Coastal Carolina Riverwatch

Water Quality for Fisheries

An Assessment of Water Quality Concerns

Introduction

The purpose of the Water Quality for Fisheries (WQ4F) Project is to identify and address the impacts of water quality on the North Carolina fisheries.

Part of this process includes researching and assessing what is currently being done to address water quality issues that impact fisheries. The assessment part of this project will include what is being done to address sources of pollution from all areas of NC (including those outside of the coastal area).

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Table of Contents:

Priorities Identified by Coastal North Carolina Fishermen:

Agriculture and Factory Farm Runoff
Stormwater Runoff from Roads, Highways, and Parking Lots
Industrial Pollutants
Plastic Pollution
Municipal Wastewater Treatment Plants and Septic Tanks

Figure 1. Coastal Carolina Riverwatch. 2021. "Commercial and Recreational Fishermen Survey." ECU Center for Survey Research, Thomas Harriot College of Arts and Sciences, East Carolina University, Greenville, NC. March 4-21.

Stormwater Runoff from Roads, Highways, and Parking Lots

Introduction

Due to rapid growth in coastal areas, increased construction, and the draining of wetlands, the amount of impervious surfaces has increased tremendously in coastal North Carolina. Impervious surfaces are developed areas such as roads, sidewalks, parking lots, rooftops, and construction sites that are impermeable; therefore, water does not soak through the surface. Instead, stormwater runs over the impervious surfaces, catches contaminants, and washes the contaminants into drainage ditches or storm drains which lead to surface waters and beach areas. Development of housing subdivisions, roads, shopping centers, industrial parks, and parking lots have prohibited forests and wetlands' naturally occurring draining and filtration processes in the coastal region (Mallin, 2006). Now the stormwater enters local streams, beaches, and marinas.

Generally, stormwater is untreated because it is difficult to control nonpoint source pollution draining from a large area. Nonpoint source pollution is identified as the leading cause of water-quality issues by the Environmental Protection Agency (EPA). Stormwater runoff is one of the greatest contributors to nutrient loading in surface waters. This type of nonpoint source pollution comes from the drainage in urban and suburban areas. As a result of N loadings, eutrophication has been described as the "single largest threat to the integrity of coastal ecosystems" (Song, et al., 2014).

Impervious surfaces prevent the removal of fecal bacteria and viruses present in runoff through the filtration process occurring in soil (Mallin, 2006). The resulting waterborne microbes found in samples have significant health implications such as increased risk for liver disease, respiratory infections and gastrointestinal disorders. Shellfish beds face extreme implications from contaminated stormwater runoff because they are filter feeders and concentrate organisms in the water. Contaminated shellfish pose severe health implications to consumers. The U.S. Public Health Service established a nationwide safety standard for shellfish based on fecal coliform bacteria levels in the water (Mallin, 2006).

In addition to the microbes carried by stormwater runoff, fertilizers, pesticides, heavy metals, and petrochemicals enter waterways as well. However, there are infrastructure, policies, research, and educational opportunities focused on stormwater control measures that assist in the mitigation of water contamination.

Infrastructure Assessment

Current Actions:

Type of Infrastructure	Water Quality Impacts	Lead Organization

Constructed Stormwater Wetlands	• Removes pollutants such as bacteria and fertilizers • Limits flooding • Decreases amount of contaminated sediments in runoff due to reduced erosion • Improves fish and wildlife habitat	UNCW Center for Marine Science 910.962.3000 NC State Stormwater Engineering Group 919.515.6780
Natural Stormwater Runoff Filtration Systems	• Filters suspended solids and fecal bacteria from water • Reduces pollutant concentrations • Increases natural vegetation for habitat	UNCW Center for Marine Science 910.962.3000
Stormwater Runoff BMPs and Nature-Based Stormwater Strategies	• Reduces risk of nutrient loading and fecal bacteria pollution • Decreases amount of stormwater discharge	NC Department of Environmental Quality 877.634.6748

The use of developed infrastructure and Best Management Practices (BMPs) have been essential in filtering pollutants from stormwater runoff and reducing its impact on fish populations. One example includes constructed stormwater wetlands (CSWs) which have proven to be effective in reducing contaminants from runoff (Song, et al., 2014). CSWs are engineered wetlands that utilize vegetation, sediments, and microbial processes to filter

pollutants from runoff. Denitrification is a process that occurs in wetland sediments that assists in removing nitrogen from water by breaking down nitrogen compounds and consuming available organic carbon (Song, et al., 2014). Therefore, wetlands are an important infrastructure used to decrease nitrogen loading in surface waters.

Dr. Mallin from the UNCW Center for Marine Science along with other scientists, completed a study in Wrightsville Beach, North Carolina to assess the effectiveness of BMPs implemented from 2013 to 2015 in reducing contamination of coastal waters from stormwater runoff. Wrightsville Beach, North Carolina is faced with fecal bacteria loading, affecting recreational and shellfishing waters resulting from stormwater runoff (Mallin, et al., 2016).

Originally, a pipe carried runoff straight into Banks Channel, but the pipe was replaced by a buried infiltration chamber which allowed for stormwater to seep into and filter through the sandy soils. The monitoring study found that the new infiltration chamber reduced stormwater discharge by 93%, fecal bacteria by 96%, Enterococcus bacteria load by 90%, and total suspended solids load by 99% (Mallin, et al., 2016). Also, Wrightsville Beach installed curb cuts, reversed stormwater inlets, a large rain garden, and restored grassed swales to assist in stormwater infiltration.

Mallin, et al. describe successful stormwater runoff filtration systems and processes. For example, sand filters function as effective, common water purifiers for suspended solids and fecal bacteria by creating a physical filter and utilizing the protozoa, nematodes, and microzooplankton found in the sand to consume fecal microbes (Mallin, et al., 2016). Grassed swales support infiltration, which occurs when water enters the soil rather than draining into surface waters. This aids in reducing pollutant concentrations in stormwater. Roadside swales are utilized in a similar manner. The vegetation planted or naturally occuring near roadsides assists in filtration and infiltration of runoff. Finally, rain gardens have significant impacts in reducing nutrient and fecal bacteria runoff. These vegetated areas are designed to receive stormwater and allow for seepage into various layers: a

vegetated area, a mulch layer, a soil layer, a sand bed, and a gravel bottom (Mallin, et al., 2016).

After studying the changes in water quality after the implementation of BMPs, Mallin, et al. found that with the use of the BMPs, there was a significant decrease in stormwater discharge in Wrightsville Beach, NC (Mallin, et al., 2016). This research has a significant impact for other coastal communities who can utilize similar BMPs to protect their estuarine waters from polluted stormwater runoff successfully.

Similarly, Dr. Mallin and Dr. Grogan found that the implementation of BMPs in Wilmington caused a reduction in stormwater runoff by 62%, total nitrogen was reduced by 87%, and enterococcus bacteria was reduced by 76% (Beck, 2021).

Another team focused on assessing and developing stormwater infrastructure and technology includes the Stormwater Engineering Group at NC State University. Some of their projects include constructing stormwater wetlands; monitoring pond retrofits such as wetland islands, upflow filter, and sand filters; and researching green street infrastructure (NC State, n.d.).

Recommended Future Actions:

Type of Infrastructure	Water Quality Impacts
Sustainable Development	• Reduces stormwater runoff discharge • Preserves habitat • Filters contaminants from runoff
Replacement of Current Stormwater Outfalls	• Decreases drainage into beaches and shellfishing waters • Reduces contamination of coastal waters
Evaluate Hurricane and Flooding Impacts on Stormwater Infrastructure and Update Technologies Accordingly	• Reduces overloading of stormwater control systems • Decreases risk of water contamination

Though there has been a significant amount of implementation and assessment of BMPs and stormwater runoff filtration systems, there are other technological developments that could assist in reducing stormwater runoff discharge in the future. For example, beginning more sustainable development by avoiding clear-cutting forests, draining wetlands, and extensive use of pavement would aid in protecting water quality. Examples of "smart-growth" development strategies include increasing vegetated areas and decreasing the use of impervious surfaces, the preservation of wetlands, and using on-site runoff treatment technologies (Mallin, 2006). An example of technologies is the utilization of porous concrete for pavement. Also, there are new collection systems that direct stormwater runoff from paved areas to filters composed of filtering layers. Finally, utilizing vegetative buffer zones near surface waters, parking lot filters, and reconstructing wetland ecosystems.

Also, halting new stormwater outfalls that drain from sites to beaches and shellfishing waters and continuing to get rid of current outfalls by replacing them with effective stormwater management infrastructure would enhance water quality.

It is important to recognize the implications of hurricanes and severe storms on stormwater infrastructure. As intense rain events and flooding become more frequent in the coastal region, the updating of stormwater infrastructure to handle these occurrences is essential. A large portion of stormwater runoff results from big rain events that are very difficult to manage. Current management strategies focus on "designed storms," defined as a rain event that generates an inch of water in 24 hours. Large storms create more precipitation than an inch per day, therefore, we are not capable of managing larger quantities.

Policy and Enforcement Assessment

Current Actions:

Type of Policies	Water Quality Impacts	Lead Organization
Coastal Area Management Act	• Preserves ecological conditions of estuaries • Encourages sustainable water resources use • Reduces permitted amount of stormwater discharge	Coastal Resources Commission 877.623.6748 Coastal Resources Advisory Council
Fisheries Reform Act	• Improves aquatic habitat quality • Increases fish populations • Reduces nonpoint source pollution runoff	NC Division of Water Resources 919.707.9023
DEMLR Stormwater Program	• Reduces sedimentation and erosion • Decreases stormwater contamination • Limits amount of stormwater discharge from entering coastal waters	Division of Energy, Mineral, and Land Resources 877.623.6748
Administrative Codes Setting Stormwater Runoff Standards	• Decreases sedimentation at development sites • Protects ORW and HWQs • Reduces pollutants	Environmental Management Commission under the DWQ 877.623.6748

	from entering waters	
20 Coastal Counties Stormwater Law	• Reduces runoff by limiting impervious surface development • Decreases runoff contamination	NC Department of Environmental Quality 877.634.6748
Phase II Post-Construction Law	• Improves drainage, limiting the amount of runoff • Filters stormwater runoff before entering surface waters	Each Locality's Stormwater Management Program
Local Watershed Restoration Plans	• Address water contamination issues with financial and technical assistance from the DEQ • Encourages implementation of BMPs, resulting in the protection of water quality • Reduces stormwater runoff discharge into nearby bodies of water	NC Department of Environmental Quality 877.634.6748 North Carolina Coastal Federation 252.393.8185

A significant amount of administrative codes, regulations, and laws have been created with the objective of decreasing the negative impacts of polluted stormwater runoff on North Carolina's surface waters. The Coastal Area Management Act (CAMA), established in 1974, is a cooperative state-local program for coastal management. Local governments in North Carolina have the authority to plan while the state government identifies areas of environmental concern (Coastal Area Management Act, n.d.). The state government's

primary role is to set standards and review the capacity of local governments' plans. The overarching goals of the act include developing a management system that will preserve the natural ecological conditions of estuaries and beaches, insure development or preservation of coastal lands and water resources based on ecological considerations, and safeguard the sustainable use of coastal resources (Coastal Area Management Act, n.d.). The Coastal Resources Commission and the Coastal Resources Advisory Council are essential in the enforcement of the law. The policy also includes a permitting program for development that assists in reducing stormwater runoff.

In 1997, the North Carolina General Assembly passed the Fisheries Reform Act which requires the Marine Fisheries, Environmental Management, and Coastal Resources commissions to adopt a conservation and restoration plan to assist the protection of fisheries (NCDEQ, 2016). The resulting management program is the North Carolina Coastal Habitat Protection Plan (CHHP).

Four priority aquatic habitat issues were identified during the creation of the plan: oyster restoration, living shorelines, sedimentation, and creating metrics to evaluate habitat trends and the effectiveness of management strategies (NCDEQ, 2016). The plan is implemented by the Division of Marine Fisheries (DMF), the Division of Coastal Management (DCM), the Division of Water Resources (DWR), and the Division of Energy, Mineral, and Land Resources (DEMLR). There has been noticeable improvement in fisheries habitat and increased fish populations since the implementation of the CHHP (NCDEQ, 2016). Some methods to reduce nonpoint runoff in the coastal region include the implementation of coastal stormwater rules by the Environmental Management Committee (EMC) and the inclusion of low impact development techniques as a Best Management Practice by the DWR and the DEMLR.

In this plan, the NCDEQ encourages the implementation of on-site infiltration of stormwater, incentivizing the creation of riparian vegetated buffers, and increasing financial assistance for land conservation (NCDEQ, 2016). Some potential strategies specific

to reducing sedimentation in estuaries include collaborating with the NC Department of Transportation to retrofit road ditches that discharge sediments into estuarine waters and creating local and state erosion control programs.

In 1996, the EPA created the Stormwater Program under the National Pollutant Discharge Elimination System (NPDES) to protect the country's bodies of water from stormwater runoff (Stormwater in North Carolina, 2021). Many parts of North Carolina have implemented the program since 2001 as required by the federal agency. The NPDES requires urbanized areas to utilize best management practices (BMPs) and comply with measures that reduce the environmental effects of development (Stormwater in North Carolina, 2021).

The legislation was developed to protect the state's surface water from stormwater runoff impacts. The EPA gave the NCDEQ the authority to administer and regulate water quality policies throughout the state. The DEQ uses "a combination of communication, innovation, leadership, and regulation" to accomplish this goal (Stormwater Program, 2021). The NC Division of Energy, Minerals and Land Resources (DEMLR) is responsible for implementing the Stormwater Permitting Program for the state. The guidelines come from stormwater control programs regulated under the NPDES, Post-Construction Program, and Water Supply Watersheds Program (NC DEQ, 2021).

Under the overarching Stormwater Program, there are several programs focused on one aspect of stormwater runoff management. First, the Post-construction Stormwater Program requires new construction sites to install permanent stormwater management strategies and maintain their efforts in the future. The NPDES Construction Stormwater Program provides permits for construction activities that occupy more than an acre. Those receiving permits must develop and implement a Sedimentation and Erosion Control Plan, follow the regulations, inspect sites, and manage records of their participation in the program (Stormwater Program, 2021). Similarly, the NPDES Industrial Program requires that industrial activities monitor their sites for potential sources of stormwater

contamination and utilize the permitting system (Stormwater Program, 2021). Finally, the NPDES MS4 Program provides permits to sites within urbanizing areas such as municipalities, counties, universities, and military bases. Those monitored by the program must implement strategies to prevent stormwater pollution from developed areas.

There are developed administrative codes used to regulate and implement stormwater runoff management strategies. They are enforced by the Environmental Management Commission under the Division of Water Quality (DWQ). One specific code, Stormwater Requirements: Coastal Counties (15A NCAC 02H .1005), states that any nonresidential or residential development activity must develop a Sedimentation and Erosion Control Plan or a CAMA Major Development Permit to manage stormwater runoff (NCDEQ, 2021).

There are also requirements for High Quality Waters (HQWs) that mandate stricter stormwater management measures for all construction sites that use a stormwater management permit and are located within one mile of waters classified as High Quality Waters (HQW) (NCDEQ, 2021). Similarly, all development activities using a stormwater management permit and located within one mile of Outstanding Resource Waters (ORW) may need to follow more stringent rules and regulations for stormwater runoff.

Other codes focus on developing specific regulations for development in urbanizing areas, guidelines for the program implementation, and requirements for post-construction practices (NCDEQ, 2021). Administrative code, 15A NCAC 02H .0100, also known as the Surface Waters and Wetlands Standards, establishes the process of classifying bodies of water based on the Department of Natural Resources (DENR) water quality standards (NCDEQ, 2021).

North Carolina has developed several laws regulating stormwater discharge as well. The 20 Coastal Counties Stormwater Law adds additional requirements and water quality standards to the administrative codes for coastal counties. The statute requires a stormwater permit for non residential development that disturbs less than one acre, adds more than 10,000 square feet of impervious surface and residential developments within a

half mile of shellfish waters, and disturbs less than one acre but adds more than 10,000 square feet of impervious surface (NCDEQ, 2021). It also explains the requirements for nonresidential and residential development in North Carolina's coastal counties. Some of these requirements include the implementation of a Sedimentation and Erosion Control Plan, the use of a Coastal Area Management Act Major Development Permit, strategies to protect ORW and SA waters, prohibition of stormwater discharges, and requirements for structural stormwater controls (NCDEQ, 2021).

The state of North Carolina has specific post-construction standards created under the Phase II Post-Construction Law to regulate new development in specific watersheds (EPA, Office of Water, 2011). They include standards such as creating buffers, defining implementation authority, and drainage specifications. These additional requirements are based on the identification of high or low density areas and the location of the development if it is in coastal counties or within a half mile of saltwater-freshwater and saltwater (EPA, Office of Water, 2011).

Under this policy, regulated entities' impervious surface areas need to be located at least 30 feet inland of all surface waters, use a fecal coliform reduction program, and have deed restrictions (EPA, Office of Water, 2011). Areas that drain into Class SA waters, Trout Waters, and Nutrient Sensitive Waters have additional regulations. There are policies in place to limit percent impervious cover used for parking lots and require a bioretention area for parking lots greater than 1 acre with 20% impervious surface cover (EPA, Office of Water, 2011). Enforcement of the statute is led by each locality's stormwater management program.

Finally, the NCDEQ, in collaboration with the North Carolina Coastal Federation, has developed watershed restoration plans for Swansboro, Bradley and Hewletts Creek, Beaufort, White Oak River, and Pine Knoll Shores. The goals of these government funded programs are to protect water quality, encourage the implementation of BMPs regarding

stormwater runoff, and utilize restoration strategies to improve the health of the watersheds.

Recommended Future Actions:

Type of Policies	Water Quality Impacts
Green Infrastructure Policies	• Reduces stormwater runoff discharge on-site • Filters contaminants in runoff • Maintains healthy ecosystems
Increase Government Funding for Stormwater Infrastructure and Treatment Systems	• Decreases surface water pollution • Increases the use of effective stormwater reduction methods
Stormwater Contamination Source Control	• Reduces stormwater contamination on-site • Filters pollutants such as chemicals, nutrients, and metals from runoff

As discussed in the infrastructure assessment, the use of Green Infrastructure and sustainable development provides many benefits to water quality protection. Incorporating stormwater management incentives and funding opportunities into city planning and development may standardize the use of permeable pavement, green streets, and filtration systems even more. Moving forward with building sustainable communities and policies will include more extensive environmental assessments, prioritize protecting water resources, and take into consideration ecological systems when constructing new sites.

Providing additional government funding to incorporate stormwater infrastructure into the DOTs practices could greatly assist in reducing water contamination. Last year, the EPA provided a report to Congress regarding the funding options for constructing, rehabilitating, and maintaining stormwater infrastructure (National Municipal Stormwater Alliance, 2020). Also, providing financial assistance for regional EPA offices to create a national performance verification program for stormwater control infrastructure would ensure effectiveness of the measures.

In order to successfully implement stormwater infrastructure in a specific region, it is suggested to collect precipitation data to select the correct technologies to implement (National Municipal Stormwater Alliance, 2020). Another potential policy development includes controlling stormwater contaminants at the source and creating local pollutant source control programs (National Municipal Stormwater Alliance, 2020).

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
Effectiveness of Stormwater Infrastructure and Strategic Placement	• Reduces stormwater discharge • Decreases surface water contamination • Prevents nutrient overload • Decreases sedimentation	UNCW Center for Marine Science. 910.962.3000 NC Sea Grant 919.515.2454
Nutrient Analyses	• Prevents nutrient overload • Decreases risk of eutrophication and fish kills	UNCW Center for Marine Science 910.962.3000
Water Quality Monitoring in Coastal Watersheds	• Decreases anthropogenic effects on water quality • Protects water resources and aquatic habitats • Prevents water toxicity	National Monitoring Network 353.468.4400 NC Department of Environmental Quality 877.634.6748

		NC Division of Water Resources 919.707.9023 NC Sea Grant 919.515.2454
Correlational Studies of Water Quality and Percent of Impervious Surface	• Reduces turbidity and pollution from bacteria, metals, and nutrients • Decreases sedimentation	UNCW Center for Marine Science 910.962.3000
North Carolina Coastal Habitat Protection Plan Research	• Protects aquatic habitat • Decreases anthropogenic threats to coastal habitat • Restores habitat and water quality	NC Department of Environmental Quality 877.634.6748

The impacts of stormwater runoff on aquatic ecosystems and the effectiveness of stormwater infrastructure have been studied by research institutions and government agencies. UNC Wilmington's Center for Marine Science is a leader in these studies; they complete stormwater research and the efficiency of engineered wetlands in removing contaminants from runoff using water samples and nutrient analyses (Song, 2014). They have made significant findings relating to sediments' ability to hold nutrients for long periods of time. They found that sediments with vegetation lose nitrogen at greater rates than unvegetated sediments which indicates that wetland vegetation assists in the denitrification process (Song, 2014).

Researchers such as Dr. Burchell from NC State University have found the placement of stormwater BMPs is important in ensuring their success. Rain gardens and buffer zones should be located strategically in the landscape to maximize their benefits. For example, buffer zones need to be located near bodies of water and have dense vegetative growth in order to be effective.

The National Water Quality Monitoring Council's National Monitoring Network (NMN) for US Coastal Waters and Tributaries chose the Albemarle Sound in North Carolina as a test site for a US Geological Survey (USGS) pilot study. The NMN for U.S. Coastal Water and Tributaries' objective is to develop a greater understanding of the health of the region's oceans, coastal ecosystems, and the effects of anthropogenic activities on coastal waters. Their findings will assist in establishing better resource management strategies (South Atlantic Water Science Center, 2014).

They found that there is a decline in fish populations such as river herring, shad, blue crab, and Atlantic and shortnose sturgeon (South Atlantic Water Science Center, 2014). Fisheries recovery initiatives to combat overfishing have not been successful because of significant water quality impairment as a result of eutrophication, toxic algal blooms, contaminated sediments, and hypoxic and anoxic states (South Atlantic Water Science Center, 2014). Their research included the evaluation of the monitoring programs in use; the determination of toxicity levels and pollution sources; and the assessment of water, biota, and sediment quality.

The NC Division of Water Quality, NC Division of Marine Fisheries, and the US Fish and Wildlife Service have implemented monitoring programs through which they collect water quality data. They assess nutrient levels; cyanotoxins; phytoplankton community composition; and pesticide, metals, suspended solids, and chlorophyll *a* levels (South Atlantic Water Science Center, 2014). This study will bring to light significant data regarding community structures' relation to water quality and food availability in the sound.

The North Carolina Sea Grant and the Albemarle-Pamlico National Estuary Partnership (APNEP) have developed substantial research focused on water quality in coastal North Carolina. These groups take on graduate student fellows to assist in their creation of research projects focused on the Albemarle-Pamlico Watershed. Specifically, fellows have completed projects that have provided a greater understanding of the effect of coastal habitat restoration strategies on estuarine systems in coastal communities (Pharr, 2020).

One specific area of stormwater research includes the association of impervious surface percentage and water quality. Dr. Mallin's research with UNCW's Center for Marine Science has established a strong correlation between E. coli counts and the percentage of impervious surfaces in a given watershed. He found that increased stormwater runoff causes increased amounts of sediments, polluting waters and increasing turbidity. Also, sediments bind with other contaminants such as ammonium, phosphate, metals, and fecal bacteria and viruses which survive for longer amounts of time because they are protected from ultraviolet radiation (Mallin, 2006).

The NCDEQ has developed the North Carolina Coastal Habitat Protection Plan (CHPP) which creates an outline of the ecological and economic value of coastal fish habitats, their condition, and the threats to their ability to thrive including stormwater runoff contamination (NCDEQ, 2016). They update the plan with new research and scientific findings often in order to assess the habitats' statuses, ecological functions, economic values, threats, and foals to restore fish habitat.

Many educational institutions including UNCW, ECU, and NCSU have completed assessments on the effectiveness of the implementation of stormwater runoff management techniques. They evaluate the success of filtration systems, wetland restoration, and green roads on improving water quality and aquatic habitats.

Recommended Future Actions:

Type of Research	Water Quality Impacts

Research Effectiveness of Stormwater Management Control Efforts, Including Buffer Zones	• Reduces stormwater runoff discharge • Filters contaminants in runoff • Protects fish populations • Restores aquatic habitat
Enhance Monitoring of Stormwater Runoff	• Evaluates areas of concern for water quality • Decreases pollution levels • Restores aquatic habitat

Moving forward, there is a need to develop a greater understanding of the most effective stormwater management control efforts in order to continue their implementation. It would be beneficial to assess urban and suburban stormwater runoff in the coastal region in order to assess the success of infrastructure in the flat plains, sandy terrain.

Specifically, it would be useful for future stormwater management implementation to understand the effectiveness of buffer zones. Dr. Burchell from NC State University discussed the success riparian buffers have in mitigating nutrient pollution. However, there are several factors that contribute to their efficiency including their proximity to bodies of water and the type of soil on which they are located (M. Burchell, personal communication, June 16, 2021). For example, buffers are effective when they are located downstream and have adequate connectivity to streams.

During the National Monitoring Network's study focused on the Albemarle Sound's health, the research team acknowledged the gaps in our understanding of the effectiveness of restoration and stormwater runoff management. They believe with improved monitoring and the definition of water and sediment pollutants, scientists will be able to fill gaps in current management efforts and develop effective restoration strategies (South Atlantic Water Science Center, 2014).

Advocacy, Outreach, and Education Assessment

Current Actions:

Type of Outreach	Water Quality Impacts	Lead Organization
NC Stormwater Plan	• Reduces stormwater discharge through professional training on stormwater management strategies • Decreases surface water contamination	North Carolina Coastal Federation 252.473.1607
Public Releases of Stormwater Research	• Educates public on implications of stormwater runoff and current water quality statuses • Reduces runoff discharges once management strategies are implementing	NC State Stormwater Engineering Group 919.515.6780 UNCW Center for Marine Science 910.962.3000
Guidebooks for Water Quality Protection Strategies (CHHP and the Stormwater Design Manual)	• Reduces effects of flooding on stormwater systems • Protects fishery habitats • Utilization of filtration systems reduces the amount of contaminants in runoff	National Oceanic and Atmospheric Administration NC Department of Environmental Quality 877.634.6748

There are many non-governmental groups, research institutions, and government agencies that provide educational materials for stormwater reduction techniques, encourage the implementation of controls, and advocate for cleaner watersheds. For example, the North Carolina Coastal Federation has developed a statewide stormwater plan that encourages

government agencies and stakeholders to accelerate education, outreach, and professional training efforts regarding watershed management techniques (Shutak, 2021). Their goals include developing a comprehensive watershed management network, creating a cost-benefit analysis for nature-based stormwater methods, encouraging policy-making that encourages nature-based stormwater strategies, and educating North Carolina congressional leaders on opportunities to provide adequate resources for conservation efforts (Shutak, 2021).

Educational institutions have developed extensions to assist in stormwater management outreach and research. The Stormwater Engineering Group established at NCSU has the goal of leading the way in Green Infrastructure management, education, and research (NC State, n.d.). Also, Dr. Mallin with UNCW, is part of a water quality testing team that reports their data to the city of Wilmington officials to update the public on pollutant levels in surface waters (Lennon, 2020).

Divisions of the government such as the National Oceanic and Atmospheric Administration (NOAA) provide technical assistance and information regarding water quality protection. NOAA developed a website to assist communities across the country in understanding the effects of flooding on stormwater systems (NOAA Office for Coastal Management, 2021). Also, the NCDEW created a guide, the CHPP, for the Marine Fisheries, Environmental Management, and Coastal Resources commissions in order to assist in the protection and improvement of fishery habitats in the state (NCDEQ, 2016). Collaborating with the NCDEQ in the development of the CHHP, the National Estuarine Research Reserve creates educational information and workshops (NCDEQ, 2016).

The NCDEQ has developed several initiatives to include the public in stormwater management and increase awareness on the effects of runoff on aquatic ecosystems. They coordinate Wow Stormwater Webinars to update the public on current research and initiatives in place to protect water quality from stormwater runoff (Stormwater Program, 2021). The Stormwater Design Manual was developed by the NCDEQ to provide examples

and guidelines for the implementation of stormwater runoff control measures. The guidebook includes research on runoff treatment, soils, vegetation, impacts of impervious surfaces, and construction (Stormwater Design Manual, 2020). Then, it provides minimum design criteria and suggestions for stormwater management strategies such as the use of infiltration systems, bioretention cells, wet ponds, stormwater wetlands, permeable pavements, sand filters, rainwater harvesting, green roofs, and treatment swales (Stormwater Design Manual, 2020). The NC DEQ includes information on updated technologies that were newly developed to manage stormwater runoff. Finally, they provide recommendations for stormwater control based on the specific type of construction site including residential developments, low density, airport, roads and greenways, and solar farms (Stormwater Design Manual, 2020). NC State University's Department of Biological and Agricultural Engineering collaborates with the NCDEQ to update the Stormwater Design Manual that provides communities with a list of approved engineering practices that reduce stormwater runoff.

Recommended Future Actions:

Type of Outreach	Water Quality Impacts
Guidebooks for Homeowners	• Reduces stormwater runoff discharge from suburban settings • Filters contaminants from stormwater runoff
Outreach to Business Owners	• Decreases urban runoff into surface waters • Filters contaminants from stormwater runoff
Publicizing Successful Stormwater Control Efforts	• Improves a town or company's participation in BMPs • Reduces city-wide stormwater runoff discharge

	• Decreases the quantity of nutrient and contaminants from entering bodies of water

In the future, informing homeowners on stormwater management strategies would be beneficial in decreasing suburban stormwater runoff. The focus has been on urban stormwater runoff because it has a greater impact on water quality; however, runoff from residential areas contains high levels of nutrients and fecal bacteria from pet waste and chemical use.

Government agencies and environmental NGOs can assist in reducing suburban runoff by developing guidebooks and educational material for stormwater management techniques such as the implementation of rain gardens, using native vegetation and mulch for water absorption, and developing with porous surfaces. Increasing awareness of these practices among suburban property owners could greatly reduce surface water contamination. The NC State Extension has created a stormwater control manual to share with the public.

Also, completing outreach to business owners and providing educational material regarding urban strategies to reduce stormwater discharge will be effective. Similarly, they could place native plants and mulch in front of their business to increase water uptake. They could utilize sand filters on their property as well to reduce the amount of contaminants entering the urban runoff.

Finally, publicizing the success of a specific city's or company's implementation of stormwater control techniques would promote economic growth for the town as well as encourage other locations to participate.

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