TO RESTORE OR NOT TO RESTORE?
ASSESSING PRE-PROJECT CONDITIONS OF A HABITAT RESTORATION PROJECT ON THE NEW RIVER, NORTH CAROLINA

A Thesis
by
BOBBIE JO SWINSON

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Department of Geography and Planning

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Abstract

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The primary objective of the habitat restoration project is to improve the aquatic habitat; however, the primary outcomes will most likely be protecting athletic fields and greenway, increased flood protection, and improved access to the river. The evaluation highlights the ongoing problem of the lack of communication between scientists that collect data, and environmental managers that implement restoration plans. A lack of data collected within the restoration project reach and underutilization of existing data hinders the ability to properly evaluate the effect of restoration measures on habitat and water quality.

Acknowledgments

I am forever grateful for my faculty mentor and thesis chairperson, Dr. Jeffrey D. Colby, whose guidance, support, and unending patience made this thesis research possible. Dr. Kristan Cockerill, your passion for water and thirst for knowledge has inspired me in ways that I never imagined. Dr. Shea Tuberty, without you and your wonderful students this research would not be possible. Dr. Chuanhui Gu, thank you for all of your guidance throughout my graduate career as well as this thesis. It was an honor to be a part of AppAqua, and I am grateful for you all allowing me to examine and evaluate your wealth of data and to have had you on my thesis committee. I cannot thank all of you enough for your guidance and support throughout this entire process. Rich Crepeau, I am grateful for you joining my committee and offering your guidance and not-so-cynical criticism. All of you have helped me grow both personally and academically, and I have truly enjoyed every moment.

I offer my warmest regards and thanks to all of the students, faculty, and staff of the Department of Geography and Planning at Appalachian State University, it is truly an honor to know you all. Most notably to Dr. Kathleen Schroeder, whose encouragement, guidance, and support throughout the past year I will never forget.

Finally, I would like to thank the Cratis D. Williams Graduate School Graduate Research and Mentoring Program, the Office of Student Research, the Research Institute for Energy, Environment and Economics, and the Department of Geography and Planning at Appalachian State University for their financial support of this research.

Dedication

I dedicate this thesis to my parents, Pam and Doug Swinson, for whose unending love, support, and patience throughout my life and academic journey I am forever grateful.

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Foreword

The article presented in this thesis will be submitted to *Water Resources Management*, an international, multidisciplinary journal for the publication of original contributions and the exchange of knowledge and experience on the management of water resources. *Water Resources Management is* supported scientifically by the European Water Resources Association, a scientific and technical nonprofit. The organization and formatting of the article main body strictly follows the instruction to authors for manuscript submission for the journal.

Introduction

The number of river restoration projects aimed at enhancing water quality, improving in-stream habitat, and stabilizing eroding banks have exploded in the past decade (Bernhardt et al. 2005). Still, little is known about the success of river restoration projects, because relatively few restoration sites are monitored post-project (Kondolf and Micheli 1995; Bernhardt et al. 2005; Palmer et al. 2005; Alexander and Allan 2007; Bernhardt and Palmer 2011). Nevertheless, stream restoration projects are typically undertaken as an aspect of water quality management, amounting to what has now become a multi-billion dollar a year industry (Bernhardt et al. 2005).

A growing body of literature is reporting findings from individual and synthesized reports, with results repeatedly indicating a lack or underuse of ecological indicators for proper evaluation (Bernhardt et al. 2005; Alexander and Allan 2007), lack of communication between researchers and practitioners (Rhoads et al. 1999; Wohl et al. 2005; Wheaton et al. 2006), and underwhelming results (Shields et al. 2003; Sudduth et al. 2006; Alexander and Allan 2007; Cabin 2007; O'Donnell and Galat 2008; Palmer et al. 2010; Bernhardt and Palmer 2011; Cockerill and Anderson 2014). In addition, restoration efforts are often small-scale projects that focus on technical solutions to site-specific problems (Christian-Smith and Merenlender 2010), and frequently occur where land is available rather than in particular areas that would have the most significant impact on water quality (Bernhardt et al. 2007; Palmer and Allan 2006; Alexander and Allan 2007; Christian-Smith and Merenlender 2010; Cockerill and Anderson 2014).

The literature offers debate about the Rosgen (1994; 1996; 2006) method of river classification and its associated Natural Channel Design (NCD) techniques, which are strongly criticized for oversimplifying the complexity of fluvial systems (Kondolf 2006; Simon et al. 2007; Lave 2009). Case studies and synthesized reports have found varying results, with accounts of widespread failures of in-stream structures (Miller and Kochel 2010), and others finding that when designed correctly NCD techniques can improve habitat conditions (Ernst et al. 2010; Radspinner et al. 2010; Buchanan et al. 2014). In addition, Baldigo et al. (2010) found that initial conditions limit the relative improvements that can be achieved, and habitat quality and stability do not automatically respond in unison. Despite the debate, the NCD approach is the preferred method for most local, state, and federal agencies (Lave 2009; Ernst et al. 2010) and is implemented to some extent for most federally funded stream or river restoration efforts.

The bulk of the rest of the river restoration debate centers on the lack of baseline ecological inventories or guiding criteria for evaluating project success. Improving benthic macroinvertebrate population numbers and diversity is commonly used as an indicator of success (Tullos et al. 2009; Palmer et al. 2010; Violin et al. 2011). Fish abundance and diversity are also often evaluated to determine the effect of restoration measures on habitat (Baldigo et al. 2010; Ernst et al. 2010; Buchanan et al. 2014). Other projects analyze water quality parameters such as temperature, conductivity, and turbidity to determine the effects of riparian vegetation measures on water quality (e.g., Cockerill and Anderson 2014) or the effects of restoration on riparian ecosystems (e.g., Kaase and Katz 2012).

Benthic macroinvertebrates are useful as biological monitors because they are found in all aquatic environments, are not highly mobile, and are easily collected (Resh et al.1995). Furthermore, complex chemical and physical analysis for various pollutants is usually not practical due to time and financial constraints (Lenat 1988). The aquatic biota, however, have synergistic and/or antagonistic responses to a wide range of pollutants, allowing for rapid assessment of habitat quality using benthic macroinvertebrates as a proxy for in-stream water quality (Bonada et al. 2006). Benthic community assemblages denote highly localized conditions, and although comparisons can be made between sites in close proximity to each other (Braccia and Voshell 2006), compounding stressors reduce the ability to accurately detect water quality problems (Lenat and Barbour 1994).

Post-project audits are an invaluable resource for restoration practitioners. However, academic scientists, not restoration managers, typically conduct the majority of these audits. The lack of communication between researchers who have, or can more readily obtain, potentially useful data and practitioners who implement projects is an on-going problem in environmental management. Moreover, ecological benefits can take years or decades to manifest, so accurately evaluating the success or failure of young projects is problematic.

Additional case studies and restoration examples are vital for understanding the effects of restoration measures and for improving decision-making during river restoration planning and implementation. The literature offers few comprehensive analyses of restoration activities prior to the effort, or a pre-project assessment. The highlighted project in this paper is a $2.6 million aquatic habitat restoration project at a public greenway in Boone, North Carolina. The restoration is a partnership between the United States Army Corps of Engineers (USACE); the Town of Boone, North Carolina; Appalachian State

University (ASU); and The National Committee for the New River (NCNR). This paper presents a pre-project evaluation of the impending restoration effort based on information obtained from in-depth stakeholder interviews, the project environmental assessment, project construction plans, and available ecological indicators, including benthic macroinvertebrate community, fish community, and ambient water quality measurements.

This assessment focuses on answering the following research questions:

1 What are the motivations and goals for restoration?

2 Does available data suggest the need for restoration, and does this data allow for post-project assessment?

3 How likely are the stated goals to be met based on implemented design measures and available data?

4 How do the project sponsors plan to monitor the effects of restoration measures?

Author's Role in the Article Section of this Thesis

The thesis author conducted interviews with the project sponsors, and undertook coding and analysis of the interview data. In addition, she acquired all biologic and water quality data from various sources that were necessary for examining the restoration project. She also examined and evaluated the Detailed Project Report and Environmental Assessment as well as construction documents for the presented habitat restoration project. Finally, with guidance from her thesis committee, she drafted this thesis along with the manuscript that will be submitted to *Water Resources Management*.

To Restore or Not to Restore: Assessing Pre-project Conditions of a Habitat Restoration Project on the New River, North Carolina

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Abstract:

The number of river restoration projects aimed at enhancing water quality, improving in-stream habitat, and stabilizing eroding banks have exploded in the past decade, with a recent shift in focus on enhancing ecosystem services for human benefit. Case studies and synthesized reports have found varying results, with accounts of widespread failures of in-stream structures, and others reporting that when designed correctly restoration techniques can improve habitat conditions. In addition, initial conditions have been shown to limit the relative improvements that can be achieved. The presented study offers a pre-project evaluation of an impending restoration based on information obtained from in-depth stakeholder interviews, the project environmental assessment, project construction plans, and available ecological indicators, including benthic macroinvertebrate community, fish community, and ambient water quality. The primary objective of the project is to improve the aquatic habitat, however the primary outcomes will most likely be protecting athletic fields and greenway, increased flood protection, and improved access to the river. The evaluation highlights the ongoing problem of the lack of communication between scientists that collect data, and environmental managers that implement restoration plans. A lack of data collected within the restoration project reach and underutilization of existing data hinders the ability to properly evaluate the effect of restoration measures on habitat and water quality.

Keywords: stream restoration; water management; benthic macroinvertebrate; fish community; water quality

1 Introduction

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1.1 Water Resources Development Act

The restoration being evaluated is authorized by Congress under Section 206 of the 1996 Water Resources Development Act. A revolving $25 million budget gives authority to USACE to carry out aquatic restoration projects of no more than $5 million that will improve the quality of the environment, is in the public interest, and is cost-effective (Water Resources Development Act 1996). USACE is a U.S. federal agency that is one of the largest public engineering, design, and construction management agencies in the world.

A request from a public agency or national non-profit organization initiates the Section 206 process. Upon receiving funding, USACE prepares a feasibility study to determine whether the project is in the federal interest and is cost effective. The feasibility study formulates alternatives to achieve the restoration as well as a no action alternative, evaluates the environmental effects of the alternatives, documents the project requirements, and provides a scope and cost estimate for project implementation. If implementation is recommended, USACE prepares detailed project plans and obtains any necessary federal permits. USACE then oversees construction of the project by a private contractor. USACE provides the first $100,000 of the feasibility study costs while the local sponsor must contribute 50% of the cost of the study after the first $100,000, 35% of the cost of design and construction, and 100% of operation and maintenance costs (Water Resources Development Act 1996).

The USACE Huntington District, located in Huntington, West Virginia, is overseeing the restoration project in Boone. In 1998 Boone requested the restoration project and is the local project sponsor. The Town of Boone partnered with a local land conservation organization, The National Committee for the New River (NCNR), for funding acquisition. NCNR will hold a permanent conservation easement on the riparian area surrounding the river after project completion.

1.2 Study Area

The restoration site lies at the outlet of the headwaters of the South Fork of the New River in Watauga County in the northern mountains of western North Carolina (Figure 1). The headwater catchment, also known as the Upper South Fork New River (USFNR) watershed, encompasses the towns of Boone and Blowing Rock and is unique in that it represents a dynamic headwater catchment characterized by pristine reaches (e.g., supporting native brook trout populations), three stream reaches currently listed as impaired, and an expanding urban environment.

Boone is home to 17,122 full time residents according to the 2010 United States Census, and is also home to Appalachian State University, which enrolls about about 17,000 students (Institutional Research Assessment and Planning [IRAP] 2013). Watauga County experienced a twenty percent growth rate according to the 2000-2010 Census (U.S. Census Bureau 2010). This growth rate and continued development pose a significant threat to the water quality of the South Fork of the New River, which is designated as an American Heritage River.

The American Heritage Rivers Protection Program was initially created by Executive Order 13061 in 1997. American Heritage Rivers receive special attention to advance three objectives: natural resource and environmental protection, economic revitalization, and historic and cultural preservation. A designated "River Community" receives support from all involved federal agencies and is assigned a "River Navigator" whose job is to serve as a link between the designated communities and federal agencies and to provide recommendations for environmental restoration and revitalization of waterfronts (Exec Order 13061 1997). The East and Middle Forks of the USFNR join in Boone to form the South Fork of the New River 610 meters upstream of the Boone Greenway (a public greenway) the location of the restoration project, and which lies along the floodplain of the USFNR. Winklers Creek, which flows through the most urbanized area of Boone, joins the South Fork of the New River 457 meters upstream of the restoration area. The South Fork is a tributary to the New River, which is part of the Ohio River drainage basin. The river flows northeast into Virginia where it joins the Kanawha, eventually the Ohio, and finally the Mississippi River before flowing into the Gulf of Mexico (U.S. Army Corps of Engineers [USACE] 2009) (Figure 1).

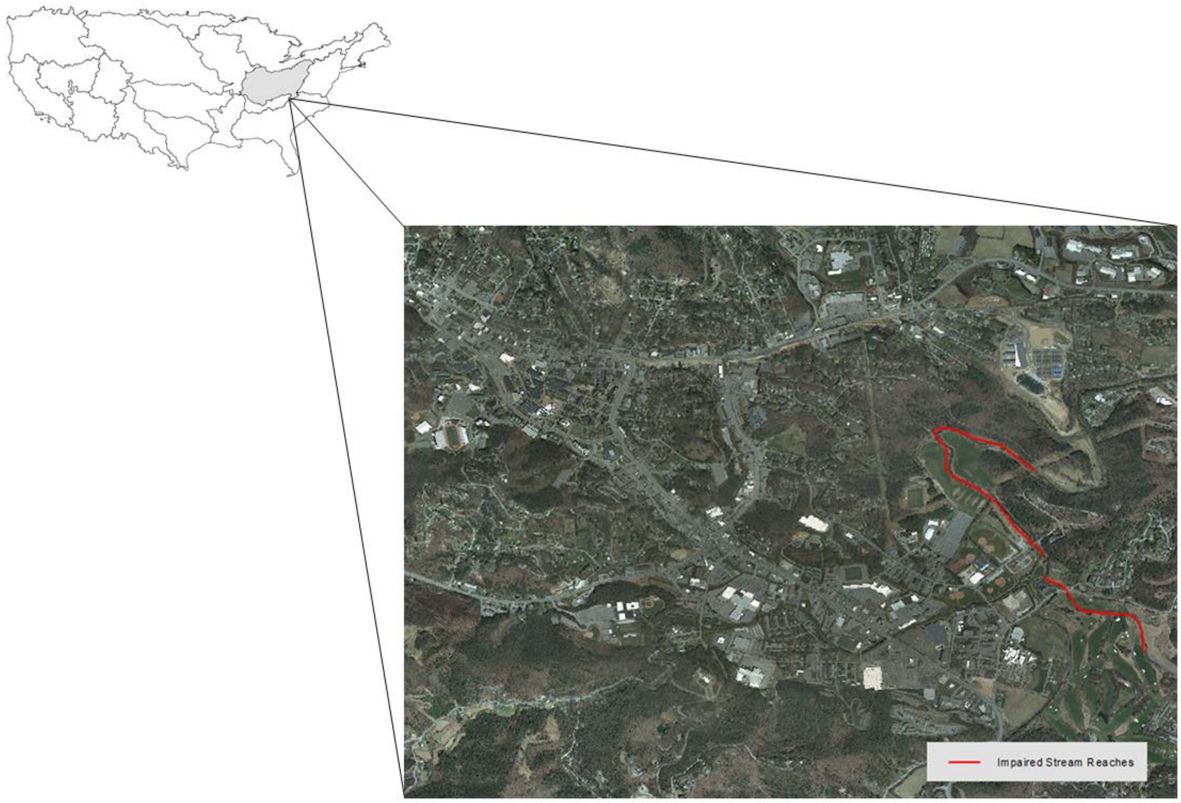

Fig 1 The location of the habitat restoration project is in the headwaters of the South Fork of the New River in the Town of Boone, North Carolina. The South Fork is a tributary of the New River, and part of the Ohio River drainage basin. Current impaired stream segments within the general vicinity of the study area are shown in red. Drainage basins of the continental United States are shown in the inset map with the Ohio River drainage basin highlighted.

The Boone Greenway is located in one of the few relatively flat areas within the USFNR watershed. The restoration site encompasses a 1,137 meters reach along with approximately six hectares of adjacent floodplain. The adjacent topography largely confine the river, which has resulted in the floodplain at the site extending approximately 304.8 meters wide in the upstream portion of the reach then narrowing to less than 30.48 meters downstream, where two valley walls come together. The channel gradient is mild with an average slope of 0.00133 meters/meter, and the bed material is predominately sands and gravels, with some cobbles, and small areas of exposed bedrock (USACE 2009).

Four distinct habitats are found in the study area and include riverine, riparian, forestland, and manicured urban grassland as the dominant habitat type (USACE 2009). ASU owns the property along the Greenway, which is open space and used for recreation. Athletic fields border the left overbank (river left – facing downstream) for the majority of the upper reach, with forest bordering the entire left bank of the lower reach of the restoration site. A paved trail borders the right overbank (river right) of the entire reach and is managed by the Town of Boone. Soccer fields and open space are located in the middle of the site in the area between the upper and lower reach.

2 Methods

Both qualitative information obtained from stakeholder interviews and quantitative ecological data were used to evaluate the likelihood of restoration success. Ecological data used for developing the detailed project report and environmental assessment (EA) were also evaluated for feasibility for monitoring restoration efficacy. In addition, fish, benthic macroinvertebrate, and water quality data collected in 2013 and 2014 at the restoration site and analyzed by a research team at ASU, the Appalachian Aquatic Science Research Group (AppAqua), were evaluated.

2.1 Interviews

Interviews were conducted with the four primary project sponsors (USACE, the Town of Boone, NCNR, and ASU) to evaluate the planning and design process and to assess how well the project design aligned with available physical data and the stated goals for the restoration project.

A three-hour interview with USACE took place in Huntington, West Virginia, at the Huntington District offices. Participants who were interviewed included the lead engineer, lead planner, and the lead real estate specialist for the project. The interview with NCNR took place at the West Jefferson, North Carolina office with the Executive Director of the organization and lasted approximately two hours. The assistant to the Boone town manager is the restoration project manager and was interviewed at a local restaurant over an hour-long lunch. The lead engineer for ASU offered valuable insight during a thirty-minute interview at his office.

The interviews were conducted to gain insight into project motivations and importance, expected outcomes, and the data used for planning and/or monitoring the restoration project. Interviewees were asked a set of identical questions with relevant follow-up questions when appropriate. The interviews were all recorded and written notes were also taken. Immediately following each interview the notes were reviewed and expanded as appropriate using the recordings as needed to add detail or clarify points. The lead and second authors independently coded the notes. The coding matrix included four themes: project motivations and importance, expected outcomes, data used for developing the design, and monitoring plan for evaluating restoration efficacy. The two sets of coded material were compared for consistency and in the few places where information had not been coded similarly, the recordings and/or original notes were revisited and the coding aligned as appropriate.

2.2 Detailed Project Report and Construction Plan

USACE provided the Detailed Project Report and the EA, completed in 2009, during the interview in addition to the December 2013 draft construction plans for the project. The Detailed Project Report and December 2013 draft final construction plans were examined in order to assess how likely sponsor expected outcomes are to be met using restoration techniques. These plans included an overall site plan as well as detailed construction information regarding specific treatments, including bank sloping, invasive species eradication and re-vegetation measures, and the placing of in-stream structures along the project reach. In addition to treatment specifics, trail, fence, and culvert relocation detail were included in the construction plans.

2.3 Data Review

The data used for generating the EA were composed of a combination of geologic, biologic, and water quality data collected by USACE, a USACE contractor, and the North Carolina Department of Environment and Natural Resources (NCDENR) throughout the time period from1998-2008. Biologic data included electrofishing survey results from 2004 (USACE), and benthic macroinvertebrate samples from 2003 and 2008 (NCDENR). Water quality data (e.g., specific conductivity, pH, turbidity) from the NCDENR ambient monitoring system (AMS) for the time period from 1998-2003 was also used to generate the EA.

The data used to develop the EA were limited in terms of both temporal range and geographic location. The EA was drafted in 2009, yet the NCDENR AMS data reported in the EA only included data from 1998-2003. In addition, NCDENR benthic macroinvertebrate monitoring stations and AMS stations used for developing the EA were located outside the boundaries of the project reach. Also, AMS data reported in the EA did not include temperature, an important water quality indicator for trout supporting streams.

To further assess pre-restoration conditions of the project area, the author retrieved specific conductance, pH, turbidity, and temperature data from 1998 through 2013 via the U.S. Environmental Protection Agency's Storet/WQX website (EPA STORET/WQX). The EPA Storet website is a repository for water quality data for government agencies, including NCDENR. An updated dataset for the same AMS site that was used to develop the EA was downloaded to further evaluate water quality.

Additionally, as part of an on-going effort to study land cover and water quality relationships in the USFNR watershed, the AppAqua research team at ASU, have collected data within the watershed including the restoration project reach. The various datasets available within the project reach include digital elevation data derived from 2012 helicopter LiDAR data at 0.5m spatial resolution, particle grain size data from 2013 and 2014, as well as results from electrofishing and benthic macroinvertebrate surveys from spring 2013. In-Situ 9500 water quality sondes have also been recording water quality measurements (e.g., temperature, depth, pH, and conductivity) every 15 minutes at the upper and lower bounds of the restoration project reach since October 2013.

Although several data sources were available, the focus for this paper is benthic macroinvertebrates, fish community, and water quality. Both NCDENR data used for developing the EA and current data downloaded from the EPA STORET/WQX website, as well as data available from AppAqua are presented. These parameters were chosen as the best representation of water quality metrics currently available for pre- and post-project assessment at the restoration site. Additionally, benthic, fish, and water quality data used for generating the EA supplemented with biological and water quality data within the project reach from AppAqua presented an opportunity to examine both geographic and temporal issues associated with the data used in guiding the restoration plans.

2.3.1 NCDENR Index of Biological Integrity

NCDENR evaluates river water quality using biological communities, which includes fish and benthic macroinvertebrate communities. Criteria have been developed for assigning a North Carolina Index of Biological Integrity (NCIBI) rating for the three major ecoregions within the state: the mountains, piedmont, and coastal plain, and are used to assess the impacts of both point and nonpoint source pollution.

Criteria for assigning NCIBI ratings have been developed using diversity, abundance, and pollution sensitivity of benthic macroinvertebrates (North Carolina Department of Environment and Natural Resources [NCDENR] 2012). One of five classifications are assigned to each water body sampled: Excellent, Good, Good-Fair, Fair or Poor. Stable, pollution-sensitive, and diverse communities of macroinvertebrates result in a classification of Excellent or Good. A stream or river segment is considered impaired when one or more designated uses for the reach are not attained. A stream that is not impaired is considered to be supporting its designated use (NCDENR 2012).

Two primary macroinvertebrate collection methods are used. The first is a standard qualitative method (SQM), which can be used to assign water quality ratings to most streams and rivers in North Carolina. The second collection method is an abbreviated version of the regular qualitative technique that focuses on a subset of the benthic community, and is called the Ephemeroptera, Plecoptera, and Trichoptera method (EPT). This technique is used to quickly determine between-site differences in water quality. Although the EPT method is a more rapid sampling technique, this method can provide too little information for an adequate assessment of water quality in certain situations such as in areas with naturally low EPT richness and areas where the abundance of more tolerant groups must be assessed (NCDENR 2012).

The NCIBI for the Stream Fish Community Assessment Program incorporates information about species richness and composition, pollution indicator species, trophic composition, fish abundance, fish condition, and reproductive function via a cumulative assessment of 12 parameters. The values provided by the metrics are converted into river drainage specific biological index scores on a 1, 3, and 5 scale. A score of 5 represents conditions associated with undisturbed reference streams in the ecoregion. A score of 1, however, indicates that conditions deviate greatly from those typically observed in undisturbed streams of the region. The scores for all metrics are then summed to obtain the overall NCIBI score, an even number between 12 and 60. The score is then used to determine the biological integrity class of the stream (i.e., Excellent, Good, Good-Fair, Fair, or Poor) (North Carolina Department of Environment and Natural Resources 2013).

2.3.2 Benthic Macroinvertebrate Assessment

Two NCDENR benthic macroinvertebrate monitoring sites (KB1 and KB12) used for developing the EA are located approximately 650 meters upstream from the restoration area on the Middle Fork, tributary of the South Fork of the New River, and the East Fork, tributary of the South Fork of the New River, respectively. The third monitoring site (KB16), carrying the longest data record, is located approximately 2.6 km downstream of the project area (Figure 2). All samples on the Middle Fork and East Fork streams were assessed using the EPT method, while the South Fork site (KB16) has historically been assessed using the full SQM.

Fig 2 North Carolina Department of Environment and Natural Resources benthic macroinvertebrate sampling locations.

The lack of benthic macroinvertebrate data collected within the restoration reach prompted AppAqua researchers to collect and analyze macroinvertebrate populations within the study area in spring 2013. The restoration reach was divided into three sections based on the geomorphic characteristics of the channel. The two large bends in the river create a distinct upper, middle, and lower reach, which was conducive to sampling and analysis of macro invertebrate populations (Figure 3). The data were analyzed and assigned NCIBI ratings according to a modified protocol of the NCDENR SQM. This modification differs from the SQM in that members of insect families are averaged rather than genus and species.

Fig 3 AppAqua benthic macroinvertebrate sampling sites and in-situ water quality monitoring stations within the restoration project reach.

2.3.3 Fish Community Assessment

USACE undertook a comprehensive electrofishing survey throughout the project reach in 2004. An electric seine electrofishing unit with 9m wires was used to collect fish samples from five 150m sections along the reach. Surveys were classified according to the North Carolina Index of Biological Integrity (NCIBI) for mountains of the New River drainage (NCDENR 2013), and the results were then used for developing the EA.

AppAqua researchers conducted an electrofishing survey within the project reach in summer 2013. Three backpack electrofishing units (Smith-Root, Inc.) were used to collect fish samples from 100m reaches. The results were classified as outlined by *Standard Operating Procedures for Biological Monitoring of Stream Fish Community* (NCDENR 2013). These surveys were compared to the 2004 survey undertaken by USACE.

2.3.4 Water Quality Assessment

Data from the NCDENR AMS station K2100000, which is in the same geographic location as benthic station KB16 (see Figure 2), was used for drafting the EA in 2009. Dissolved oxygen, specific conductivity, pH, total suspended solids, turbidity, and nutrient data collected via grab samples were included in the EA in the form of minimum, median, and maximum values for the time period from 1998-2003. The EA, however, did not include nearly five years of data that were available at the time it was drafted in 2009. In addition, the EA did not include temperature data that was available for AMS station K2100000.

To further evaluate water quality conditions at the site, the authors also examined data available from the EPA Storet/WQX website for AMS station K2100000 from 1998-2013. The additional AMS data examined by the authors in this paper included specific conductivity, pH, and turbidity as the most appropriate indicators of water quality for the region, and temperature as it is an important parameter for trout and EPT supporting streams. In addition, data obtained from the AppAqua water quality monitoring sondes that are located at the upstream and downstream bounds of the project reach (see Figure 3) were evaluated.

3 Results

Both qualitative information obtained from stakeholder interviews and quantitative ecological data were evaluated to understand project motivations and importance, expected outcomes, and monitoring plans for the restoration. Information obtained from interviews were compared to reviewed biologic and water quality data as well as the Detailed Project Report and Environmental Assessment in order to provide a mixed methods pre-restoration assessment of the project.

3.1 Interviews

Information obtained from stakeholder interviews were coded and resulted in four primary categories: project motivations and importance, expected outcomes, data used for planning the project and developing the design, and monitoring plans for evaluating restoration efficacy. The results from coding the interviews are shown in Table 1. Summaries of the interviews are provided in subsequent sections.

Stakeholder	Importance/Objectives	Expected Outcomes	Data Used for Planning	Monitoring Plan
USACE	Buffer stormwater impact Reduce sedimentation Improve aquatic habitat Create access for recreation Prevent loss of greenway	Reduce meander Reduce bank loss Improve habitat Provide recreation Protect greenway	Assumption of historic channel behavior Contractor produced hydrologic model USACE Fish Study NCDENR macroinvertebrate Visually assess bank failure, vegetation	Monitor vegetation mortality for 1 year No other monitoring required Produce O&M manual for Town of Boone
TOB	Improve aquatic habitat Stabilize streambank Prevent loss of greenway	Reduce turbidity Improve habitat Protect greenway	Banks are 1:1 - falling in river Corps oversees all environmental assessment	USACE will monitor in a limited sense NCNR will monitor
NCNR	Stabilize streambank Improve aquatic habitat Reconnect floodplain Create access for recreation Prevent loss of greenway	Improve habitat Reduce erosion/sediment Economic potential Public education	NCDENR macroinvertebrate Water quality Visually assess bank failure, vegetation Corp did extensive environmental survey	Monuments for stream channel change Plant mortality Sediment data
ASU	Improve athletic fields	Raise fields 6 inches	"no-rise" model to show potential for up-stream flooding	None

Table 1: Stakeholder responses to questions concerning restoration objectives, expected outcomes, and monitoring plan, listed in order of response. Interviewees included The Army Corps of Engineers (USACE), the Town of Boone (TOB), the National Committee for the New River (NCNR) and Appalachian State University (ASU).

3.1.1 Project Motivation and Importance

The lead engineer for the project at USACE said that when he first visited the site, he thought that it was a “Grade A-/B+ stream in good shape,” but that ASU expansion and parking lots were a concern. He and other USACE interview participants noted that sedimentation as a result of erosion “is killing benthic macroinvertebrates,” and the project will provide habitat improvements and stabilization of the banks. In addition, interviewees said that recreational benefits in the form of river access and protection of the greenway are a vital part of the project.

The interview with NCNR revealed that upstream watershed impacts and the need to stabilize the streambanks to stop the “unbelievable erosion” were the main motivators for the restoration project. By stopping the erosion, NCNR hopes to improve the aquatic habitat by reducing sedimentation in the river. In addition the project is important for reconnecting the floodplain and providing access to the river as well as increasing NCNR’s visibility.

The project manager for the TOB said that the project is important for improving the aquatic habitat, reducing turbidity, and protecting the recreational fields. He indicated that the banks are falling into the river and that this is the primary issue that must be addressed.

The Town manager said that there is a need for more upstream projects, but that the Town is not currently planning any. The ASU engineer said that this project was important because ASU is able to "piggyback" from the restoration efforts and improve conditions for the athletic fields.

3.1.2 Expected Outcomes

The USACE engineer said that he is expecting to reduce the river meander and "fix" bank stability issues within the river reach. This stabilization is expected to improve the habitat corridor and increase diversity while providing increased recreational opportunities and protection of the greenway. The engineer also mentioned that trout stocking was an option but it is not a part of this project, and has been a controversial topic.

The executive director for NCNR said that improvements to habitat through the reduction in sediment could "serve an economic purpose," as the potential for stocking the river with trout has been discussed though not being pursued at this time. Additionally, he said that NCNR "is not striving for a pristine river course," and that a "bunch of non-ideal projects could be better than one ideal project." He noted that the project has the potential to enhance educational outreach in the community and influence behavior on private property.

The project manager for the Town of Boone said that the project partners "all have the same goals: improve habitat, lower turbidity, and protect the recreational fields." The lead engineer for ASU said that ASU is able to utilize the spoil from bank excavation to raise the fields. Raising the fields approximately 15cm is expected to help with flooding issues and generally improve the athletic fields.

3.1.3 Data Used for Planning and Design

USACE acknowledged that it does not have good on-site geomorphic survey data within the project reach due to changing conditions and difficulties with environmental data collection. Instead of collecting data, the engineer revealed that USACE used "assumptions of historic channel behavior" to plan the project. The engineer also acknowledged that often engineering decisions are made "on the fly" during construction.

The executive director for NCNR said that he relies on USACE to carry out the environmental assessment. However, the director said that NCNR assessed where stream banks were slumping, vegetation was lacking, and "where pressure points undermine the bank." In addition the director referenced various sources of biologic and water quality data, which was largely provided by the AppAqua research group.

The project manager for the Town of Boone said that they did not collect any data for planning the project. He also said that USACE oversees all of the environmental assessment for the restoration. The project manager noted, however, that it is visually evident that the banks are "falling into the river."

The lead engineer said that ASU is required to complete a "no-rise model." This model must show that raising the recreational fields will not cause flooding to happen upstream. The engineer noted that otherwise ASU engineering was not involved in any data collection or assessment.

3.1.4 Monitoring Plan

USACE made it clear that the Town will be responsible for operation and maintenance of the restoration once the project is complete. The USACE project planner said that Section 206 projects that were authorized prior to 2007, which this project was, are not required to have a monitoring or evaluation plan, though it is required for future projects. The engineer noted that USACE will produce an operation and maintenance manual for the Town to follow. However, USACE is not authorized to monitor anything other than vegetation mortality for one year, for which the contractor is held accountable.

The project manager for the Town of Boone replied that USACE will "monitor in a limited sense," but otherwise NCNR will monitor the restoration's progress. NCNR said that it plans to "have monuments to note stream channel change," but otherwise only plan to follow up with invasive species eradication and monitoring of plant mortality. NCNR anticipates working with the AppAqua research group at ASU to collect follow up biologic and water quality data. ASU engineering has no plans for monitoring restoration efficacy, though it was not expected that the University would or should be responsible for carrying out a formal evaluation of the project.

3.2 Detailed Project Plan

Restoration is being carried out using the Rosgen classification system, and its associated method of natural channel design, which is typical for federal agencies. The restoration plan focuses on using vegetation to stabilize the banks with an emphasis on riparian and wetland enhancement. Major channel reconfiguration is not an aspect of this restoration project, however, multiple in-stream structures are being placed in order to redirect the current away from the eroding and undercutting banks.

Channel and stream bank stabilization will be attempted by installing anchored slab bundles at the toe of unstable slopes, bank grading and vegetation, and installing bendway weirs. Additionally, clusters of large boulders will be placed to help direct the flow towards the center of the channel and away from the stream banks. An overall site plan is shown in Figure 4.

Fig 4 The overall site plan for the restoration. Primary restoration measures include rehabilitation of wetland areas, invasive species control and re-vegetation, riparian buffer extension and establishment, and bottomland hardwood forest re-vegetation as well as installation of bendway weirs.

According to the EA and detailed project report, stabilizing stream banks is expected to "eliminate the input of failing soils to the stream." Slab bundles are expected to increase bank stability while increasing habitat diversity by increasing woody material in the stream and subsequently increasing colonization by macro invertebrates. Increasing the vegetation along the stream banks is anticipated to increase habitat diversity for birds, amphibians, reptiles, insects, and small mammals, while providing shade for the stream thereby lowering water temperature. The installation of bendway weirs at the two extreme curves in the river are expected to redirect the river current away from the banks, reducing bank undercutting and subsequent bank failure.

Two existing wetlands are being expanded and graded to create permanent ponding areas vegetated with native wetland species and connected to the channel to allow overflow of the river into the wetlands. In addition, culverts are being realigned to collect and divert runoff from the recreational fields and parking lots to the wetlands. The creation of these wetlands is expected to mitigate stormwater runoff to the river, aiding in flood control, reducing sediment loading, and mitigating pollution, resulting in improved stream water quality. Additionally, wetlands are expected to provide habitat for plants, waterfowl, and other small animals.

Significant riparian vegetation restoration and enhancement is being planned for the restoration. The first step being taken is eradication of invasive species via spraying. Vegetation, rather than riprap to armor the banks, will be used after grading the banks to a more gradual slope. The vegetation, once established, is expected to anchor the stream bank, while subsequently intercepting storm water runoff and providing shade for the stream.

Additional recreational enhancement measures are expected to indirectly benefit the aquatic ecosystem. Informational signage is being placed to explain the value of maintaining healthy stream systems. River access points and turnouts for viewing the river are expected to re-direct the public away from informal trails along the banks. Directing foot traffic to access points is expected to reduce erosion and decrease negative impacts to riparian vegetation.

3.3 Data Review

3.3.1 EA Benthic Macroinvertebrate Assessment

A benthic sample collected from the South Fork of the New River site KB16 (see Figure 2) in November of 2003 resulted in a declining rating from Good-Fair to Fair from August 2003. The August 2008 benthic rating echoed the November 2003 rating of Fair. A summary table of NCIBI ratings for NCDENR benthic sampling stations located in the general vicinity of the project reach and used to develop the EA is provided in Table 2.

North Carolina Biological Index Ratings for Macro Invertebrate Communities in the Upper South Fork Watershed							
Data Analyzed by the Biological Assessment Branch at NCDENR (1993-2008)							
Stream	**Site ID**	**Sample Type**	**July-1993**	**Aug-1998**	**Aug-2003**	**Nov-2003**	**Aug-2008**
South Fork New River	KB16	SQM	Fair	Good-Fair	Good-Fair	Fair	Fair
Middle Fork South Fork New River	KB1	EPT	Excellent	Good	Good-Fair	Good	Good-Fair
East Fork South Fork New River	KB12	EPT	Excellent	Good	Good	Poor	Good

Table 2: North Carolina Index of Biologic Integrity ratings for macro Invertebrate populations in the general vicinity of the restoration area used for development of the environmental assessment by the Army Corps of Engineers. Data collected by the North Carolina Department of Environment and Natural Resources July 1993-August 2008. Sampling methods included the Standard Qualitative Method (SQM) and the Ephemeroptera, Plecoptera, and Trichoptera Method (EPT) as outlined by Standard Operating Procedures for Benthic Macroinvertebrates (NCDENR 2012). Ratings fluctuated year to year at all sampling sites, but the Middle Fork tributary of the South Fork of the New River and the East Fork tributary of the South Fork of the New River, located upstream from the restoration site, have generally degraded over time.

East Fork benthic sampling site (KB12) (see Figure 2) has historically had an Excellent or Good benthic communities. In November 2003 the section was rated Poor and added to the Impaired Waters list (USACE 2009). However, the benthic community at site KB12 received a Good rating in 2008, which removed the segment from the 2010 Impaired Waters list (North Carolina Department of Environment and Natural Resources 2011).

Middle Fork benthic site (KB1) is located above the confluence with the East Fork (see Figure 2). This site has been sampled five times since 1993, when it received an Excellent rating. Ratings have fluctuated between Good and Good-Fair, however, the 2008 Good-Fair rating indicates a gradual decline in water quality over time (NCDENR 2011).

3.3.2 EA Fish Community Assessment

Electrofishing surveys, which was the only biological data collected within the project reach by USACE, resulted in biological index ratings between 46 and 55, and NCIBI ratings of Good-Fair to Good (USACE 2009). Three of the five surveyed sites had a slightly elevated percentage of tolerant species, such as *Catostomus commersoni*. In addition, percentages of omnivores and herbivores, such as *Campostoma anomalum*, were slightly out of optimal range (USACE 2009). The EA provided a list of species sampled in the 2004 assessment, which is shown in Table 3.

USACE Fish Assessment (2004)		
Common Name	**Scientific Name**	**Game/Nongame**
Central Stoneroller	*Campostoma anomalum*	Nongame
Creek Chub	*Semotilus atromaculatus*	Nongame
Fantail Darter	*Etheostoma flabellare*	Nongame
Brown Trout	*Salmo trutta*	Game
New River Shiner	*Notropis scabriceps*	Nongame
Northern Hogsucker	*Hypentelium nigricans*	Nongame
White Sucker	*Catostomus commersonii*	Nongame
Green Sunfish	*Lepomis cyanellus*	Nongame
Kanawha Minnow	*Phenacobius teretulus*	Nongame
Mottled Sculpin	*Cottus bairdii*	Nongame
Tonguetied Minnow	*Exoglossum laurae*	Nongame
Blacknose Dace	*Rhinichthys atratulus*	Nongame
Rosyside Dace	*Clinostomus funduloides*	Nongame
Greenside Darter	*Etheostoma blennioides*	Nongame
Bluntnose Minnow	*Pimephales notatus*	Nongame
Rainbow Trout	*Oncorhynchus mykiss*	Nongame
Redbreat Sunfish	*Lepomis auritus*	Nongame
Rock Bass	*Semotilus atromaculatus*	Game
Nocomis Sp.	*Nocomis sp.*	Nongame
Bigmouth Chub	*Nocomis platyrhynchus*	Nongame
Bluegill	*Lepomis macrochirus*	Nongame
Bluehead Chub	*Nocomis leptocephalus*	Nongame
Fathead Minnow	*Pimephales promelas*	Nongame
Golden Shriner	*Notemigonus crysoleucas*	Nongame
Largemouth Bass	*Micropterus salmoides*	Game
Rosyface Shiner	*Notropis rubellus*	Nongame
Siver Shiner	*Notropis photogenis*	Nongame

Table 3 Fish community assessment carried out by the Army Corps of Engineers in 2004.

3.3.3 NCDENR Water Quality Data Summarized by EA

Data from grab samples taken by NCDENR from 1998-2003 at AMS station K2100000 was used for developing the EA and is summarized in Table 4. Specific conductivity was variable with a minimum of 20 µS/cm and maximum of 266 µS/cm, with a median of 134 µS/cm. pH stays within the normal range of 6 to 9. Turbidity measurements (ntu) minimum, median, and maximum were well under the North Carolina evaluation level (>50 ntu) for trout-designated waters, with a very low median of 2 ntu. Data from the EA are shown in Table 4.

Water Quality Data from NCDENR AMS Monitoring Station K2100000 (1998-2003)					
Parameter	**N**	**Evaluation Level**	**Minimum**	**Median**	**Maximum**
Specific Conductance (µS/cm)	44	n/a	20	134	266
pH	45	<6, >9	5.9	7	7.6
Turbidity (ntu)	53	>50 (Trout Designated)	1	2	22

Table 4: Water quality data from the North Carolina Department of Environment and Natural Resources Ambient Monitoring System Station K2100000 used for developing the restoration environmental assessment. Parameters include specific conductance, pH, and turbidity.

3.3.4 NCDENR Water Quality Data summarized by authors

Data from 1998-2013 NCDENR AMS at station K2100000 presented in Table 5 show slightly higher maximum values than the data used to develop the EA for both specific conductivity and pH. Although the median measurements for specific conductivity and pH from 1998-2013 were very similar to those found from 1998-2003, the higher maximum potentially indicates that the water quality is susceptible to degradation. Maximum temperature measurements were about 5°C higher than the NC standard; however, these temperatures were likely episodic in nature or taken during hot summer days, as the median of 14°C is well under the evaluation level.

Water Quality Data from NCDENR AMS Monitoring Station K2100000 (1998-2013)					
Parameter	**N**	**Evaluation Level**	**Minimum**	**Median**	**Maximum**
Specific Conductance (µS/cm)	44	n/a	20	137	310
pH	45	<6, >9	5.9	7.3	8.4
Turbidity (ntu)	53	>50 (Trout Designated)	1	2.4	150
Temperature (°C)	53	>20°C (Trout Designated)	1.8	14	25.7

Table 5 Water quality data from the North Carolina Department of Environment and Natural Resources Ambient Monitoring System Station station K2100000 from 1998-2013 downloaded from U.S. Environmental Protection Agency's Storet/WQX website. Parameters include specific conductance, pH, and turbidity, and temperature.

Turbidity measurements over time at monitoring station K2100000 are shown in Figure 5. Generally, ntu measurements were well under the 50 ntu evaluation level in North Carolina, although spikes between 50 and 150 ntu were recorded post 2007. However, land disturbing activities just upstream of the water quality monitoring station K2100000 and benthic macroinvertebrate sampling station KB16, has been cited by NCDENR as likely to be affecting water quality and benthic populations at these sampling stations (NCDENR 2011). Also, these land-disturbing activities occurred approximately 2km downstream from the restoration site.

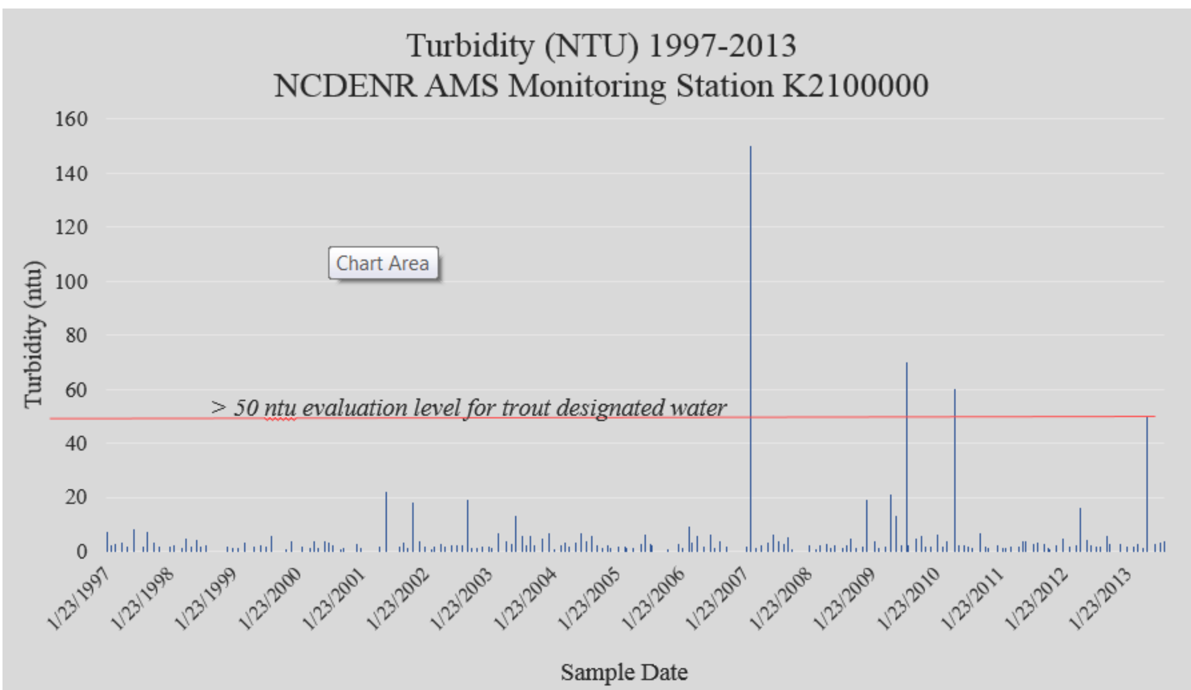

Fig 5 Turbidity (ntu) measurements recorded at the North Carolina Department of Environment and Natural Resources AMS Station K2100000 from 1998-2013. Downloaded from U.S. Environmental Protection Agency's Storet/WQX website. The North Carolina evaluation level for turbidity for trout designated streams is >50.

3.3.5 AppAqua Benthic Macroinvertebrate Assessment

Macro invertebrate populations analyzed using the NCDENR SQM method by an AppAqua biologist in spring 2013 were found in abundance within the restoration site. The NCIBI rating for mountain regions results in a score of Excellent if the overall BI value is < 4.05. Values well under 4.05 were found throughout the restoration reach, resulting in BI ratings of Excellent at all three surveyed locations (Table 6).

NCIBI Ratings for Macroinvertebrate Communities Within the Restoration Reach			
AppAqua Macro Invertebrate Sampling 2013			
Restoration Reach	**Upstream**	**Midstream**	**Downstream**
Total Number	75	132	80
Total Relative Abundance (1,3, or 10)	55	68	53
Overall BI value	2.87	2.29	2.59
BI Rating	**Excellent**	**Excellent**	**Excellent**
Average Evenness	0.878	0.716	0.522
Simpson's Index/Species Diversity	0.867	0.843	0.896

Table 6: North Carolina Index of Biologic Integrity (NCIBI) ratings for benthic communities within the restoration reach. Data collected and analyzed by AppAqua biologists using North Carolina Department of Environment and Natural Resources standard qualitative method as outlined by Standard Operating Procedures for Benthic Macroinvertebrates (NCDENR 2012).

3.3.6 AppAqua Fish Community Assessment

The AppAqua fish community assessment from 2014 showed similar results to that of the 2004 USACE assessment. A BI value of 52.8 was assigned to the surveyed site. An NCIBI class rating of Good was then applied to the fish index. Large stone roller populations, *Campostoma anomalum*, were seen in both the 2004 USACE survey and the 2013 AppAqua survey, and along with tolerant species, kept the NCIBI from obtaining an Excellent rating. The elevated herbivore population is indicative of excessive solar input into the stream allowing for algae growth, which herbivores feed on. Comprehensive data used for determining NCIBI during the AppAqua assessment are shown in Tables 7 and 8.

AppAqua Fish Assessment, Restoration Reach (2013)		
Common Name	**Scientific Name**	**Quantity**
Stone roller	*Campostoma anomalum*	126
Creek Chub	*Semotilus atromaculatus*	91
Fantail Darter	*Etheostoma flabellare*	54
Brown trout	*Salmo trutta*	19
New River Shiner	*Notropis scabriceps*	17
N. Hogsucker	*Hypentelium nigricans*	12
White sucker	*Catostomus commersonii*	10
Green Sunfish	*Lepomis cyanellus*	9
Kanawha Minnow	*Phenacobius teretulus*	9
Mottled sculpin	*Cottus bairdii*	8
Tonguetied minnow	*Exoglossum laurae*	8
Blacknose Dace	*Rhinichthys atratulus*	8
Rosyside Dace	*Clinostomus funduloides*	8
Greenside Darter	*Etheostoma blennioides*	2
Bluntnose minnow	*Pimephales notatus*	2
Rainbow trout	*Oncorhynchus mykiss*	1
Redbreast Sunfish	*Lepomis auritus*	1
Rockbass	*Semotilus atromaculatus*	1
New River Chub	*Nocomis platyrhynchus*	1

Table 7: Fish populations present during 2013 AppAqua electrofishing survey. A high number of herbivores and omnivores were present, but generally the fish habitat is good within this reach.

NCIBI Ratings for Fish Communities Within the Restoration Reach			
Metric	**Quantity**	**IBI Metric**	**Score**
# of species	19	1	5
# of fish (total)	387	2	5
# of darter sp.	2	3	3
# rockbass, smallmouth, trout sp.	3	4	5
# cyprinids	9	5	5
# of intolerant sp.	5	6	5
% tolerant sp.	29.2	7	1
% omni/herb	35.4	8	5
% insectivores	58.9	9	5
% multiple age groups	68.4	12	5
Total x 1.2 (corrected for mountain stream)			52.8
Rating			**Good**

Table 8: North Carolina Index of Biologic Integrity (NCIBI) rating for fish communities sampled during 2013 by AppAqua. The presence of a high number of omnivores and herbivores results in a NCIBI rating of Good for the reach.

3.3.7 AppAqua Water Quality Assessment

In-situ measurements at the upstream and downstream monitoring locations are summarized in Table 9. The high number of samples (n= 18141) provided by the *in-situ* sondes resulted in a highly reliable and accurate database of temperature, pH, and specific conductivity within the restoration reach. In addition, the placement of the sondes at the upstream and downstream bounds of the study area allow for analysis of water quality within the project reach.

High variability is seen with specific conductance with a minimum of 39 (upstream) to 45 (downstream) and maximums in excess of 2000 µS/cm. Median conductivity is comparable to that seen at NCDENR station K2100000, approximately 136 µS/cm. Extreme, short-lived, spikes in conductivity are seen when examining the data over time, and occur during winter snowstorms when de-icing salts enter the stream channel and during rain events when stormwater runoff enters the channel (Figure 6). It is likely that the high temporal resolution of data collection by the sondes (every 15 minutes), allowed for the recording of the spikes in conductivity, as compared to relying on grab samples.

The pH within the reach is well within normal range. Minimum values average 5.4, with maximum values averaging 7.8, and an averaged median of 6.8. Maximum temperatures just barely exceed the standard for trout designated waters in North Carolina; however, the median temperature is well under the evaluation level of 20°C.

Water Quality Data from AppAqua Monitoring Stations October 23, 2013- April 30, 2014)									
Parameter	Evaluation Level	N		Minimum		Median		Maximum	
		Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Specific Conductance (µS/cm)	n/a	18141	18141	40	47	136	138	2606	2621
pH	<6, >9	18141	18141	5.5	5.3	6.9	6.7	7.9	7.7
Temperature (°C)	>20°C (Trout Designated)	18141	18141	0	0	6.4	7.7	21.6	21.6

Table 9: Water quality parameters measured via In-Situ 9500 water quality monitoring sondes within the restoration reach from October 2013 to April 2014.

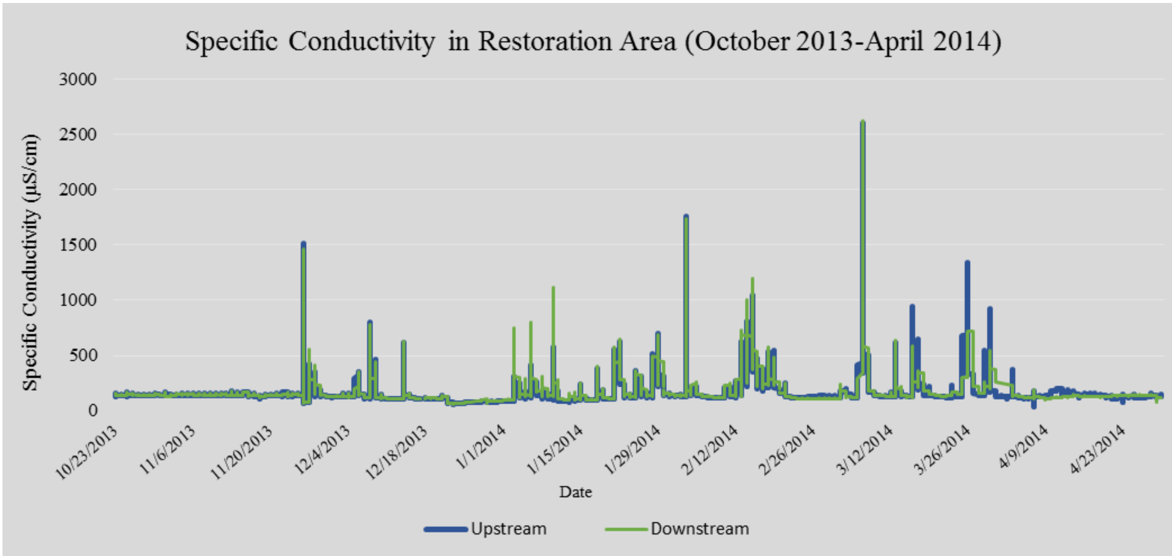

Fig 6 Specific conductivity (µS/cm) as measured at AppAqua water quality monitoring stations. One sonde is located at the upstream end of the project (blue line), and another is located at the downstream end (greenline). Significant spikes in conductivity are seen during winter storms and rain events. Typically the sondes have similar measurements, however, during precipitation events the measurements between sondes may deviate from each other. This indicates that runoff between the sondes could be influencing water quality in the reach.

4 Discussion

The restoration project along the Boone greenway reach of the South Fork is expected to improve the aquatic habitat by reducing erosion and sedimentation and lowering turbidity through streambank stabilization and riparian re-vegetation. In addition, the project is thought to be important for reconnecting the floodplain to the river, providing access to the river, and protecting the adjacent greenway space (see Table 1). The EA, which is the guiding document for the restoration project, provides NCDENR benthic macroinvertebrate community sampling results, USACE fish survey results, and water quality data from NCDENR to summarize habitat and water quality conditions for the project site.

Interviews suggest that a project goal/expected outcome is to improve aquatic habitat (Table 1). Table 2 shows a degrading trend in benthic populations for the three NCDENR sampling sites used for developing the EA, but still overall good quality. However, benthic macroinvertebrate assemblages represent highly localized conditions, and although the sampling stations are in the general vicinity of the site, the usefulness of those data as habitat indicators for evaluating restoration measures is reduced by the geographic disconnect of the sampling sites to the project reach. Moreover, Table 6 shows excellent benthic macroinvertebrate populations currently at the actual restoration site, suggesting that habitat conditions within the project reach are already of high quality.

Fish community assessments from both USACE and AppAqua summarized in Tables 3, 7, and 8 show good overall biologic integrity. There is some room for improvement in species diversity through enhanced shading of the stream. Reducing solar input through increased canopy cover could potentially help balance the fish population; however, this could take many years to see results. Furthermore, invasive species eradication will remove much of the riparian zone and likely result in a decrease of shade and increase to water temperature until the vegetation matures. Also, temporary absence of mature vegetation in the riparian zone could lead to increased susceptibility to severe bank erosion during storms. Increased canopy coverage provided by an enhanced riparian buffer, once established, could provide benefits to the fish community assemblage by reducing tolerant species and lowering stream temperatures. A post-project fish community assessment that raises the NCIBI to a rating of Excellent would indicate restoration success.

The USACE fish survey is the only habitat data collected by the project sponsors in the restoration area, and would be a good source of data to evaluate the efficacy of restoration implementation. However, there is a temporal discrepancy between when the fish data were collected (2004) and project implementation (2014). This disconnect reduces the ability to properly assess the effect of restoration on fish community based on data provided by the EA. Fish community and benthic macroinvertebrate community surveys carried out in

2013 within the project reach by the AppAqua research group have the most potential for analyzing project success post implementation.

Overall in-stream water quality is good as shown by both NCDENR AMS data (2.6 km below reach) and ASU *in-situ* data (Tables 4 and 9), however, specific conductivity can surge during winter storms at the restoration site (Figure 6). Riparian vegetation could mitigate the effects of runoff to the stream and offer increased stability for the stream bank. Establishing or rehabilitating wetlands that will reconnect the river with the floodplain is one of the most promising aspects of the restoration. The wetlands should help mitigate storm water runoff to the stream and provide a buffer from pollutants, and potentially lower spikes in specific conductivity, as well as reduce sediment entering the river channel during storm events. In addition, wetlands should provide flood protection for the recreational fields and greenway and increase habitat diversity within the riparian corridor.

Lowering turbidity is also stated to be a primary goal by all of the stakeholders (Table 1). As shown in Figure 5, turbidity levels are typically well under the 50 ntu standard for trout streams. Stabilization of stream banks could help reduce bank loss at the site during rain events, but it is unlikely that this will result in decreasing spikes in turbidity at NCDENR monitoring station K2100000 several kilometers downstream.

As development continues upstream, storm water runoff conditions may overwhelm restoration efforts, and limit the ability of the implemented measures to positively influence water quality within the stream channel. The riparian area will be re-vegetated and enhanced, but the recreational fields and greenway trail hinder extension of the riparian area. Consequently, the ability of the riparian area to provide a buffer for the stream against upstream conditions is limited.

The project sponsors do not have an official monitoring plan in place for the restoration. NCNR suggested they are motivated to understand the effects of restoration measures, because they hope to work with AppAqua researchers on collecting data within the restoration reach. However, the lack of funding and no requirement to monitor could potentially hinder these efforts. Predicting the outcome of any given environmental restoration is difficult, as ecological systems are dynamic and many factors come into play. A summary of probable outcomes based on information obtained from interviews and available data is shown in Table 10.

How likely are management goals to be met?	
Improve habitat	Habitat already in good shape Short term disruption of existing habitat, long term improvements hard to judge Added vegetation will potentially help with canopy cover of stream and provide habitat for benthics and fish
Stabilize Banks	In-stream structures shown to fail and require maintenance Riparian vegetation, if able to establish will potentially stabilize banks and reduce erosion Upstream conditions could continue to overwhelm restoration measures
Reduce Turbidity	Turbidity already low and within NC standards other than associated with land disturbance downstream from restoration area Bank stabilization, re-vegetation, wetland rehab could help reduce turbidity during rain events
Protect Greenway	If banks are stabilized then further loss of greenway could be prevented in the short term Upstream conditions could continue to overwhelm restoration measures resulting in continued erosion

Table 10 Hypothesized likelihood of implemented restoration measures meeting sponsor goals. Based on stakeholder interviews and evaluation of available data.

Finally, the sheer longevity of the planning and design process from inception (1998) to actual implementation (2013) resulted in decreased baseline data quality. Collaboration with ASU scientists could have been beneficial in numerous ways. High spatial resolution geographic datasets, high temporal resolution water quality data, as well as biologic and geologic data exists within several departments, but was not utilized by the project planners. Although the project was developed before AppAqua water quality monitoring efforts began, project sponsors could have partnered with ASU scientists to collect baseline data to monitor project outcomes. This highlights an ongoing problem of the lack of communication between scientists that collect data, and environmental managers that implement restoration plans.

5 Conclusions

This assessment highlights disconnects between data used for planning restorations and management goals. A lack of data collected within the restoration project reach and underutilization of existing data for properly evaluating restoration measures are found throughout the literature, and are seen in the presented case study as well. Although project sponsors want to improve habitat quality and say that sedimentation is killing benthic populations, the sponsors did not collect any data within the reach that would justify this statement. Additionally, data used to develop the EA and guide the project were collected between 1998 and 2008; however, the project will not begin until 2014. Furthermore, NCDENR data used for developing the EA was not located within the project reach. The geographic and temporal disconnects in data used for developing the EA, consequently, reduce the overall ability to justify restoration or evaluate the project post-implementation.

The primary objective of the project is to improve the aquatic habitat; however, the primary outcomes will most likely be protecting athletic fields and the greenway, increased flood protection, and improved access to the river. The potential for increasing aquatic habitat is diminished by anthropogenic activities (e.g., deforestation and increasing impervious surfaces) occurring within the upstream watershed. Unless measures are taken to reduce upstream ecosystem degradation, the ability of this project to have a positive impact on habitat quality may be limited. Protecting the built environment and public space is a legitimate use of public funds as public welfare is enhanced; however, justifying restoration based on ecological improvement is potentially detrimental for future management activities and funding acquisition for projects that actually could have a positive impact on habitat quality.

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Vita

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