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).

This document was prepared by Coastal Carolina Riverwatch with support and contributions from the following:

Coastal Carolina Riverwatch Staff:

Lisa Rider, Executive Director
Larry Baldwin, Waterkeeper
Rebecca Drohan, Program Coordinator
Nicole Eastman, Water Quality for Fisheries Intern and Research Lead
Noah Weaver, Water Quality for Fisheries Intern and Graphics Lead
Maria Mood-Brown, Research Advisor
Rick Kearney, Board President

Coastal Carolina Riverwatch
Water Quality for Fisheries Industry Working Group:

Thomas Newman - Williamston
Mark Hooper - Smyrna
Mike Blanton - Elizabeth City
Sam Romano - Wilmington
Glenn Skinner - Newport
Greg Ludlum - North Topsail Beach
Joey Van Dyke - Frisco
Krissi Fountain - Wrightsville Beach
Jot Owens - Wilmington

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

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.

Municipal Wastewater and Sewage

Introduction

According to the EPA, wastewater treatment systems are one of the US's most widely-used pollution control technologies (Allen, 2019). These systems' treatment process includes sewers collecting wastewater, transporting the water to treatment plants, completing a cleaning process, and finally discharging the wastewater. Municipal wastewater treatment plants, also referred to as publicly owned treatment works (POTWs), filter physical, chemical, and biological pollutants from the wastewater received from households, businesses, and industries of the area.

Differing from municipal wastewater treatment facilities, about 50% of homes in North Carolina use on-site wastewater systems also referred to as septic systems (EPA, 2017). They generally have a tank, a distribution box, and subsurface absorption lines with perforated pipes laid in a gravel bed. On-site wastewater systems provide an alternative, natural way to treat and dispose of domestic waste without being connected to a centralized municipal sewage treatment system.

Sanitary sewer overflows (SSOs) and the resulting water pollution, are generally the effects of failed wastewater infrastructure. During a SSO, the spill may consist of hundreds to millions of gallons of overflow and damaging pollutants (Deaton, et al., 2021). The implications of these malfunctions on water quality include algal blooms resulting from nutrient loading, increased bacteria and toxin levels, fish kills, and contaminated sediments. In addition to the depletion of available oxygen, algal bloomscauses a breakdown of proteins, leading to the release of toxic hydrogen sulphide and ammonia. (Shahidul, 2004).

Sewage wastes can include industrial waste, municipal wastes, animal and slaughterhouse wastes, water from domestic bathrooms and laundry, kitchen refuse, and fecal matter. Major water quality concerns associated with untreated or poorly treated wastewater entering water systems include high levels of dangerous bacteria, hazardous materials, elevated total suspended solids, pharmaceuticals, and excess nutrients.

Population centers contribute greatly to the amount of daily loads entering bodies of water from POTWs.

Inflow and Infiltration (I & I) is a severe water quality implication resulting in the pollution of estuarine waters by raw wastewater. Inflow occurs during storm events when stormwater surges into and overwhelms a sewage collection and treatment system. Infiltration is the process of groundwater entering a sewer pipe system through uncapped sewer line cleanouts, gutters connected to lateral sewer lines, inadequate sewer manhole covers, and cross connections of stormwater lines with sanitarysewer lines (Deaton, et al., 2021). Sewer pipes also receive infiltrated groundwater through faulty pipe joints, sewer pipe cracks, broken manholes, and collapsed lateral pipes.

Coastal North Carolina faces more challenges with wastewater treatment systems failing due to the sea level rise, more frequent and severe king tides, higher rainfall amounts, and seasonal temperature effects on groundwater levels (Allen, 2019).

Pump stations and wastewater treatment plants (WWTPs) are built to receive specific peak flow volumes and rates which can be exceeded with the increased flow from I & I. With a higher risk of overflow, there is also an elevated risk of untreated waters being released from a WWTP.

Additionally, communities, especially those home to low income citizens, often do not have adequate financial resources to maintain and update wastewater infrastructure.

Low-income counties face challenges with a lack of federal funding and the expenses of infrastructure upkeep and replacement, contributing to a greater risk of sanitary sewer overflows (Deaton, et al., 2021).

Infrastructure Assessment

Current Actions:

Type of Infrastructure	**Water Quality Impacts**	**Lead Organization**
Centralized Wastewater Systems	• Treats wastewater for bacteria, suspended solids, and nutrients • Decreases water contamination in streams	
Septic Systems	• Treats wastewater from individual households for bacteria and suspended solids • Reduces water and soil contamination near households	
Artificial Wetland Treatment Systems	• Uses natural processes to filter out nutrients, bacteria, and other pollutants found in wastewater • Provides habitat for wildlife	Example: Walnut Cove Wastewater Treatment Plant https://www.townofwalnutcove.org/test/water_and_sewer.php

Central wastewater systems are used most commonly. T~~which means t~~hese collection systems obtain wastewater from individual sources through~~due to~~ gravity flow. Then, the water is sent to a central treatment system. P~~Due to varying topography, there are p~~ipes that transport wastewater by gravity are called "gravity mains" and pipes that transport wastewater through a pump are known as "force mains" (Allen, 2019). The pipes used in these systems are generally composed of clay tile, iron, concrete, or PVC. Although PVC pipes are the most resistantt to corrosion, all types ofmains have potential to leak

.

Wastewater collection and treatment systems receive wastewater from sinks, showers, and toilets from homes and businesses, treat this wastewater and then release the treated wastewater back into the environment. There are three stages utilized in centralized wastewater treatment facilities. The objective of the first stage is to remove suspended solids including wood, cloth, plastic, garbage, fecal matter, etc...; heavy inorganic solids such as sand, gravel, metal, and glass; and filter out excess oils (EPA, 2017). The scum and sludge leftover in the tank are collected and heated in digesters which are enclosed tanks containing bacteria that digests the material. A process called sedimentation is used to physically remove organic and inorganic solids by slowing the velocity of the wastewater flow, allowing the heavier materials to sink to the bottom and lighter materials to float. Sedimentation removes 60% of suspended solids from the wastewater stream (EPA, 2017).

Then, secondary treatment addressesdissolved biodegradable organic matter using biological treatment processes. During this stage, aerobic microorganisms decompose any remaining organic and inorganic solids in the wastewater. Some common infrastructures used for secondary treatment include trickling filters, sludge settling tanks, intermittent sand filters, and stabilization ponds (EPA, 2017). After secondary treatment, about 90% of suspended and dissolved solids are filtered from the water.

Depending on the plant, facilities may use an advanced treatment to filter chemicals, nutrients, and other pollutants that are not removed during secondary treatment. During this tertiary treatment, the filtered wastewater goes through a disinfecting process before being discharged into the environment (Bartlett, et al., 2017). The goal of disinfecting the wastewater is to reduce the amount of microorganisms in the treated effluent. Commonly, chlorination is used to disinfect wastewater.

In septic systems utilized by single households, domestic wastewater is divided into solids, liquids, and gases through the use of bacteria and sedimentation within a two-chambered septic system (EPA, 2017). The gases are discharged from the first chamber through a plumbing roof vent and the solids either float or settle to the bottom. The liquid enters the second chamber and goes through another round of sedimentation and bacteriological treatment before exiting the septic tank. Finally, the treated effluent is discharged to a drainfield through a sequence of perforated subsurface shallow pipes. The soil absorbs and filters the liquid additionally and microbes in the environment break down the remaining waste into mostly organic material. Septic systems pose risks to water quality if they are inappropriately located or poorly constructed and maintained. Also, wastewater may be illegally discharged from households with inadequate or missing septic systems through a "straight pipe" that directs these wastes to nearby streams or land (EPA, 2017).

Contrasted to the central wastewater and septic systems, the Walnut Cove wastewater treatment plant located near Winston-Salem has utilized an alternative technology to treat their wastewater. When the city found they lacked significant funding to repair their previous plant, they instead installed an artificial wetland treatment system for a lower cost (Seyfried, 2016).

Within an artificial wetland treatment system, sewage first enters the primary holding pond and then slowly transitions to the secondary holding pond. The ponds have aerators which provide microorganisms oxygen in the water to increase the rate and amount of decomposition of the sewage. (Seyfried, et al., 2016). Next, the water filters through duckweed as it flows through constructed, serpentine shaped ponds. Nutrients are filtered out of the wastewater as the water enters into the final ponds, lined with cattails. Finally, the system uses chlorine gas to reduce fecal coliform bacteria and sulfur dioxide gas to neutralize the chlorine in a controlled environment. The water is then discharged into a nearby creek. The entire process takes about 60 days to be completed. In addition to the benefits of filtering wastewater for small-scale wastewater management, the constructed wetlands are low cost, low maintenance, and provide habitat for wildlife (Seyfried, et al., 2016).

Commented [1]: Up until here the system is easy to visualize but I don't see how the gasses are added...can a simple sentence be included?

Recommended Future Actions:

Type of Infrastructure	Water Quality Impacts
Vacuum Sewer Systems	• Reduces risk of leaking pipes transporting wastewater • Decreases water contamination risk during flood events and hurricanes
Preventative Repairs and Updates on Current Infrastructure	• Improves functionality of wastewater treatment facilities' piping systems, reducing risk of water contamination
Emerging Wastewater Treatment Technologies: Powdered-Activated Carbon and Membrane Filtration	• Disinfects wastewater and absorbs pollutants • Reduces contamination of nearby streams
Develop Technology that Filters PFAS and Heavy Metals	• Decreases PFAS and heavy metal concentrations from discharge • Protects fisheries from toxins
Increase Use of Ecologically Engineered Wastewater Treatment Technologies	• Increases filtration of nutrients and bacteria from effluent • Provides habitat to native wildlife

Some future actions suggested by DWR for infrastructure improvement include transitioning to sewer system designs that are appropriate for coastal areas such as vacuum sewer systems, increase preventative repairs to~~and~~ address potential problems, increase funding opportunities from the state and federal government, and evaluate the gaps in infrastructure regulations (Deaton, et al., 2021).

Following the DWR's lead, the DEQ established the Division of Water Infrastructure (DWI), which includes the State Water Infrastructure Authority (SWIA) and a program that funds wastewater collection and treatment systems. The SWIA developed North Carolina's Statewide Water and Wastewater Infrastructure Master Plan: The Road to Viability. The goal of the plan is to provide a guide to creating wastewater facilities that protect public health and the environment, support communities, and encourage environmentally sustainable economic development.

One way to address wastewater pollution immediately is to identify failures in septic systems and fix any leaks or fractures in the pipes. In North Carolina, nearly 50% of households use septic systems for wastewater treatment (NCDEQ, 2021). With older or unmaintained septic systems, there is an increased risk of system failure which can contaminate groundwater and surface water. Additionally, POTWs generally last 20 to 50 years while the service life of the sewage pipes can range from 15 to 100 years depending on the materials and conditions of the site. However, some cities have pipes that are between 150 to 200 years old and with a lack of revenue, they cannot afford to upgrade the facilities (Bartlett, et al., 2017). Therefore, it is essential to allocate resources to the update and replacement of aging infrastructure (both public and private) as soon as possible.

The EPA is completing investigations into emerging technologies that can be utilized in wastewater infrastructure as an alternative for centralized wastewater treatment facilities. They have made a list of physical and chemical treatment processes including absorption using granular-activated carbon or powdered activated carbon; disinfection using ozone, chlorine, halogens, and ultraviolet light; nutrient removal using air stripping, denitrification filters, and ion-exchange; chemical oxidation; primary treatment technologies such as advanced grit removal systems and screening using microsieves; and finally solids removal using dissolved air flotation treatment, disc filters, downflow filters, and filtration through membranes (EPA, 2012).

One major gap in current wastewater treatment infrastructure is its ability to completely filter micropollutants such as pesticides, heavy metals, and PFAS. There are a few technologies that can be utilized to remove micropollutants during tertiary wastewater treatment. For example, powdered activated carbon (PAC) filters organic micropollutants. However, the cost of PAC is high and the process requires a significant amount of energy. Alternatively, biochar absorbents are less expensive and sequester carbon, but the effectiveness is dependent on the biochar production conditions (Thompson, et al., 2016).

Some of the biological treatment processes scientists are studying include anaerobic breakdown, membrane bioreactors, and biofilm processes (EPA, 2012). In-plant wet weather management processes have been developed to address the excessiveout flows resulting from rainfall. Some of these technologies include dispersed air flotation, alternative disinfectant chemicals, and updated flushing systems in the storage container.

With increased flows in the wastewater collection systems, coastal communities throughout the country have also begun to install more effective piping infrastructure such as vacuum and low-pressure systems (Allen, 2019). Vacuum sewer systems use air pressure to create a vacuum within the pipe networks and transports the sewage to collection chambers to receive treatment. This process reduces water consumption and decreases construction costs because they require one central vacuum station rather than several pumping stations in a central wastewater treatment facility (Stauffer, et al., 2019). They are closed systems which are, therefore, less likely to leak. Also, they are effective in areas with a high water table because they are placed in shallow trenches.

Utilizing ecological engineering treatment systems could greatly assist in developing sustainable, cost-effective infrastructure. Scientists have been assessing the effectiveness of the implementation of constructed wetlands, paving the way for future use of natural systems to filter pollutants and provide habitat (The Fish Site, 2021). For example, Natasha Bell, a professor at East Carolina University leads a funded project to improve wastewater treatment infrastructure in order to stimulate growth in North Carolina's aquaculture industry. Bell and her fellow researchers are developing and testing such ecological engineering treatment technologies as constructed wetlands . As part of their research they will assess the water filtering ability of various materials and their effectiveness in capturing nitrogen and phosphorus for application on agricultural lands (The Fish Site, 2021).

Policy and Enforcement Assessment

Current Actions:

Type of Policy	Water Quality Impacts	Lead Organization
NPDES Permitting Program	• Regulates treated wastewater discharge, reducing pollution levels in nearby streams • Protects aquatic ecosystems from the harmful effects of contaminated wastewater • Assists in identifying pollution sources	Environmental Protection Agency (Southeast Regional Office) 800.241.1754 NC Division of Water Resources 919.707.9023

Safe Drinking Water Act	• Safeguards quality of drinking water • Increases efficiency of wastewater treatment facilities, decreasing pollutant levels in treated effluent	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Pretreatment Program	• Regulates the discharge of wastewater into nearby bodies of water • Reduces chemicals and pollutants entering water sources after receiving treatment	Environmental Protection Agency (Southeast Regional Office) 800.241.1754 DWR Pretreatment, Emergency Response and Collections Systems 919.707.9023
Commission for Public Health Rules for On-Site Wastewater Treatment	• Ensures wastewater treatment infrastructure is effective in filtering pollutants • Provides professional assistance to on-site wastewater treatment operators	Enforced by Local Health Departments, Supervised by the On-Site Water Protection (OSWP) Branch 919.707.5854
Federal Funding for Updated Wastewater Treatment Facilities	• Protects drinking water sources from pollutants • Ensures efficiency of filtering and disinfecting processes in wastewater treatment facilities	Department of Water Resources 919.707.9023 Environmental Protection Agency (Southeast Regional Office) 800.241.1754

The National Pollutant Discharge Elimination System (NPDES) permitting program was developed under the Clean Water Act in order to regulate point source pollutants. In 1972, the passing of the act updated the construction grants program which funds upgrading any publicly owned treatment works (POTWs) in order to ensure they are compliant with the new act. Additionally, the Safe Drinking Water Act amendments of 1996 established the Drinking Water program through which the EPA provides grants, loans, and other assistance to public water systems with the goal of improving the quality of drinking water (Bartlett, et al., 2017). Also, the USDA provides grants to rural communities to assist in paying for wastewater treatment systems' upgrades and community members' water bills.

In NC,, the EPA has delegated permitting authority for the NPDES program to the state. The DWQ's NPDES Permitting and Compliance Program administers the program for the state. Every NPDES permitmust clearly define the quality and quantity of treated wastewater discharged into a stream, including, the acceptable levels of any given pollutant in the discharge. These acceptable levels must be based on water quality standards. The facility receiving the permit has permission to select the technologies and infrastructure they will utilize to achieve the level of compliance (Bartlett, et al., 2017).

Under the NC DWRthe NPDES Complex Permitting and NPDES Compliance and Expedited Permitting sections issue the wastewater permits. Every 5 years the issued permits must be reviewed and possibly renewed. Under the NPDES permit, specific facilities must monitor whole effluent toxicity (WET), and the results are utilized to predict the impacts of their discharge on the receiving aquatic ecosystem (NC Department of Environmental Quality, 2021). The Aquatic Toxicology Branch (ATB) under DWR manages a compliance report for all of the permittees completing WET tests for regional offices.

Commented [2]: Any time you use an acronym in a document you introduce it the first time the entire name is used; thereafter you use only the acronym. This should be looked at for the whole document.

Commented [3]: This was already said

The NC DEQ permits centralized sewer systems and surface dispersal systems using the NPDES permitting system. When a wastewater system discharges less than 1,000 gallons per day (gpd) to surface waters, a general permit must be in place which allows a single family home to discharge treated wastewater (NC Department of Environmental Quality, 2021). The permit requires that effluent limits are met and the system is monitored annually. Plans and descriptions for any wastewater treatment facility discharging effluent with a flow of more than 3,000 gpd must be approved by the State . Similarly, any system serving a facility classified as an industrial process wastewater generator must be reviewed and approved (NC Department of Environmental Quality, 2021).

Facilities that hold wastewater discharge permits are allowed to release treated effluent directly into surface waters from a pipe, whereas facilities with non-discharge permits must apply treated effluent to land, retention ponds, or reuse it. According to the DWR, in the coastal region, there were 282 discharge WWTPs and 295 non-discharge plants permitted in 2020 (Deaton, et al., 2021). The classifications of discharge facilities include industrial/commercial, drinking water plants, water conditioning, and groundwater remediation, with municipal and domestic being the most common type of facility. Non-discharge wastewater facilities can be categorized as wastewater irrigation or high rate infiltration which is the process of lowering the water table to increase the size of the unsaturated zone before adding discharge from wells or drainage pipes (Deaton, et al., 2021).

To facilitate enforcement of the NPDES regulations, any SSOs must be reported via phone within 24 hours to the DWR by the facility holding the permit . There were reports of 501 SSOs in the 20 coastal counties from 2015 to 2019. During this 5 year period, the DMF Shellfish Sanitation Section reported that 19 recreational and shellfish closings occurred due to SSOs.

Pretreatment programs have been established at the federal, state and local level and give government the authority to regulate industrial discharges from into municipal wastewater treatment plants (NC Department of Environmental Quality, 2021). In North Carolina, pretreatment programs are controlled by the DWR Pretreatment, Emergency Response and Collections Systems (PERCS). The regulation of permitted facilities that apply residuals, reclaimed water, and wastewater effluent to land falls under the authority of the Non-Discharge Branch (NDM) within the DWR.

Septic systems that discharge to subsurface waters are regulated by the North Carolina Department of Health and Human Services (DHHS). The Commission for Public Health (CPH) established rules for on-site wastewater systems which are enforced by local health departments but supervised by the On-Site Water Protection (OSWP) Branch within the DHHS (NC Department of Environmental Quality, 2021). The OSWP Branch provides consultative services for subsurface septic systems to concerned parties including local health departments, builders, homeowners, well drillers, engineers, geologists, and environmental health consultants. The local health departments must monitor septic systems to verify they are sited, constructed, implemented, and maintained appropriately.

To support the implementation of improved wastewater infrastructure, the DWI provides funding through low-interest loans and grants to local governments. Some examples of the financial programs are the Clean Water State Revolving Fund (CWSRF), the Drinking Water State Revolving Fund (DWSRF), and the State Wastewater and Drinking Water Reserve Program. The CWSRF receives its funding from the EPA under the Clean Water Act (CWA). They provide low-interest loans for wastewater treatment and collection, reclaimed water, stream restoration, stormwater Best Management Practices (BMPs), and energy efficiency projects for treatment systems.

Recommended Future Actions:

Type of Policy	Water Quality Impacts

Mandate Annual Cleaning of Wastewater Treatment Facilities	● Increases effectiveness of wastewater treatment infrastructure ● Reduces risk of polluted aquatic ecosystems
Policies Requiring Professional Operators for Facilities	● Increases oversight at facilities, reducing risk of malfunction and overflows ● Assists in identifying needed improvements in infrastructure, ensuring untreated effluent does not enter surface waters or groundwater
Legislation Increasing Federal Funding for Updating Infrastructure	● Reduces risk of leaks and polluted discharge entering bodies of water with improved infrastructure ● Updates infrastructure to become more resilient to extreme weather events and climate change
Establish Water Quality Standards for Additional Pollutants (Plastics and Industrial Chemicals)	● Protects aquatic ecosystems from the negative impacts of plastic and chemical contamination
Pass More Stringent Regulations for Treated Discharge	● Reduces risk of water pollution by mandating disinfection of effluent ● Increases water quality of treated wastewater before entering aquatic ecosystems

The Estuarine Policy Steering Committee established by the NC DEQ included SSOs as an issue that should be addressed through policy, and the 2020 NC Climate Risk Assessment and Resilience Plan advises the updating of wastewater infrastructure (Deaton, et al., 2021). A report completed by the Committee suggested requiring 10% of deemed permitted collection systems receive cleaning treatment annually (Deaton, et al., 2021). Deemed permitted collection systems are facilities that have an average daily flow of less than

200,000 gallons. Currently, the DEQ requires only permitted systems to clean their facilities annually.

The report also suggests that the NC Environmental Management Commission (EMC) and DEQ update current rules so that they mandate municipal wastewater collection systems with a daily flow of 100,000 gallons or more to have a certified operator for the facility (Deaton, et al., 2021). Including oversight from certified professionals and providing criteria for them would greatly decrease the risk of SSOs. They would measure and calculate the maximum gallons per day from the system, record past problems, map weak lines, measure the impacts of SLR and storms, and map/measure the risk to nearby high quality waters and valuable habitats. In the 1990s, the city of Kinston's sewage plant malfunctioned and officials did not allocate funds for upgrades. City officials told plant operators to alter water quality test results, but agency professionals caught their illegal activity. The operators violated the CWA and they were fired but no one was prosecuted. Moving forward, it is important to increase enforcement and regulation of wastewater treatment systems to ensure another event like the one that occurred in Kinston does not happen.

Another recommendation from the Estuarine Policy Steering Committee includes creating a working group of stakeholders and experts who would educate and collaboratewith the NC General Assembly in order to help secure adequate funding for wastewater infrastructure.

Experts have shown thats the vulnerability of municipal sewage systems is due to their inability to handle large rain events, and high water tables, such as those that occur in association with hurricanes, in the coastal region of the state. Unfortunately, the cost to install updated infrastructure or fix any breaks in the system is high. Therefore, it is important to increase federal funding specifically for all types of wastewater treatment infrastructure monitoring and updates.

Developing legislation requiring the monitoring of additional pollutants such as plastics and industrial pollutants that exit wastewater treatment systems would greatly reduce the amount of contaminants entering surface waters. These policies would require the updating of wastewater treatment facilities' infrastructure and filtering processes in order to address water contamination resulting from PFAS chemicals, GenX, and microplastics.

Finally, establishing more stringent regulations for the treated effluent discharging from municipal systems sets higher standards for the facilities' filtering capabilities. This will improve the quality of the disinfected wastewater before it is discharged into a nearby stream. One way facilities can comply with more stringent regulations would be to require all their systems to install a tertiary treatment stage that includes a strict disinfecting process. However, it is essential to financially assist small municipalities, especially those with lower-incomes or located in rural areas in order for them to successfully implement new technologies.

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
The Coastal Habitat Protection Plan (CHPP)	• Studies the effects of sanitary sewer overflows and contamination due to inflow and infiltration • Identifies points of concern for wastewater treatment facilities that are at	NC Division of Marine Fisheries, Anne Deaton Anne.Deaton@ncdenr.gov

	risk of polluting surface waters	
Monitoring Effects of Sanitary Sewage Overflows on Water Quality	• Increases sampling and understanding of the impacts of untreated effluent entering bodies of water • Protects aquatic ecosystems from large overflow events	NC Division of Marine Fisheries, Anne Deaton Anne.Deaton@ncdenr.gov
Assessing Increased Risk of Facility Malfunctions with Flooding and Hurricanes	• Identifies necessary infrastructure updates to increase resilience to flooding and hurricanes • Assists in researching alternatives to current infrastructure to ensure proper function of treatment facilities during flooding • Protects aquatic ecosystems from the risk of overflow and contamination	Dr. Larry Cahoon, UNCW cahoon@uncw.edu

Studying the Impacts of Improved Wastewater Treatment Infrastructure on Water Quality	● Identifies technologies that most effectively filter pollutants and reduce risk of malfunction ● Reduces amount of pollutants in treated wastewater entering aquatic ecosystems	Dr. Michael Mallin, UNCW mallinm@uncw.edu
Developing Emerging Technologies to Assist in Wastewater Treatment	● Reduces sustainably water contamination from wastewater discharge through the development of new technologies ● Decreases cost for more effective technologies	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Impacts of Wastewater Contaminants on Aquatic Ecosystems	● Improves our understanding of the effects of bacteria, nutrients, total suspended solids, and pharmaceutical levels on fisheries ● Identifies gaps in wastewater treatment infrastructure and technology ● Protects fish populations and habitat from water contamination	Department of Water Resources 919.707.9023 Environmental Protection Agency (Southeast Regional Office) 800.241.1754

The Coastal Habitat Protection Plan (CHPP) completed by the NC Division of Marine Fisheries compiles research information in their report. One focal area of the plan is addressing sanitary sewer overflows and the contamination of water sources due to inflow and infiltration (Deaton, et al., 2021). One specific study they included was conducted in Wilmington, NC, evaluating specific water quality parameters after a sewer main break that resulted in 3 million gallons of raw sewage being discharged into Hewlett Creek (Deaton, et al., 2021).

The sewage traveled through the creek and into the Intracoastal Waterway (IWW). The first round of sampling after the break identified very high levels of fecal coliform bacteria (270,000 Colony Forming Units/100ml), and after three days the levels in the channel and lower part of the creek fell below 100 CFU/100ml (Deaton, et al., 2021). In two tributaries, the fecal coliform levels remained high for five days, decreased marginally, and then increased again after a rain event.

The second increase was a result of the stormwater carrying contaminated sediments after the rain event. The fecal coliform in the sediment continued to report high levels for more than an additional month, meanwhile after a few weeks the water column's fecal bacteria levels returned to normal. Through this study, scientists discovered that the sediments acted as storage for fecal bacteria and contributed to increased levels in the water column after experiencing bottom disturbance from rain events (Deaton, et al., 2021). With the sewage discharge increasing overload of the aquatic ecosystem with nutrients, the water became hypoxic, depleted in oxygen, which caused several considerable fish kills a couple days after the spill. Nutrient levels started to decrease after a day due to the growth of phytoplankton and algal blooms. Also, the scientists discovered the wetlands were successful in filtering nutrients and protecting the ecosystem.

One study completed by Larry Cahoon from UNCW, found 19 wastewater collection systems on the coast of North Carolina using gravity collection systems are at risk for breaches due to groundwater levels increasing. The increased sea level, rainfall, and temperature causes infrastructure deterioration which will result in the leaching of sewage into the environment (Allen, 2019).

Dr. Cahoon discussed how inflow and infiltration (I&I) are main contributors to the increased flow through wastewater collection systems. Inflow has less significant impacts and can be addressed more easily because it generally results from rainfall entering the systems through manholes. Contrastingly, infiltration is a result of groundwater entering the collection systems through joints and fractures in the pipes, which is much more difficult to correct (Allen, 2019).

As a result of the study, Cahoon discusses a large concern with sea level rise flooding coastal North Carolina's underground wastewater collection systems and also corroding the infrastructure from the sea water. He suggests looking into alternatives to central systems which have high costs for installation and maintenance. During this study, the researchers found statistically significant effects of rainfall events and temperature effects on extraneous flow 95% of the time for both factors (Cahoon, et al., 2018). Sea level effects were statistically significant in contributing to extraneous flow for 58% of the 19 sites (Cahoon, et al., 2018).

Dr. Mallin from ECU studied the impacts of improved wastewater treatment infrastructure on water quality of a receiving water system. They studied the New River Estuary which is located in Onslow County. In the 1980s-90s it was a very eutrophic estuary in the southeast region of the state. The New River had severe phytoplankton blooms, anoxia and hypoxia, outbreaks of a toxic dinoflagellate, and resulting fish kills due to nutrient loading from municipal sewage treatment plants. However, when the city of Jacksonville and the Camp Lejeune Marine Corps Base made upgrades to their sewage treatment plants, nitrogen levels decreased by 57% and phosphorous levels decreased by 71% (Mallin, et al., 2005). Also, dissolved oxygen levels improved and there was a reduction in phytoplankton biomass which improved water quality. With decreased turbidity and available sunlight due to the decrease in algae, native vegetation thrived and fish habitat improved.

The updated wastewater treatment facility in Jacksonville had a 6 million gallon per day capacity. The plant had primary settling and secondary aeration in its lagoons. The chlorinated effluent from the lagoons was sprayed on 8 areas with 104 ha of pine forest. With the upgrade, they created a plant that completed nutrient removal which caused significant decreases in nitrogen and phosphorus (Mallin, et al., 2005). Therefore, the research indicates that improved infrastructure and filtering technologies have positive effects on water quality.

In regards to the impacts of wastewater contaminants entering fish habitat, research has indicated that specific viruses that are zoonotic can be contagious to marine mammals when exposed to human sewage (Shahidul, et al., 2004). Different bacteria found in sewage water have been discovered in marine mammals such as e. Coli, vibrio cholera, and salmonella. The researchers for this study also found as a consequence of consuming toxic algae, fish populations have experienced mass mortality (Shahidul, et al., 2004).

Additionally, researchers assess potential wastewater treatment technologies. A group of scientists analyzed the effectiveness and environmental impacts of wood biochar, biosolids biochar, and coal-derived PAC to remove sulfamethoxazole, an antibiotic, from wastewater. They found wood biochar can be associated with energy recovery and carbon sequestration when used in place of coal-based PAC, and is successful in removing micropollutants from wastewater (Thompson, et al., 2016). Biosolids biochar is a less environmentally-friendly alternative because it requires large energy inputs to dry the biosolids.

The Urban Water Consortium (UWC) is an operation composed of 12 of the states' largest water/wastewater utilities. The Water Resources Research Institute (WRRI) runs the consortium along with voting representatives from each member utility. The goal of the UWC is to provide guidelines for research and technology transfer relating to water resources issues in urban locations and water utility sites. Some research projects supported by the UWC include studies of cyanobacteria blooms, treatment options for industrial pollutants, and the microbial quality of drinking water affected by wastewater (Urban Water Consortium, 2021).

The EPA conducted research on wastewater's impacts on water quality and fisheries for their NPDES Compliance Inspection Manual. They found decomposing organic matter and some chemicals in wastewater consume oxygen and contribute to decreased dissolved oxygen levels. The bacterial decomposition of organic waste from sewage reduces DO levels quickly and significantly (EPA, 2017). When DO levels fall rapidly, the aquatic ecosystem greatly suffers and can cause fish kills and habitat reduction.

As a result of sewage spills or inadequate water treatment methods, total suspended solids (TSS) may contaminate surface waters. High levels of TSS remain in the water column and block light from reaching aquatic vegetation below the surface. With a decreased amount of sunlight, the native vegetation cannot thrive nor produce oxygen (EPA, 2017). Therefore, there can be a great reduction in available dissolved oxygen. Also, large amounts of TSS will increase turbidity and make it difficult for fish to catch their prey.

Bacteria is another concern for water quality if untreated wastewater enters aquatic ecosystems. They pose threats to public health and may cause infections (EPA, 2017). Also, during the disinfection process, the chlorination of organic material can create chlorinated-organic compounds that may be carcinogenic or dangerous to the environment (EPA, 2017).

Finally, pharmaceuticals and their effects on aquatic life have been studied by the EPA due to their presence in wastewater. They can enter waterways from human excretion in wastewater and then the lack of filtration in the wastewater treatment plants (Kostich, et al., 2021). Scientists studied organisms exposed to pharmaceutical ingredients and found that there were concentrations of pharmaceuticals in the organisms that could not eliminate them efficiently (Kostich, et al., 2021). This may lead to antimicrobial resistance which means bacteria no longer responds to antibiotics, posing severe health risks to public health and animals.

Recommended Future Actions:

Type of Research	Water Quality Impacts
Increased Monitoring of Waterborne Diseases in Wastewater	• Protects public health by monitoring bacteria and waterborne diseases coming from wastewater discharges • Assesses the effects of these diseases on aquatic ecosystems
Analyzing the Impacts of Reclaimed Water Introduction into Aquatic Ecosystems	• Determines the effects of disinfecting chemicals on fisheries and habitat • Assists in identifying which wastewater treatment processes are effective and which pose risk to fisheries
Researching Effective Wastewater Treatment Infrastructure for Coastal Regions with High Water Tables and Flooding	• Assists in developing technologies that will accommodate increased flows with flooding and hurricanes • Reduces risk of overflows and leaks resulting in polluted waters
Developing Technologies to Filter Emerging Contaminants and Landfill Leachate	• Reduces industrial pollutants, microplastics, and hazardous waste from entering surface waters with improved filtration • Protects fisheries from toxins and related negative health impacts

In the book, Water Supply Through Reuse of Municipal Wastewater, the authors address future research needs relative to wastewater. They found that the technology created for water reclamation facilities are well-developed, but they believe research could assist in improving the effectiveness of existing technologies and the safety of public health. The authors recommend increasing waterborne disease monitoring and methodology in order to better identify instances when bacteria from wastewater is contaminating surface waters (National Research Council, 2011).

In addition to assessing the impacts of contaminated wastewater, they suggest that scientists assess the effects of reclaimed water introduction into aquatic ecosystems. For example, it is important to research the effects of potentially hazardous products resulting from disinfecting processes on the environment (National Research Council, 2011). Through chlorination, different substances are introduced into the treated effluent then discharged into local water. Also, accelerating the studies of pathogen filtering technologies could improve our understanding of the effectiveness of current wastewater treatment practices. Another recommendation includes developing technologies that can reuse reclaimed water in place of directly discharging the treated effluent into nearby streams. This will reduce the risk of insufficiently treated water from entering bodies of water.

Another main area of research that requires additional attention and resources includes the development of wastewater treatment infrastructure to be used in high-water table, coastal, flood-prone regions such as eastern North Carolina. Moving forward, it is important to study the effectiveness of current technologies in controlling wastewater treatment and transport as well as determine strategies to enhance these technologies to accommodate increased flow. With accelerated inflow and infiltration occurring, traditional wastewater treatment facilities may not be adequate in protecting water quality from sewage overflows.

With increasing studies relaying the harmful impacts of emerging contaminants and microplastics on aquatic ecosystems, it is important to discover new ways to mitigate their entrance into the environment through wastewater discharge. Therefore, researching technologies that can filter these micropollutants can greatly protect water quality.

Pharmaceuticals and other toxins enter bodies of water through landfill leachate which is a liquid that is composed of organic and inorganic pollutants coming from landfill waste. When rainwater washes over a landfill, the runoff containing contaminants are considered landfill leachate. The resulting substance is dangerous because it has very high concentrations of ammonia and organic nitrogen that negatively affect aquatic organisms. Wastewater treatment plants receive this substance and researchers are studying the effectiveness of the facilities in filtering these toxins from the wastewater (DAS Environmental Experts, 2021). They found wastewater treatment facilities can effectively treat landfill leachate if they utilize specific technologies such as activated carbon filters, ionization, and moving bed biofilm reactors which contain sieves and utilize biological processes to treat wastewater (DAS Environmental Experts, 2021). In the future, it is essential to continue researching techniques that may be utilized to filter the hazardous waste, landfill leachate from wastewater in order to protect aquatic ecosystems from toxins, bacteria, and ammonia.

Advocacy, Outreach, and Education Assessment

Current Actions:

Type of Outreach/Advocacy	Water Quality Impacts	Lead Organization
Notifying Public of Wastewater Treatment Malfunctions	• Provides solutions to overflow events and decreases future risk of infrastructure malfunctions	NC Rural Water Association 336.731.6963 Southeast Rural Community Assistance Project 540.345.1184
Non-Point Source Pollution Management Program's Educational Efforts and Outreach	• Provides Best Management Practices to mitigate leaks and infrastructure malfunctions in septic systems	On-Site Water Protection (OSWP) Branch 919.707.5854

	• Reduces water contamination including bacteria, suspended solids, and chemicals resulting from wastewater discharge	
Releasing Educational Material Regarding the Use of Current and Emerging Wastewater Treatment Technologies	• Ensures proper functioning of current infrastructure, reducing the risk of water contamination from leaks • Encourages more effective technologies to protect water quality from untreated wastewater contamination	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
The Urban Water Consortium	• Identifies wastewater treatment concerns in local communities by including major facilities in infrastructure assessments and research	Wastewater Treatment Facilities Across the State The Urban Water Consortium https://wrri.ncsu.edu/partnerships/uwc/

Many organizations and institutions provide information regarding infrastructure issues and potential solutions to sewage leaks or breaks such as the North Carolina Rural Water Association, Southeast Rural Community Assistance Project, regional North Carolina Councils of Government, and the University of North Carolina at Chapel Hill School of Government Environmental Finance Center.

Similarly, the Nonpoint Source (NPS) Pollution Management Program in the OSWP Branch prioritizes education and outreach regarding Best Management Practices (BMPs) in order to reduce nonpoint source pollution resulting from septic systems (NC Department of Environmental Quality, 2021). The program aims to locate potential nonpoint source pollution from on-site systems and notify nearby communities.

At the household and local levels, the EPA provides information to homeowners and state and local governments to ensure proper functioning and maintenance of on-site or decentralized wastewater management systems (EPA, 2012). Their objective is to inform operators and homeowners on alternatives to the centralized facilities and encourage the use of emerging wastewater treatment technologies.

In order to include North Carolina wastewater utilities in the advancement of research and infrastructure development, the Urban Water Consortium was created to provide adequate representation. The utilities that join the consortium must pay membership dues and assist with enhancement funds for research activities. The members and researchers review research proposals and share their concerns for their specific region (Urban Water Consortium, 2021).

Recommended Future Actions:

Type of Outreach/Advocacy	Water Quality Impacts
Request Assistance from the EPA's Creating Resilient Water Utilities Initiative	• Identifies areas of improvement for coastal wastewater treatment plants' infrastructure will reduce risk of overflow • Protects fisheries from harmful wastewater contamination due to flooding and hurricanes
Provide Educational Material Regarding Importance of Maintained Wastewater Treatment Facilities	• Improves public understanding of the importance of functioning facilities

	• Leads to updated, effective systems that filter contaminants from wastewater
Increase Community Outreach and Support for Improving Wastewater Treatment Infrastructure	• Improves malfunctioning wastewater treatment facilities and influences the amount of funds received for updates • Reduces risk of water contamination as a result of old or broken infrastructure

Moving forward, utilizing federal resources and expertise relative to wastewater treatment facilities' updates will greatly assist in protecting water quality near the plants. The EPA runs the Creating Resilient Water Utilities Initiative which completes assessments on wastewater infrastructure and provides engineering recommendations and financial advice for communities (Deaton, 2021). The state may be able to request the assistance of the Creating Resilient Water Utilities Initiative in identifying the areas of needed improvement in coastal wastewater treatment plants' infrastructure. They have provided assistance to other coastal cities, therefore, their advice for protecting regions with high water tables and higher risk of flooding and hurricanes would be useful.

The state of North Carolina can increase its release of educational material regarding the importance of clean water, its value, and needs of water infrastructure. This way, the public understands the cost of their water bills and taxes, potentially increasing support for updates to infrastructure in their municipalities. Other organizations can utilize this strategy to gain support for infrastructure improvements and fund allocation to wastewater treatment facilities.

The EPA has expressed the importance of community involvement in developing a campaign to address wastewater system water pollution issues. Some counties in the US have rallied support from their communities to improve septic systems in the area and to contribute to monthly fees in order to assist with the cost of monitoring, maintaining, and repairing their local facilities. Although this strategy may be difficult for communities with lower-income to utilize, the support of community members can influence their representatives to make necessary changes.

References

Allen, J. (2019, March 7). Study: Expect Worsening Wastewater Woes: Coastal Review. *Coastal Review Online*. https://coastalreview.org/2019/03/study-expect-worsening-wastewater-woes/

Bartlett, S., Cisneros, H., Heartwell, G., McAndrew, K., & Warnock, A. (2017). (rep.). *Understanding America's Water and Wastewater Challenges*(pp. 1–22). Washington, D.C.: Bipartisan Policy Center.

Cahoon, L. B., & Hanke, M. H. (2018). Inflow and infiltration in coastal wastewater collection systems: effects of rainfall, temperature, and sea level. *Water Environment Research*, *91*(4), 322–331. https://doi.org/10.1002/wer.1036

DAS Environment Experts. (2021). *Processes for Landfill Leachate Treatment*. DAS. https://www.das-ee.com/en-us/wastewater-treatment/industries/landfill-leachate/

Deaton, A., & Johnson, J. (2021). (issue brief). *Addressing Sanitary Sewer Overflows Associated with Wastewater Infrastructure to Improve Coastal Water Quality*(pp. 1–19). Morehead City, NC: NC Division of Marine Fisheries.

EPA. (2012). (rep.). *Emerging Technologies for Wastewater Treatment and In-Plant Wet Weather Management*(pp. 1–23). Washington, D.C.

EPA. (2017). Wastewater and Water Quality Impacts. In *NPDES Compliance Inspection Manual* (pp. 133–147). essay.

Kostich, M. S., & Lazorchak, J. M. (2007). Risks to aquatic organisms posed by human pharmaceutical use. *Science of The Total Environment*, *389*(2-3), 329–339. https://doi.org/10.1016/j.scitotenv.2007.09.008

Mallin, M. A., McIver, M. R., Wells, H. A., Parsons, D. C., & Johnson, V. L. (2005). Reversal of eutrophication following sewage treatment upgrades in the New River Estuary, North Carolina. *Estuaries*, *28*(5), 750–760. https://doi.org/10.1007/bf02732912

National Research Council. (2011). Research Needs. In *Water Reuse: Potential for expanding the nation's water supply through reuse of municipal wastewater*(pp. 193–202). essay, National Academy Press.

NC Department of Environmental Quality. (2021). (issue brief). *White Oak River Basin Water Resources Plan*. Raleigh, NC.

Seyfried, C., Myers, N., Kirk, E., & Talley, T. (2016, September 23). *Constructed Wetlands for Wastewater Treatment*. Environmental Finance Blog. https://efc.web.unc.edu/2016/09/23/constructed-wetlands-wastewater-treatment-walnut-cove-nc/

Shahidul Islam, M., & Tanaka, M. (2004). Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis. *Marine Pollution Bulletin*, 48(7-8), 624–649. https://doi.org/10.1016/j.marpolbul.2003.12.004

Stauffer, B., & Spuhler, D. (2019, May 29). *Vacuum Sewers*. SSWM. https://sswm.info/sswm-university-course/module-2-centralised-and-decentralised-systems-water-and-sanitation/further/vacuum-sewers.

Stefanakis, A., Akratos, C. S., & Tsihrintzis, V. A. (2014). Treatment of special wastewaters in vfcws. *Vertical Flow Constructed Wetlands*, 145–164. https://doi.org/10.1016/b978-0-12-404612-2.00007-6

Thompson, K. A., Shimabuku, K. K., Kearns, J. P., Knappe, D. R., Summers, R. S., & Cook, S. M. (2016). Environmental Comparison of Biochar and Activated Carbon for Tertiary Wastewater Treatment. *Environmental Science & Technology*, *50*(20), 11253–11262. https://doi.org/10.1021/acs.est.6b03239

Urban Water Consortium. Water Resources Research Institute of the UNC System. (2021). https://wrri.ncsu.edu/partnerships/uwc/.

Wastewater breakthrough could fuel North Carolina aquaculture boom. The Fish Site. (2021, June 22). https://thefishsite.com/articles/wastewater-breakthrough-could-fuel-north-carolina-aquaculture-boom

Commented [4]: Add material from O'driscoll, Humphreys, and Burchell