Watershed assessments typically occur in much more messy situations than those of earlier studies completed under controlled environments. Government managers and researchers need simple and effective ways to complete comprehensive watershed assessment in these complex systems (Zandbergen, 1998). This means watershed assessment beyond simple monitoring, including social and political influences as well. This includes a plan to preserve the quality of water in the watershed, or in some cases to improve that water quality as the goal of a comprehensive watershed assessment (DeBarry, 2004).
Historical approaches in watershed assessment and its use in both research-based and applied settings have varied greatly. Many examples of watershed assessments occurred at the catchment scale at research facilities under controlled environments (Waide and Marion, 2002) or in agricultural areas (Easton and others, 2007; Puckett, 1995; Richter and others, 1997). These important research studies and many more continue and allow for a more complete understanding of the processes involved in water movements and hydrologic systems. Typically, research-based watershed assessments are led and completed by university or government researchers with little public involvement. Considering the social and historical context of watersheds, including use since the arrival of Europeans to North America, is rarely done. These types of historical understandings can allow understanding of land management effects on watersheds (Pess and others, 2003), which can also apply to urban watersheds. As the United States population has become increasingly urban, there is a need for greater focus on urbanizing and urban watersheds (Zandbergen, 1998). These watersheds are characteristically impaired biologically and are becoming of greater concern in watershed assessments across the United States (Richter and others, 1997). Water quality issues from these types of watersheds have rarely been assessed historically due to the hesitancy of researchers to avoid more messy situations that urban areas present but water quality monitoring has occurred on the local scale by volunteer monitoring organizations (VMOs).

These complex watershed boundaries vary greatly from municipal and even state boundaries. This can create unique challenges for modern research-based watershed
assessments completed in the real world. With a greater interest on the completion of a comprehensive watershed assessment that includes a meaningful watershed plan to maintain or improve water quality after the initial watershed assessment period, it is important data collected that can be used within the study. An applied watershed assessment is conducted for the purpose of city or community planning or management. Applied watershed assessments may be lead by non-profit organizations, community groups, municipal officials, or university or government researchers, but usually involve watershed assessments completed for the purpose of aiding community planning issues, advocacy for the watershed, environmental education (Conrad, 2006; Spellerberg, 2005), or to develop TMDLs to address impaired waters (Little and others, 2007). Watershed assessment may be completed by any number of different participants, and may involve many different stakeholder groups.

Data included in a watershed assessment are typically “biological, physiographic, hydrologic, chemical, and may include political or social aspects as well” (DeBarry, 2004). Biological monitoring normally includes the study of benthic macroinvertebrates, amphibians, and/or fish. Algae or aquatic plants may also be a part of biological monitoring in a watershed assessment, depending on the feasibility. Physiographic aspects of watershed assessment may include stream bank stability, erosional properties, topography, and other physical aspects of the watershed that may influence hydrology or water quality. Hydrologic aspects of watershed assessment typically involve hydrogeology, precipitation, stream flow or rainfall-runoff modeling, among others. Many different chemical parameters can monitored as part of a watershed study, as these are the parameters the public may be most
familiar with. Turbidity, pH, nutrients such as nitrates and phosphates, metals, and emerging contaminants such as PAHs are all parameters that may be monitored as part of a watershed assessment. Political or social aspects of watershed assessment tend to be ignored by many research-based watershed assessments. These factors may be considered unscientific or even irrelevant by research scientists who are more accustomed to hard numerical data, but these should be considered in each watershed assessment (Ziemer, 2000). Applied watershed assessments, especially those administered by CBM groups, are often started for political or social reasons, i.e. for community members to be able to affect change in their local government (Gouveia and others, 2004). These assessments take political and social aspects into account more so than research-based watershed assessments. Groups involving watershed assessment for the purpose of management that are led by community members are called community-based management (CBM) groups (Brown and Schreier, 2007).

Watershed assessments by local municipal governments tend to be completed by CBM groups in the form of volunteer monitoring organizations, environmental consultants, state environmental agencies, or municipal officials in order to address a particular problem or to research potential causes of problems already known to be present in local water bodies (Ely, 2008). Studies by these groups tend to be more applied and community-based, rarely extending far beyond the municipality or local community. A recent survey of volunteer monitoring groups by Nerbonne and Nelson (2008) found that many watershed assessments currently being run are applied studies completed to either complete a snapshot-in-time picture of the watershed in question instead of a longitudinal general health study. Water
quality parameters chosen are focused on a particular problem (Stein and Bernstein, 2007). Research scientists who complete watershed assessments tend to look more generally at the entire picture, but they too tend to only take data limited either spatially or temporally. Data collection limitations are more than likely due to time, personnel, and cost limitations (Cohn, 2008). Because of grant cycle funding, most research projects do not extend beyond 1-5 years. In North Carolina, watersheds are monitored by the NC Division of Water Quality (NCDWQ) for macroinvertebrate assessments on an average of every five years (NCDENR, 2008). The ambient monitoring system of the NCDWQ monitors physical and chemical parameters on a monthly basis on average as well as bacterial monitoring depending on the location (NCDENR, 2009). Macroinvertebrates are commonly used as an indicator of water quality (see Armitage and others, 1983; Growns, and others 2006), particularly by volunteer groups due to their interest to participants (Fore and others, 2001; Savan and others, 2003). Water quality parameters include biological monitoring (fish species, macroinvertebrate sampling, and bacteria), physical monitoring (habitat condition, pollution inventory) or chemical monitoring (nutrients, pH, metals, organic contaminants). These onetime studies are limited in frequency of monitoring; the low quantity of available data sometimes makes effective and timely decisions difficult.

Onetime studies are positive in that they provide some information on watersheds in the local area. Even having one dataset can be useful because it can show changes over time if the same data collection is repeated at a later date. Limiting aspects of these snapshot types of assessments are that they do not provide a complete picture of many different
aspects of a watershed assessment. They tend to focus on one or two issues of the watershed and may leave out some of the data to be included in watershed assessment listed by DeBarry (2004). Because of the large number of potential watersheds to study, it would be impossible to obtain data for every urbanizing watershed. Engaging VMOs may provide a solution for obtaining broader data collection both temporally and spatially.

**Importance of Volunteer Involvement in Watershed Assessment**

The use of water quality VMOs by state government and researchers in many states has allowed a broader geographic range of data and increased frequency of data collection (Stokes and others, 1990; Cohn, 2008). But volunteer monitor data are still not accepted broadly by municipalities, government agencies, or research scientists, thereby hindering their usefulness (Nerbonne and Nelson, 2004). Because researchers may not be from the local area of the watershed being studied, they may not have a complete historical perspective of the watershed or full understanding of the issues involved in water quality. Involving the community in watershed assessment research projects helps researchers to more fully understand the historical perspective of the watershed or issues involved in the community (Gouveia and others, 2004). Additionally, community volunteers may benefit through development of larger community environmental knowledge, awareness and involvement due to their participation in watershed monitoring (Conrad, 2006; Spellerberg,
Many community monitoring groups began and continue without any relationship to government agencies or research universities. Because of this bottom-up approach, many volunteer watershed monitoring and assessment projects are grossly underrepresented in the literature (Ely, 2008b). These data are being lost to government agencies and research scientists. Many of these groups are hoping to affect change in their local government politically by collecting data on water quality in the watershed in question (Bliss and others, 2001; Whitelaw and others, 2003), but the data may not be used. With the proper organization working in partnership with municipal and research scientists and creation of a quality assurance plan, these data could contribute to create a more continuous pattern of water quality monitoring data.

Water quality parameters and readings are generally easy to collect and translate. Volunteer monitoring groups have been shown to be capable and cost-effective in providing water quality data at a geographic and temporal frequency required to improve management capacities (Kerr and others, 1994; Nelson and others, 2003; Obrecht and others, 1998). Effective watershed monitoring is important for many different government agencies and university research studies, not only for comprehensive watershed assessments, but also to explore the effectiveness of stream restorations and best management practices (BMP) implementations and TMDL regulations. Depending on the type of data, a volunteer may have more trouble understanding many different aspects of water quality. For example, there are specific thresholds for safety levels in drinking water, but recreational water has different standards which can be confusing and may require training provided by professional
scientists for volunteers to better understand. Macroinvertebrates are one of the most efficient, popular and easy to understand water quality parameters because of the evaluated organisms’ biotic relationships to acceptable and unacceptable water quality conditions (Fore and others, 2001; Savan and others, 2003). These indicators are easy to understand and easy to measure with a bit of help from a professional and a solid knowledge of freshman biology.

Water quality chemical parameters have traditionally been collected by technicians for municipalities and consultants, and undergraduate or graduate students for research projects at universities. These samples are easy to collect and water quality testing may even be as easy for volunteer monitors to complete with the same basic training received by technicians and graduate students, but further research is needed in this area. Additionally, VMOs tend to be most interested in these water quality parameters because these indicators tend to be used for drinking water standards. As community members of the watershed, water quality issues directly impact volunteers.

Watershed assessments by researchers and government agencies can often paint an incomplete picture of the entire watershed, as they tend to focus on watershed issues largely defined by sampling capacities. This behavior may limit the ability to complete a comprehensive watershed assessment (DeBarry 2004). Involving the public in watershed assessment research projects through VMOs can help researchers to more fully understand the historical perspective of the watershed or issues involved in the community (Gouveia and others, 2004). Other benefits include cost savings through inclusion of free volunteers (Cuthill, 2000; Stadel and Nelson, 1995; Stokes and others, 1990; Strieter and Blalock, 2006;
Whitelaw and others, 2003) and volunteer availability outside of regular office hours (Stokes and others, 1990). Engaging volunteer monitors boosts required public participation in watershed assessments and planning (Au and others, 2000; Cuthill, 2000; Whitelaw and others, 2003).

Monitoring programs also exist where community groups of volunteers are collaborating with government agencies or research universities on larger regional scale assessments (Bonney and others, 2009; Cohn, 2007). In spite of these growing partnerships, many scientists and researchers are still hesitant to use volunteer citizen scientist monitors’ data because of perceived potential limitations, regardless of the usefulness of that data or the benefits it could provide (Ely, 2008). Recent trends, however, have begun to show many more government agencies and university researchers seeking out volunteer monitors despite the perceived limitations because the benefits are simply too great (Cohn, 2007). Volunteer data can bring more rapid attention to a problem area and does not have to compete with scientific data, but can instead be used as indicator data. Indicator data, sometimes referred to as soft data, are often used in watershed assessment to identify watershed characteristics (Seibers and McDonnell, 2002). Soft data are gaining popularity with climate scientists as well by using indigenous knowledge to fill data gaps. The extent to which community members and volunteers are used for soft data is unknown. Volunteers receive personal benefits from monitoring, potentially including increased knowledge and higher community involvement. This increased scientific literacy of the general public is a goal of science in the 21st Century (Nelson, 1999).
Volunteer Monitors as Citizen Scientists

A crucial and similar aspect of all community-based environmental monitoring is the involved citizen scientist or volunteer monitor who collects and distributes information. Community-based monitoring (CBM) is defined as “a process where concerned citizens, government agencies, industry, academia, community groups and local institutions collaborate to monitor, track and respond to issues of common community concern” (Whitelaw and others, 2003). According to the Cornell Lab of Ornithology, citizen science can be defined as “projects in which volunteers partner with scientists to answer real-world questions” (Cornell, 2007). For the purposes of this paper, volunteer monitors are synonymous with citizen scientists. With the perceived rise in environmental issues, urbanization, and global climate change, many more everyday citizens are interested in understanding science and pursuing scientific endeavors (Cantwell and Day, 1998; Landre and Knuth, 1993; Savan and others, 2003; Whitelaw and others, 2003). Earliest volunteer environmental monitors in the United States were weather observers for the National Weather Service in the late 1800s and are still a major component of weather service data collection (Firehock and West, 1995). Volunteer water quality monitoring programs emerged as environmentalist programs where community members were advocates or protectors of rivers, similar to ancient and modern Riverkeepers (Firehock and West, 1995). Many of the modern existing CBM groups focused on water quality began in the 1970s or
1990s (Stapp and others, 1997), but many more grassroots groups are formed each year and are spread across North America and beyond (Griffin, 1999; Nerbonne and Nelson, 2004; Lathrop and Markowitz, 1995; Savan and others, 2003; US EPA, 1998).

Including Volunteer Monitors in Research Studies

Many citizen science projects have dedicated volunteers who were already interested in their specific fields before the citizen science projects started. For example, the Citizen Weather Observer Program requires participants to own a weather station to participate. Most participants likely owned a weather station (as can be seen from the many types of non-recommended weather stations listed on the site), and then discovered they could link their data to a useful network of other stations (http://www.wxqa.com/). Birding has also become a popular past time for nature lovers across the world. The ornithology projects, such as the Great Backyard Bird Count, NestWatch and others benefit from the hobbyists who spend their weekend time in search of birds anyway (Cohn, 2007). The citizen science web site hosted by Cornell University contains a broad database of citizen science projects (www.citizenscience.org).

Very, very little information has been published on the affects of scale on the effectiveness of citizen monitoring groups. Many large regional to national scale volunteer citizen scientist models use the top-down or “Cornell model” of volunteer management (Ely,
2008b). At this level, all research questions are scientist-directed and data collected is analyzed by professional scientists. These large projects have the advantage that they are able “to coordinate large numbers of volunteers, span a wide geographic area, and collect and manage a large amount of data” thus potentially answering questions that would be impossible to answer without volunteer assistance (Ely, 2008b). Many regional scale lake surveys from the Midwest seem to follow this model, in which a simple parameter, usually Secchi disc depth being measured by a large number of volunteers over a long duration (Bruhn and Soranno, 2005; Heiskary and Wilson, 1989; Obrecht and others, 1998). Another model, the bottom-up or community-based model involves “participants in every step, from defining the problem through communicating the results and taking action.” This does not discount the professional scientists, who are needed to ensure the project produces valid data and assist volunteers with the research process, but allows for fullest volunteer participation. Professional scientists serve as a guide for volunteer monitors, who create a research question, collect and analyze data and may use the data to act on local policy issues.Partnering professional scientists should be sure to take local knowledge into account when designing watershed assessment and address all community concerns. These community-based projects seem to fit local scale watershed assessments best (Ely, 2008b).
Volunteer Monitors Participation in Watershed-based Research

Water quality monitoring is of particular interest to volunteers because of the personal connection to water that many individuals feel (Measham and Barnett, 2008; Gooch, 2005). There are numerous benefits to engaging volunteers and VMOs for watershed monitoring. Volunteer monitoring allows for greater monitoring duration and larger sampling area and greater sampling frequency due to low costs (Canfield and others, 2002; Salmon and others, 2008; Strieter and Blalock, 2006). Additionally, volunteers may develop larger community environmental knowledge, awareness, and involvement due to their participation in watershed monitoring (Conrad, 2006; Spellerberg, 2005). Many community groups indicate they are much more concerned about education and the social impacts of data collected, than the data use for research or policy change (Nerbonne and Nelson, 2004). Environmental education is defined as “a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action” (UNESCO, 1978). Keeping the focus on the potential opportunities for environmental education could be helpful for researchers or municipalities wanting to try to work cooperatively with CBM groups. Environmental education is one of the greatest positive outcomes of community-based environmental monitoring programs (Conrad, 2006; Spellerberg, 2005). Many VMOs choose water quality monitoring because
of the opportunity for hands-on learning it provides, thereby expanding volunteers own knowledge of the environment (Nerbonne and Nelson, 2004). Teachers are highly motivated to partner with researchers and communities to conduct monitoring research with students as a way to engage their students in scientific inquiry and research (Au and others, 2000; Edwards, 2004).

Many VMOS began and continue without any relationship to government agencies or research universities. Because of this bottom-up approach, many volunteer watershed monitoring and assessment projects are grossly underrepresented in literature, thus some benefits listed here are based upon studies from other fields. For example, volunteer monitors can maintain monitoring for a longer duration than grant funding may allow for researchers. This provides longevity to data that can be very important during data analysis. One extreme example of this found that biologist volunteers had been completing frog surveys in Belize for nine years without funding or supervision using the original protocol designed for the area (Kaiser, 2008). These dedicated volunteers were scientists themselves who found this tiny local project worth continuing even without the promise of payment or publication. Volunteer monitors also provide a large workforce that can be spread over a large area or have a larger sampling frequency than a smaller workforce. When watershed monitoring is occurring on a large scale, such as regionally or nationally, volunteer monitors can save on travel time, and simultaneously sample over a very broad area and collect data over a broad area with a greater frequency than a small team of professional scientists. Additionally, volunteers can save researchers thousands of dollars by collecting data free of
charge. One example given in by Sam Droege at the Citizen Science Toolkit Conference is of a Breeding Bird Survey (BBS) volunteer who completed ten routes per year for thirty-five years at his own expense and saved researchers and taxpayers about $70,000 by doing so (McEver and others, 2007). Imagine volunteers monitoring water quality at the same site for thirty-five years, ten times per year; what a dataset that would be! Other than lake Secchi disk depth measurements by long-term water quality programs, such volunteer collected datasets do not exist for surface waters or are not being used by researchers at this time. Not only is this a huge grassroots undertaking on the part of these community-based environmental monitoring groups, but it is an enormous potential data source and workforce for cash-strapped research scientists and government officials (Canfield and others 2002; Salmon and others 2008; Strieter and Blalock 2006). The massive social capital possibilities make volunteers an essential resource to researchers (Bliss and others 2001; Cuthill 2003).

There are limitations for engaging volunteer monitors and working with VMOs. For example, there is questionable variability and reliability of volunteers collected data (Nelson and Vondracek, 2003; Penrose and Call, 1995). High volunteer numbers could potentially introduce more error, and low levels of scientific knowledge in volunteers may hinder their work performance. Some of these opinions held by professional scientists about volunteer citizen scientists may result from the perception there is a low level of public understanding of science and scientific literacy in the United States (DeBoer, 2000). Other common misperceptions about volunteers include that volunteers are unreliable and may forget to complete their monitoring tasks when asked. Volunteers also have the reputation of
impacting monitoring validity by introducing more variability; however this may not only be exclusive to volunteers. One example of this is the Mohonk Preserve phenologic and weather data, where only 4 people have made scientific observations on basic weather instruments and about the plants and animals around them for over 112 years (Cook and others, 2008). Cook and others (2008) chose this dataset for a climate study even though all the data was volunteer collected, because it was so consistently observed for over a hundred years that more accurate “professional” data could not be found. Volunteer citizen scientist monitors range from the well-educated person with a career in a scientific field to one who may or may not have graduated from high school. This variability in scientific literacy can often serve as a turn-off for research scientists, who want their data to be accepted into a journal for publication. Ely (2008a) found that most volunteer data used in watershed studies was not questioned by the article reviewers for scientific journals. This perceived bias on the part of reviewers and journals may stem from the professional scientists own personal stereotypes, and in fact may not exist at all. Fortunately, it seems that the irrational fear of citizen scientist collected data is a dying trend. Because of the massive amounts of data needed for large scale projects, more scientists seem to be willing to concede that help is needed from trained volunteers in order to successfully obtain all the data needed for these types of studies.
Translating Scientific Watershed Research into Useable Data

Even after engaging volunteer monitors or VMOs to collect data, researchers need to be sure that information from their research is usable by community watershed associations, research scientists, and government managers. Traditionally, use of watershed research data does not affect policy unless managers are part of the research process (Danielsen and others, 2005; Griffin, 1999). Community-based monitoring is considered a way to increase citizen participation in policy decisions and environmental management (Pollock and Whitelaw, 2005).

More and more government agencies and research universities are willing to use volunteer collected watershed monitoring data, but the professional scientific community continues to question the validity of data collected. Validity studies have been completed for various types of watershed monitoring studies, including turbidity and biologic monitoring to name a few. Fore and others (2001) found that citizen volunteer field samples did not vary from professionally collected field samples of macroinvertebrates. The volunteer taxonomic identification data varied from professional data by only about 13%, and did not affect the conclusions reached by either team. Macroinvertebrate sampling and identification are relatively complex monitoring tasks requiring a great deal of knowledge on the part of the volunteer citizen scientists. Another study found that volunteer monitoring data is only as valid as the watershed monitoring protocols the volunteers use (Engel and Voshell, 2002). In
their study, Engel and Voshell (2002) found that the monitoring protocol for macroinvertebrates being used by volunteers in the Virginia Save Our Streams (SOS) program was too simplified to obtain an accurate assessment. After rewriting the protocol, the citizen scientists were able to obtain results that were very similar to professionally collected data, and reached conclusions that agreed closely (96%) with the professional scientists. Though the scientific community has been reluctant to accept citizen collected scientific monitoring data for some fields such as water quality monitoring, citizen scientist data is readily accepted in others, such as weather station or storm data collected for the National Weather Service and in bird surveys collected at the continental and even world scale. As with any other type of research data collected, a good procedure and quality assurance and quality control plan should be in place in order to show validity of results. As long as the person taking the data, including a citizen scientist, follows the procedures, the data is of the same quality as that of any other person collecting the data. Interestingly, Hamann and Drossman (2006) found that there are many reports analyzing water quality data, none were published that analyze the quality of undergraduate college student collected data, though their level of expertise is similar to that of a volunteer citizen scientist. Further research is needed with undergraduates to discover the frequency of use of undergraduate researchers for data collection and the perceptions by professional scientists concerning the accuracy and validity of using this data for research studies.

Some sort of training is necessary to ensure full understanding of the standardized procedures to be used. A quality training program may be necessary for novice
macroinvertebrate samplers to complete accurate identifications and assessments (Metzeling and others, 2003). This training is comparable to training needed by researchers the first time they conduct water quality monitoring. Considering the volunteer audience is important for training community members to serve as volunteers in monitoring exercises. Training should vary based on the experience and education levels of the volunteers. When many of the volunteers are scientists or well-educated, then less training may be required to obtain consistent and valid monitoring results (Overdevest and others, 2004). This training may be different if one wants data that is comparable at the local and regional scales. Larger scale projects are sometimes very simplified, involving the collection of only one simple parameter such as Secchi disc depth, as opposed to a more complex measurement such as macroinvertebrate sampling.

The task of monitoring all of the waters in the United States and across the world is a daunting one. Long term repetitive monitoring is not sustainable at current scientific monitoring scales. Technology increases the range of scientists’ ability to collect data, but only so far. Human social capital is one of the strongest resources volunteers bring to environmental monitoring (Bliss and others 2001; Cuthill 2003). Even if the focus remains one where researchers or volunteer citizen scientists monitor their own local watersheds, there are literally as many potential monitoring sites as there are citizens. This task would be impossible without a huge workforce. Obtaining a clearer picture of the health of watersheds within the United States will require the use of volunteer citizen scientist monitors who can not only inform researchers about the local area but also who are interested in seeking the
health of their local water sources over the long-term. By standardizing techniques, completing appropriate training and periodically checking validity of citizen collected data, government agencies and university researchers can effectively use volunteer citizen scientist watershed monitoring data and assessment programs to recognize current and future watershed-related environmental issues on a regional scale.
References


31


CHAPTER 3: A COMPREHENSIVE ASSESSMENT OF THE BLACK CREEK WATERSHED MONITORING PROJECT: ENGAGING COMMUNITY MEMBERS TO DEVELOP A COMPREHENSIVE WATERSHED ASSESSMENT FOR MANAGERS AND RESEARCHERS
A comprehensive assessment of the Black Creek Watershed Monitoring Project: Engaging community members to develop a comprehensive watershed assessment for managers and researchers.

Shelby Gull Laird, North Carolina State University, Dept. of Forestry and Environmental Resources, Campus Box 8008, Raleigh, NC 27695. shelby_laird@ncsu.edu

Stacy A.C. Nelson, North Carolina State University, Dept. of Forestry and Environmental Resources, Campus Box 7106, Raleigh, NC 27695. stacy_nelson@ncsu.edu

Christy Perrin, North Carolina State University, Watershed Education for Communities and Officials, Campus Box 8109, Raleigh, NC 27695-8109. christy_perrin@ncsu.edu

James Gregory, North Carolina State University, Dept. of Forestry and Environmental Resources, Campus Box 8008, Raleigh, NC 27695. jim_gregory@ncsu.edu
ABSTRACT

Comprehensive assessments of watersheds, particularly in rapidly urbanizing areas, push boundaries of traditional watershed assessment techniques. As the US population has become increasingly urban, there is a need for greater focus on urbanizing and urban watersheds. These watersheds are characteristically impaired biologically and are becoming of greater concern and focus of watershed assessments across the United States. With the limited temporal scale of research studies, data collected by these projects may be of limited usefulness to managers seeking to understand the long-term impacts of urbanization on water quality and storm water issues. This paper reviews a case study of the creation of a citizen-led watershed association in concert with university-based research in order to continue data collection and research efforts beyond the average grant cycle. Citizen involvement in the research process through data collection and guidance as well as watershed association formation provided for a strong association group with the skills to continue research monitoring activities. This cooperative research strategy will enable the citizen-led watershed association to apply for future funding while also working with city planners to implement BMP and/or other strategies to improve localized flooding problems and water quality.

KEY WORDS

Community participation, watershed monitoring, volunteer monitoring, watershed assessment
Introduction

Increasing urbanization presents a variety of logistical challenges that make monitoring, modeling and watershed assessment somewhat challenging (Barrett and Guyer, 2009; Easton and others, 2007). Government managers and researchers need simple and effective ways to complete comprehensive watershed assessment in these complex systems (Zandbergen, 1998). Watershed assessment must move beyond simple monitoring to include social, political and historical influences as well as the development of a comprehensive plan to preserve the quality of water in the watershed. This plan should be the goal of a comprehensive watershed assessment (DeBarry, 2004).

Historical approaches in watershed assessment and its use in both research-based and applied settings have varied greatly. In the literature are many examples of watershed assessments that were conducted on the catchment scale at research facilities under controlled environments (Waide and Marion, 2002) or in agricultural areas (Easton and others, 2007; Puckett, 1995; Richter and others, 1997). These important research studies and many more ongoing studies allow for a more complete understanding of the processes involved in water movement and hydrologic systems. Typically, these research-based watershed assessments are led and completed by university or government researchers with little public involvement. In such watershed assessments, consideration of the social, political and historical context of watersheds is rarely included. These types of social
understandings allow for an understanding of land management effects on watersheds (Pess and others, 2003), which can also apply to urban watersheds. As the United States population has become increasingly urban, more streams have been impacted by the urban environment. Stream networks in these watersheds are characteristically impaired biologically and are becoming of greater concern in watershed assessments across the United States (Richter and others, 1997).

With a greater interest in watershed assessments that support implementation of watershed plans to maintain or improve water quality, it is important that water quality monitoring be carefully planned as part of the assessment and as follow up evaluation of water quality management practices. These applied watershed assessments may be led by community groups, municipal officials and university or government researchers, but usually involve watershed assessments completed for the purpose of aiding community planning issues, advocacy for the watershed, environmental education (Conrad, 2006; Spellerberg, 2005), or to develop TMDLs to address impaired waters (Little and others, 2007).

The high variability of municipal governmental policies makes it difficult to create a systematic watershed assessment technique for urbanizing areas that can be utilized for many different watersheds. Including managers early in the watershed assessment process and monitoring increases the potential for policy changes and government participation (Danielsen and others, 2005). Current methods of conducting watershed assessments by municipalities include specific activities carried out by community groups, environmental consultants, state environmental agencies, or municipal officials designed to address
particular problems or research potential causes of problems already known to be present in local water bodies (Ely, 2008). Watershed studies by these groups tend to be more applied and community-based, rarely extending far beyond the municipality or local community. In fact, the development of community watershed associations as part of research projects are often recommended, but few efforts to actually do so have been described in the literature (Blomquist & Schlager, 2005). A survey of volunteer monitoring groups by Nerbonne and Nelson (2008) found that many current watershed assessments are applied studies planned to complete a snapshot picture of the watershed and streams in question instead of conducting a longitudinal aquatic ecosystems health study. Water quality parameters chosen are focused on a particular problem (Stein and Bernstein, 2007). Research scientists who complete watershed assessments tend to look more generally at the entire picture, but because of grant cycle funding, most research projects do not extend beyond 3-5 years. There is further interest in community water quality monitoring due to grant funders requirements for greater public education components in research grants. In North Carolina, watersheds are monitored by the N.C. Division of Water Quality (NCDWQ) for macroinvertebrate assessments on an average of every five years (NCDENR, 2008). The ambient monitoring system of the NCDWQ monitors physical and chemical parameters on a monthly basis on average as well as bacterial monitoring depending on the location (NCDENR, 2009). Macroinvertebrates are commonly used as an indicator of water quality (see Armitage and others, 1983; Growns and others, 2006) to determine overall watershed health, particularly by volunteer groups due to their interest to participants (Fore and others, 2001; Savan and
other common water quality indicator parameters are also important to examine in urbanizing watersheds, but existing monitoring may be spread to far apart spatially to effectively monitor urban areas. Even having one dataset can be useful because it can show changes over time if the same data collection is repeated at a later date.

Because of the large number of potential watersheds to study, it would be impossible to obtain data for every urbanizing watershed (Bonney and others, 2009). Engaging community groups may provide a solution for obtaining broader data collection both temporally and spatially. The use of community-based monitoring (CBM) groups by government agencies in many states has allowed a broader geographic range of data and increased frequency of data collection (Stokes and others, 1990). But volunteer monitors’ data are still not accepted broadly by municipalities, government agencies, or research scientists, thereby hindering their usefulness (Nerbonne and Nelson, 2004). Because researchers may not be from the local area of the watershed being studied, they may not have a complete historical perspective of the watershed or full understanding of the issues involved in water quality. Involving the community in watershed assessment research projects helps researchers to more fully understand the historical perspective of the watershed or issues involved in the community (Gouveia and others, 2004). Additionally, volunteer monitors may benefit through development of larger community environmental knowledge, awareness and involvement due to their participation in watershed monitoring (Conrad, 2006; Spellerberg, 2005). Many CBM groups began and continue without any relationship to government agencies or research universities. Because of this bottom-up approach, many
volunteer watershed monitoring and assessment projects are grossly underrepresented in the literature (Ely, 2008). These data are being lost to government agencies and research scientists. Many of these groups are hoping to affect change in their local government politically by collecting data on water quality in the watershed in question (Bliss and others, 2001; Whitelaw and others, 2003), but the data end up not being used. With the proper organization through working with municipal and research scientists and creation of a quality assurance plan, these data could contribute to create a more continuous pattern of water quality monitoring data. For researchers and managers willing to work with CBM groups cooperatively, perhaps through the creation of a watershed association, valuable local knowledge through engagement with community members can be gained (Conrad, 2006; Savan and others, 2003; Mackinson, 2001). CBM efforts are classified into five different categories according to who organizes the monitoring efforts, local communities or professional researchers (Danielsen and others, 2008). Table 1 represents a combination of classifications from both Danielsen and others (2008) and Whitelaw and others (2003), who both represented almost identical interpretations of varying types of CBM schemes.

One way community groups, municipal governments and researchers can begin to work together for comprehensive watershed assessments is through the use of geographic information science (GIS). GIS has been widely used in watershed studies to measure geomorphic descriptors of the watershed and stream network. Through the incorporation of user-friendly GIS software interfaces, this tool has become available to wider audiences beyond researchers and municipal governments. With the large amount of GIS data readily
available today at a high resolution and from many sources, GIS continues to increase its popularity in watershed assessment studies (Pess and others, 2003). The development of a GIS-based watershed assessment can be used to engage citizen-scientists, create education curricula and possibly increase scientific data for further study or comparison (Gouveia and Fonseca, 2008). The ease or difficulty of the development of that watershed assessment can determine the longevity of the project, particularly where citizen groups are engaged in continuing research without expert assistance or leadership in monitoring or GIS (Luchette and Crawford, 2008). Many examples show the integration of watershed assessments using GIS for research and decision-maker education (Arnold, 1996; Bodzin, 2008). These studies used GIS for its map creating abilities in order to educate municipal officials and the public and less for its ability to analyze complex data. Current studies tend to use GIS for modeling in watersheds and many new models exist to aid in these GIS-based watershed assessments (Goodall and Maidment, 2009). In addition to these research based GIS examples, many CBM groups understand the importance of GIS in watershed assessment, and have begun to develop mapping websites based on GIS data for their watershed (Luchette and Crawford, 2008) and to enhance public participation (Smith, 2002). These watershed participatory GIS projects are happening beyond the world of research and appear rarely in peer-reviewed literature (Goodchild, 2007).

The case study presented here examines: (1) how water quality and GIS data collection can incorporate volunteers from the community in an urbanizing watershed, (2) an evaluation of the baseline community engagement compared to more traditional research
methods and other CBM efforts, and (3) suggested methods for increasing community member participation in watershed assessment, including the creation of a community-led watershed association in concert with university-based research.

**Study Area**

The Black Creek watershed is an 8.19 km² (3.16 mi²) drainage basin in Cary, North Carolina a suburb of the state capital of Raleigh in Wake County and lies within the Neuse River Basin (Figure 1). Black Creek occurs in the hilly terrain of the Piedmont and the range of elevation in the watershed varies over 60 meters (200 feet) from the highest ridge to the stream output. Though the main stem of Black Creek and its two major tributaries are surrounded by a wide, forested buffer and greenway, the entire watershed is urbanized with greater than 35 percent largely connected impervious surface. Black Creek flows to the North, draining into Lake Crabtree. The watershed contains several major roads, two parks, several large shopping centers, and many single and multi-family residential developments (Figure 2). Black Creek was designated as biologically impaired and added to the North Carolina 303(d) list in 1998 by the NC Division of Water Quality and US Environmental Protection Agency. This classification signifies low benthic macroinvertebrate diversity and density as determined by North Carolina methods (NCDENR, 2006; NCDENR, 2007).
Case Study Analysis

The Black Creek watershed assessment in Cary, NC began in 2006. The comprehensive watershed assessment included work conducted by a technical team of scientific researchers from North Carolina State University in Raleigh, NC. The project included the formation of a watershed association group comprised of community volunteers and local government representatives, called the Black Creek Watershed Association (BCWA). The watershed plan was developed by NCSU Extension faculty under direction of the BCWA, with the original research direction and data interpretation determined by the university research team. Water quality and GIS data collected by researchers and community volunteers were then used by the technical team and watershed association to develop a watershed plan.

Water Quality Data Collection

Various data were collected as a part of this study by both the research team and the BCWA. The watershed assessment included development of the BCWA and originally the community participants were not involved in data collection. The university research team decided on the use of volunteer monitors as part of the watershed assessment process partially due to the opportunity to increase work hours by engaging volunteers. Several data parameters were determined to be important to collect but were also delayed for lack of time.
on the part of researchers. These data were collected by BCWA volunteers during the watershed assessment process.

Water quality parameters for monitoring were chosen based on the impacts on the watershed and local influencing factors (Table 2). The technical team of university researchers determined the parameters to be collected for the Black Creek watershed assessment. The Black Creek watershed assessment is similar to many research-based watershed assessments in the types of data collected, including nutrients and other chemical parameters, stream and rain gauge installation, stream bank stability and habitat, pollution inventory and macroinvertebrate sampling. Other data collected included some indicator data for emerging contaminants.

The university research team included university professors, extension agents, and graduate students. Originally, all data were to be collected by graduate students and professors. These data were then presented to community participants during the monthly meetings of the BCWA. As data collection continued researchers determined that the time-intensive nature of several desired parameters would require a larger labor force or a larger grant. In order to compensate for this volunteers were engaged to collect data. These data were collected for two observational parameters, a stream habitat assessment and a pollution inventory of the streams. Another goal of engaging volunteers was the desire on the part of the BCWA and research technical team to more authentically involve community participants in the technical data collection process. For the stream habitat analysis, volunteers attended a four hour training session in the watershed to learn about stream
habitats. This training was presented by a research technical team professor and extension professionals. It included lecture presentation as well as on-site stream practical experience. Teams of two to three individuals were created and given a period of a few weeks to analyze one of 18 sites across the watershed. Data included a set of observations about the quality of stream habitats in the watershed (Appendix A).

Pollution inventory data collection required much less training. Participants were trained online and at the regular watershed meeting to identify potential sources of pollution, ranging from piles of garbage to storm water outfalls. Researchers compiled all data collected to create a final report on the status of the watershed for grant reporting (Perrin and others, 2009). Watershed volunteer data was used as a part of this comprehensive assessment. A final technical report was completed by the university research team, and that report was used by the BCWA to make recommendations to the Town of Cary as well as to create a watershed plan. A storm water professional with the town storm water engineering unit Town served as technical support to the BCWA and a liaison to the Town, providing a necessary link to decision-makers. This transparent collection of data created a more complete watershed assessment picture, particularly from the political and social aspects of assessment.
**Geodatabase Creation**

In the Black Creek watershed assessment, GIS was used largely for the creation of a geodatabase containing all layers considered relevant to the investigation (Table 3). The geodatabase was developed to assist in the watershed assessment, particularly for modeling purposes and determining potential pollutant sources. An accurate map of storm water outfalls and an accurate stream map were needed for a complete assessment. The technical team made many of the decisions in regards to what layers would be included in the watershed geodatabase.

The GIS data were easily attainable, with most layers obtained from the Town of Cary. Other necessary feature datasets were available from state agencies and other public sources. Certain GPS and GIS data were also collected by the technical team in order to provide a comprehensive geographic perspective of the watershed area. The watershed association was asked to contribute opinions to the development of the geodatabase that was ultimately given to them by the technical team for use in future studies. Town officials also participated in GIS data collection by providing newly developed storm water GIS data layers for the town created by environmental consultants to meet storm water requirements.

The consultants were directed by the Town to make data collection in the Black Creek watershed a first priority in order to meet the timeline of the watershed assessment. The GIS stream layer created as a part of this study eliminated errors from the Town of Cary stream map that typically exists in GIS layers created from USGS quadrangle maps (Colson,
Due to budget limitations, it was determined that volunteers could be trained in using mapping grade Trimble GPS units in order to expedite the data collection process. Three non-university volunteers and several undergraduate students assisted with data collection on stream locations. Volunteer stream mappers were accompanied by a technical team leader on all assignments and only collected points along the streams, not the origin points. In the end, these points closely correlated with the USGS topographic map lines, and were ultimately not used as part of the final geodatabase. To complete an accurate stream map, the locations of first order streams and their origins were determined by members of the university technical team skilled in use of the NCDWQ methods for stream origin identification (NCDWQ 2005). The GIS stream layer created as a part of this study also allows municipal government to consider the errors in stream depiction that exists in stream layers created from USGS quadrangle maps (Colson, 2006; Williams, 2005).

Community Engagement

The watershed assessment included the formation of a community watershed association in order to continue research started by the university researchers as well as to consider the social, political and historical subtext within the watershed area. The formation of a watershed association makes this project a combination of a research-based and applied watershed assessment. University researchers, at least one member of the municipal government, the county government, and citizens composed the watershed association.
Extension faculty from the university coordinated and facilitated watershed association meetings.

The BCWA was developed as an informal entity that serves to look out for the best interests of the watershed and to protect Black Creek. Because this watershed area is already impaired, the watershed association is seeking ways to improve already degraded water quality. The watershed association did not actively participate in the development of research parameters or the analysis of data at first, making the initial classification a Scientist Controlled CBM (Table 1). The community group eventually did actively participate in volunteer monitoring activities throughout the assessment process. The technical team reported to the BCWA on a monthly basis with updates on progress in research activities, monitoring status, and other activities. At the end of the grant cycle period of 3 years, NCSU Extension faculty are still assisting the watershed association with watershed assessment and planning activities and currently are identifying storm water best management practices (BMPs) for implementation across the watershed. A new technical team from NCSU and Clemson University is helping the watershed association continue research efforts to determine BMP effectiveness. The creation of this community-led watershed association in concert with university-based research has allowed data collection and research efforts to continue beyond the average grant cycle.

The watershed association was developed as part of the watershed assessment, but now serves as the lead group for the continuing assessment of Black Creek in partnership with NCSU Extension faculty. Work continues on the Black Creek project thanks to
continued grant funding and efforts on the part of NCSU Extension faculty who is also a resident in the watershed. Without funding and expertise, the work of the watershed association would be much more difficult due to the time commitment required on the part of volunteers who may not be as well trained. The technical team from the university served largely in order to complete scientific research, but not to manage any activities or watershed modifications. See Figure 5 for an organizational chart of groups involved in the Black Creek watershed assessment. The BCWA was involved in the research aspects of the watershed assessment through presentations to the watershed group at association meetings, collection of pollution inventory and habitat assessment data, and collection of GPS stream points. This level of involvement falls into the Interpretive Approach Community Based Monitoring (CBM) defined in Table 1. After the grant period ends, however, the Black Creek Watershed Association serves as the lead organization, driving research through grant applications and perhaps collecting and interpreting data if they determine the need to do so. This moves the association to a Community Controlled Multiparty CBM, since the group desires to work with professional scientists to complete research. The group still benefits from the leadership of the NCSU Extension faculty.
Discussion

The case study of the Black Creek watershed assessment examines how water quality and GIS data collection can incorporate volunteers from the community in an urbanizing watershed. Urbanized watersheds have potentially hundreds of community members who could serve as volunteers. Data collection by volunteers served as one of the ways to engage community members in assessment and monitoring efforts and helped to link the community group to the stream. Volunteer data collection was initiated in the interest of saving time and money for the university technical team, and proved useful for the qualitative parameters collected. These types of procedures would be accessible to any watershed association, particularly the pollution inventory in an urbanized watershed. Volunteers simply photographed and briefly described potential pollution sources and noted GPS coordinates for locations. With only two graduate students assigned to this project, some tasks covering the entire watershed became quite labor-intensive. Using GIS and volunteers from the BCWA allowed for a division of labor. The watershed association has used the university research data to justify continuing work in the watershed. The researchers used the volunteer data to understand more about the processes and factors influencing stream health.

In Black Creek, we found that volunteers were enthusiastic and excited to participate in research. The formation of the watershed association allowed for frequent community involvement and consistent accountability for university researchers. Engaging volunteers to
collect data for the habitat assessment and pollution inventory allowed researchers to obtain a greater amount of data used to create a more complete picture of the watershed. This transparent collection of data and presence of many different stakeholders helps to create a more complete watershed assessment picture. Basic methods used to collect data by volunteers including visual observations allowed for accurate data as compared to technical team members as observed anecdotally. Volunteer data was instrumental in determining the quality of stream habitat available to benthic macroinvertebrates. The combined volunteer and research effort provided a more comprehensive sampling of a broader spatial area in the watershed, while engaging community members in the simplest way possible in the scale of community based monitoring schemes (Table 1), Interpretive Approach CBM. Though development of watershed associations as part of research projects are often recommended, few similar efforts have been described in the literature (Blomquist & Schlager, 2005). Smith (2002) describes a similar undertaking in the Gunpowder Watershed in Maryland with what the author terms a clearinghouse approach, which included comprehensive use of internet technology to enhance stakeholder participation. The Black Creek Watershed project did incorporate internet-based information communication with a web site that made available to all residents of the watershed the maps and GIS data, documents, and discussions, largely duplicating documents provided at association meetings.

GIS data are also invaluable in an urbanized watershed assessment. GIS data must be used for the development of an integrated watershed assessment, and inclusion of accurate maps is essential for determining watershed dynamics. A complete geodatabase can serve as
baseline for community engagement and linked the watershed monitoring to community members particularly through internet technologies. GIS data served as one of the ways to engage community members in monitoring program efforts and served as a link between the group and the monitoring conducted by the research team. GIS use in the development of an integrated comprehensive watershed assessment and monitoring was necessary as part of comprehensive watershed assessment. Community participants expected complete mapping efforts and suggested many community interest feature datasets to be included in the geodatabase, like community parks and greenways. This combined approach is beneficial to researchers because it provides a comparable set of data for use in later projects by the citizen watershed association or the municipality. The municipal government also provided a great deal of spatial information to be included in the project, including storm water infrastructure layers created by municipal contractors during the project time period. These layers were valuable in explaining storm water impacts on the watershed ecology. The GIS stream layer created as a part of this study can be used by the municipal government as an example of how current stream maps may be inaccurate. This approach is beneficial from a community planning aspect because the incorporation of city planning and GIS data allows for use of the data by the town and citizen monitoring group. Data layers available also allow the citizen watershed association to create and choose subwatersheds to implement possible BMP retrofits. The NCSU technical team converted the geodatabase GIS layers into KMZ formatted files, which allows the data to be viewed by anyone who downloads a Google Earth application. The KMZ files have been posted on the project website for public use.
This has increased the utility of the data; users do not need to be experts in GIS or even have ArcGIS to use the data.

The creation of a community-led watershed association in concert with university-based research enabled researchers to continue data collection and research efforts beyond the first grant cycle. Future research groups creating community watershed associations as part of a grant project should consider these recommendations based on our experience. First, consider allowing the watershed association to assist with the choice of water quality parameters to collect. This could help build an understanding of the research process for community participants. We also recommend choosing deliberate ways to include community groups before the project begins. In Black Creek, volunteers were included in the data collection, annual stream clean-ups, and monthly watershed association meetings to guide the assessment and watershed plan and make policy recommendations. Watershed association formation and educational presentations were purposeful parts of the original watershed assessment project. Researchers decided later in the process to include participants in volunteer data collection for the purposes of collecting more data due to limited funding and time of the researchers. Inclusion of community participants in watershed data collection proved to be a great educational activity as well. This process was so beneficial to the watershed association that we recommend developing a cohesive program that incorporates community watershed associations and volunteer monitoring activities from the beginning. Inviting municipal leaders to participate in data collection activities could also prove helpful in obtaining future funding for the watershed association. Integrating the
watershed association into data interpretation and research management worked quite well for this group, particularly since the group moved up the scale to more autonomy after the research project time period ended. This transition from Interpretive Approach CBM to Community Controlled Multiparty CBM will helpfully allow the watershed association to better manage continuing research on their own.

Conclusion

The creation of a watershed association in the Black Creek watershed study was essential to completion of a comprehensive watershed assessment. Not only did the inclusion of community members enhance the watershed assessment process, but it allowed for more comprehensive data collection. Community participant involvement in the watershed assessment included creation of and participation in a watershed association. Members of the association participated in data collection as volunteer monitors through a pollution inventory and stream habitat assessment. Technical research team members presented research and answered questions at monthly watershed association meetings, and the watershed association continued work started by the research technical team by obtaining grant funding to continue research. So far the watershed association has been effective in continuing research beyond the grant funding period. The association received a grant to implement BMPs and monitor for effectiveness.
Grant funding requirements for education and outreach components make involving the public necessary, but token websites or one time education functions do not keep the community engaged in the process occurring in the watershed. Creating a sense of ownership is essential for continuing community interest in watershed assessment projects. Involving volunteers in the watershed assessment process is one way to engage the community. Participants in Black Creek were involved in data collection, annual stream clean-ups and monthly meetings. Benefits for creation of a watershed association for citizen water quality monitoring involvement include community control over watershed assessment outcomes, community involvement and future involvement (long-term engagement), and education of citizens about local water quality. Further research is needed to determine the relationships that exist between university researchers and volunteer watershed associations. Volunteer monitoring as a whole is in need of more research to determine more ways university researchers and communities can work together. The US EPA volunteer monitoring site (http://www.epa.gov/owow/monitoring/volunteer/) and USDA Water Quality Extension programs (www.usawaterquality.org/volunteer/) may be useful to managers or researchers interested in incorporating more community involvement into their research. Of interest is the involvement of community members in volunteer watershed activities, and possible attitude change or behavior modification as a result. Volunteer monitoring groups and university researchers need to work more closely together in order to create more published and publishable data from volunteer groups (Cohn, 2008). This will ensure that
these data are not being lost due to quality control problems or simply a lack of communication.

Community member involvement in the research process through data collection and guidance as well as watershed association formation provided for a strong association group with the skills to continue research monitoring activities. This cooperative research strategy will enable the community member led watershed association to apply for future funding while also working with city planners to implement BMP and/or other strategies to improve localized flooding problems and water quality.
ACKNOWLEDGEMENTS

Thanks to the Watershed Education for Communities and Officials program at North Carolina State University including Patrick Beggs, the Black Creek Watershed Association, the Town of Cary, the Department of Forestry and Environmental Resources at NCSU, the US EPA 319 grant program administered through the NCDENR Division of Water Quality and to manuscript reviewers.
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Figure 1: Location of Black Creek watershed in North Carolina.
Figure 2: Black Creek watershed boundary with orthophotography, 2005.
Figure 3: Temporal extent of various monitoring agencies and groups. State monitoring may occur on a five year cycle. Research monitoring typically happens very frequently for a grant cycle, shown here as three years, but then stops. Community monitoring is able to continue frequently and over a long period of time when dedicated volunteers are involved.
Figure 4: Spatial extent of various monitoring agencies. Depending on the size of the watershed, municipal or state governments may not even consider monitoring the site.
Figure 5: Organizational chart for the comprehensive watershed assessment by reviewing various participants in the watershed association.
Table 1: Community based monitoring (CBM) scale of community involvement. Various roles of community members and scientists in different approaches to CBM programs. This table has been compiled from work completed by both Danielsen, et.al (2008) and Whitelaw, et.al (2003).

<table>
<thead>
<tr>
<th>Category</th>
<th>Who Drives Research / Monitoring?</th>
<th>Who Interprets Data?</th>
<th>Notes</th>
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<td>Professional Scientists</td>
<td>Research project within a community that does not involve any community participation in research</td>
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<td>Community members serve only as data collectors here for educational purposes, and do not interpret data</td>
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<td>Community Members / Professional Scientists</td>
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<td>Community Members</td>
<td>Community members only are using the data, but they have professional scientist assistance in monitoring</td>
</tr>
<tr>
<td>Advocacy CBM</td>
<td>Community Members</td>
<td>Community Members</td>
<td>Local community controls the research and data interpretation</td>
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Table 2: Local influencing factors on the Black Creek watershed area.

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<th>Category</th>
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<tr>
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<td>High density storm water system</td>
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<tr>
<td></td>
<td>Older storm water management</td>
</tr>
<tr>
<td></td>
<td>Proximity of sewer system</td>
</tr>
<tr>
<td></td>
<td>Suburban lawn care including fertilizer and pesticides</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Large flow volume during storm events</td>
</tr>
<tr>
<td></td>
<td>Consistent base flow even during severe drought</td>
</tr>
<tr>
<td></td>
<td>Incised channel</td>
</tr>
<tr>
<td>Biology</td>
<td>Impaired due to low quality and quantity of macroinvertebrates</td>
</tr>
<tr>
<td></td>
<td>Forested buffer and greenway</td>
</tr>
<tr>
<td>Other</td>
<td>PCBs contamination in downstream lake (Lake Crabtree Superfund site)</td>
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Table 3: Relevant GIS layers for the Black Creek watershed assessment.

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CHAPTER 4: A SURVEY OF VOLUNTEER MONITORING ORGANIZATIONS (VMOS) IN NC AND THE US: ORGANIZATIONAL STRUCTURES AND DATA USE
TITLE
A Survey of Volunteer Monitoring Organizations (VMOs) in NC and the US: Organizational Structures and Data Use

AUTHORS
Shelby Gull Laird, North Carolina State University, Dept. of Forestry and Environmental Resources, Campus Box 8008, Raleigh, NC 27695, shelby_laird@ncsu.edu

Stacy A.C. Nelson, North Carolina State University, Dept. of Forestry and Environmental Resources, Campus Box 7106, Raleigh, NC 27695, stacy_nelson@ncsu.edu

Menius, Erika, Rho, Inc., 6330 Quadrangle Drive, Chapel Hill, NC 27517, erika_menius@rhoworld.com

Harriett S. Stubbs, North Carolina State University, Dept. of Mathematics, Science and Technology Education, Sci-Link Environmental Programs, Raleigh, NC 27695, harriett_stubbs@ncsu.edu

April L. James, North Carolina State University, Dept. of Forestry and Environmental Resources, Campus Box 8008, Raleigh, NC 27695, april_james@ncsu.edu
ABSTRACT

A survey of volunteer monitoring organizations (VMOs) currently active in the United States was completed to better understand the leadership structure, data collection procedures and data use of water quality monitoring by volunteers within North Carolina and at the national level. Organizational structures and origins of monitoring groups and revealed a wide variety of types and history. Data collection procedures including whether or not groups require training and quality assurance were explored and discussed through the survey. Multiple types of volunteer monitoring data uses included management and research. This survey suggests that a lack of structure at the state level in North Carolina which may hinder the usefulness of data collected for purposes other than environmental education.

KEY WORDS

volunteer monitoring, citizen science, community-based environmental monitoring, water quality, volunteers
Introduction

Community volunteers serve as a valuable resource in environmental monitoring. Many environmental systems are so complex that widespread monitoring and assessment efforts are impossible without large amounts of funding, available personnel, and work hours (Bliss and others 2001). Various fields of science have utilized volunteer participation for years both for environmental education purposes and to collect data, including the weather service through the National Weather Service spotter program (Firehock and West 1995), ornithological researchers through various long-standing bird watching programs (Bonney and others 2009; Greenwood 2007) and lake monitoring programs for turbidity using Secchi disks (Heiskary and others 1994; Kerr and others 1994; Obrecht and others 1998). These programs in which citizen scientists or volunteer monitors complete scientific observations and collect data, are also referred to as community-based environmental monitoring (Danielson and others 2008). Community-based monitoring is defined as “a process where concerned community members, government agencies, industry, academia, community groups and local institutions collaborate to monitor, track and respond to issues of common community concern” (Whitelaw and others 2003).

Water quality assessment by volunteer monitoring organizations (VMOs) is an example of community-based environmental monitoring. These programs typically consist of a vast quantity of highly motivated and trained volunteers (Measham and Barnett 2008)
who want to make a difference. Some of these water quality VMOs have existed at the grassroots level for decades (Bruhn and Soranno 2005; Stapp and others 1997). Earliest volunteer environmental monitors were weather observers for the National Weather Service in the late 1800s. They are still a major component of weather service data collection today (Firehock and West 1995). Volunteer water quality monitoring programs emerged as environmental programs in which community members were advocates or protectors of rivers, similar to ancient and modern Riverkeepers (Firehock and West 1995). Many of the existing community-based environmental monitoring groups focused on water quality began in the 1980s and 1990s, but many more grassroots groups are formed each year and are spread across North America and beyond (Griffin 1999; Lathrop and Markowitz 1995; Savan and others 2003; US EPA 1998). Group formation structures can vary. Some, such as stakeholder groups, are created as part of the planning process, while others are formed from the ground up by concerned communities hoping to “protect and improve natural resources in their local areas” (Nerbonne and Nelson 2004). These two group types are referred to in this article as bottom-up, or community-based monitoring, and top-down, or Cornell model monitoring (Ely 2008b).

Water quality VMOs are everywhere. A 2003 survey response (Nerbonne and Nelson 2008) estimates that there may be as many as 500+ volunteer macroinvertebrate monitoring groups with more than 15,000 volunteers across the United States. These volunteers monitor as many as 3,500+ sites and work more than 180,000 hours per year. The Nerbonne and Nelson (2008) study presented only an estimate for macroinvertebrate
monitoring, and so did not include other water quality parameters or involved school groups. National directories of volunteer monitoring groups indicate similar numbers of organizations involved in volunteer water quality monitoring across the United States (US EPA 1998). Not only is this a huge grassroots undertaking for these community-based environmental monitoring groups, but it is an enormous potential data source and workforce for cash-strapped research scientists and government officials (Canfield and others 2002; Salmon and others 2008; Strieter and Blalock 2006). The massive social capital possibilities make volunteers an essential resource to researchers (Bliss and others 2001; Cuthill 2003).

A crucial part of all community-based environmental monitoring is the involved citizen scientist or volunteer monitor who collects and distributes information. According to the Cornell Lab of Ornithology, citizen science can be defined as “projects in which volunteers partner with scientists to answer real-world questions” (Cornell 2007). With the perceived rise in environmental issues, urbanization, and global climate change, many more everyday citizens are interested in understanding science and pursuing scientific endeavors (Cantwell and Day 1998; Landre and Knuth, 1993; Savan and others 2003; Whitelaw and others 2003). Water quality volunteer monitoring is of particular interest because of the land ethic and personal connection to water of many individuals (Measham and Barnett 2008; Gooch 2005).

This connection to the land is not being used to the advantage of researchers. Within the scientific water resources community these volunteers are less recognized and their data are much less likely to be taken seriously (Nerbonne and Nelson 2004). With the notable
exception of volunteer turbidity data collection using Secchi disks (Canfield and others 2002; Heiskary and others 1994; Nelson and others 2003), many groups collect data that are only used for their own personal reporting purposes. These volunteer monitors can serve as a potentially invaluable resource to complement the efforts of research scientists and government agencies.

**Purpose and Data Use**

Water quality monitoring by volunteers in the United States is largely completed for environmental educational purposes (Borden and others 2007; Koehler and Koontz 2008; Nerbonne and Nelson 2008). Volunteers become more educated about local environmental issues through the completion of monitoring activities. Other reasons for VMO formation include community activism, networking, and a desire to affect change in the local area (Bliss and others 2001; Whitelaw and others 2003). Volunteer monitors who complete these community-based environmental monitoring projects attempting to complete scientific data collection in order to complete monitoring goals. VMOs have different training requirements and data collection procedures. Many volunteer monitoring organizations feel that they are simply collecting background data that can help to notify government agencies of any problem, but some VMOs use their data to publish their own documents and reports (Nerbonne & Nelson, 2004). A few groups use their own data for research purposes to report in peer-reviewed journals (Bruhn and Soranno 2005; Terrell and others 2000). These groups
are growing in number, but are still very few and far between (Ely, 2008a). Because of the nature of volunteer data collection, questions of data quality can arise. Nerbonne and Nelson (2004) suggest caution when accepting volunteer data without considering the needs of policy makers and scientists who desire high quality data. State agencies interviewed by Nerbonne and Nelson, noted they felt volunteer data was valuable and could be used for state and local level databases.” Interviewees also cautiously noted, however, that they could not accept data that did not conform to certain standards. These interviews produced several state level agencies that do not accept any volunteer data because of its questionable quality (Nerbonne and Nelson 2004). Many states struggle to find a meaningful uses for the volunteer collected data. Several studies have found that volunteer collected data are comparable to that of scientists (Canfield and others 2002; Fore and others 2001; Edwards 2004), while others have noted that volunteers make mistakes, largely when identifying macroinvertebrates (Penrose and Call 1995; Nerbonne and Vondracek 2003). Volunteers are more likely to make errors in complex biological assessments as compared to experienced scientists (Metzeling and others 2003). But, by keeping procedures clear and simple (Bonney and others 2008; Cohn 2008), conducting high quality training including sample insects (Fore and others 2001) and developing strong partnerships between professional scientists and volunteers (Greenwood 2007), high quality data can be obtained. One would expect that VMOs that use their data for management and research purposes would have higher quality data. However, Nerbonne and Nelson (2008) found data use and data quality were not related, and data quality did not increase based on perceived outcomes of data.
collection. This being said, data of high quality is out there, but may not be what is currently being used by VMOs and agencies.

Current lack of volunteer monitoring in the research literature (Nerbonne and Nelson 2004; Ely 2008a) does not necessarily indicate that these data are not serving a use. Researchers and managers willing to work with VMOs can gain valuable local knowledge through engagement with community members (Conrad 2006; Savan and others 2003; Mackinson 2001). Involving the public in watershed assessment and research projects can help researchers more fully understand the historical perspective of the watershed as well as issues involved in the community (Gouveia and others 2004). Researchers gain valuable work hours when funding is tight (Salmon and others 2008; Strieter and Blalock 2006). VMOs will publicize data in order to increase their networking potential and social capital, even though publication could also serve to impact policy change or gain scientific credibility. Scientists may benefit from the ability of VMOs to encourage community awareness (Nerbonne and Nelson 2008). The rise of community-based watershed associations has created an increase in federal agencies acting as experts, providing resources and experience to community-led efforts (Pess and others 2003). Local planners and researchers can benefit from engaging VMOs as a way to enhance public communication and education.

Firehock and West (1995) cautioned 15 years ago that VMOs thrived serving to accomplish the goal of increased awareness about the environment, and that increased emphasis on data quality might serve to discourage volunteers. At least one study from
Australia points to volunteer burnout in a watershed project (Byron and Curtis 2002). VMOs should serve to motivate community members towards behavior change and involvement in stream health projects (Firehock and West 1995) and not tire them by using them only for data. Nerbonne and Nelson (2008) found that volunteer macroinvertebrate monitoring groups with more training hours, in-kind support, and higher education levels of group leaders did not necessarily lead to better quality data. Does this indicate that volunteers willing to do more of the work on their own are more likely to be motivated and to collect higher quality data? Scientists and program leaders need to foster feelings of ownership in their volunteer monitoring groups if these programs are encouraged by local, state or regional agencies.

Many community groups indicate they are much more concerned about education and the social impacts of data collected, than their use for research or policy change (Nerbonne and Nelson 2004). Environmental education is defined as “a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action” (UNESCO 1978). Keeping the focus on the potential opportunities for environmental education could be helpful for researchers or municipalities wanting to work cooperatively with community-based environmental monitoring groups. Environmental education is one of the greatest positive outcomes of community-based environmental monitoring programs (Conrad 2006; Spellerberg 2005). Many VMOs choose water quality monitoring because of
the opportunity for hands-on learning it provides, thereby expanding volunteers own knowledge of the environment (Nerbonne and Nelson 2004). Teachers are highly motivated to partner with researchers and communities to conduct biomonitoring research with students as a way to engage their students in scientific inquiry and research (Au and others 2000; Edwards 2004). Geographic information science (GIS) has also emerged as a tool which improves scientists’ ability to conduct comprehensive watershed assessments (Pess et al., 2003). Using this tool through the integration of webGIS or information and communication technologies (ICT) assists researchers in effectively communicating with volunteer monitors (Gouveia & Fonseca, 2008). Participatory GIS, when community members submit locations online (Goodchild 2007), might also be helpful for watershed assessments engaging volunteers, though research results are limited in this area.

While exploring the purpose, advantages and challenges of community-based environmental monitoring by water quality VMOs, we will focus on the following three questions comparing VMOs in North Carolina and the rest of the United States: (1) What is the leadership structure of volunteer monitoring organizations? (2) What data collection procedures improve water quality data for volunteer monitoring organizations? (3) How are volunteer monitoring data currently used by volunteer monitoring organizations, managers and researchers?
Methods

A survey was made to obtain specific information from VMOs about the types of water quality data collected for the North Carolina Division of Water Resources (DWR) and a cooperating nonprofit organization. Data were needed in order to update stream monitoring efforts. Volunteer monitoring organizations in North Carolina were targeted, but answers from other states were desired for comparative purposes. The seven page online survey consisted of 25 questions, such as: how did your organization begin? are you associated with a professional scientist? how many years have you been collecting data? and how are data used? The survey included several sections: organizational information, monitoring and volunteer history, physical, chemical, and biological parameters collected, and data use. This study used questions pertaining to organizational structure, data collection procedures and data use in order to answer study questions and compare North Carolina to other states. The survey was created by the primary author while employed with DWR and reviewed by water resource professionals and professors prior to distribution (Appendix A).

Even though North Carolina does not have an official state sponsored monitoring program beyond a purely observational scope, there are still a wide variety of monitoring groups actively participating in monitoring with techniques developed on their own or through work with universities and the US EPA. With the Division of Water Resources contemplating the completion of an online water quality mapping interface for students to
upload their water quality data onto a state-wide map, it was essential to assess if other
VMOs from around the state existed and whether they might want to participate. It was
crucial to understand the types of data commonly collected by volunteer monitoring
organizations in order to understand the size requirements for a database.

The survey was sent to several public education and volunteer monitoring listservs
both within North Carolina and nationally (Table 4) over a period of approximately one
month. Respondents were self-selected and were not distributed randomly across the United
States. As is an issue with most surveys, participants both within North Carolina and around
the United States may have self selected not to participate. Because of the prolific nature of
email, the potential organizations who received the survey link cannot be quantified. Survey
respondents are not a complete list of organizations, which does not exist. This sample is a
self-selected sampling of volunteer monitoring organizations in the United States with access
to email. The US EPA National Directory of Volunteer Monitoring Programs website
provides a self-selected list of volunteer monitoring organizations
(http://yosemite.epa.gov/water/volmon.nsf/Home?OpenForm). Survey data analyzed include
quantitative response comparisons for North Carolina organizations versus organizations
outside of North Carolina. Data from questions with binary (Yes/No) responses were
analyzed using Chi-square analyses in SAS version 9.1.3 to determine if a significant
difference existed between North Carolina and volunteer monitoring groups in the rest of the
United States. Differences were tested at an alpha level of 0.05. Qualitative analysis was
also performed on select short answer questions in order to look for patterns in the response.
Results

One hundred forty different organizations and individuals responded to the survey. Eight filled out the survey but had not participated in monitoring activities by the time of the survey. Eleven more did not complete the survey through to the end, stopping the online questionnaire approximately halfway through for an actual number of responses at 121 completed surveys (n=121), with a response rate for those who clicked from their e-mail to open the survey document of 86.4%. Considering there may be more than 500 volunteer monitoring groups in North America (Nerbonne & Nelson, 2008), the adjusted response rate based on the potential total number of volunteer monitoring groups in the United States lowers to about 24%. Only half of those monitoring organizations subscribed to the volunteer monitoring listserv however, providing an increased response rate of 48%. However, considering only 24 organizations are presently listed from North Carolina in the National Directory (US EPA, 1998), and responses were received from 48 organizations in North Carolina, accurate numbers are unknown. Responses were received from groups in 32 states, including North Carolina. Figure 6 shows that the geographic distribution of survey responders is heavily skewed to the Eastern United States, with a few responders from Washington, Oregon, and Alaska being the exceptions.
Leadership Structure

Organizations were asked to self-identify by selecting an organization type, and were allowed to choose more than one option (Figure 7). Over half the total participants self identified as a non-profit organization. When describing the current leadership style for their volunteer monitoring organization, about two-thirds responded their group is a “bottom-up” or community-based organizations (Table 5) with no significant difference between North Carolina and other states (p=0.83). Survey participants were given the opportunity, but not required to explain how their organization began in short answer form. Qualitative analysis of the short answer responses indicated 43 groups had their origins in educational programming at the secondary (grades 6-12) or tertiary (13+) level. Sixty-eight organizations also indicated that their group origins were volunteer-based, with at least two mentioning that their organization had begun as a group of active volunteers and became a more structured program over time. A large number of organizations indicated origins with a state agency (18) or with city or county government (12).

Organizations were asked to provide information about whether their organization had always been top-down or bottom-up (Table 6). Several groups indicated that they did not think their groups fit into any one of the categories. This question was optional, and 15 groups opted to skip this question. There were 106 respondents total, 43 from NC and 63 from the rest of the US. These groups indicated that their leadership styles sometimes changed depending on the people involved at the time. No significant difference was
observed between North Carolina and other states (p=0.84) with respect to changing leadership styles. Fifty-seven percent of organizations indicated they have always been bottom-up.

Organizations were asked to indicate if they were associated with a professional scientist (Table 7). For the statistical analysis, No and Don’t Know answers were combined and treated as No. The logic here is that if the group did not know, then they probably were not working with a professional scientist. This question resulted in a significant difference between North Carolina, with 43.8% of groups not associated with a professional scientist and 26.0% of groups in the rest of the United States not associated with a professional scientist. The rest of the US is more than twice as likely as NC to be associated with professional scientists. (OR=2.21, p=0.04).

Organizations also were asked to describe the age of their organization, which is presented here in four categories: less than 1 year, 1 to 5 years old, 6 to 10 years old, and greater than 11 years old (Table 8). A majority of organizations from the United States excluding North Carolina (68.5%) were older than 6 years. In contrast, groups from North Carolina were much younger, with 64.6 percent less than 5 years old. Short answer responses to the question asking for a brief description of how organizations began confirmed program ages, with the two oldest groups originating in 1973.
Data Collection Procedures

Within the 121 groups who completed the survey, over 125 sites are sampled for some water quality value by organizational staff, over 330 sites are sampled by volunteers, and over 170 sites are sampled by volunteers and staff together. These totals amount to an astounding amount of work being accomplished. A total of 38 groups have been sampling for 11 or more years, with 8 of those sampling for more than 20 years (Table 8). Twenty-one groups were less than one year old, and 33 have been operating for 1 to 5 years (n=121). When comparing the age of groups in the United States to those in North Carolina, organizations within North Carolina were generally younger (p<0.001).

Organizations were asked whether training is required of their volunteers. One hundred twelve (92.6%) indicated that they required volunteers to receive training (Table 9). No significant difference was found between North Carolina and the rest of the United States with respect to training requirements for volunteers (p=0.31). An open-ended question allowed for specific information about what types of training are required. Forty of the organizations required some sort of classroom or workshop training or orientation. Several (17) actually use some sort of field training, and at least 13 require over 6 hours of training for volunteers. A few groups noted they performed sample collection only and professional labs analyzed the data. Nine groups indicated a required recertification or training annually, hoping to ensure greater data quality, but fourteen groups indicated they required little or no training of volunteers,
Typically, the implementation of a Quality Assurance / Quality Control (QA/QC) or QAPP is required for certain grant funders such as the EPA as well as many structured or top-down volunteer monitoring programs. Having a quality assurance plan for data quality is considered good practice for volunteers (US EPA 1996). When asked if a QA/QC exists for the monitoring site in question (Table 10), significantly greater number organizations in the US excluding NC have a QA/QC plan for their monitoring sites ($p<.001$). In fact, the rest of the US was 7.69 times more likely to have a plan in place than NC.

Data Use

Survey responses indicated that all organizations use the data collected by volunteer monitors for some purpose. Many organizations noted uses for management purposes, which included BMP implementation measurement, pre/post experiment data, state and local agency programs or regulations, and implementing change or policy advocacy. All noted some other use for data, including environmental education, awareness, internal publications, and long-term ambient monitoring. Several different data use purposes were analyzed: personal or intra-group uses (including education and activism), research, and for policy/management. When asked to list ways data collected by volunteers are used by their own organization, at least 31 were trying to identify water quality or stream health problems. Other data uses included TMDL calculations, modeling, education, advocacy, compliance and reporting, lawsuits, lobbying, and stream stewardship. Several groups admitted to not
making good use of volunteer collected data, but hoped to be able to use volunteer data more effectively in the future. Overall, most (75.2%) indicated that their data were used for some management purpose (Table 11). The US excluding NC is 8.67 times as likely to use the data for this purpose as groups within NC (p<0.0001).

Of particular interest to this study was whether or not data being collected by volunteers were used in published research or for management purposes. Many organizations indicated that they had published their data, but were not able to list the citation for the document. Many listed publications in gray or white literature including internal publications and reports to grantors. These were included in the Yes responses given in Table 12. Significantly fewer, only 12.5% of organizations in North Carolina indicated they had published data than the rest of the United States at 38.4% (p<0.01).

Discussion

Surveying VMOs can be difficult because of many organizations continuing creation, temporary nature, and volunteer leadership turnover. Using the listserv distribution method allowed for a quick response from more active organizations to obtain a maximum number of responses. Knowing correct contact information for monitoring organizations is difficult, considering only 24 organizations are presently listed from North Carolina in the National Directory (US EPA, 1998), and responses were received from 48 organizations in North
Carolina. These challenges in identifying the scope of monitoring organizations made truly random sampling very difficult. With 121 responses, however, we feel confident that an adequate sampling was made in order to develop discussion about the status of volunteer water quality monitoring in both North Carolina and the United States.

**Leadership Structure**

Most of the organizations both United States and North Carolina surveyed considered their organization to be bottom-up or community-based organizations (Table 5). These community-based organizations are considered more grassroots monitoring groups, which creates the working assumption they are less rigorous in terms of standards for training and quality control due to their reduced likelihood of access to professional scientists or trained personnel. However, comparing North Carolina to the rest of the United States adjusting for top-down versus bottom-up leadership styles revealed no significant difference in terms of training requirements ($p=0.4969$, Table 13). This suggests that leadership style does not impact whether or not training is required of volunteer monitors. Several groups indicated that their leadership styles have changed at some time (Table 6). Most started as bottom-up and remained community-based organizations over time. A large number of organizations indicated origins with a state agency (18) or with city or county government (12). These origins seemed to be the same no matter where the organization was located. Some groups were confused about whether or not having paid employees makes them a top-down
organization. The addition of paid employees for a watershed organization does not mean that the organization becomes top-down. The transition would occur slowly over time, and would depend on who controlled the decision making process. Six separate groups noted that they felt their organizations were either both or neither of the options given. These may indicate the groups that are truly cooperative, where top-down and bottom-up meets in the middle ground of collaboration. These results may show that the focus of many volunteer monitoring organizations is currently on local watershed areas. The assumption is that the localized bottom-up approach creates more dedicated volunteers. Though one survey question asked organizations about their volunteers being invested in the watershed, the question may have confused survey respondents. Further study is needed to determine what factors create dedicated volunteers, including the characteristics of a dedicated volunteer.

Qualitative analysis indicated school groups were important to volunteer monitoring organizations, with at least 43 groups indicating origins within a school or college. State agencies and city or county government also played an important role, although this was largely in groups from outside of North Carolina. With so many groups (68) indicating their group origins were related to volunteers, it is easy to see that many of the respondents were indeed bottom-up organizations at some point during their development. These organizations started monitoring as a small group of volunteers and monitoring methods were controlled by volunteers to serve the purpose of advocacy and education. There were also organizations that mentioned government origins, which confirmed the numbers of top-down organizations
represented. Qualitative results for origin year confirmed program ages as well - the two oldest groups originated in 1973.

When organizations were asked to indicate if they were associated with a professional scientist (Table 7), a majority of all organizations (66.9%) responded that they were. There was a significant difference between North Carolina and the rest of the United States (p=0.0426) in association with professional scientists, where North Carolina was only half as likely to have associations with professional scientists. Data collected by those groups associated with professional scientists seem to indicate a greater proportion of them used for publication in the United States. In fact, it was 3.76 times as likely in the rest of the US that data were used for publication when associated with professional scientists than in North Carolina (p=0.0099, Table 14). No existing group from North Carolina was able to list a scientific journal publication citation for their data.

Data Collection Procedures and Data Use

Data use was the most interesting aspect of the survey. Considering that 330 sites are monitored by volunteers alone, huge amounts of data are being collected by this small sample of volunteer monitoring groups. Data from these sites were used by all organizations. Many noted that their data were primarily for educational purposes, which is also noted in several other studies (Nerbonne & Nelson, 2008, Ely 2008a). This environmental education purpose for volunteer water quality monitoring is a very important part of volunteer water
quality monitoring programs, as it allows the participants to gain awareness about environmental issues in their communities. If the end goal of volunteer water quality monitoring is gaining awareness of environmental issues, then any data collection is considered a success.

Survey participants of 87 organizations (71.9%), reported their data have never been used for research purposes, nor have their data been published in a research journal. Publishing data in a peer reviewed journal provides a level of scientific rigor that would be necessary for more research scientists to accept reports from volunteer monitoring organizations as accurate. Many of the groups indicated that their group had published data, but were not able to provide citations or listed a citation that was from gray literature, such as a government report. Several groups published their own reports, and one was in the process of publishing data in a peer-reviewed journal. Two VMOs were able to provide three citations from peer-reviewed literature. These discrepancies may be largely due to miscommunications between cooperating scientists and the monitoring group leaders, many of whom needed to talk to their cooperating scientists for more information. Researchers may indeed be using these volunteer monitoring group data for publication, but not indicating data collection methods that included volunteers or may not be communicating with groups after publication to help the volunteers to understand how their data assisted with research efforts. Researchers may benefit from sharing how they use volunteer collected data collected with environmental monitoring volunteers in order to help monitoring groups understand watershed assessment techniques and the importance of volunteer work. Several
groups admitted to not making good use of volunteer collected data, but hoped to be able to use volunteer data more effectively in the future. Volunteer groups may be over reporting published data because they are proud of their efforts and want their data to be used by the scientific community. Working through strong partnerships with professional scientists may help these groups realize their goal of effective data use.

Similar to data use for research, 91 (75.2%) organizations indicated that their data were being used for watershed management purposes (Table 11). Again, North Carolina volunteer monitoring organizations trailed behind other organizations from around the United States, with only 52.1% of VMOs reporting management uses for data. Of the groups in North Carolina that indicated their data were being used for some sort of watershed management purpose, several noted they hoped that their data could be used by state government to classify a water body as impaired or to inspire government organizations to investigate a local water body further. This underuse of data may be due to the lack of organization on the state level or hesitancy to use volunteer data due to quality concerns (Penrose and Call 1995).

North Carolina was defined by Nerbonne and Nelson (2004) as a “limited support” system state. This means that there are volunteer macroinvertebrates programs older than one year in North Carolina, but there is little or no guidance to support these efforts at the state level. Survey answers from this study agree with those found on the EPA volunteer monitoring national directory (US EPA 1998) that certain areas and states across the United States have better engaged their volunteers than others. Groups within North Carolina
associated with researchers and municipalities have successfully implemented training for volunteers, as well as QA plans that are accepted by the EPA. Their data, however, continue to be absent from peer-reviewed literature. Further research is needed, including a case study to present these examples and use them to develop further programming. Volunteer networks in each state have different levels of training required. With the adaptation of state or regional level training standards, more collection and study results could make it to publication. This increases and improves data available for research and agency use, as well as establishing local or regional benchmarks pertaining to the watersheds studied.

**Conclusion**

According to Nerbonne and Nelson (2004), state employees interviewed noted they felt that volunteer data could contribute to the state and local monitoring needs but also noted they could not accept data that did not conform to certain quality control standards. These interviews also identified several states that do not accept volunteer data because of its “questionable quality.” These states were not identified. Many states struggle to find a meaningful use for the volunteer collected data. Survey results indicate that volunteer monitoring can be part of the solution to the limited availability of environmental monitoring data for watershed assessment and management. Volunteers collect large amounts of data through VMOs for free without knowing if their data will ever be used. Many volunteer
monitoring groups expressed a strong interest in having their data used beyond just environmental education purposes. In order for this to happen, quality assurance measures must be met to ensure high quality data are collected. Our survey shows that water quality VMOs across the United States are in fact requiring training of volunteers and work with governments and research scientists on a regular basis. The next step towards ensuring high quality data is organization at the state or regional level in order to standardize training or quality assurance requirements. This is necessary to ensure data of a high enough quality to be useful to researchers and managers.

Volunteer monitoring is also useful for researchers, managers, and communities through the large amount of social capital it provides. Engaging volunteers to collect data could save money and time, allowing researchers to spend their time actually analyzing data. Many grantors such as the National Science Foundation (NSF) require public education components as part of grant programs, and volunteer monitoring organizations serve that need through their strong environmental education components. Many groups are, and should be, proud of their use of monitoring data for educational purposes. Working with a local monitoring group can help researchers integrate education into their research. Volunteers also benefit from this partnership through their data being more widely recognized and used. Research partnerships allow volunteer monitoring groups to gain more exposure as well; however researchers need to do a better job of working with community members to explain the publishing process and provide articles to VMOs.
Because of the limited leadership at the state level in North Carolina, VMOs have developed on their own with little guidance from government officials. At the time of this survey, North Carolina water quality VMOs are largely young (64.6% less than 5 years old), bottom-up organizations (66.7%) who have always been bottom-up (60.4%). NC VMOs are affiliated with professional scientists (56.3%), but are unlikely to publish in peer-reviewed journals, with only 12.5% having published any data at all. Though most VMOs in North Carolina require some sort of training for volunteers (89.6%), only 35.4% have some sort of quality assurance / quality control plan in place for data quality assurance. About half of all NC VMOs indicate they use their data for management purposes.

Though data use for watershed management purposes is currently limited within North Carolina, the establishment of standards for volunteer collected data at the state level would help to begin the process of volunteer data use across North Carolina. Implementing standards at the state level creates an environment of rigor and standards for data quality. Thus, improved organization at the state level could enhance the use of volunteer water quality data in North Carolina by municipal governments and researchers. Many other states use data significantly more for both management and research purposes, and considering the time and money that can be saved with volunteers, there is good reason to consider volunteer contributions. Even purely as an environmental education exercise, having a set of quality assurance standards and collection methods could add to the greater understanding of the scientific process for volunteer monitors. Teachers are highly motivated to partner with researchers and communities to conduct monitoring research with students as a way to
engage their students in scientific inquiry and research (Edwards, 2004). This may provide an opportunity to develop and test volunteer monitoring methods and standards. Volunteer monitors can serve to benefit from both data use for environmental education purposes as well as by the use of their data to improve management or research data.

Volunteer monitoring organizations can effectively monitor water quality. Programs across the US have volunteers monitoring successfully, including Alabama Water Watch (AWW) and Maryland and Virginia Save Our Streams (SOS). Many lake monitoring programs have existed for decades and their data are frequently used for water quality assessment. These organized groups operating at the state level help organizations feel like they are contributing to the greater good and also that state government officials value their contribution. Programs such as these should be developed such that they create a positive atmosphere of ownership on the part of the local VMOs, in order to avoid burnout by volunteer participants. With the rise of social media and the potential social capital gained from volunteer monitoring, it may be time to explore development of state or regional level programs with developed quality assurance plans. VMOs can be a great asset to researchers and managers.

Researchers, managers, and VMOs can choose to work together towards common goals through strong working partnerships, even without state level participation. These positive partnerships can make a difference for researchers and local environments. Water quality is important to each and every one of us, and as surface waters become more taxed
and impaired due to anthropogenic influence, it is important we have an accurate and detailed picture of water quality before it’s too late!
References


Edwards P (2004) Improving Aquatic Insect Identifications Made by Students and Volunteers. In Best Education Practices (BEPs) for Water Outreach Professionals, Madison, WI.


Gooch M (2005) Voices of the volunteers: an exploration of the experiences of catchment volunteers in costal Queensland, Australia. Local Environment 10:5-19


Table 4: Survey link distribution via various listservs. Exact numbers of respondents from each listserv group are unknown.

<table>
<thead>
<tr>
<th>Listserv Name</th>
<th>Audience</th>
<th>4/27/09 12:02am</th>
<th>5/11/09 11:18pm</th>
<th>5/26/09 9:36pm</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="mailto:ncscteach@lists.ncsu.edu">ncscteach@lists.ncsu.edu</a></td>
<td>Science Teachers in North Carolina</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><a href="mailto:nc-ee@lists.ncmail.net">nc-ee@lists.ncmail.net</a></td>
<td>Environmental Education listserv in North Carolina</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><a href="mailto:volmonitor@lists.epa.gov">volmonitor@lists.epa.gov</a></td>
<td>US EPA volunteer monitoring listserv</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><a href="mailto:stormwater.outreachandeducation@mail.net">stormwater.outreachandeducation@mail.net</a></td>
<td>Storm water in NC and beyond</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><a href="mailto:watereducatorsusa@lists.uwex.edu">watereducatorsusa@lists.uwex.edu</a></td>
<td>Water Educators from around the United States</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Table 5: Top-down versus bottom-up volunteer water quality monitoring organizations (n=121).

<table>
<thead>
<tr>
<th>Organization Leadership Style / Area</th>
<th>Top-down number (%)</th>
<th>Bottom-up number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=73)</td>
<td>23 (31.5%)</td>
<td>50 (69.5%)</td>
</tr>
<tr>
<td>NC (n=48)</td>
<td>16 (33.3%)</td>
<td>32 (66.7%)</td>
</tr>
<tr>
<td>Entire US (n=121)</td>
<td>39 (32.2%)</td>
<td>82 (67.8%)</td>
</tr>
</tbody>
</table>
Table 6: Historical organization leadership style of volunteer monitoring organizations (n=106).

<table>
<thead>
<tr>
<th>Historical Organization Leadership Style / Area</th>
<th>Always Top-down (%)</th>
<th>Always Bottom-up (%)</th>
<th>Top-down to Bottom-up (%)</th>
<th>Bottom-up to Top-down (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=63)</td>
<td>16 (25.4%)</td>
<td>34 (54.0%)</td>
<td>6 (9.5%)</td>
<td>7/63 (11.1%)</td>
</tr>
<tr>
<td>NC (n=43)</td>
<td>11 (25.6%)</td>
<td>26 (60.4%)</td>
<td>3 (7.0%)</td>
<td>3/43 (7.0%)</td>
</tr>
<tr>
<td>Entire US (n=106)</td>
<td>27 (25.5%)</td>
<td>60 (56.6%)</td>
<td>9 (8.5%)</td>
<td>10 (9.4%)</td>
</tr>
</tbody>
</table>
Table 7: Professional scientist associations of volunteer monitoring groups (n=121)

<table>
<thead>
<tr>
<th>Professional Scientist Association / Area</th>
<th>Yes (%)</th>
<th>No (%)</th>
<th>Don’t Know (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=73)</td>
<td>54 (74.0%)</td>
<td>11 (15.0%)</td>
<td>8 (11.0%)</td>
</tr>
<tr>
<td>NC (n=48)</td>
<td>27 (56.3%)</td>
<td>19 (39.6%)</td>
<td>2 (4.2%)</td>
</tr>
<tr>
<td>Entire US (n=121)</td>
<td>81 (66.9%)</td>
<td>30 (24.8%)</td>
<td>10 (8.3%)</td>
</tr>
</tbody>
</table>
Table 8: Years each volunteer organization has been completing monitoring activities at their oldest site (n=121).

<table>
<thead>
<tr>
<th>Years Experience Monitoring / Area</th>
<th>≤1 year (%)</th>
<th>2 to 5 years (%)</th>
<th>6 to 10 years (%)</th>
<th>11+ years (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=73)</td>
<td>6 (8.2%)</td>
<td>17 (23.3%)</td>
<td>22 (30.1%)</td>
<td>28 (38.4%)</td>
</tr>
<tr>
<td>NC (n=48)</td>
<td>15 (31.3%)</td>
<td>16 (33.3%)</td>
<td>7 (14.6%)</td>
<td>10 (20.8%)</td>
</tr>
<tr>
<td>Entire US (n=121)</td>
<td>21 (17.4%)</td>
<td>33 (27.3%)</td>
<td>29 (24.0%)</td>
<td>38 (31.4%)</td>
</tr>
</tbody>
</table>
Table 9: Training required of volunteers (n=121).

<table>
<thead>
<tr>
<th>Training Required for Volunteers / Area</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=73)</td>
<td>69 (94.5%)</td>
<td>4 (5.5%)</td>
</tr>
<tr>
<td>NC (n=48)</td>
<td>43 (89.6%)</td>
<td>5 (10.4%)</td>
</tr>
<tr>
<td>Entire US (n=121)</td>
<td>112 (92.6%)</td>
<td>9 (7.4%)</td>
</tr>
</tbody>
</table>
Table 10: Does a Quality Assurance / Quality Control (QA/QC) plan exist for this monitoring site? (n=121)

<table>
<thead>
<tr>
<th>QA/QC plan / Area</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=73)</td>
<td>59 (80.8%)</td>
<td>14 (19.2%)</td>
</tr>
<tr>
<td>NC (n=48)</td>
<td>17 (35.4%)</td>
<td>31 (64.6%)</td>
</tr>
<tr>
<td>Entire US (n=121)</td>
<td>76 (62.8%)</td>
<td>45 (37.2%)</td>
</tr>
</tbody>
</table>
Table 11: Are data collected by volunteers used for any of these watershed management purposes? (n=121)

<table>
<thead>
<tr>
<th>Area</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=73)</td>
<td>66 (90.4%)</td>
<td>7 (9.6%)</td>
</tr>
<tr>
<td>NC (n=48)</td>
<td>25 (52.1%)</td>
<td>23 (47.9%)</td>
</tr>
<tr>
<td>Entire US (n=121)</td>
<td>91 (75.2%)</td>
<td>30 (24.8%)</td>
</tr>
</tbody>
</table>
Table 12: Has volunteer collected data been published for research? (n=121) This question asked about published research in peer-reviewed journals, but some respondents noted white or gray literature citations. Many could not give the citations, but were told by the professional scientist that data were used in publications.

<table>
<thead>
<tr>
<th>Published Data / Area</th>
<th>Yes (%)</th>
<th>No (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>US excluding NC (n=73)</td>
<td>28 (38.4%)</td>
<td>45 (61.6%)</td>
</tr>
<tr>
<td>NC (n=48)</td>
<td>6 (12.5%)</td>
<td>42 (87.5%)</td>
</tr>
<tr>
<td>Entire US (n=121)</td>
<td>34 (28.1%)</td>
<td>87 (71.9%)</td>
</tr>
</tbody>
</table>
Table 13: Leadership Structure versus Training Requirements: Is Training Required? (n=121).

<table>
<thead>
<tr>
<th>Area</th>
<th>Leadership Structure</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No (%)</td>
</tr>
<tr>
<td><strong>NC</strong></td>
<td>Bottom-up</td>
<td>5 (15.6%)</td>
</tr>
<tr>
<td></td>
<td>Top-down</td>
<td>0 (--)</td>
</tr>
<tr>
<td><strong>US excluding NC</strong></td>
<td>Bottom-up</td>
<td>2 (2.7%)</td>
</tr>
<tr>
<td></td>
<td>Top-down</td>
<td>2 (2.7%)</td>
</tr>
<tr>
<td><strong>Entire US</strong></td>
<td>Bottom-up</td>
<td>7 (8.5%)</td>
</tr>
<tr>
<td></td>
<td>Top-down</td>
<td>2 (5.1%)</td>
</tr>
</tbody>
</table>
Table 14: Publication of Data versus Professional Scientist Association (n=121).

<table>
<thead>
<tr>
<th>Area</th>
<th>Professional Scientist Association</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No (%)</td>
</tr>
<tr>
<td><strong>NC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No/Don’t Know</td>
<td></td>
<td>20 (41.7%)</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td>22 (45.8%)</td>
</tr>
<tr>
<td><strong>US excluding NC</strong></td>
<td></td>
<td>15 (20.5%)</td>
</tr>
<tr>
<td>No/Don’t Know</td>
<td></td>
<td>30 (41.1%)</td>
</tr>
<tr>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Entire US</strong></td>
<td></td>
<td>35 (28.9%)</td>
</tr>
<tr>
<td>No/Don’t Know</td>
<td></td>
<td>52 (43.0%)</td>
</tr>
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</table>
Table 15: Table of Statistical Results, including odds ratios and p-values.

<table>
<thead>
<tr>
<th>Table</th>
<th>OR US vs NC = ’Yes’</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2: Top-down versus bottom-up volunteer water quality monitoring organizations&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.920</td>
<td>0.423, 2.001</td>
<td>0.8334</td>
</tr>
<tr>
<td>Table 3: Historical organization leadership style of volunteer monitoring organizations&lt;sup&gt;b&lt;/sup&gt;</td>
<td>N/A</td>
<td>N/A</td>
<td>0.8396</td>
</tr>
<tr>
<td>Table 4: Professional scientist associations of volunteer monitoring groups&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.211</td>
<td>1.020, 4.792</td>
<td>0.0426</td>
</tr>
<tr>
<td>Table 5: Years each volunteer organization has been completing monitoring activities&lt;sup&gt;d&lt;/sup&gt;</td>
<td>N/A</td>
<td>N/A</td>
<td>0.0003</td>
</tr>
<tr>
<td>Table 6: Training required of volunteers&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.006</td>
<td>0.510, 7.884</td>
<td>0.3113</td>
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<tr>
<td>Table 7: Quality Assurance / Quality Control (QA/QC) plan exist for this monitoring site&lt;sup&gt;e&lt;/sup&gt;</td>
<td>7.685</td>
<td>3.350, 17.629</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Table 8: Has volunteer collected data been published for research&lt;sup&gt;e&lt;/sup&gt;</td>
<td>4.356</td>
<td>1.640, 11.569</td>
<td>0.0020</td>
</tr>
<tr>
<td>Table 9: Are data collected by volunteers used for any of these watershed management purposes&lt;sup&gt;e&lt;/sup&gt;</td>
<td>8.674</td>
<td>3.311, 22.726</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Table 10: Organizational Leadership Structure versus Training Requirements&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.008</td>
<td>0.408, 10.689</td>
<td>0.4969</td>
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<tr>
<td>Table 12: Publication of Data versus Professional Scientist Association&lt;sup&gt;f&lt;/sup&gt;</td>
<td>3.759</td>
<td>1.317, 12.436</td>
<td>0.0099</td>
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<sup>a</sup> Unadjusted Odds Ratio and 95% CI for Top-down organizational structure in the US excluding NC. P-value based on Pearson Chi-Square test.

<sup>b</sup> P-value based on Cochran Mantel Haenzel test for General Association.

<sup>c</sup> Unadjusted Odds Ratio and 95% CI for “Yes” response in the US excluding NC. P-value based on Pearson Chi-Square test.

<sup>d</sup> P-value based on Cochran Mantel Haenzel test for Non-Zero Correlation.

<sup>e</sup> Exact Odds Ratio, 95% CI, and P-value from Logistic regression model controlling for Organizational Structure within Region predicting Training Requirements.

<sup>f</sup> Exact Odds Ratio, 95% CI, and P-value from Logistic regression model controlling for Association with Professional Scientist within Region predicting Publication of Data.
Figure 6: Geographic Distribution of Survey Responders. North Carolina had the highest number at n=48, which was expected due to the targeting of North Carolina organizations.
Figure 7: Self-selected organization type, where each organization was allowed to choose more than one response.
CHAPTER 5: CONCLUSION

The goal of this study is to understand the dynamics of volunteer water quality monitoring in the United States, specifically North Carolina, as well as to provide an example of closely monitored volunteer data that could be used in watershed assessment studies with community members or students, particularly in urbanizing areas. Involving community members as volunteer monitors may not require extra work, but simply networking and partnering with local volunteer monitoring groups already sampling in the watershed area. With so many water quality volunteer monitoring organizations (VMOs) in existence across the United States, a community group may already be involved in an area being considered for watershed research. Many of these VMOs are bottom-up, grassroots organizations that already conduct some sort of training for their volunteers and try to develop data quality control procedures. But, this greatly varies by location. North Carolina has fewer groups that already work with professional scientists and develop quality assurance plans for their data collection. Perhaps through the encouraging prospect of volunteer monitoring as a tool for environmental education as well as data collection, more research scientists and managers will be inspired to incorporate VMOs into their research plans. Though some researchers are hesitant to use volunteer collected data for use in their research, with the proper training for volunteers and data validity analysis in place, there is no reason volunteer data is any less acceptable than say student collected data, but more study is needed to confirm this comparison.
Volunteer monitoring has long been completed for environmental education purposes, when volunteers collect data and gain knowledge and awareness of the watershed process. This environmental education purpose to volunteer monitoring is not without merit on its own, and is likely to continue. However, with the huge amounts of data required to monitor climate change as well as extensive surface water networks on which we have become increasingly dependent, volunteer environmental monitoring for the data itself is becoming more accepted. It is important for researchers to be sure to include volunteers in a meaningful way and keep a strong education component in volunteer monitor training. Volunteer monitors allow data to be collected over a greater spatial and temporal range, thus increasing data collection beyond the normal range of state, local, or research abilities (Cohn, 2008). Various studies have utilized data collected by volunteer monitors or citizen scientists for years both for environmental education purposes and to collect data, including the National Weather Service through the National Weather Service spotter program (Firehock and West, 1995), ornithological researchers through various long-standing bird watching programs (Bonney and others, 2009; Greenwood, 2007) and lake monitoring programs for turbidity using Secchi disks (Heiskary and others, 1994; Kerr and others, 1994; Obrecht and others, 1998).

Through the use of volunteer monitors in the Black Creek watershed assessment in North Carolina, researchers were able to include community members as part of a watershed association to better understand the tasks of the watershed research team and gain knowledge and environmental awareness about issues affecting the watershed. Simple data collection
procedures allowed the volunteers to assist with the monitoring efforts, and the creation of a geodatabase served to engage the citizens through development of a sense of place. These simple methods for certain water quality and GIS data collection engaged volunteers from the community. Activities such as a pollution inventory or stream habitat assessment are easily completed by a watershed group after a few hours of simple training. Involving community members in some way even minimally in an interpretive approach CBM, can create a community that is environmentally aware and excited about watershed protection. Data collected can be used to develop a more complete picture of the watershed area.

The use of volunteer monitoring data beyond that of indicator or soft data serves several important purposes. First, volunteers benefit by enhanced learning about the environment through watershed activities such as data collection. Volunteer monitors may benefit through development of larger community environmental knowledge, awareness and involvement due to their participation in watershed monitoring (Conrad, 2006; Spellerberg, 2005). The use of monitoring for environmental educational purposes is of great benefit to many researchers now. As granting organizations such as the National Science Foundation (NSF) require more often that researchers communicate their findings to the public in a meaningful and educational way, volunteer monitoring can serve that purpose. The environmental education aspect of volunteer water quality monitoring is very positive, with many VMOs acknowledging that environmental education is their primary purpose (Borden and others, 2007; Koehler and Koontz, 2008; Nerbonne and Nelson, 2008). In addition to environmental education, volunteer monitoring can also serve as a valuable source of high
quality data for a much broader range spatially and temporally than researchers are currently able to collect (Cohn, 2008). Thanks to the very nature of volunteering, the only money necessary for volunteer assistance is money for training and equipment for volunteer use in the field. This allows researchers to engage volunteers to continue monitoring over a longer period of time or to monitor a larger number of sites. This extension of monitoring is in the best interest of researchers completing long term research or seeking to obtain baseline data and then comparison data sometime later.

Because of the limited leadership at the state level in North Carolina, VMOs have developed on their own with little guidance from government officials. At the time of this survey, North Carolina water quality VMOs are largely young (64.6% less than 5 years old), bottom-up organizations (66.7%) who have always been bottom-up (60.4%). NC VMOs are affiliated with professional scientists (56.3%), but are unlikely to publish in peer-reviewed journals, with only 12.5% having published any data at all. Though most VMOs in North Carolina require some sort of training for volunteers (89.6%), only 35.4% have some sort of quality assurance / quality control plan in place for data quality assurance. About half of all NC VMOs indicate they use their data for management purposes.

We must also consider the volunteer. Keeping the volunteers excited about monitoring even after grant funding expires is important for these programs. Through the course of data collection, the volunteer monitors become a resource in which professional scientists have invested time and money. But, even without funding, many volunteer monitoring organizations exist purely due to the desire of community members to keep their
local stream or lake clean and safe. Engaging these dedicated volunteers for data collection is a positive and simple move in the direction of a more complete temporal and spatial picture of water quality across the United States.

Baseline community engagement can be visualized using the scale of community involvement (Table 1). Increasing community member participation in watershed assessment through the creation of a community-led watershed association in concert with university-based research is recommended. The Black Creek watershed assessment also benefited through the creation of a watershed association. The BCWA has allowed for research to continue beyond the original grant period of three years. The Black Creek watershed assessment moved through the scale of community involvement. Many research projects are scientist controlled CBM, where professional scientists collect and interpret the data. With the creation of a watershed association, the Black Creek watershed assessment began to move towards the community involvement end of the scale. While in the grant period, the CBM took a largely interpretive approach. While seeking further grant funding and a new technical team, the BCWA ran much of the show in the watershed and could be considered and externally controlled or even community controlled CBM. Because of the organization origins in the realm of university research, it is unlikely BCWA will ever be considered an advocacy CBM, but researchers may benefit from involvement with advocacy CBMs. The middle part of the scale may be ideal for high quality data and community involvement, but more research is needed to understand group dynamics.
There are several challenges that still need to be addressed concerning volunteer monitoring. Researchers cannot say what the error is on volunteer collected data versus other groups. Validity data for test other than Secchi disk depth (Heiskary and others, 1994; Kerr and others, 1994; Obrecht and others, 1998) and macroinvertebrates (Fore and others, 2001; Nerbonne and Vondracek, 2003; Penrose and Call, 1995) are unavailable and warrant further research. Research efforts that include volunteer monitoring data can help address this challenge through validity testing where the researcher collects data in tandem with the volunteers. This would allow for error to be calculated on data collected by volunteers. But this data would not necessarily hold true for each VMO, which brings up another challenge. If volunteer monitoring is to be widely accepted, standardized procedures at the state or even regional scale may be necessary. This could create an environment of control or top-down structure where there is less ownership of the monitoring and data collection by community members. Keeping the focus local may help to obtain or attract and maintain high quality volunteers, but there is no data either way. Studies need to be completed in several state programs as well as in states with less centralized programs to determine if organizational structure affects volunteer motivation. This is important because volunteer monitors are often perceived to be unreliable and can burn out (Byron and Curtis, 2002). The more motivated the volunteer, the more reliable they may be when collecting data. Another challenge for volunteer monitoring lies in training volunteers. The optimal training methods for volunteer monitoring need to be determined in order to increase accuracy of volunteer collected data. The training involved needs to be of high quality and also directly relevant
for the tasks the volunteer monitor will encounter (Fore and others, 2001). Questions about whether or not training should be ongoing, should be repeated or even should require a certification are important. Further study is needed to determine the most effective training to obtain better quality data from volunteers.

Perceptions of the research community need to be positively influenced in order to create a more accurate picture of the quality of data volunteers are able to collect. By increasing validity studies and the use of volunteer collected data in published research studies, data can be seen as more acceptable in the scientific world. Even if professional scientists only begin working with volunteer monitoring organizations for the environmental education benefit, there may still be great benefits for VMO who want to have their data used by researchers and managers to help protect the watersheds they love.
References


REFERENCES


Edwards, P. (2004). Improving Aquatic Insect Identifications Made by Students and Volunteers. In Best Education Practices (BEPs) for Water Outreach Professionals, Madison, WI.


Appendix A: Stream Habitat Assessment Sheet with Training Notes

Notes

Streambank Stability Parameter Scores

<table>
<thead>
<tr>
<th>Streambank 1</th>
<th>Parameter</th>
<th>Excellent (4)</th>
<th>Good  (3)</th>
<th>Fair (2)</th>
<th>Poor (1)</th>
<th>Score</th>
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<td></td>
<td>Bank Height Ratio</td>
<td>1.0 - 1.2</td>
<td>1.2 - 1.5</td>
<td>1.5 - 2.0</td>
<td>&gt; 2.0</td>
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<td>40 - 60</td>
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<tr>
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</tr>
<tr>
<td></td>
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<td>40 - 60</td>
<td>20 - 40</td>
<td>&lt; 20</td>
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</tr>
<tr>
<td></td>
<td>Near Bank Stress</td>
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<td>Moderate</td>
<td>High</td>
<td>Very High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Score</td>
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</table>

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<td>&lt; 45</td>
<td>45 - 60</td>
<td>60 - 75</td>
<td>&gt; 75</td>
<td></td>
</tr>
<tr>
<td>Surface Protection %</td>
<td>60 - 100</td>
<td>40 - 60</td>
<td>20 - 40</td>
<td>&lt; 20</td>
<td></td>
</tr>
<tr>
<td>Near Bank Stress</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Very High</td>
<td></td>
</tr>
<tr>
<td><strong>Total Score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mean Total Score for All Four Reaches**

### Bedform Macrohabitat Scores

Observe condition and density of channel geomorphic features while walking the reach. Rate each macrohabitat feature in the table below in accordance with the conditions along the entire reach.

<table>
<thead>
<tr>
<th>Macro-Habitat</th>
<th>Excellent (4)</th>
<th>Good (3)</th>
<th>Fair (2)</th>
<th>Poor (1)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riffles</td>
<td>About half of stream length with long, steep riffles with clean gravel - high flow</td>
<td>Some good riffle features</td>
<td>Few good riffle features</td>
<td>Non-existent</td>
<td></td>
</tr>
<tr>
<td>Pools</td>
<td>About half of stream length with deep pools located in meander bends with stable outside banks</td>
<td>Some good pool features</td>
<td>Few good pool features</td>
<td>Non-existent</td>
<td></td>
</tr>
<tr>
<td>Structure-related habitats</td>
<td>Many structure-related features providing flow diversity, refuge, and habitat enhancement</td>
<td>Some good structures</td>
<td>Few good structures</td>
<td>Non-existent</td>
<td></td>
</tr>
</tbody>
</table>

**Total Score**

### Cover and Refuge Scores

Walk the stream and note the presence and quality of cover features, including the cover types listed below. For each cover type, score the functional value based on its availability for enhancing habitat. On the last line of this Table, assign a score based on the percent stream length containing some form of cover and refuges to enhance habitat.
Cover Type | Excellent (4) | Good (3) | Fair (2) | Poor (1) | Score
---|---|---|---|---|---
Undereat Banks | Abundant | Moderate | Sparse | None | 
Leaf Pack | Abundant | Moderate | Sparse | None | 
Overhanging Vegetation | Abundant | Moderate | Sparse | None | 
Pools > 2 ft deep | Abundant | Moderate | Sparse | None | 
Root Wads | Abundant | Moderate | Sparse | None | 
Boulders | Abundant | Moderate | Sparse | None | 
Oxbows, backwaters | Abundant | Moderate | Sparse | None | 
Aquatic Macrophytes | Abundant | Moderate | Sparse | None | 
Logs and Woody Debris | Abundant | Moderate | Sparse | None | 
Overall Cover & Refuge | > 50% | 25 - 50% | 5 - 25% | < 5% | Total Score

Notes

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Floodplain Condition

First determine the riparian vegetation structure and density, then walk the reach observing the features noted in the floodplain condition table below and rate each feature based on the average condition along the entire reach. To determine riparian vegetation structure and density, locate four line transects 30 ft long extending outward from the streambank, perpendicular to streamflow. Locate the transects at a distance to represent the range of riparian vegetation conditions. Estimate the percent bare ground and percent cover of herbaceous vegetation along the transect in a zone 5 ft either side of the transect centerline. Estimate the percent cover of shrubs along the transect in a zone 10 ft either side of the transect centerline. Estimate the percent cover of trees in a zone 20 ft either side of the transect centerline. Note presence of exotic invasive shrubs, trees, or vines.

Riparian Vegetation Cover

<table>
<thead>
<tr>
<th>Structural Element</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trees</td>
<td></td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
</tr>
<tr>
<td>Herbs</td>
<td></td>
</tr>
<tr>
<td>Bare Ground</td>
<td></td>
</tr>
</tbody>
</table>

Notes

---

4
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Excellent (4)</th>
<th>Good (3)</th>
<th>Fair (2)</th>
<th>Poor (1)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floodplain Connection</td>
<td>High flows (greater than bankfull) and bankfull can enter floodplain. Stream not deeply incised.</td>
<td>High flows (greater than bankfull) and bankfull can enter floodplain. Some incision occurring.</td>
<td>High flows (greater than bankfull) but less than 2X bankfull not able to enter floodplain. Stream not deeply incised.</td>
<td>High flows (greater than 2X bankfull) and bankfull not able to enter floodplain. Stream deeply incised.</td>
<td></td>
</tr>
<tr>
<td>Vegetated Buffer Width</td>
<td>Width of buffer zone &gt; 50 feet; human activities (e.g. parking lots, roadbeds, clear cut, lawns, crops) have not impacted zone.</td>
<td>Width of buffer zone 25-50 feet; human activities have impacted zone minimally.</td>
<td>Width of buffer zone 10-25 feet; human activities have impacted zone significantly.</td>
<td>Width of buffer zone &lt; 10 feet; little or no riparian vegetation due to human activities.</td>
<td></td>
</tr>
<tr>
<td>Riparian Vegetation Structural Complexity and Diversity**</td>
<td>All 3 classes of vegetation present, &gt; 70% tree cover and at least 20% shrub cover - class C very poor.</td>
<td>At least one woody class and one herbaceous class present, &gt; 70% combined cover.</td>
<td>At least one woody class present, &gt; 70% combined cover.</td>
<td>No woody class present, herbaceous cover &gt; 50%.</td>
<td></td>
</tr>
<tr>
<td>Floodplain Habitat</td>
<td>Mix of wetland and non-wetland habitats, evidence of standing/pooling water.</td>
<td>Mix of wetland and non-wetland habitats, no evidence of standing/pooling water.</td>
<td>Either all wetland or all non-wetland habitats, evidence of standing/pooling water.</td>
<td>Either all wetland or all non-wetland habitat, no evidence of standing/pooling water.</td>
<td></td>
</tr>
<tr>
<td>Floodplain Encroachment</td>
<td>No evidence of floodplain encroachment in the form of fill, land development, or manmade structures.</td>
<td>Minor floodplain encroachment in the form of fill, land development, or manmade structures, but not affecting floodplain function.</td>
<td>Moderate floodplain encroachment in the form of fill, land development, or manmade structures, some effect on floodplain function.</td>
<td>Significant floodplain encroachment (i.e. fill material, land development, or manmade structures), significant effect on floodplain function.</td>
<td></td>
</tr>
<tr>
<td>Percent Exposed or Bare Ground</td>
<td>10% or less of the site with exposed soil surface.</td>
<td>10% to 20% of the site has exposed soil surface.</td>
<td>20% to 50% of the site has exposed soil surface.</td>
<td>&gt; 50% of the site has exposed soil surface.</td>
<td></td>
</tr>
<tr>
<td>Stormwater Outfall Quality (urban projects only)</td>
<td>Excellent</td>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
<td>Total Score</td>
</tr>
</tbody>
</table>

---

Note: The table provides a qualitative assessment of floodplain conditions based on various parameters. The score is calculated based on the extent to which each parameter is met or exceeded.
### Final Assessment Table

<table>
<thead>
<tr>
<th>Category</th>
<th>Metric</th>
<th>Range of Scores</th>
<th>Score</th>
<th>Divide by</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Condition</td>
<td>Streambank Stability</td>
<td>6 – 24</td>
<td></td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bedform Condition</td>
<td>3 – 12</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cover and Refuge</td>
<td>10 – 40</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Riparian Condition</td>
<td>Floodplain and Riparian Vegetation</td>
<td>7 – 28</td>
<td></td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Overall Mean Score
Appendix B: Volunteer Monitoring Survey

Volunteer Water Quality Monitoring in the US

1. Introduction

These data are being collected by the North Carolina Department of Environment and Natural Resources, Division of Water Resources to assess volunteer water quality monitoring groups across North Carolina and the United States. This survey will fill in gaps in information about how many different volunteer monitoring groups exist and what impact their data has on management practices.

There are no "right" or "wrong" answers. Please help by allowing us to follow up with any questions we might have later on by providing accurate contact information. Please feel free to distribute this survey to a broad audience and complete your answers by May 28, 2009.

Thank you in advance for taking the time to complete this survey.

2. Organizational Information

* Contact Information

<table>
<thead>
<tr>
<th>Organization:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Name:</td>
</tr>
<tr>
<td>Address:</td>
</tr>
<tr>
<td>Address 2:</td>
</tr>
<tr>
<td>City/Town:</td>
</tr>
<tr>
<td>State:</td>
</tr>
<tr>
<td>ZIP/Postal Code:</td>
</tr>
<tr>
<td>Email Address:</td>
</tr>
<tr>
<td>Phone Number:</td>
</tr>
</tbody>
</table>

* Type of Organization

- Elementary School (K-5)
- Middle School (6-8)
- High School (9-12)
- Community College
- University
- University Research
- University Extension
- State Government Agency
- County Government
- City/Town Government
- Non-profit Organization
- Homeowner's Association
- Individual
- Partnership
- Other (please specify)
Volunteer Water Quality Monitoring in the US

* Leadership styles of monitoring organizations typically fall into one of two groups. These are "top-down" and "bottom-up." Did your organization begin as a "top-down" or "bottom-up" organization?

Definitions:
"Top-down" monitoring begins with an "expert" or professional scientist/engineer who is completing a study and needs volunteers to assist with data collection. Typically scientific questions are asked by the "expert" and data is analyzed by the same "expert."

"Bottom-up" monitoring begins with a community group or interested citizen. Volunteers are involved in all steps of the process of scientific analysis, but may call on an "expert" for assistance as the project progresses. This expert does not control the monitoring process.

- "Top-down"
- "Bottom-up"
- Other (please specify)

The leadership style may change over time. Has the organization leadership style changed at all since the beginning?

- Always "top-down"
- Always "bottom-up"
- "Top-down" to "bottom-up"
- "Bottom-up" to "top-down"
- Other (please specify)

Please provide a BRIEF story of how your monitoring began. What year did monitoring begin? Who was involved in the first monitoring?
Volunteer Water Quality Monitoring in the US

Is your monitoring group associated with any type of "professional" scientist?

- Don’t know
- No
- Yes (please provide name and affiliation)

3. Monitoring History / Volunteer Information

How many sites does your organization currently monitor?

<table>
<thead>
<tr>
<th>By organization staff</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5+</th>
</tr>
</thead>
<tbody>
<tr>
<td>By volunteers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By staff and volunteers together</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By other (please explain below)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* How many years have volunteers been monitoring at this site? (If your organization monitors more than one site, please choose the OLDEST VOLUNTEER SITE to answer this question and the following questions.)

- less than 1 year
- 1 year
- 2-5 years
- 6-10 years
- 11-15 years
- 16-20 years
- 20+ years
Volunteer Water Quality Monitoring in the US

* How frequently do volunteers monitor this site?

☐ Daily
☐ Weekly
☐ Monthly
☐ Seasonally
☐ Yearly
☐ Other (please specify)

Do large gaps exist where data collections were missed for any reason?

☐ No
☐ Yes (please specify gap length in days, weeks, months, and/or years)

How many different volunteers have taken samples or monitored this site?

☐ 1
☐ 2-5
☐ 5+
☐ Sampling is always done by a large group
☐ Other (please specify)

Are your volunteers "invested" in the watershed?

☐ Yes
☐ No
☐ Don't know
☐ Other (please specify)
Volunteer Water Quality Monitoring in the US

Do your volunteers live or work in the watershed and care about its well-being, etc.?
- Yes
- No
- Don’t know
- Other (please specify)

Is it difficult for you to find new volunteers?
- Yes
- No
- Depends on the event
- Don’t know
- Other (please specify)

* Is training required for volunteers who monitor water quality at this site?
- No
- Yes

What type of training is required of volunteers?

* Does a Quality Assurance / Quality Control (QA/QC) plan exist for this monitoring site?
- No
- Yes (please briefly explain plan)

4. Physical Monitoring
Volunteer Water Quality Monitoring in the US

* Please check the physical parameters that are measured at this monitoring site (check all that apply):

- Flow (cfs, cms)
- Velocity (feet/sec, meters/sec)
- Depth
- Width
- Profile
- Substrate analysis (bottom type: cobble, sandy, etc)
- Other (please specify)

5. Chemical Monitoring

* Please check the chemical parameters that are measured at this monitoring site (check all that apply):

- Temperature
- pH
- Conductivity
- Dissolved Oxygen
- Total Organic Carbon
- Hardness
- Alkalinity
- Nitrate
- Nitrite
- Other (please specify)

- Ammonia
- Phosphate
- Orthophosphate
- Biological Oxygen Demand
- Total Suspended Solids
- Total Dissolved Solids
- Turbidity
- Organics (please specify)
- NONE

6. Biological Monitoring
**Volunteer Water Quality Monitoring in the US**

* Please check the biological parameters that are measured at this monitoring site (check all that apply):
  - [ ] Fecal Coliform
  - [ ] Macroinvertebrates
  - [ ] Fish
  - [ ] Amphibians
  - [ ] NONE
  - [ ] Other (please specify)

### 7. Data Use

How are data used by your agency or others?

List ways data collected by volunteers are used by your organization.

* Has your organization or anyone else ever used data taken at this site for published research? If yes, please provide citation.
  - [ ] No
  - [ ] Yes (please provide citation)

* Who has used volunteer-collected data from this site?
  - [ ] I have
  - [ ] My organization
  - [ ] Local government
  - [ ] State government
  - [ ] Federal government
  - [ ] Other (please specify)
Volunteer Water Quality Monitoring in the US

* Are data collected by volunteers used for any of these watershed management purposes?

- Used for pre/post data for Best Management Practices (BMP) implementation
- Used for pre/post data for project(s) in the watershed that could affect water quality
- Used by state/local agencies to implement programs/regulations
- Used to implement change or improvement within the watershed
- No, data is not used
- Other (please specify)

8. Follow Up Questions

We may need to contact you in the event follow-up information is needed.

We thank you for your time and information. As a token of our appreciation your monitoring organization will be entered in a drawing for $50 to be announced on June 1, 2009.

* Please contact:

  Name: 

  Email Address: 

  Phone Number: 