Coastal Carolina Riverwatch

Water Quality for Fisheries

An Assessment of Water Quality Concerns

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https://coastalcarolinariverwatch.org/water-quality-for-fisheries/

Introduction

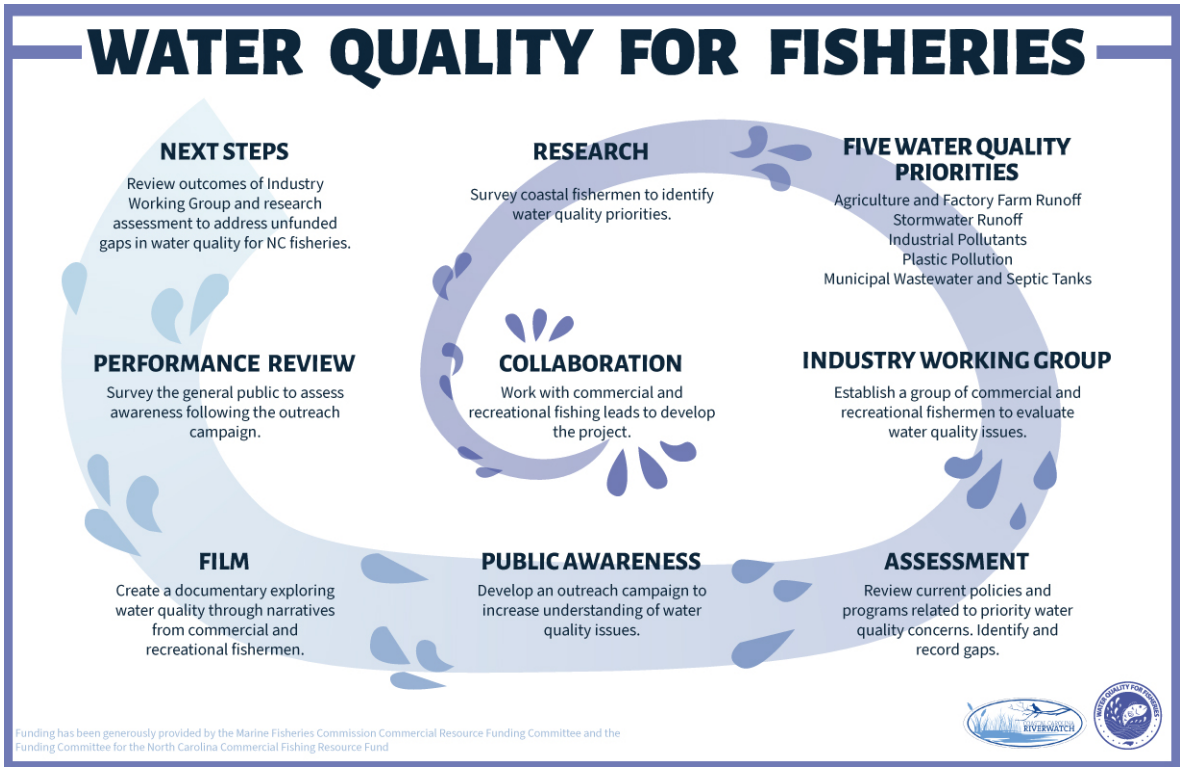
The purpose of the Water Quality for Fisheries (WQ4F) Program is to identify and address the impacts of water quality on North Carolina fisheries. This assessment is a living document that serves to address impacts on water quality that are identified by the coastal fishing community. Updates to the assessment can be found here: https://coastalcarolinariverwatch.org/water-quality-for-fisheries/

This assessment is categorized by the following methodologies for addressing each water quality concern: Infrastructure, Policy and Enforcement, Research, and Outreach.

Water Quality Priorities Identified by Coastal North Carolina Fisheries Representatives:

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. https://surveyresearch.ecu.edu/wp-content/pv-uploads/sites/315/2018/06/Carolina_Riverwatch_Summary_Report1.pdf



GRAPHIC: Noah Weaver, *Water Quality for Fisheries Program Outline*, 2021

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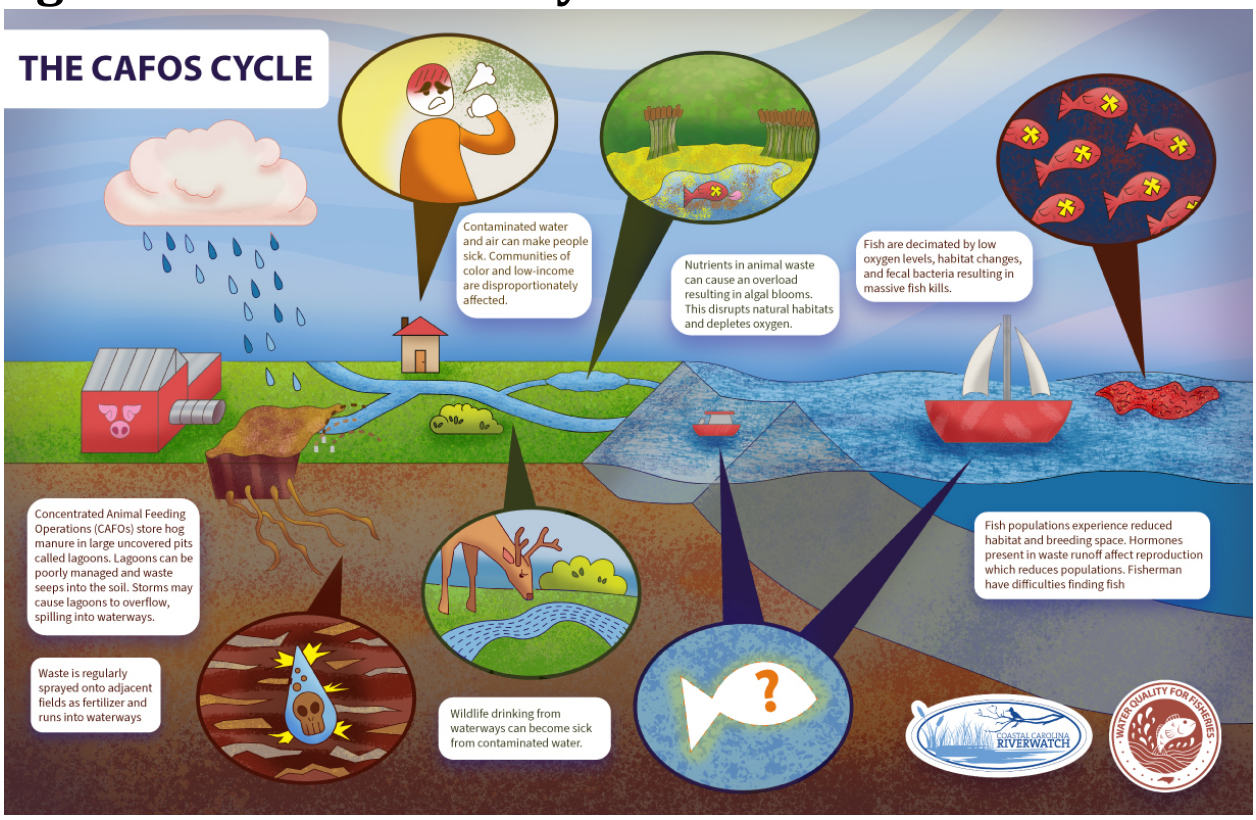
Agriculture and Factory Farm Pollution



GRAPHIC: Noah Weaver, *The CAFOs Pollution Cycle*, 2021

Introduction

In the United States, nearly 85% of commercially harvested fish rely on estuaries and coastal waters for a portion of their life cycle (McCarthy, 2002). Pesticides are a major concern for the health of these important estuaries; 75% of estuarine sediments have been found to contain pesticides (McCarthy, 2002).

Beginning in the 1940s, the use of modern synthesized pesticides became a widespread agricultural practice in North Carolina to reduce crop losses, increase production, and control pests. However, pesticides are toxic to humans, animals, and plants.

Fish and other wildlife species can be poisoned from pesticides and fertilizers entering aquatic ecosystems, causing a decrease in fish populations. Herbicides found in runoff from croplands have detrimental effects on native aquatic plant life. With estuarine nurseries being impacted by the contamination, fish lose cover and shelter needed for young individuals to feed and escape predators.

Fertilizers are rich in nutrients to assist with crop growth, but nutrient overload can have major implications for aquatic ecosystems. Algal blooms occur as water becomes nutrient-rich, which results in a depletion of dissolved oxygen causing vegetation and fish die-offs.

These conditions also provide a suitable ecosystem for cyanobacteria to thrive. Cyanobacteria are aquatic and photosynthetic bacteria that produce toxins. These cyanotoxins pose health risks to humans, wildlife, and fish.

In the last three decades, CAFOs became a large component of the state's agricultural industry. North Carolina went from the 7th to the 2nd greatest swine-producing state in a matter of 5 years during the 1980s. (Burkholder, et al., 1997).

CAFOs are defined by the federal governments as an operation that has animals confined or maintained for a total of 45 days or greater in a 12-month period (EPA, 2002).

CAFOs are animal feeding operations that confine at least 1,000 animal units or confine between 301 and 1,000 animal units and discharge pollutants (EPA, 2002). Concentrated animal feeding operations (CAFOs) were initially implemented in upland areas of the US Midwest where the water table was lower and covered by more soil depth. Later on, they were placed in low-lying wetlands with high water tables, close to rivers and estuaries in North Carolina. Land zoning laws and inspection programs were not applied to these factory farms or the lagoons used to hold the effluent.

As a result of waste spills and runoff from factory farms, there are reports of anoxic conditions and high levels of ammonium, total phosphorus, suspended solids, and fecal bacteria in nearby waterbody samples (Burkholder, et al., 2006).

Studies in Coastal NC suggest that CAFOs can be a more significant source of nitrogen than fertilizers from row crop agriculture. Under certain hydrological conditions, this nitrogen can be detected in estuaries many miles downstream (Brown et al., 2020).

The excess nutrients cause eutrophication, habitat destruction, and algal blooms that block sunlight from reaching aquatic vegetation. The decrease in sunlight causes plants to die. An increase in dead plant material allows bacteria to thrive, further depleting the dissolved oxygen supply.

Algal blooms may contain toxic microorganisms such as a *Pfiesteria* which has contributed to public health issues and fish being plagued with large sores. These factors have caused massive fish kills in freshwater including species such as minnows, gar, largemouth bass, striped bass, and flounder (Burkholder, et al., 2006).

CAFO runoff can also lead to the presence of fecal bacteria or pathogens in surface water. Fecal bacterial pathogens that can cause human health problems and may lead to shellfish collection restrictions (Hribar, C.).

Water samples have revealed hormones in surface water surrounding CAFOs. Hormones found in water can affect the reproductive success and fertility of female fish (Hribar, 2010).

Infrastructure Assessment

Current Actions:

Type of Infrastructure	Water Quality Impacts	Lead Organization
Wetland Restoration	• Removes pollutants such as bacteria and fertilizers • Limits flooding • Decreases contaminated sediments due to reduced erosion • Improved fish and wildlife habitat	US Department of Agriculture (Natural Resources Conservation Service) 919.873.2100 NC Division of Water Resources 919.707.9023
Nutrient Management	• Decreases nutrient loading • Reduces algal bloom frequency • Increases survival of natural aquatic vegetation	North Carolina State University (Crop and Soil Science Department) sbkulesz@ncsu.edu NC Division of Soil and Water Conservation 919.707.3770
Conservation and Sustainable Agriculture Practices	• Decreases contaminated sediments due to reduced erosion • Reduces contaminants such as pesticides and fertilizers	NC State Extension 919.515.2813
Controlled Drainage Systems	• Increases crop yield without requiring additional water input • Reduces agricultural runoff • Decreases N and P loading in surface waters • Requires less fertilizer use due to	NC State Extension 919.515.2813

	enhance nutrient retention in the stored water	
Integrated Pest Management	● Reduces pesticides ● Increases survival of natural aquatic vegetation	NC State Extension 919.515.2813

According to several studies, the livestock waste management practices and infrastructure being utilized CAFOs do not effectively protect water from contamination such as excessive nutrients, pathogens, and pharmaceuticals. There are many issues associated with current CAFO infrastructure, especially in waste management.

Contaminants from CAFOs may enter water sources by leaking from poorly constructed manure lagoons, overflow of pits during rain events, runoff from waste sprayed onto fields, or gases entering the air and joining the water cycle.

An example of a faulty waste management system includes the 1995 rupture of an Onslow County swine lagoon, spilling 25.8 million gallons of raw effluent. As the effluent approached the lagoon's maximum holding capacity, a faulty pipe weakened the wall of the lagoon and caused a spill (Burkholder, et al., 1997). The operators were unable to use spraying to dispose of waste as the surrounding soils were too saturated from extreme rain. Therefore, the lagoon met capacity rapidly.

Currently, the majority of CAFOs utilize water or slurry-based systems which require these large pits to store the effluent. The state requires that lagoons have a 180-day storage capacity, have 1-2 feet of freeboard, and must have a sound infrastructure that will not be inundated by a 100-year flood (EPA, 2002).

Seepage into the surrounding soil cannot total more than 1/28 inch per day. With more frequent severe weather events and hurricanes, the current CAFO infrastructure is subject to damage causing defects. After Hurricane Florence, 49 lagoons were identified as "damaged structurally, actively discharging material, or inundated with surface water, while another 60 nearly flooded, according to the state's Department of Environmental Quality" (Surrusco, 2019).

There has been some improved infrastructure development in recent years such as the restoration of wetlands which has proven to be successful in removing pollutants including bacteria, sediments, and fertilizer and livestock runoff. To decrease pollution levels in water and create more cost-effective and productive farming operations, farmers may implement best management practices (BMPs) to reduce contaminated runoff.

The utilization of nutrient management plans can decrease farmers' fertilizer use. Nutrient management strategies include the use of vegetative buffer zones, wetlands, riparian forest

buffers, filter strips, terracing, and managing the form, amount, timing, and method of nutrient application (EPA, 2015).

Conservation practices have been developed to provide cost-effective methods for farmers to improve water quality in their communities such as the use of streamside fencing to prevent livestock from entering the water, continuous no-till practices, and using multi-species cover crops to avoid erosion and promote soil health.

Riparian buffers are naturally vegetated areas along banks that buffer contaminants from runoff, reduce erosion, and create habitat. Studies completed by the North Carolina State Extension have shown that riparian buffers filtering agricultural runoff have decreased N levels by 30% (D. Osmond, Interview, June 4, 2021). Also, the Extension has found that using exclusion fences, preventing cows from entering streams, has caused a 40% reduction in phosphorus and sediments (D. Osmond, Interview, June 4, 2021).

In an interview, with Dr. François Birgand from NC State University's Department of Biological and Agricultural Engineering emphasized the effectiveness of controlled drainage systems in protecting bodies of water. These systems allow the farmer to adjust the amount of drainage coming from croplands and conserve water. During the winter and rain events, nutrient loading in aquatic ecosystems increases as a result of agricultural runoff; therefore, this technology assists in preventing complete drainage and utilizing the water received in these months.

Integrated pest management (IPM) is another example of a BMP utilized to decrease agricultural contamination. IPM is the implementation of a diverse range of strategies to reduce pest impacts, prioritizing natural strategies. Initial provisions of the IPM process include setting pest thresholds and monitoring and identification of pests. First lines of pest control include preventative measures such as crop rotation, inclusion of pest-resistant plant varieties, and pest-free rootstocks. Upon evaluation, if control measures are necessary, less impactful methods are chosen first such as highly targeted pheromone use to discourage mating or mechanical control through trapping or uprooting. If these measures are not effective, other controls may be evaluated such as very targeted spraying of pesticides rather than broadcast spraying, which would be a last resort (EPA).

Recommended Future Actions:

Type of Infrastructure Recommended	Water Quality Impacts
Updated Waste Management Systems to environmentally superior technologies	● Treats and eliminates pathogens ● Reduces runoff ● Stabilizes nitrogen levels ● Decreases contaminants
CAFO Buyout Programs	● Decreases contamination from pathogens, nutrients, hormones, toxins ● Reduces algal blooms and promotes natural habitat vegetation growth ● Assists CAFO owners in transitions
Sustainable Crop and Livestock Production	● Reduces sediments ● Reduces fertilizers and pesticides ● Reduces bacterial contamination

There are efforts to protect the aquatic and wetland ecosystems of coastal North Carolina, but there is an urgent need for advancement in infrastructure development in order to mitigate the impacts of CAFOs and fertilizers on fisheries. Current waste management processes in place for factory farms are in need of reconstruction.

Through a 2000 agreement known as the "Smithfield Agreement" between a leading pork producer-Smithfield Food, its subsidiaries, and the Attorney General of NC, environmentally superior technologies (EST) were to be funded for development for use. ESTs are defined as those technologies that:

- Eliminates the discharge of animal waste to surface waters and groundwater through direct discharge, seepage or runoff;
- Substantially eliminates atmospheric emissions of ammonia;
- Substantially eliminates the emission of odor that is detectable beyond the boundaries of the parcel or tract of land on which the swine farm is located;
- Substantially eliminates the release of disease-transmitting vectors and airborne pathogens; and
- Substantially eliminates nutrient and heavy metal contamination of soil and groundwater.

ESTs include onsite separation of solid and liquid waste along with wastewater treatment options prior to discharge. This includes the Terra Blue system, tested in Duplin, Sampson, and Wayne Counties. The system replaces lagoons with tanks. It has been shown to separate solids and liquids, biologically remove ammonia and nitrogen, remove phosphorus, and reduce emissions of odorant compounds, ammonia, pathogens, and heavy metals. The treatment system was documented to remove approximately 99% of total suspended solids, 98% of COD, 99% of TKN (Total Kjeldahl nitrogen), 100% ammonia, 92%

phosphorus, 95% copper, and 97% zinc from the flushed manure. Fecal coliform reductions were measured to be 99.98%. (Williams,2013). Several options for ESTs have been compiled and documented by NC State University, Duke University and associates. As generations of these technologies develop, costs are reduced as well.

Collaborating with the farming communities on alternative grazing and pest control strategies will contribute to a reduction in contaminated sediments from entering the waters. Sediments are a main source of water pollution resulting from agricultural practices. Other contaminants such as fertilizers and pesticides are found in samples and enter water sources along with the soil particles. Livestock overgrazing contributes to water pollution because the practices cause an increase in exposed soil leading to erosion.

Farmers may decrease grazing intensity, exclude livestock from sensitive areas, direct the animals to alternative sources of water, and plant vegetation to prevent soil exposure. Another approach to decreasing the levels of toxic contaminants in bodies of water includes the use of charcoal. Discovered during a study focused on the impacts of pesticides on the Albemarle-Pamlico Estuarine System, charcoal has been shown to reduce crab mortality significantly when used as a water filter (McCarthy, 2002). Incorporating substances with filtration capabilities such as charcoal into the infrastructure could be an effective way to protect the estuaries.

Buyouts of CAFOs located in the flood plains of North Carolina will have the greatest impact in improving water quality. Funding from the government to compensate farmers for permanent decommissioning of their CAFOs could prevent a significant amount of contaminants from entering North Carolina waters, particularly those in floodplains.

Industry Working Group Gap Analysis: Industrial Agriculture and Factory Farming Infrastructure Priorities

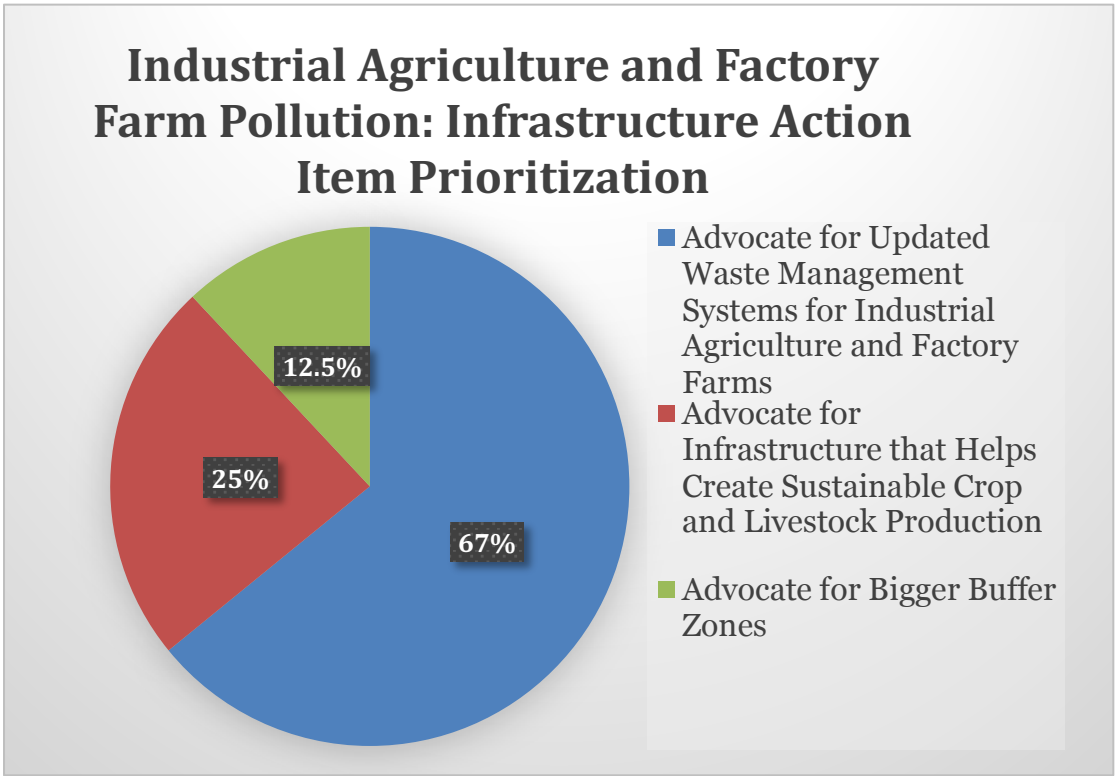


CHART 1: *Industrial Agriculture and Factory Farming Infrastructure Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Advocating for updated waste management systems for industrial agriculture and factory farming practices has been identified as the top priority in 2021-22.

Policy and Enforcement Assessment

Current Actions:

Type of Policy and Enforcement	Water Quality Impacts	Lead Organization
Clean Water Act Amendments of 1987 and 2003	• Encourages nonpoint source pollution control technologies • Requires pollution permits and nutrient management plans for CAFOs • Reduces contamination • Decreases nutrient-loading	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
National Pollutant Discharge Elimination System (NPDES)	• Restricts type and quantity of contaminants that can be discharged • Improves animal waste storage and disposal	Environmental Protection Agency (Southeast Regional Office) 800.241.1754 NC NPDES Committee Head 919.707.8236
North Carolina Swine Waste Management System General Permit	• Requires certified waste management plans • Sets standards and operation rules to decrease agriculture runoff	NC Division of Water Resources 919.707.9023
Clean Water Responsibility and Environmentally Sound Policy Act	• Limits construction and expansion of North Carolina hog farms • Requires approved animal waste management systems	NC Division of Water Resources: The Environmental Management Commission 919.707.9023

Federal Insecticide, Fungicide, and Rodenticide Act	• Regulates the selling, allocation, and use of pesticides • Assesses chemicals' impacts on the environment such as toxicity, accumulation potential, and breakdown rates	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
North Carolina Pesticide Law of 1971	• Regulates handling, transportation, storage, and disposal of pesticides	North Carolina Pesticide Board 919.733.3556
Wetlands Reserve Easement Program	• Government provides technical and financial assistance to landowners who restore and protect wetlands	US Department of Agriculture (Natural Resources Conservation Service) 919.873.2100
Agriculture Cost Share Program	• Government provides funding to farmers to implement sustainable techniques to assist with water conservation	NC Division of Soil and Water Conservation 919.707.3770

The CAFO industry boomed in North Carolina beginning in the 1970s. However, CAFOs were not regulated until the 1980s under the Clean Water Act (CWA), and only a small proportion of operations had pollution permits by 1995. The CWA Amendments of 1987 created the Section 319 National Monitoring Program which assessed the effectiveness of nonpoint source pollution control technologies and monitoring (Graham & Nachman, et al., 2010). The CWA Amendments created in 2003, also known as the CAFO rules, require any facility with more than 1,000 animal units to obtain a water pollution permit and develop a nutrient management plan (Graham & Nachman, 2010). The EPA or state agencies are

responsible for providing the pollution permits to the operators. States who develop their own CAFO legislation must develop policies that are at least as stringent as the federal standards. Still only 40% of livestock waste is regulated and the legislation does not address pathogenic microorganisms found in animal waste (Graham & Nachman, 2010).

The NPDES (National Pollutant Discharge Elimination System), under the CWA, places restrictions on the type and amount of contaminants that may be discharged from CAFOs into United States water bodies. The NPDES program mandates technology-based regulations on water pollution including appropriate animal waste storage and wastewater, adequate disposal of dead animals, deviation of clean water from the facility, restriction of contact between livestock and waters, safe disposal of chemicals, implementation of conservation techniques to reduce contaminated runoff, annual nutrient assessments, compliance with nutrient management plans for land application of effluent, and adequate record of the operations (Graham & Nachman, 2010).

The state of North Carolina has their own CAFO legislation substituting objectives of the NPDES program. Beginning in 1992, the NCDEQ developed the Animal Feeding Operations Program. Under General Statute 143-215.10B, animal operations in North Carolina are identified as feedlots with greater than 250 swine, 100 cattle, 75 horses, 1,000 sheep, or 30,000 poultry that utilize a liquid waste management system (NC DEQ, n.d.). The North Carolina Swine Waste Management System General Permit defines the required standards, operation and maintenance rules, monitoring and documenting requirements, and policies for inspections of farms and penalties. North Carolina mandates all permitted AFOs to have a Certified Animal Waste Management Plan (CAWMP). The plan determines which fields receive waste application, the types of crops produced, and other specifics of the facilities (NC DEQ, n.d.).

Poultry operations in North Carolina that use dry waste systems (dry litter poultry operations) are not required to obtain permits from the Division of Water Resources (NC DEQ. n.d.).

The Department of Water Quality (DWQ) within the Department of Environmental and Natural Resources (DENR), implements the permitting program and certification program for animal waste management in the state.

In 1997, North Carolina implemented a moratorium on new and expanded swine farms. That moratorium was made permanent in 2007 for farms that use anaerobic waste lagoons as primary waste treatment (EPA, 2002).

In 2000, the North Carolina Attorney General made an agreement with one of the largest hog producers in the state, Smithfield Foods, with the goal of enforcing regulations on their current waste management practices. The Smithfield Agreement mandated Smithfield Foods to provide $15 million towards updating waste management technologies on their farms in North Carolina in order to protect the surrounding environment. However, this agreement was not effectively enforced and there were not significant improvements in the company's and their subsidiaries' practices.

As part of the enforcement process of North Carolina's permitting system for farming operations, state government agencies are to monitor and impose consequences on operations that fail to comply. There are grace periods that give the operators time to address their discharges and avoid penalties. However, there are civil and criminal penalties of up to $10,000 per day and/or imprisonment when an operator is not in compliance with water quality standards and discharges illegally. If there is a citizen complaint or water quality problems, the North Carolina Department of Environmental Management (NCDEM) is to inspect animal waste facilities.

NC legislation *G.S. 143-215.9D (2014-H366)* states that "complaints against agricultural operations" and all other records accumulated in conjunction with the investigation of these complaints shall be considered confidential records unless and until a determination of a violation has occurred."

According to DEQ's most recent annual reports to the NC General Assembly, violations are as follows:

- FY 2019-2020 Approximately 11 percent of the 2,062 inspections identified violations. There were 224 violations identified.
- FY 2018-2019 Approximately 16 percent of the 2,814 inspections identified violations. There were 445 violations identified.
- FY 2017-2018 Approximately 7 percent of the 2,571 inspections identified violations. There were 177 violations identified.

Inadequate freeboard, unpermitted discharges from the systems, and evidence of over application were the most common violations and deficiencies (NC DEQ Agricultural Complaint Data).

In regard to the regulation of fertilizers and agricultural chemicals through policy is the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA is a policy established at the federal level that regulates the selling, allocation, and use of pesticides throughout the country. This policy gives states the discretion to regulate pesticides at the state level assuming the state law is as stringent as the federal standards. The agency completes cost-benefit analyses in regard to each specific pesticide. Some factors taken into account are the ingredients, production process, physical and chemical properties, environmental state (breakdown rates, volatility, accumulation potential), toxicity to life, and carcinogenic properties (Helfrich, 2009).

The Food Quality Protection Act of 1996 (FQPA) is an amendment to FIFRA which establishes more stringent regulations for food-use pesticides. The EPA is responsible for evaluating the chemicals and enforcing the act (NCDA&CS. n.d.). Also, the Endangered Species Act (ESA) of 1973 is influential in protecting aquatic species and their habitats from chemical contamination. The law prohibits any registered pesticides from harming threatened or endangered species or their habitat (Helfrich, 2009). Local game wardens and the US Fish and Wildlife Service (USFWS) are responsible for officially responding to reported pesticide incidents and enforcing these policies.

Legislation developed specifically in North Carolina includes the North Carolina Pesticide Law of 1971. This policy sets the boundaries for programs regarding pesticide management with the goal of protecting public health and the state's ecosystems. This policy mandates the registrations of pesticide products; the certification of applicators; appropriate handling, transportation, storage, and disposal of pesticides; and the certification of sellers (NCDA&CS, n.d.). The North Carolina Pesticide board controls the enforcement of this law. The board is made up of seven officials appointed by the state governor with the authority to implement the NC Pesticide Law.

The United States Department of Agriculture (USDA) and the states have developed cost-share, technical assistance, and economic incentives to encourage farmers to implement nonpoint source management strategies. An example of a program created by policy, includes the Wetlands Reserve Easements (WRE) program, implemented by the USDA and the Natural Resources Conservation Service (NRCS).

Private landowners and Native American tribes may receive technical and financial assistance from the NRCS "to restore, protect, and enhance wetlands through the purchase of a wetland reserve easement" (NRCS, 2021). To be eligible for WRE funds, the land must be farmed or converted wetland that can be properly restored in a cost-effective manner.

Another example of governmental assistance used for conservation efforts is the Agriculture Cost Share Program for Nonpoint Source Pollution Control, implemented by the NC Division of Soil and Water Conservation. The objective of the program is to protect the state's water resources. Through this initiative, farmers may receive up to 75% of the average cost of utilizing BMPs and technical assistance.

Recommended Future Actions:

Type of Policy and Enforcement Recommended	Water Quality Impacts
Groundwater and Surface Water Protections: Metals, Pathogens, and Antibiotic Contaminants	● Evaluates and regulates the discharge of metals, pathogens, and antibiotics into NC waterways
Regulatory Policies for Small and Medium-Sized CAFOs	● Decreases livestock runoff ● Mandates waste management systems for small and medium-sized CAFOs
Improved Cost-Share Sustainable Agricultural Programs	● Encourages decreased fertilizer and pesticide use ● Increases participation in Best Management Practices including the implementation of buffer zones and

	reduce grazing intensity
Hurricane Preparation Requirements for Factory Farms and Agricultural Lands	● Reduces nutrient application before large rain events ● Decreases lagoon overflow risk ● Requires proper waste management strategies
Develop Policies Based on Other States' Water Quality Issues Associated with Agricultural Runoff	● Prevents recurring nutrient overloading across the nations' coasts ● Reduces agricultural runoff discharge ● Manages nutrient levels
Improve Buffer Rules to Include Sea Level Rise Concerns	● Increases effectiveness of the filtering of pollutants from bodies of water ● Reduces flooding ● Decreases nutrient loading

There are laws created with the intent to bridge the needs of the environment with the needs of farming communities in North Carolina. However, they have fallen short in protecting water resources and communities affected by the surrounding factory farms and fertilizer-use. In the future, policymakers can transition from developing laws that protect the offenders to laws that protect local communities from negative health impacts, decreased fish populations, and private nuisances.

More stringent waste management standards for CAFOs should be a priority for future policymaking in the state of North Carolina to assist in mitigating their impacts on aquatic ecosystems. The US Government Accountability Office (GAO) has stated that the EPA nor the states have all of the resources needed to successfully implement the CAFO rules (Graham & Nachman, 2010). Several states' permitting programs for CAFOs do not adequately meet the NPDES standards or classify many operations as CAFOs allowing them to avoid regulation (Graham & Nachman, 2010). There is a gap in regulation for assessing groundwater and surface water in regards to heavy metal, pathogens, and antibiotics contaminants. Also, since small and medium-sized CAFOs generally avoid mandatory regulation, 40% of livestock waste in the country is not managed (Graham & Nachman, 2010).

For small (less than 300 animal units) and medium (300-999 animal units) CAFOs, the regulatory framework relies virtually exclusively on operator's voluntary nutrient management practices. Creating more incentives for operator compliance or transitioning to more traditional command-and-control regulation may be beneficial in protecting coastal communities' water resources.

Also, a major setback in enforcement and regulation of CAFOs and fertilizers is the lack of resources and government staff available to monitor their compliance with water quality standards and regulations. In the future, water quality would benefit from the allocation of more financial resources to state environmental agencies in order to properly enforce the permitting system and assessments.

Finally, updating infrastructure policies such as buffer rules to include sea level rise concerns proves to be necessary as the implications of climate change become more apparent. Ensuring the buffer zones are adequately sized and placed will further protect the nearby bodies of water from increased runoff and agricultural discharge.

Industry Working Group Gap Analysis: Industrial Agriculture and Factory Farming Policy Priorities

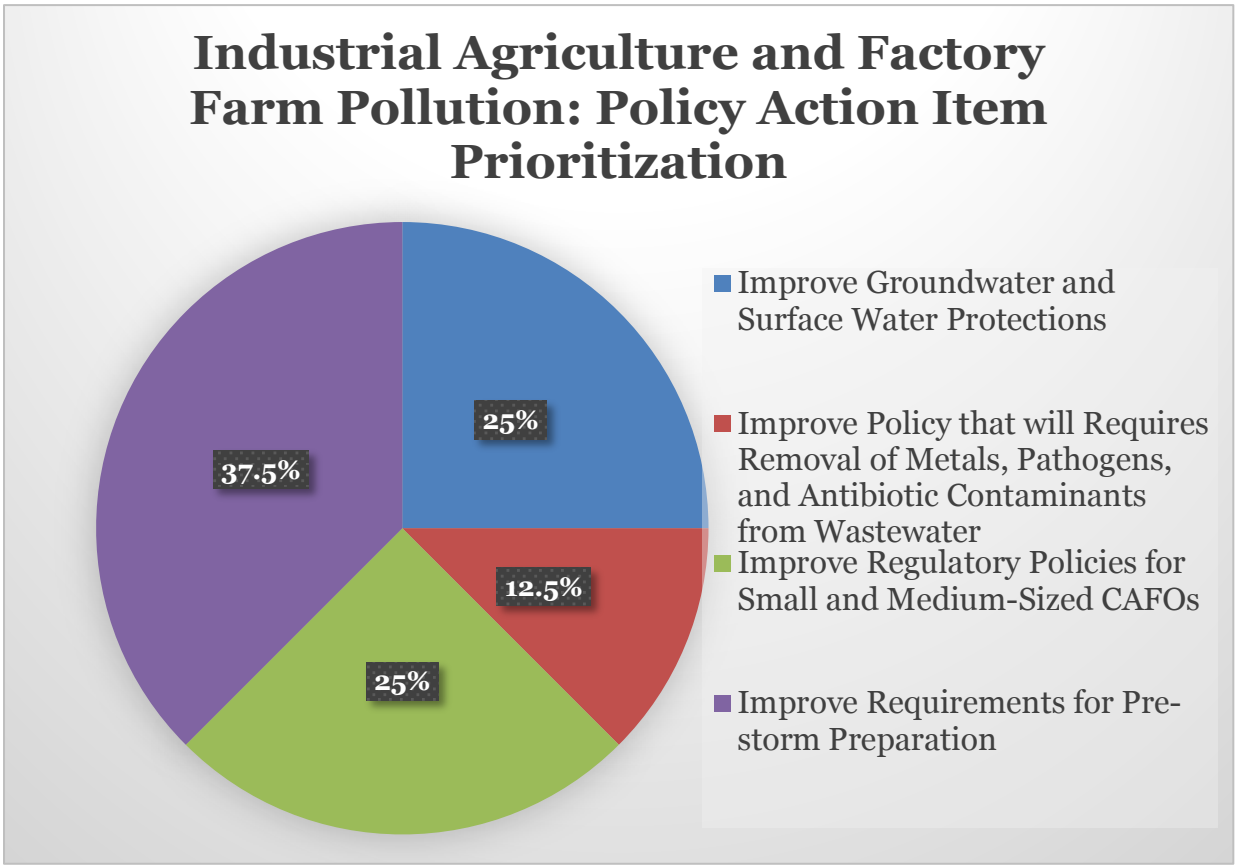


CHART 2: *Industrial Agriculture and Factory Farming Policy Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Improving the requirements for pre-storm preparation has been identified as the top priority in 2021-22.

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
Assessment of Restored Wetlands and Agricultural Runoff Impacts	• Reduces runoff • Filters contaminants from agricultural runoff • Identifies positive outcomes for aquatic habitat • Influences environmental policy-making	North Carolina Sea Grant 919.515.2454
Effects of Nutrients on Aquatic Vegetation	• Determines high levels of nitrogen, phosphorus, and sediments in water decreases habitat quality • Assesses nutrients contributions to eutrophication and the harmful impacts on fish populations	NC State University (Dr. Burkholder) NC Division of Water Resources 919.707.9023
Swine Waste Spills Monitoring	• Synthesizes the harmful consequences aquatic ecosystems face as a result of waste spills	NC State University (Dr. Burkholder and Dr. Mallin)
Impacts of Fertilizers and Pesticides on Water Quality	• Reports that chemicals in water systems cause rapid fish death, changes in behavior, and reduced reproduction	Virginia Cooperative Extension 540.231.9347

A large amount of research has been conducted to assess the risks and implications of agricultural activities on water quality. Fertilizers and pesticides have been studied since the middle of the 20th century while CAFO research became more extensive in the late 20th century.

During the past few decades, large research institutions such as North Carolina State University, University of North Carolina-Wilmington, Eastern Carolina University, Duke University, the DEQ, and the North Carolina Sea Grant have led the way in aquatic ecosystem research. For example, the NC Sea Grant has assessed the use of restored wetlands to control runoff, utilized new technologies to assess water quality in tidal marshes, and studied the impacts of agricultural practices on fisheries (Register, 2014).

Similarly, agricultural engineer at NCSU, Mike Burchell collaborates with the USDA, the NC Coastal Federation, local farmers, and the NC Sea Grant in order to assess wetlands' capabilities to remove fertilizers coming from local farms, entering shellfish habitat (Register, 2014). These studies have greatly contributed to the development of mitigation strategies against harmful agricultural runoff impacting coastal communities.

One specific area of concern for fisheries resulting from agricultural runoff includes the decomposition of waste from feeding operations causing increases in ammonia in aquatic ecosystems. A particular study completed by Professor of Biology and Chemistry, D.J. Randall found that ammonia is harmful to all vertebrates causing health implications such as convulsions, coma, death, and influx of excessive CA2+ which causes cell death in the central nervous system (Randall, et al., 2002). They also discovered that some fish species are more tolerant of the high levels of environmental ammonia which may be an indicator of why some fish species are more likely to make up a fish kill when known contamination has occurred (Randall, et al., 2002).

Another specific study focused on the decreased aquatic vegetation cover and water quality in North Carolina's Lake Mattamuskeet, a lake receiving significant drainage from agricultural lands. It was found that as a result of high nitrogen, phosphorus, and sediment levels, shallow lakes are susceptible to a change from a healthy habitat for fish and waterfowl to turbid waters with increased cyanobacteria (Moorman,et al., 2017). The lake even showed significant increases in the parameters related to eutrophication including chlorophyll a, total nitrogen, total phosphorus, total suspended solids, turbidity, and pH (Moorman, et al., 2017). These studies led to an overall understanding in the science community that the effects of nutrient-loading on aquatic environments and the implications for fish populations are severe.

North Carolina State's professor and researcher, Dr. JoAnn Burkholder has made significant contributions regarding CAFOs' impacts on aquatic toxicity levels and the deterioration of habitat. She is a part of a work-group that wrote an article focused on assessing the impacts of CAFO waste on water quality. This work-group is part of the *Conference on Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards-Searching for Solutions*. They believe it is necessary to identify the requirements for ecosystem monitoring in areas impacted by CAFOs and a better understanding of the

resulting toxicants and their effects on environmental and public health. They found that effluent spills are the main contributors to toxic algal blooms that restrict the survival of essential aquatic habitat and species (Burkholder, 2006).

North Carolina Sea Grant is currently researching the effects of algae toxins on aquatic ecosystems and fisheries. Overall, present research emphasizes the importance of enforcing BMPs to prevent the excessive amounts of nutrients and contaminants from entering water sources, further influencing positive environmental policy-making (Burkholder, 2006).

Dr. Burkholder was also a part of a team of several scientists, including NCSU researcher, Dr. Michael Mallin, who monitored a swine waste spill in NC that caused a 29-km freshwater area to become anoxic and killed about 4,000 fish by day two (Burkholder, et al., 1997). Their ability to follow the spill over the course of several weeks gave important insight into the day-to-day impacts of water contamination following a waste spill. They discovered that there were high levels of N contributing to large algal blooms which increased by up to 8 times the state standard and lasted through most of the summer (Burkholder, et al., 1997). Also, there were high P, suspended solids, and fecal coliform levels in the water samples, and they noted an extreme number of fish deaths. This study also increased our understanding of contaminated sediments entering aquatic ecosystems. Their research found that the sediments generally contain 100 to 1000 times more fecal bacteria than the water. These bacteria accumulate in the sediments and presents health concerns for the public and wildlife. The pollution identified in these sediments (pathogens, nutrients, and organic materials found in swine waste) by most likely altered the aquatic ecosystem by making it more difficult for subsequent fish year classes to spawn.

In addition to academic institutions, the government agencies, specifically the North Carolina Division of Water Resources (DWR), the Department of Environmental Quality (NCDEQ), and the Department of Coastal Management (DCM) are influential in researching important water quality issues. For example, the NC DWR collaborated with the US Geologic Survey and developed a study of nitrogen levels in watersheds located close to AFOs in Eastern North Carolina.

Fertilizers present additional negative water quality implications. Virginia Tech researchers discovered that modern pesticides are toxic to humans, animals, and plants and remain in aquatic environments for long periods of time. The result is poisoned fish populations and a decrease in fisheries size (Helfrich, 2009). Helfrich's research assisted in closing a gap in knowledge regarding pesticides impacts on fish populations and habitat. He reported that pesticides could be lethal and cause rapid death in fish and wildlife, or they could be sublethal. Sublethal chemicals may cause a change in behavior, weight loss, reduced reproduction, and decreased tolerance to water temperature changes (Helfrich, 2009).
Fish inhabiting waters close to agricultural lands receive low doses of pesticides repeatedly. This type of exposure has negative effects such as reduced fish egg production and hatching, nest abandonment, increased susceptibility to disease, reduced weight, hormonal changes, and reduced avoidance of predators (Helfrich, 2009). Fish and aquatic

wildlife can be in danger of pesticides through the absorption of chemicals in the water through their skin, respiring pesticides through their gills, or by drinking polluted water or feeding on toxic prey (Helfrich, 2009).

Recommended Future Actions:

Type of Research Recommended	Water Quality Impacts
Evaluation of Hormonal, Pharmaceutical, and Microbiological Contaminants	• Closes gap in knowledge regarding the effects of these contaminants on fish populations and native vegetation
Evaluation of Best Management Practices	• Evaluates effectiveness of environmentally superior technologies and wetland restoration • Identifies successful water quality efforts
Enhancement of Water Quality Monitoring Technologies	• Increases temporal resolution of monitoring which allows for the analysis of rapid changes in water quality • Utilizes flow proportional composite sampling, a mixture of several samples into one, providing a representative sample for a given period of time
Conservation Practices for Coastal, Flat Topography	• Identify successful conservation techniques for coastal region • Decreases soil erosion • Reduces contaminated agricultural runoff
Apply Research from Other States' Implemented BMPs and Water Conservation Initiatives	• Provides information on effectiveness of water quality efforts • Reduces nutrient loading from agricultural lands

There are still gaps in our understanding of the impacts of CAFOs on fisheries. For example, it is essential to evaluate hormone activity and pharmaceuticals and microbiological contaminants' impacts on water and fisheries. Also, due to the delayed effects of chemicals on the genetics of aquatic organisms, the continuance of long-term studies is essential to our understanding of fertilizers in aquatic ecosystems.

The management of dry waste in place of liquid waste still requires solid and effective infrastructure such as roofed confinement-areas. These systems still pose risks of water contamination when rain events contribute to increased runoff from agricultural lands. In order to prevent contaminated runoff from entering nearby bodies of water, CAFOs can utilize curbs, diversions, reception pits, and sediment basins (US EPA, 2004).

Researchers and scientists play a critical role in the development of sound, sustainable policy. They provide the scientific knowledge required in developing effective environmental laws. Therefore, it is important to continue the funding of research and provide opportunities for the presentation of scientific findings to the public and the government.

In recent years, there has been a lack of funding to continue studying the effects of agricultural conservation practices on water quality. Specifically, there is a need for research on the impacts of agricultural conservation practices in the coastal region where the topography is flat. The majority of research and practices were implemented in the piedmont and mountains where the topography is hilly (D. Osmond interview, June 4, 2021).

There has been significant progress towards research on agricultural practices and their relationship to decreased water quality and fish populations, but more strategies to restore these habitats are needed to assist in the vitality of the fisheries and fishing communities in coastal North Carolina. R completed in other states such as Florida could be used to assist in establishing agricultural runoff management strategies that are effective in reducing nutrient pollution.

One limitation to current water quality monitoring is the lack of developed technology to measure and record the rapid changes occurring in water quality. Concentrations of pollutants such as nutrients and bacteria are difficult to calculate because they can change by 10,000-fold in a matter of hours. Therefore, it is important to develop high temporal resolution monitoring technologies that permit the collection of water quality parameters every hour or minute (F. Birgand, personal communication, June 3, 2021).

Industry Working Group Gap Analysis: Industrial Agriculture and Factory Farming Research Priorities

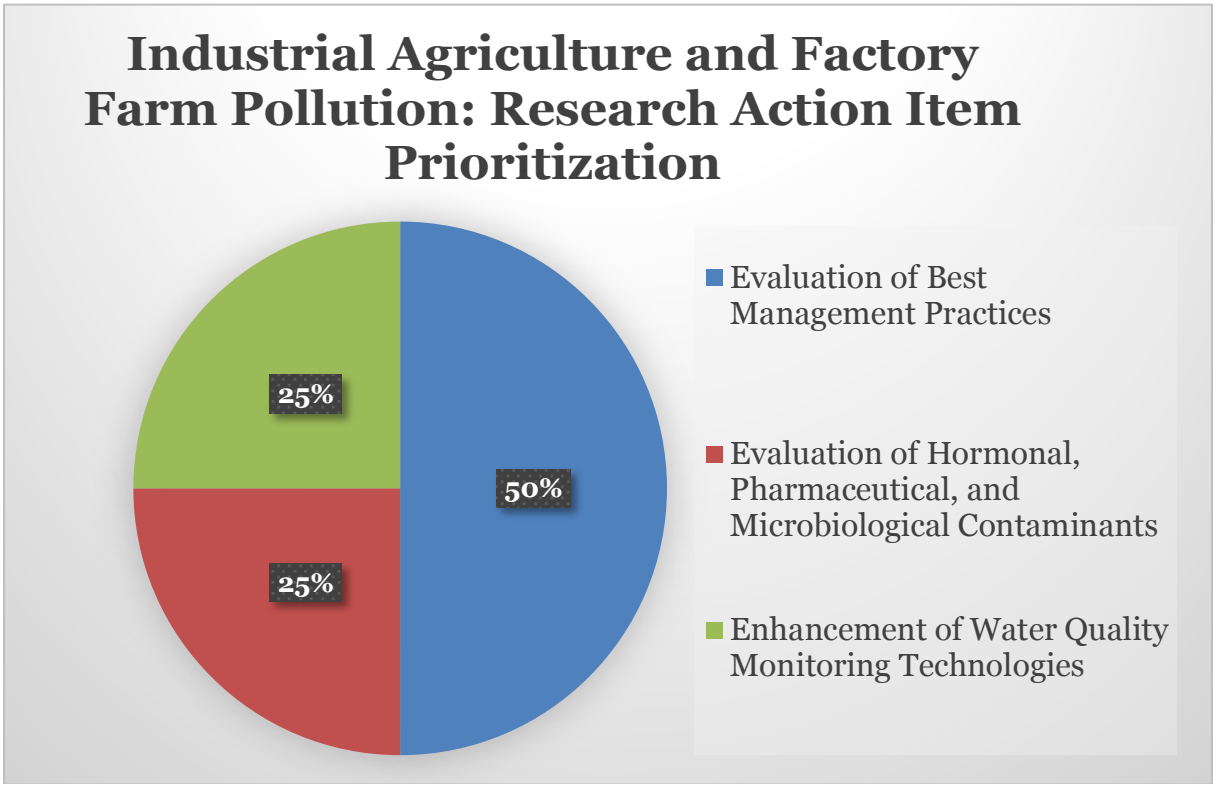


CHART 3: *Industrial Agriculture and Factory Farming Research Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Conducting a thorough evaluation of best management practices that reduce or eliminate agriculture and factory farming pollution has been identified as the top priority in 2021-22.

Advocacy, Outreach, and Education Assessment

Current Actions:

Type of Advocacy, Outreach, and Education Assessment	Water Quality Impacts	Lead Organization
Environmental Non-governmental Organizations (NGOs)'s Advocating for Local Communities	• Lobby for environmental policies that protect fisheries • Use litigation to defend communities' rights • Connect local communities with local politicians • Educate community members on pollution issues • Coalition building for statewide advocacy	Waterkeeper Alliance www.waterkeeperalliance.org Clean Water for North Carolina 919.401.9600 N.C Conservation Network 919.857.4699 Others: Center for Biological Diversity, Clean AIRE NC, NC Environmental Justice Network, REACH, Southern Environmental Law Center, Duke University, Food and Water Watch, Mercy for Animals, Farm Sanctuary, We Animals, Public Justice, Environmental Working Group
Environmental NGOs Develop Community-led Environmental Projects	• Develop educational materials regarding water quality issues and sustainable agriculture techniques • Provide action items and technical assistance to farmers, fishermen, and those who wish to get involved with initiatives	NC State Extension 919.515.2813 Waterkeeper Alliance www.waterkeeperalliance.org Clean Water for North Carolina 919.401.9600 Triangle Land Conservancy 919.908.8809

	• Create grassroots efforts for environmental and social change • Connects participants in environmental initiatives with grants	N.C Conservation Network 919.857.4699
Government Agencies' Educational Opportunities and Funding	• Develop grants to assist with habitat reconstruction and the implementation of BMPs • Provide technical assistance to farmers regarding sustainable agriculture • Create educational and outreach materials for the general public	US Department of Agriculture (Natural Resources Conservation Service) 919.873.2100 NC Division of Soil and Water Conservation 919.707.3770

Non-governmental organizations (NGOs) such as Waterkeeper Alliance are primary advocates for environmental change and policy. They act as a bridge between scientists and substantial change necessary in developing awareness and implementation of environmental laws. NGOs build coalitions to develop community-focused projects, advocate for environmental policy, and provide communities access to resources.

NGOs may advocate for sustainable agricultural practices and regulations through the use of legal petitions. Litigation tactics are utilized by NGOs to establish a public understanding of the impacts of fertilizers and CAFOs on ecosystems. The Waterkeeper Alliance, Sierra Club, Natural Resources Defense Council, and the American Littoral Society raised a case, *Waterkeeper Alliance et al. v. Environmental Protection Agency,* on the grounds that CAFO rules are inadequate in requiring governmental review of CAFOs' nutrient management plans (Graham & Nachman, 2010). The court ruled in agreement that there is a lack of "meaningful review" of the nutrient management programs and required that government officials review nutrient management plans created by CAFOs (Graham & Nachman, 2010). Also, the court mandated that the nutrient management plans be a main component of the NPDES permitting and compliance with the CWA (Graham & Nachman, 2010). Court cases allow for more strict interpretations of environmental laws to protect ecosystems, while increasing public awareness of the environmental issues and rallying support among local communities.

The North Carolina State University (NCSU) Cooperative Extension plays a role in providing educational materials regarding sustainable agricultural practices. The Center for Environmental Farming Systems at NCSU dedicates a large portion of their programming on extension and outreach with the goal of engaging the public at the grassroots level and providing connections to state-level resources.

Government agencies work to provide educational opportunities for professionals in the agriculture field in order to assist in developing farming techniques that maintain soil and water health, protect critical habitat, and reduce environmental contamination. For example, the local Soil and Water Conservation District Boards locate appropriate treatment areas, apportion the resources required, establish a contract, and provide technical assistance to the farmer (EPA, 2002). Also, the USDA funds programs to help small farmers in assessing their operations and management systems, then they make suggestions for the implementation of voluntary techniques (Graham & Nachman, 2010). In addition, government agencies have teams within their departments dedicated to providing education and outreach materials to the public.

Recommended Future Actions:

Type of Advocacy, Outreach, and Education Recommended	**Water Quality Impacts**
Bridge Gap Between Scientists and Policymakers	● Incorporates experts in the policymaking process ● Develops science-backed policies
Educate Consumers on Sustainable Products	● Increases consumers' understanding of their role in supporting sustainable farming operations ● Encourages farming operations to adopt sustainable practices
Address the Inequitable Access to Educational and Financial Resources	● Assists farmers in rural areas in applying for grants and writing proposals ● Aids farmers in implementing conservation strategies and sustainable farming techniques
Provide Educational Material to Homeowners about Impacts of Suburban Agriculture	● Reduces chemical use in suburban areas ● Decreases runoff discharge from small, private properties ● Provides nutrient management strategies

In order to continue advocacy, outreach, and education on behalf of aquatic ecosystems and fishing communities that rely on these resources in North Carolina, it is essential to have government backing. Environmental NGOs are critical in lobbying for the allocation of resources to farming communities who could benefit from increased government funding and technical assistance. Therefore, it is important to increase the government officials' understanding of the issue and bridge the gap between scientists and policymakers. Also, there have been great improvements in educating the general public on the consequences of factory farming and fertilizer-use, but there is still a need for increasing consumers' knowledge of their role in supporting more sustainable farming operations which may encourage the implementation of environmentally-friendly practices on other farms.

Finally, addressing the inequitable access to educational materials and financial resources could greatly assist many farmers in utilizing sustainable farming and conservation strategies. Some professionals in the agricultural field are unaware of the application process for receiving grants that support environmental efforts on farms. Therefore, improved outreach for programs such as the Wetlands Reserve Easement and assistance in developing grant-proposals will increase participation.

Industry Working Group Gap Analysis: Industrial Agriculture and Factory Farming Outreach Priorities

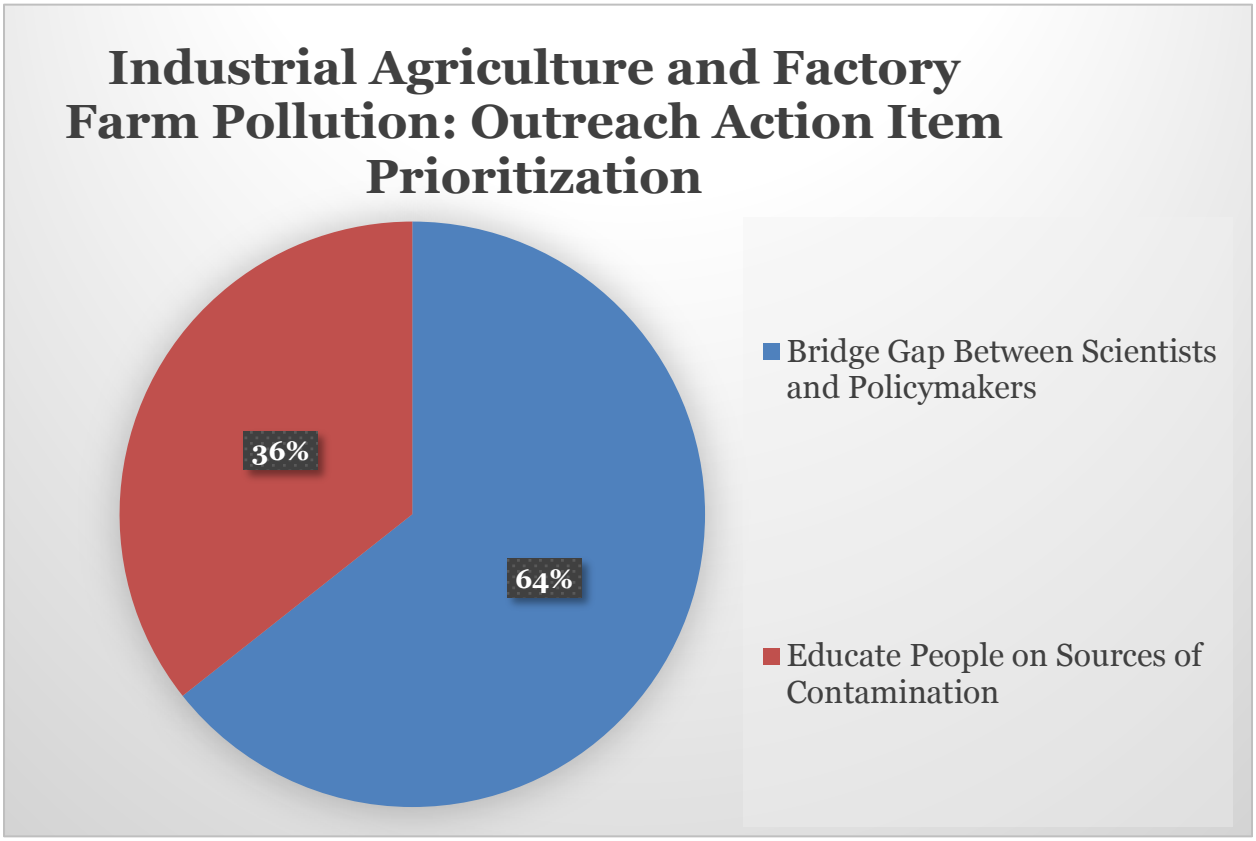


CHART 4: *Industrial Agriculture and Factory Farming Outreach Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Bridging the gap between scientists and policymakers has been identified as the top priority in 2021-22.

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Factory Farming and Industrial Agriculture Pollution Assessment Revisions in 2022:

Recommended Infrastructure

Changed wording "decommission floodplain CAFOS" to "CAFO buyout programs". Meaning the same thing, but is more specific, voluntary, and implies compensation.

Remove "dry handling" change to onsite treatment options such as Terra Blue or Sequence Batching. Included citations and info on that.

Current Policy and Enforcements

Included DEQ position on poultry permitting

Included data on recent violations in reports to NC General Assembly

Advocacy Lead Organizations additions

- Clean AIRE NC
- NC Environmental Justice Network
- REACH
- SELC
- Food and Water Watch
- Mercy for Animals
- Farm Sanctuary
- We Animals
- Public Justice
- Environmental Working Group

Research

Studies in Coastal NC suggest that CAFOs can be a more significant source of nitrogen than fertilizers from row crop agriculture. Under certain hydrological conditions, this nitrogen can be detected in estuaries many miles downstream (Brown et al., 2020).

Removed information attributed to Heavican, K., *Environmental Groups Lobby EPA to Regulate CAFOs*. https://brownfieldagnews.com/news/environmental-groups-lobby-epa-to-regulate-cafos/. As focus was on air quality and dairy industry.

Recommendations to include:

Remove dry waste handling as a recommended action. This doesn't make sense and should be replaced with onsite wastewater treatment.

Policy

- Strengthen DEQ oversight and enforcement
- Cumulative impact assessments
- Strengthen and increase monitoring provisions
- Evaluate and expand current buyout programs
- Place liability of animal waste management on integrators (Moore et al. 1995)
- Limit co-location of swine and poultry facilities (Gilchrist et al. 2007; Thorne 2007)
- Prioritize watersheds in terms of vulnerability to food-animal waste impacts (Kellogg 2000)
- Develop permitting for poultry

Infrastructure

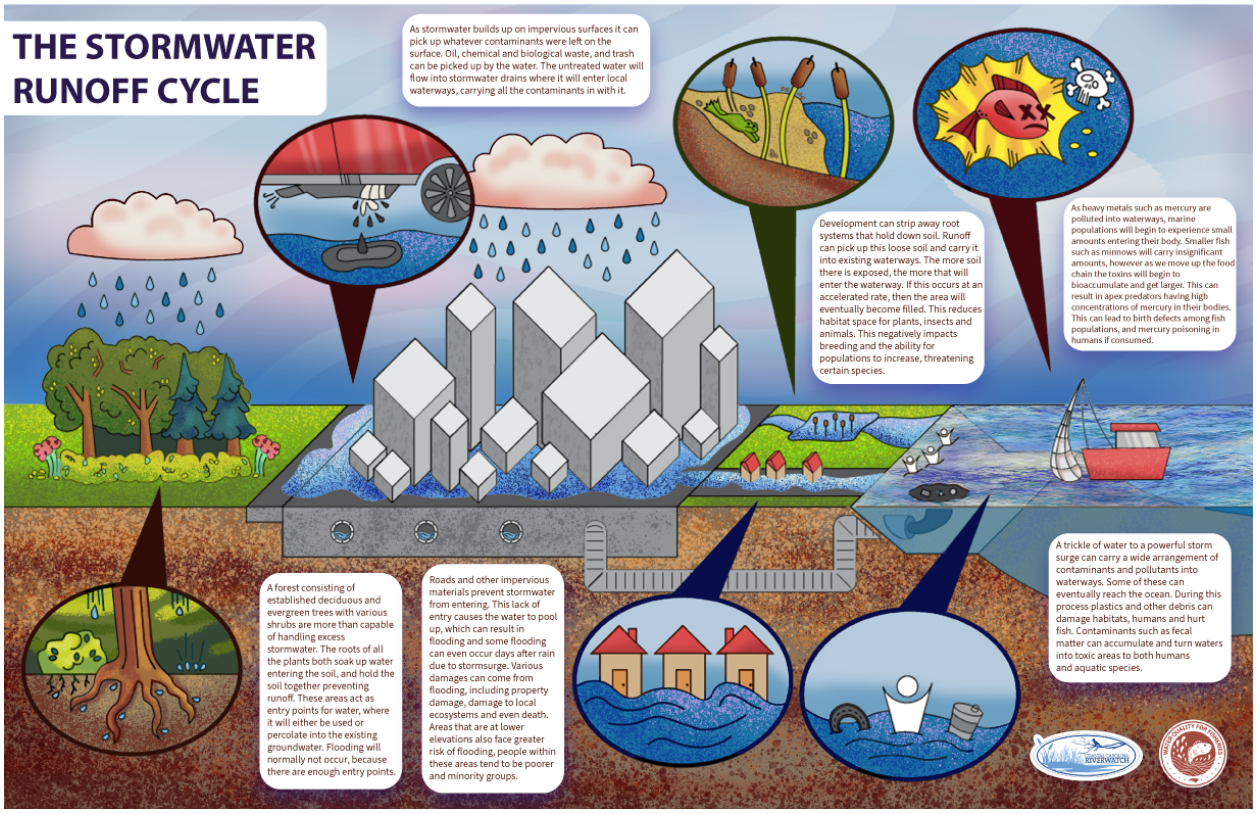
- Treat waste and wastewater prior to discharge
- Develop vegetation buffers (i.e. trees & shrubs) around facilities (Tabler 2004)

Research

- Continue to develop reliable, sensitive and affordable methods for the detection of pathogens in environmental samples
- Monitor private wells, streams and aquifers located in regions densely populated by food animals (Kellogg 2000; Burkholder et al. 2007)
- Use environmental assessment tools such as cumulative risk index analysis to systematically assess AFO impacts (Osowski et al. 2001)
- Increase studies of ecosystem health in proximity to CAFOs (Burkholder et al. 2007)
- Develop and implement an oversight and enforcement

https://sustainability.duke.edu/sites/default/files/cafos_nc_paper.pdf

Stormwater Runoff from Roads, Highways, and Parking Lots



GRAPHIC: Noah Weaver, *The Stormwater Pollution Cycle*, 2021

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 and concentrates contaminants, and washes them into drainage ditches or storm drains which lead to surface waters and beach areas. Contaminants include , but are not limited to, sediment, nutrients, and bacteria. Development from housing subdivisions, roads, shopping centers, industrial parks, and parking lots have inhibited forests and wetlands from naturally occurring draining and filtration processes in the coastal region (Mallin, 2006). Now the stormwater flows directly into 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
Stormwater Runoff BMPs and Nature-Based Stormwater Strategies • Constructed stormwater wetlands • Natural Filtration Systems • Swales • Rain gardens	• Reduces risk of nutrient loading and fecal bacteria pollution • Decreases amount of stormwater discharge • Decreases pollutants such as bacteria, nutrients, and sediments • Limits flooding • Increases vegetation • Improves fish and wildlife habitat	NC Department of Environmental Quality 877.634.6748 UNCW Center for Marine Science 910.962.3000 NC State Stormwater Engineering Group 919.515.6780
Pervious surfaces	• Allows percolation to reduce runoff • Reduce suspended solids • Filter pollution	
Infiltration chambers	• Create spaces for temporary storage of stormwater, allowing it to infiltrate into the underlying native soil.	

The use of developed infrastructure and BMPs have been essential in filtering pollutants from stormwater runoff and reducing their impact on fish populations. One example is 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.

Researchers at UNCW Center for Marine Science 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.

A pipe that carried runoff straight into Banks Channel 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%. Also installed were curb cuts, reversed stormwater inlets, a large rain garden, and restored grassed swales to assist in stormwater infiltration. (Mallin et al.)

A study published in 2021 found that the implementation of BMPs in Wilmington caused a reduction in stormwater runoff by 62%, total nitrogen was reduced by 86.9%, and enterococcus bacteria was reduced by 76.3%. These included reduction of impervious surfaces and construction of an infiltration chamber in a parking lot. (Grogan et al., 2021).

Researchers describe successful stormwater runoff filtration systems and processes. For example, sand filters function as 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. 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. Rain gardens reduce 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).

NC State Stormwater Engineering Group is working on research regarding new designs of swales to better target pollutants.

Recommended Future Actions:

Type of Infrastructure	Water Quality Impacts
Sustainable Development	● Reduces stormwater runoff discharge ● Decreases impervious surfaces ● Preserves habitat ● Filters contaminants from runoff ● Nature based solutions ● Includes BMPs
Updates of Current Stormwater Outfalls	● Decreases drainage into beaches and shell fishing 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, practicing sustainable development by avoiding clear-cutting forests, draining wetlands, and extensive use of pavement would aid in protecting water quality.

"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, evaluating the replacement of stormwater outfalls draining to shell fishing waters with newer, more effective stormwater management infrastructure, and continuing to replace current outfalls to improve 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 1.5 inches of water in 24 hours, for coastal NC counties. Large storms generate

more precipitation than this, therefore, current strategies are less able to manage these larger quantities of rainwater.

Industry Working Group Gap Analysis: Stormwater Infrastructure Priorities

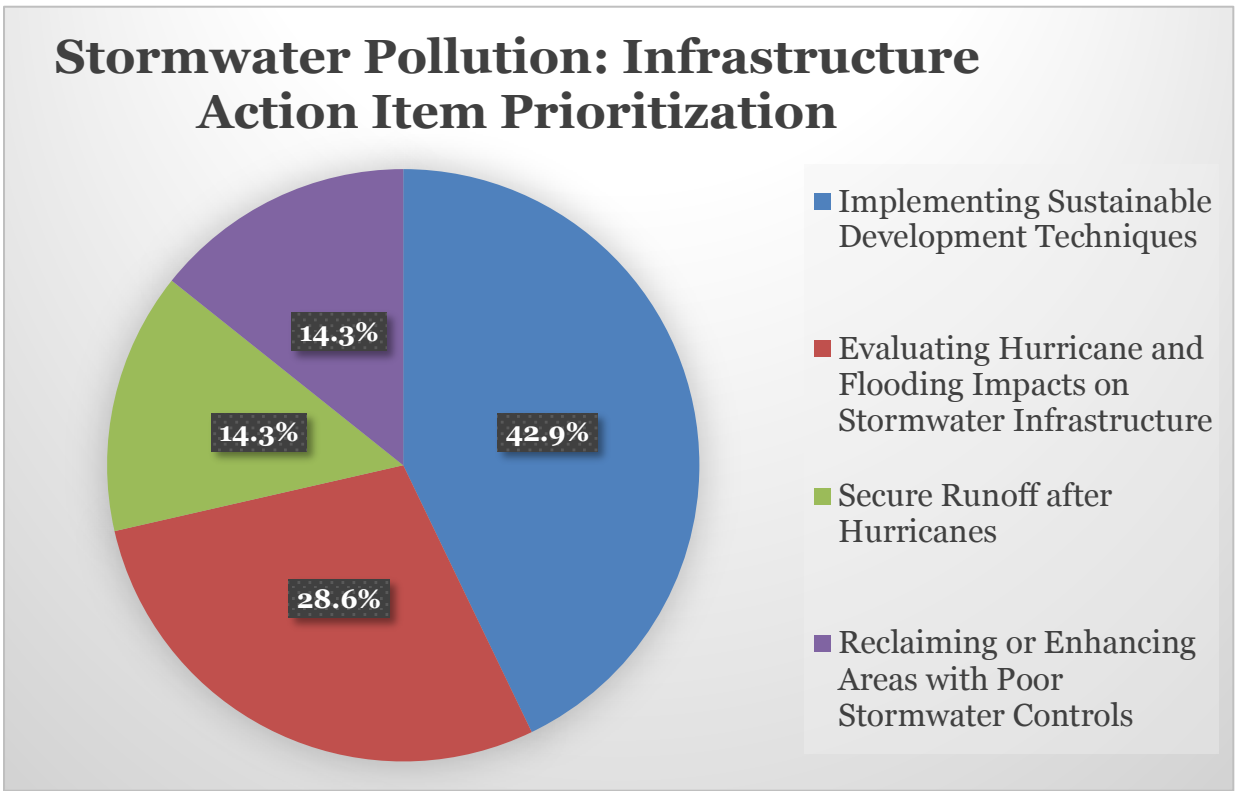


CHART 5: *Stormwater Infrastructure Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Implementing sustainable development techniques (wetland and forest protection, permeable surfaces, increased vegetated areas, on-site runoff treatment technologies) has been identified as the top priority in 2021-22.

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 • Post Construction Program • NPDES Construction Program • NPDES Industrial Program • NPDES MS4 Program • Water Supply Watershed Program	• Requires new developments in subject areas of the state to install and maintain permanent stormwater management measures after the project is built. • Regulates construction activities that disturb more than one acre under a general permit. • Requires industrial operations to manage and monitor their facilities for potential sources of stormwater	Division of Energy, Mineral, and Land Resources 877.623.6748

	pollution. ● MS4 permittees such as municipalities, counties, universities, military bases, and NCDOT, implement measures within their jurisdictions to prevent and control stormwater pollution from developed areas. ● Regulate water supplies that contribute to drinking water from stormwater contaminants.	
Administrative Codes Setting Stormwater Runoff Standards	● Decreases sedimentation at development sites ● Protects ORW and HWQs ● Reduces pollutants from entering waters	Environmental Management Commission under the DWQ 877.623.6748
20 Coastal Counties Stormwater Rules	● 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	NC Department of Environmental Quality 877.634.6748

	from the DEQ • Encourages implementation of BMPs, resulting in the protection of water quality • Reduces stormwater runoff discharge into nearby bodies of water	North Carolina Coastal Federation 252.393.8185
Coastal Habitat Protection Plan		NCDEQ DCM
Erosion and Sediment Control	• Guide development within our state while preventing pollution by sedimentation.	NC DEQ DELMR Water Resources Research Institute (WRRI) of the UNC System

A significant number 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 generate a 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, ensure 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 improvement in fisheries habitat and increased fish populations since the implementation of the CHHP (NCDEQ, 2016).

Some implementations designed to reduce nonpoint runoff in the coastal region include the coastal stormwater rules by the Environmental Management Committee (EMC) and the inclusion of low impact development techniques as a Best Management Practice by DWR and DEMLR. MS4 permitting guides management plans for point source pollution.
In this plan, 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 waters from stormwater runoff impacts. The EPA gave NCDEQ the authority to administer and regulate water quality policies throughout the state. 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 disturb 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 urbanized areas such as municipalities, counties, universities, and military bases. Those monitored by the program must implement strategies to prevent stormwater pollution from developed areas.

Stormwater runoff management strategies are enforced by the Environmental Management Commission under the Division of Water Quality (DWQ). 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 located within one mile of Outstanding Resource Waters (ORW) may need to follow more stringent rules and regulations for stormwater runoff.

Other focuses are 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 for coastal counties, but the statue requires a stormwater permit be obtained for non-residential development that disturbs less than one acre, adds more than 10,000 square feet of impervious surface and for 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 (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 Hewlett's 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).

Industry Working Group Gap Analysis: Stormwater Policy Priorities

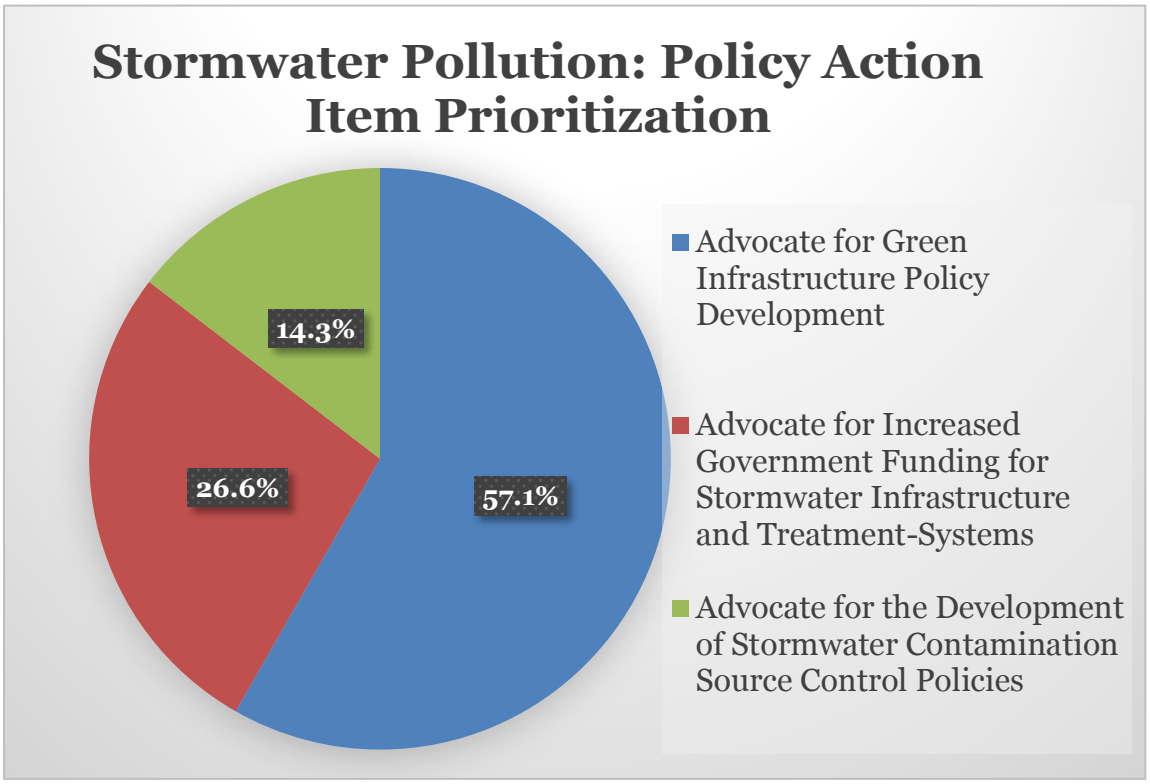


CHART 6: *Stormwater Policy Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Advocating for green infrastructure policy development (standardize the use of permeable pavement, green streets, filtration systems, and nature-based infrastructure) has been identified as the top priority in 2021-22.

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
Effectiveness of Stormwater Infrastructure and Strategic Placement • Bioswales, wet pond retrofits, regenerative stormwater conveyance systems, constructed wetlands, permeable pavement, green streets, permeable pavement, draw down cisterns	• Reduces stormwater discharge • Decreases surface water contamination • Prevents nutrient overload • Decreases sedimentation	NC State University Stormwater Engineering Group 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 are being studied by research institutions and government agencies.

NC State Stormwater Engineering Group is researching several stormwater BMPs including bioswales, wet pond retrofits, regenerative stormwater conveyance systems, constructed wetlands, permeable pavement, green streets, and draw down cisterns (NCSU).

Promising examples include swales, which are vegetated channels designed to store and manage stormwater. They are gaining popularity in stormwater treatment and in green infrastructure. To achieve higher pollutant reductions, NCSU is researching swale alternatives with engineered media (bioswales) and wetland conditions (wet swales). Grass swales with check dams or infiltration swales are the best options for runoff volume reduction and removal of sediment and heavy metals. Wet swales are the most effective for nitrogen reduction. Bioswales are best for phosphorus and bacteria removal; both wet swales and bioswales can also treat heavy metals. The need to collect more data has been identified (Ekka et al., 2021)

Recent combinations of stormwater controls have also been researched to be effective. In another study NCSU was involved in, a combination of pretreatment using permeable pavement and final polishing through underground stormwater harvesting was shown to produce water quality improvements. A 27% reduction in runoff and 40% reduction of sediment bound nutrients and total nitrogen was observed. Sequestration of copper, lead, and zinc also occurred, and pollutant loading was improved (Winston et al. 2020).

UNC Wilmington's Center for Marine Science has also completed stormwater research and the efficacy 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).

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* level (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. Research has established a strong correlation between E. coli counts and the percentage of impervious surfaces in a given watershed. It was 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 goals 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	● 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 NCSU discussed the success riparian buffers have in mitigating nutrient pollution. However, there are several factors that contribute to their efficacy 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 the 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).

Industry Working Group Gap Analysis: Stormwater Research Priorities

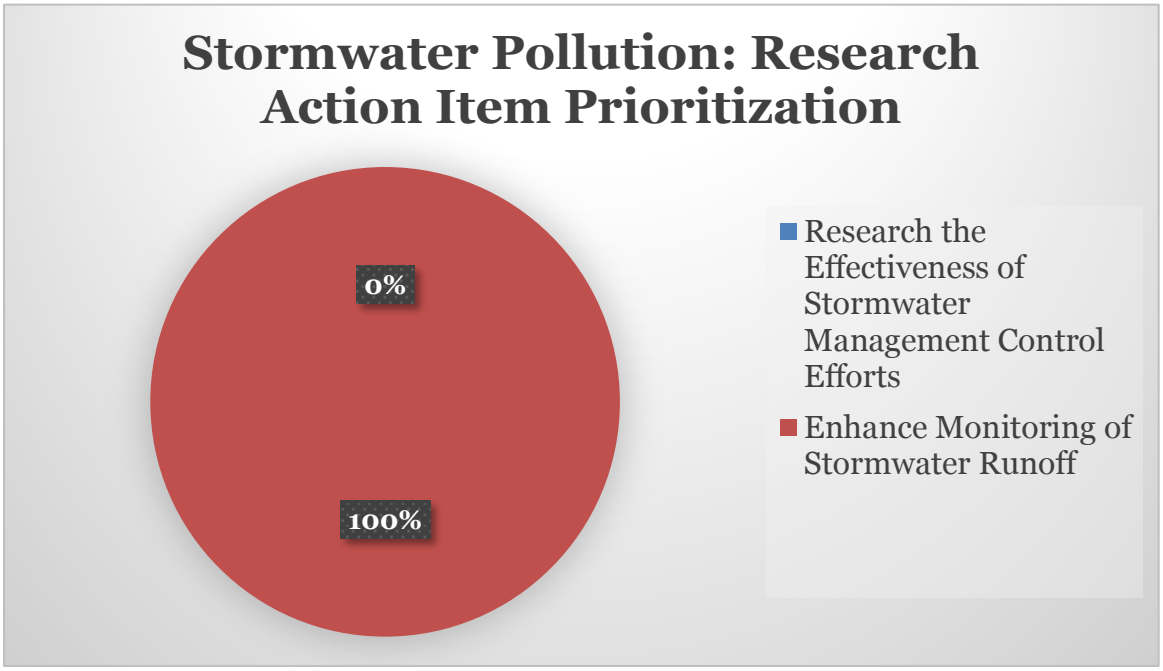


CHART 7: *Stormwater Research Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Enhancing the monitoring of stormwater runoff has been identified as the top priority in 2021-22.

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 implemented	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, supporting 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 (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 NCDEQ 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 NCDEQ includes information on updated technologies, 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). NCSU'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 others to participate.

Industry Working Group Gap Analysis: Stormwater Outreach Priorities

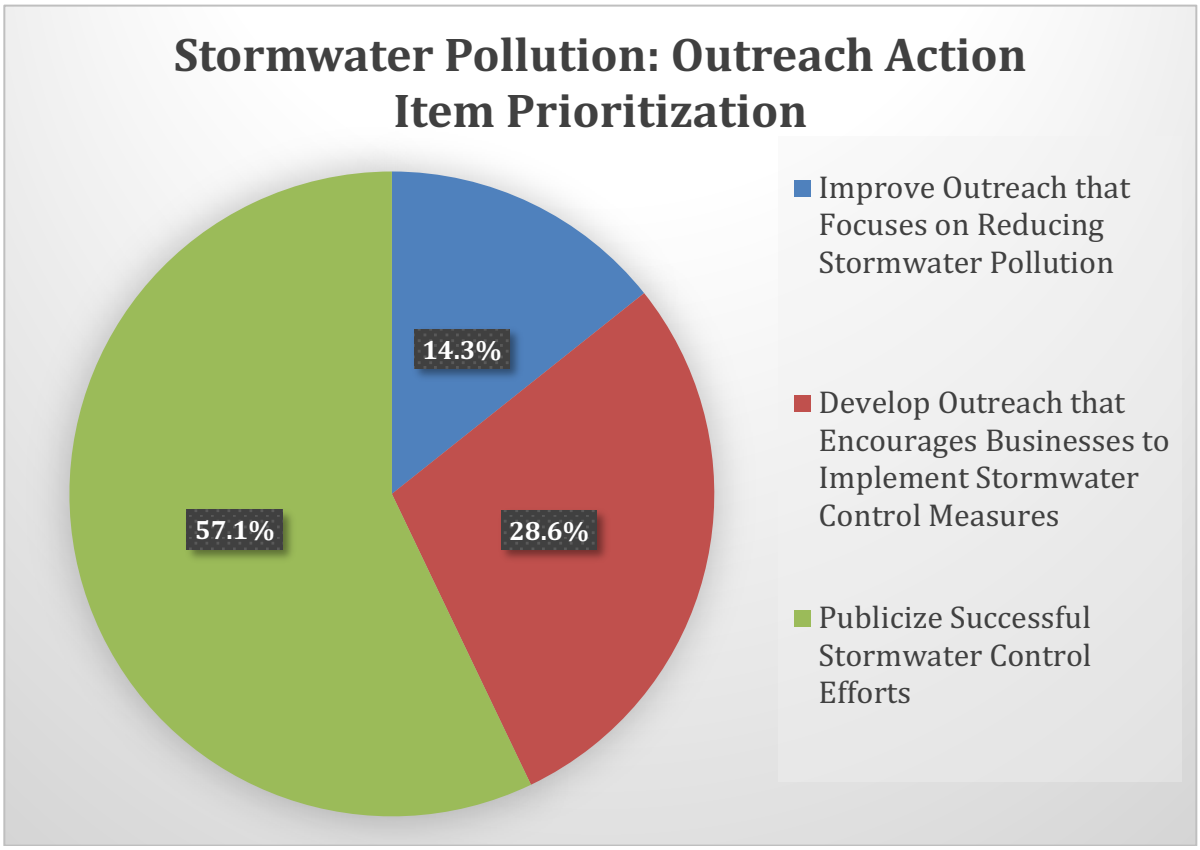


CHART 7: *Stormwater Outreach Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Publicizing successful stormwater control efforts has been identified as the top priority in 2021-22.

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Stormwater Pollution Assessment Revisions in 2022:

Included specific programs under DEMLR

Added Erosion and Sediment Control by DEMLR and UNC

Removed "constructed stormwater wetlands" and consolidated with BMP

Included CHPP in policies

Changed Coastal Review citations to published study citations

Included 2021 Grogan/Mallin study

Pulled quantitative data from citations to specify stormwater improvements

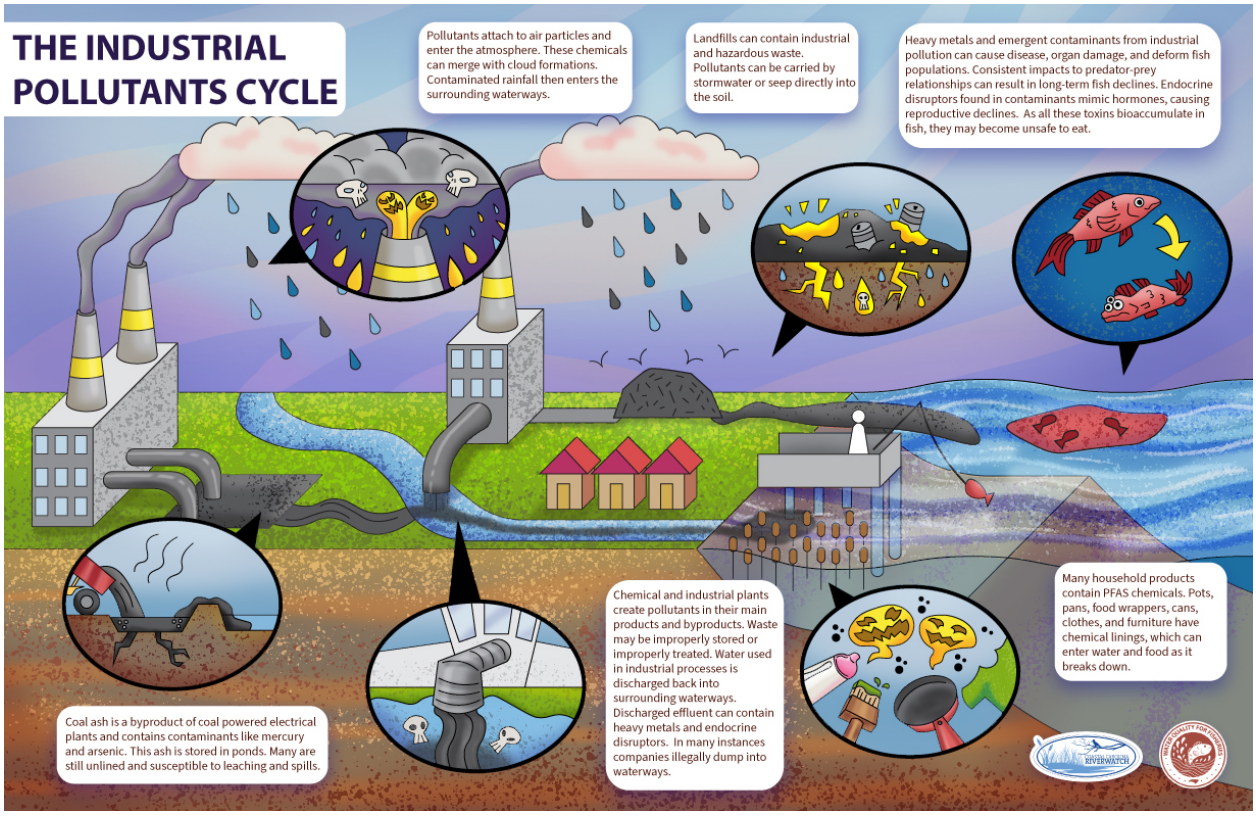
Removed Natural Stormwater Runoff Filtration Systems from current infrastructures as advised by Pat–too broad. Consolidated with Nature Based Solutions. Included impervious surfaces and infiltration chambers.

Needs:

Included research from Dr. Hunt

NC State Stormwater Engineering Group: North Carolina recently provided many incentives for the use of permeable pavement, thereby ensuring widespread and frequent application across the state. NC State researches the importance of identifying key design and construction elements, while producing long-term annual water budget models for hundreds of permeable pavement design configurations. Field monitoring elements include clay underlined soils, hydraulic loading ratios, and the creation of subsurface storage reservoirs for increased infiltration potential.

Industrial Pollution Assessment



GRAPHIC: Noah Weaver, *The Industrial Pollution Cycle*, 2021

Introduction

Industrial pollutants have contaminated North Carolina waters for decades as a result of manufacturing processes and industrial activities. For example, facilities such as Dupont/Chemours release chemicals into the air as well as local bodies of water, coal-based operations discharge contaminants into coastal rivers, and Superfund (inactive) sites leak hazardous materials into the environment. It has also been found that industries may knowingly discharge toxic chemicals into the environment unbeknownst to the public or governmental agencies.

Common contaminants found in Southeastern NC include 1,4 dioxane, bromides, and PFAS (perfluoroalkyl and polyfluoroalkyl substances) (Southern Environmental Law Center, 2021). There is still a significant amount of uncertainty associated with these “emerging compounds” and a need for additional research, regulatory, and outreach efforts. Fish can take in these pollutants through absorption in their food, contact with contaminated sediments or when polluted water passes through their gills. Studies have indicated that the toxins are concentrated in fish’s skin, organs, and other tissues. Bottom-dwelling fish tend to contain higher concentrations of pollutants due to a large amount of contaminated sediments settling on the bottom due to runoff (Environmental Defense Fund, 2013). Also, fish considered top predators have greater levels of degradation resistant toxins, such as

PCBs and mercury, present in their tissues. This is due to biomagnification or the process of a contaminant increasing its concentration in tissues of organisms as it moves up the food chain.

PFAS have been used in products for decades and their utilization has continued to increase in recent years due to these compounds' effective resistance to physical, chemical, and biological degradation. Commonly, they are found in products with nonstick coatings, nonconducting materials for electronics, firefighting foam, and waterproof materials (Kluck, et al., 2021).

PFAS contain strong carbon-fluorine bonds which contribute to their fire and water resistance capabilities and their resistance to biodegradation, hence their alternative name, "forever chemicals." PFAS chemicals generally bioaccumulate in organisms and attach to dust and air particles which allows for easy transfer from food packaging into food products (Kluck, et al., 2021).

The use of PFAS accelerated in the 1970's and 1980's. Researchers have found PFAS in every body of water in North Carolina that has been sampled as of 2021 (Kluck, et al., 2021). Crops, livestock, fish, and shellfish have all been found to contain PFAS (Kwiatkowski, 2020). PFAS enters water from manufacturing emissions, land application of contaminated biosolids, facilities' wastewater, firefighting foam, household product use, and landfill leachate.

When environmental impacts of PFAS were first discovered and studied, some companies transitioned from the traditional long-chain PFAS to short-chain PFAS. The replacements were advertised as safer alternatives, but research has proven short-chain PFAS exposure results in similar health risks (Kwiatkowski, 2020).

In the early 2000's, DuPont Chemours Company, located in Fayetteville, North Carolina, began commercial production of the PFAS chemical, GenX. Subsequent to this, PFAS contamination was found in bodies of water in the Cape Fear River basin (NC PFAS Testing Network, 2021). Specifically, in 2014 researchers found high levels of PFAS in the Cape Fear River and in the drinking water of Wilmington, NC (Sun et al., 2016).
In 2017, Dr. Knappe and his team's discoveries were published, resulting in media reports that brought attention to the PFAS issue in North Carolina (NC PFAS Testing Network, 2021).

Dupont Chemours was mandated to cease discharge of its wastewater, but PFAS still contaminates Wilmington's water through runoff, groundwater, and river sediments (Barnes, 2021). In addition, PFAS air emissions result in the chemicals' deposition by the way of regional rainwater (Kluck, et al., 2021).

Safe human exposure levels for PFAS and GenX have yet to be determined. However, laboratory studies on animals indicate these chemicals may act as endocrine disruptors associated with thyroid problems, cancer, and pregnancy complications (GenX and Emerging Industrial Contaminants, 2018).

Heavy metals resulting from industrial activities can be toxic to marine life. High levels of heavy metals concentrate in marine organism's protein-rich tissues. Responses include lung pathology, immuno-suppression, nutritional deficiencies, and lesions. Toxic heavy metals include mercury, cadmium, silver, nickel, selenium, lead, copper, chromium, arsenic and zinc. These pollutants can also bioaccumulate in aquatic species (Tanaka, et al., 2004).

Currently, coal ash (waste from coal burning power plants) can be found in soil and surface water throughout southeastern North Carolina. Even though Duke Energy was required to relocate their coal ash waste to dry, lined storage, some coal ash spills remain unmonitored and coal ash has also been utilized as a soil fill (Duke Today, 2020).
Contaminants still found in North Carolina waters resulting from the residue includes the carcinogen, hexavalent chromium.

Similarly, to PFAS, heavy metals and VOCs are industrial pollutants that can be toxic to marine life and are known to bioaccumulate in aquatic species (Tanaka, et al., 2004).

Infrastructure Assessment

Current Actions:

Type of Infrastructure	Water Quality Impacts	Lead Organization
Implementation of Filtration Systems	• Decreases PFAS, heavy metals, and VOC Concentrations in water • Protects aquatic life from harmful health effects	Environmental Protection Agency (Southeast Regional Office) 800.241.1754 PFAST Network ncpfastnetwork@unc.edu
City-Wide advanced systems for Wastewater Treatment	• Reduces PFAS and other industrial pollutants levels • Promotes safe drinking water sources	Local Municipalities
Use of Public Water Supplies as an alternative to private wells	• Reduces consumption of contaminated water	Local Municipalities

With public knowledge of industrial pollutant management being relatively new, there is a lack of confidence in the effectiveness of the few processes utilized to filter chemicals from water. The EPA has identified effective ways to treat PFAS in drinking water using four different technologies:

- First, granular activated carbon (GAC) causes chemicals to adsorb to small pieces of carbon as the water passes through the filter. GAC has been used for almost 15 years and is successful in adsorbing some PFAS in water (Kluck, et al., 2021).
- Powdered activated carbon (PAC) adds powdered carbon to water and then chemicals like PFAS will adsorb to the particles (Environmental Protection Agency, 2018).
- Ion exchange resins are small beads made of plastics that cause charged chemicals to stick to the beads as the water runs through them.

- Finally, nanofiltration and reverse osmosis is a process that occurs when water is pushed through a membrane with small pores (Environmental Protection Agency, 2018). This membrane behaves as a barrier that stops chemicals and particles from entering drinking water.

Similarly, reverse osmosis, membrane filtration, ion exchange, and adsorption are techniques utilized to remove heavy metals from water sources. Additionally, methods such as advanced wastewater treatment processes, UV irradiation, ozonation, and ultrasound have been effective in removing VOCs and other endocrine disruptors according to the Water Quality Association (Scavetta, 2021).

Recently, local North Carolina governments have begun to invest funds in improving infrastructure that filters emerging compounds like GenX. For example, Wilmington and New Hanover County will allocate approximately $46 million to filter out "forever chemicals" from drinking water that supplies about 200,000 people (Barnes, 2021). Similarly, Brunswick County approved a bid for $137 million to develop a similar filtration system that will remove PFAS within the next two years (Barnes, 2021).

Also, using alternative water sources is another means of halting the consumption of contaminated drinking water as fast as possible. Cumberland County will spend approximately $10 million to run public water lines to schools and homes whose wells are contaminated with industrial pollutants (Barnes, 2021).

Recommended Future Actions:

Type of Infrastructure	Water Quality Impacts
Reducing Industrial Activities that Utilize harmful Chemicals in their Processes	• Reduces industrial pollutant contamination in local waters and drinking water supplies • Protects the natural habitat and aquatic life
Improved Industrial Wastewater Treatment at the Local Level	• Reduces industrial pollutant discharge at a larger-scale, city-wide • Reinforces healthy fish populations and aquatic ecosystems

Development of New Advanced Water Treatment Technologies	• Decreases PFAS, heavy metals, and VOCs in water • Protects aquatic life from harmful health effects
Creation of Coal Ash Treatment Technologies	• Treats coal ash ponds and reduces risk of contamination in nearby rivers • Reduced health risks for fish populations and people

Reducing industrial activities utilizing pollutants such as PFAS should be a priority in future infrastructure development. Ceasing these activities and finding safer alternatives would decrease the level of contaminants from entering local waters.

Though a few cities have begun to invest in new infrastructure, the need for improved water supply treatment in municipalities is urgent. Current water treatment plants' filtration systems lack the ability to remove all PFAS. However, scientists at UNC have developed a resin that will filter PFAS molecules.

Some newer methods that may assist in breaking down PFAS compounds include advanced reduction processes (ARPs), plasma-based water treatment, and using β- cyclodextrin polymers (Kluck, et al., 2021). There are still unknowns about the effectiveness of using ARPs to break down PFAS and reduce toxicity levels in water. Therefore, investigating the effectiveness of these processes could greatly assist in accelerating their implementation.

Technologies are also currently being developed to assist in treating coal ash found in water bodies. One company, Saltworks Technologies, treats coal ash pond water through biological, reverse osmosis, and filtering membrane methods (Saltworks Technologies, 2019).

Industry Working Group Gap Analysis: Industrial Pollution Infrastructure Priorities

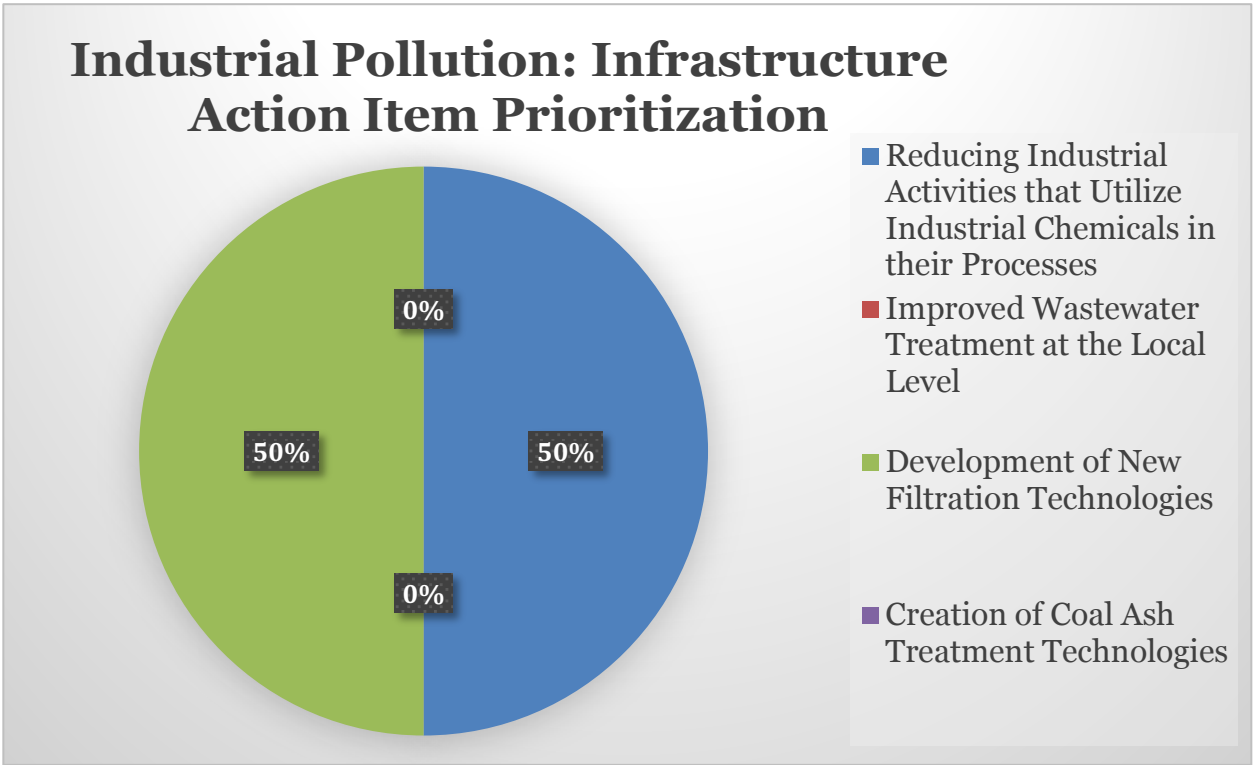


CHART 7: *Industrial Pollution Infrastructure Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Both reducing industrial activities that utilize industrial chemicals in their process and the development of new filtration technologies have been identified as top priorities in 2021-22.

Policy and Enforcement Assessment

Current Actions:

Type of Policy	Water Quality Impacts	Lead Organization
Health Advisory (70 ppt) for PFOS and PFOA	• Limits concentrations of PFOS and PFOA in drinking water • Protects public health from negative effects of PFOS and PFOA	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
NPDES for Industrial Activities	• Limits industrial pollutants entering bodies of water through stormwater discharges • Regulates environmental exposure from industrial activities	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
National Defense Appropriations Act	• Reduces environmental contamination by decreasing the use of PFAS firefighting foam • Manages and monitors contamination levels in bodies of water	Department of Defense

NC Legislation Providing Funding for the NC PFAST Network	• Increases understanding of effects of PFAS on aquatic ecosystems • Identifies areas of concern within NC coastal watersheds	NC PFAST Network ncpfastnetwork@unc.edu NC General Assembly 919.733.4111
Public Utilities are State-Mandated to Have Discharge Permits	• sets allowable levels of emerging compounds in wastewater • Encourages monitoring of industrial pollutant concentrations in bodies of water • Implements city-wide contaminant reduction efforts	NC Division of Water Resources 919.707.9023
Safe Drinking Water Act (SDWA) Fifth Unregulated Contaminant Monitoring Rule	• Monitors concentrations of 30 emerging compounds and identifies areas of concern	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (Superfund Legislation)	• Proposes adding PFOA and PFOS to the legislation, defining the chemicals as hazardous • Increases management efforts for PFOA and PFOS	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

Hazardous and Solid Waste Amendments	• Minimizes the production of hazardous waste • Reduces water contamination from hazardous waste	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Toxic Substances Control Act (TSCA)	• Reduces water contamination from PCBs • Reduces PFOS and PFAS use in US commerce, decreasing their impacts on water quality	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Toxics Release Inventory	• Monitors concentration levels of industrial pollutants in bodies of water • Identifies areas of concern	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

Legislation regulating emerging compounds and other industrial pollutants is severely lacking. North Carolina follows the 70 parts per trillion (ppt) advisory level for PFOS and PFOA in drinking water that was established by the EPA, but the state made another objective to have less than 140 ppt of GenX chemicals in all drinking water (Kluck, 2021). The EPA has not created health advisory levels for any additional PFAS chemicals.

The National Pollutant Discharge Elimination System (NPDES) included permitting for stormwater discharges from industrial activities beginning in January of 2021 (National Pollutant Discharge Elimination System, 2021). This program enforces federal regulations for stormwater discharge resulting from material handling and storage, equipment maintenance, and additional industrial activities. Some of the facilities regulated under the legislation include heavy manufacturing sites such as mills, coal and mineral mining facilities, hazardous waste treatment plants, landfills, transportation facilities, and construction sites (National Pollutant Discharge Elimination System, 2021). The EPA gives the state the authority to administer and enforce the permitting system.

The National Defense Appropriations Act passed in 2020 included sections that addressed the application of PFAS in government activities. The policy phases out the use of firefighting foam with more than 1 ppb PFAS contents and prohibits the purchase of PFAS firefighting foam by 2022 (Cook, 2019). The act also provides funding for the creation of a replacement for non-fluorinated firefighting foams. The legislation requires collaboration between state governments and the Department of Defense (DoD), mandating cooperation with testing, monitoring, removing, and remedial actions relating to contamination from DoD facilities.

The NC Division of Water Resources (NCDWR) has begun implementing programs focused on addressing concerns with emerging contaminants. In 2018, the NC General Assembly passed the first piece of legislation regarding PFAS that funded the NC Policy Collaboratory with over $5 million to create the PFAS Testing Network. However, the General Assembly has rejected initiatives to reduce firefighter foam usage and limited the DEQ's technological capabilities to test water for PFAS.

Some positive progress for legislation development in North Carolina includes the DWR's mandating of publicly owned utilities (POTWs) with pretreatment programs, and industrial dischargers located within the Cape Fear River Basin to acquire state permits. Their goal is to monitor a group of emerging compounds in this area's wastewater. All participants in the permitting program were required to sample their wastewater for 1,4-dioxane and PFAS for three months (NC DEQ, 2021).

After completing the monitoring project, they found that 1,4 dioxane levels were elevated in Greensboro's, Reidsville's, and Asheboro's POTWs while the rest of the samples were lower (NC DEQ, 2021). The cities were mandated to implement reduction efforts to address the issue. In comparison, only one sampling site for PFAS located in Sanford indicated concentrations exceeding the health advisory for PFOS and PFOA (NC DEQ, 2021). The DEQ has begun monthly sampling and assisting the city with locating the source of contamination.

Under the Safe Drinking Water Act, every five years EPA is required to issue a new list of unregulated contaminants to be monitored by public water systems. The EPA's current Fifth Unregulated Contaminant Monitoring Rule identifies 30 chemical contaminants, 29 being PFAS and 1 being lithium, that would require sample collection to establish data on frequency and levels.

Research under the Third Unregulated Contaminant Monitoring Rule and found that there are high concentrations of 1,4 dioxane and PFAS in the Cape Fear River Basin (NC DEQ, 2021). The DWR's monitoring programs supported the EPA's results.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), also known as the Superfund Legislation, allows the federal government to regulate any listed contaminant's environmental release. Currently, PFAS are not listed under CERCLA, but the EPA has proposed defining PFOA and PFOS as "hazardous substances" under CERCLA (Environmental Protection Agency, 2021).

The federal regulations governing hazardous wastes, specifically Superfund Sites, in North Carolina date back a few decades. Some important pieces of legislation include the Clean Air Act (CAA), the Clean Water Act (CWA), and the Hazardous and Solid Waste Amendments (HSWA) to the Resource Conservation and Recovery Act (RCRA) (Patterson, 1989).

The goal of the HSWA is to minimize the production of hazardous waste and support regulatory action by governmental agencies, industries, and the public. Also, the Superfund Amendments and Reauthorization Act (SARA) forces the public release of information regarding toxic waste discharges into the environment (Patterson, 1989). The Emergency Planning and Community Right-to-Know Act (EPCRA) was added to the legislation to increase public awareness. There are about 1700 Superfund sites prioritized for cleanup by the EPA on the National Priority List (Roth, 2014). However, only a small number of hazardous waste sites are addressed through the Superfund program.

Under (CERCLA) and (SARA), PCBs are classified as a hazardous substance and if an operation has a greater quantity than the specified reporting threshold of PCBs, they are required to report annual releases of PCBs (EPA, 2014). The Toxic Substances Control Act (TSCA) prohibits the manufacturing, processing, and distribution of PCBs in US commerce. Some PCB substances that are regulated include dielectric fluids, solvents, oil, hydraulic fluids, paints, sludges, sediments, and soils (EPA, 2014). Also, the TSCA phased out PFOA and PFOS use in United States commerce.

The EPA manages the Toxics Release Inventory which is a report developed based on the collection of information from industrial operations using 770 chemicals. PFAS were added in 2019. However, not all toxic chemicals are evaluated with the inventory and the data is self-reported by the polluters (Sorg, 2021).

Recommended Future Actions:

Type of Policy	Water Quality Impacts
PFAS Action Act of 2021	• Reduces PFAS use and pollution across the country • Encourages public release of information regarding PFAS
Groundwater Quality Standards for PFOS and PFOA	• Reduces PFAS contamination throughout the state • Limits discharge from industrial activities

Enforceable Maximum Contaminant Levels for Municipal Water Treatment Facilities	● Reduces industrial pollution from entering bodies of water ● Decreases negative health effects for fish populations
Adding PFAS to the Contaminant Candidate List under the Safe Drinking Water Act	● Provides additional information and data regarding the pollutants ● Encourages regulatory action to limit industrial pollutant discharges based on their findings
Banning or Mandating Reduced Use of PFAS in US Products	● Reduces risk of industrial pollutants contaminating water sources ● Eliminates discharge from industrial facilities
Legislation Providing Funding for Research and Treatment of Industrial Pollutants	● Reduces water contamination from industrial activities ● Allows monitoring and managing of water resources ● Protects aquatic ecosystem health

In 2021, the House of Representatives passed the PFAS Action Act of 2021 and, as of the fall of 2021, the bill had entered the Senate. This legislation would require that the EPA list PFAS as hazardous substances under CERCLA (PFAS Action Act of 2021, 2021). As a result of this act, the EPA would test for PFAS, companies would be required to disclose use of PFAS, and national drinking water regulations would be set and enforced.

The NCDWR has proposed developing a regulated Groundwater Quality Standard in place of a health advisory for PFOA and PFOS of 70 ppt. Also, they have created in-stream target values of 0.35 ug/L for 1,4-dioxane and a target of 80 ug/L for all other surface waters (NC DEQ, 2021). However, NC needs enforceable statewide PFAS drinking water standards that establish maximum contaminant levels (MCL) for municipal water.

EPA Administrator Regan announced in April of 2021 that the agency will establish a new "EPA Council on PFAS." The goal of the council is to address the risks associated with PFAS using scientific information that will provide the basis to create regulations (Environmental Protection Agency, 2021). Additionally, the agency has suggested adding

PFAS to the Contaminant Candidate List (CCL) under the SDWA. The CCL was created to assist in determining whether specific contaminants should be regulated with a National Primary Drinking Water Regulation (NPDWR). This preliminary determination to regulate PFOA and PFOS may be useful in developing regulatory policies for PFAS.

One way to prioritize the regulating of specific chemical classes would be to use their persistence in the environment as a determining characteristic. Also, measures have been suggested such as banning products that use PFAS or limiting the use of hazardous chemicals to instances where they are uniquely essential to public health (Kwiatkowski, 2020). Meanwhile, encouraging the use of replacements could greatly reduce impacts on fisheries.

One way the government could become more involved in regulatory actions for industrial pollutants includes implementing and enforcing strict standards for emerging compounds such as PFAS rather than relying solely on health advisories. In NC, ten different bills have been introduced with the goal of addressing the water quality implications associated with industrial pollution (Barnes, 2021). Some bills aim to hold the industries responsible for the pollution while others hope to ban the manufacture, sale, and distribution of PFAS in North Carolina. Creating political and public support for these laws will assist in the management of industrial pollution.

Additionally, it is important to provide additional funding for researching treatment and disposal methods for PFAS chemicals. Also, it would help if the federal agencies would hold guilty contaminating companies accountable for their contamination to prevent recurring pollution and to deter other operators as well.

Industry Working Group Gap Analysis: Industrial Pollution Policy Priorities

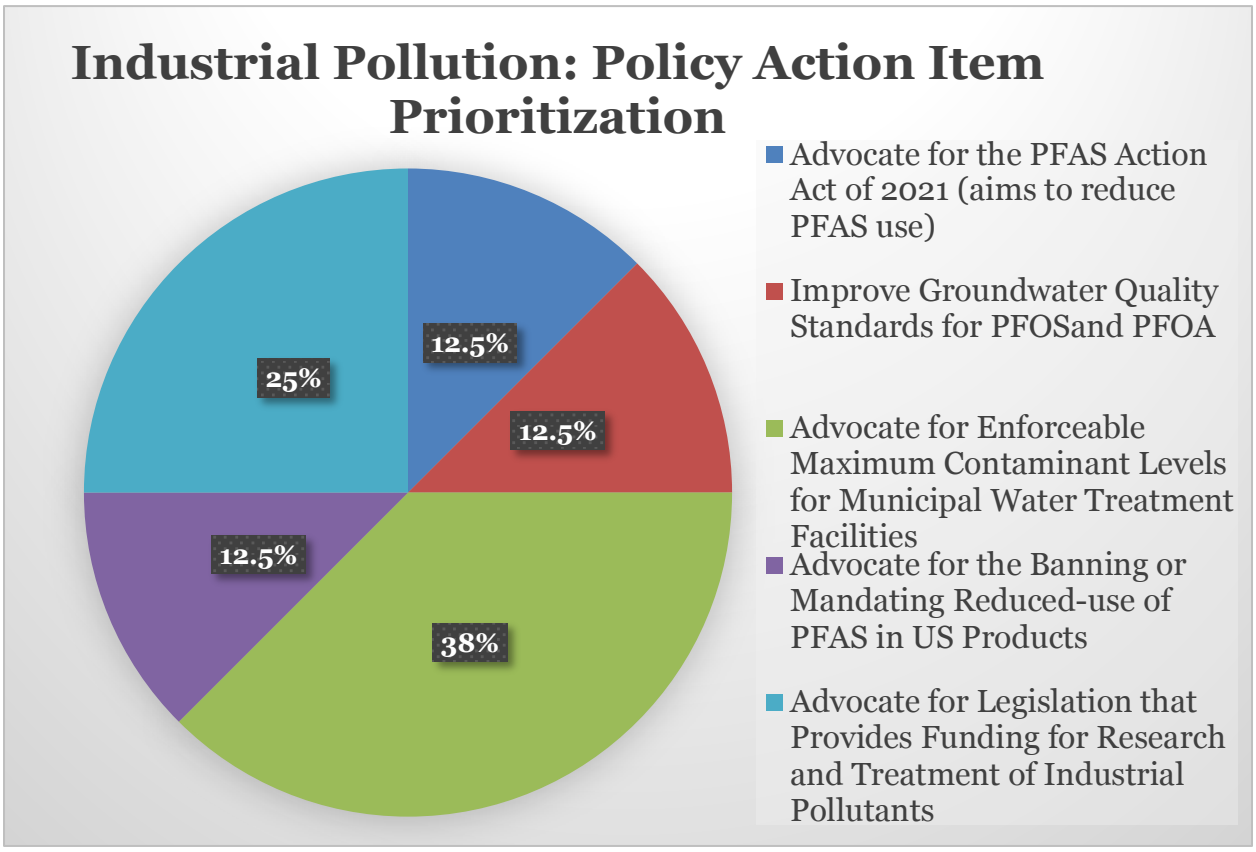


CHART 8: *Industrial Pollution Policy Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Advocating for policy that enforces the maximum contaminant levels for municipal water treatment facilities has been identified as the top priority in 2021-22.

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
PFAS Testing Network Research	• Evaluates risk of PFAS and effects on aquatic ecosystems • Monitors and reports findings, encouraging political action relative to water quality improvement	PFAST Network ncpfastnetwork@unc.edu
Emerging Contaminants in Drinking Water Sources	• Monitors PFAS levels in surface waters and groundwater • Treats water for industrial pollutants	Michael and Annie Falk Foundation's Laboratory at Duke University https://falk.exposomics.duke.edu/contact
Coal Ash Effects on Fisheries in Lake Sutton	• Protects fish populations from coal ash contamination and selenium poisoning • Restores water quality after coal ash contamination in Lake Sutton and the Cape Fear River	Wake Forest University Research

Endocrine Disrupting Chemicals Research	● Decreases DBP contamination ● Protects fish populations from development impairments and malformations	University of Illinois Research Project by Andressa Gonsioroski
Effects of Toxic Pollutants on Fish	● Improves our understanding of the effects of legacy and emerging contaminants on fish population ● Assists in determining strategies to protect fisheries from these pollutants	Researchers at UC-San Diego Aquatic Pollutants Report Environmental Protection Agency (Southeast Regional Office) 800.241.1754

One of the greatest research efforts regarding PFAS and their impacts on public health and aquatic ecosystems is led by the PFAS Testing Network (PFAST Network). A group of researchers including Lee Ferguson, Heather Stapleton, Detlef Knappe, and Avner Vengosh are studying emerging contaminants in North Carolina's drinking water (Duke Today, 2020). North Carolina is one of three states that has organized researchers to evaluate the risks and effects of PFAS on people and the environment. The PFAST Network's objective is to sample every public water source in North Carolina and research the following topics: modeling for well water risk, PFAS removal effectiveness testing, air emissions and atmospheric deposition, immunotoxicology effects, and exposure to North Carolina wildlife species (Cook, 2019).

The PFAST Network has noticed positive outcomes of the monitoring and reporting project. When the scientists identify high concentrations of PFAS in a water source, they contact community leaders, and the local government authorities are able to take the actions needed to change water sources or manage the problem. Also, the results from their evaluations are made public therefore local community members are made aware of the risks.

Similarly, the Michael and Annie Falk Foundation's Laboratory at Duke University has conducted studies on emerging pollutants in every public drinking water source in North Carolina. The goal of the research is to increase the understanding of PFAS chemicals in

groundwater and surface waters and assist in the creation of effective water treatment infrastructure (Duke University, 2021). The laboratory collaborates with Riverkeeper organizations to assess various watersheds.

Some studies have associated PFAS pollution with greater accumulation of chemicals in fish species. A study completed two years ago in South Carolina indicated that 83% of the research species of fish had greater levels of PFOS than the advisory levels set to protect animals (Kluck, et al., 2021).

Researchers have also completed studies focused on the effects of heavy metals on fish populations. Heavy metals are a common pollutant resulting from industrial and agricultural activities. A study conducted on bowfin in the Cape Fear River found that tissue analyses identified concentrations of arsenic, cadmium, mercury, selenium, and PCBs (Mallin, et al., 2011). The concentrations of mercury, selenium, and PCBs were greater than the levels defined as safe by the EPA for fish, their predators, and people (Mallin, et al., 2011). These chemicals present fish population health issues such as disease, reproductive decline, and loss of prey.

Coal ash residue research has been conducted to assess the impacts of the residue and resulting selenium concentrations on fisheries in Lake Sutton, a body of water managed as a public fishery just a few miles northwest of Wilmington. The lake was created as a cooling reservoir for Duke Energy's coal-fired electric generating plant (Lemly, 2014). Water from the Cape Fear River, used to cool steam condensers in the facility is then discharged into Lake Sutton to cool. Finally, the water is then returned to the river.

The lake was contaminated with selenium, causing fish developmental abnormalities and lack of reproductive success (Lemly, 2014). The chemical enters the water through the coal ash wastewater from the plant and bioaccumulates in the aquatic ecosystem. During this study of fish in Lake Sutton, Lepomis spp. showed abnormalities 28.9% of the time, a biological indicators of selenium poisoning (Lemly, 2014). In 2013, the LV. Sutton Steam Plant started transitioning from coal operations to natural gas. However, selenium continues to affect fish populations due to its prevalence in the lake sediments (Mallin, et al., 2011).

Finally, endocrine disrupting chemicals (including VOCs) have been researched by scientists due to the recent knowledge of their prevalence in North Carolina water bodies. Research on endocrine disrupting chemicals indicates that a large number of people are exposed to a specific class of chemicals, DBPs, due to the common use of disinfectant products for treating water (Gonsioroski, et al., 2020). A study focused on the effects of DBPs on zebrafish found that exposure leads to negative developmental effects, decreased tail lengths, and increased malformation rates. In humans, research shows DBPs disrupt ovarian function, reduce sperm viability, prevent healthy fetal development, and contribute to chromosomal abnormalities (Gonsioroski, et al., 2020). The researchers found similar effects on wildlife and humans resulting from PFAS exposure. Finally, BPAs used in resin coatings of canned foods, food storage containers, water bottles, and baby bottles act as endocrine disruptors as well (Gonsioroski, et al., 2020).

Persistent organic pollutants (POPs) are industrial and agricultural pollutants that have been discovered in fish populations across the globe (ScienceDaily, 2016). Studies have shown that POPs identified in fish have extremely variable concentrations, and the levels of these contaminants in individual organisms have decreased since the 1980s. Due to the decreased use of legacy chemicals such as DDT and mercury (ScienceDaily, 2016). Additionally, the EPA has been conducting fish tissue studies to analyze the concentration of these chemicals in fish populations.

The authors of the *Aquatic Pollutants Report* made similar findings and suggests that emerging chemicals will increase in the coming decades (Beeler, et al., 2021). The author found that chemicals persist in the environment for a long time and become more toxic. Due to bioaccumulation or the constant buildup of toxic chemicals within an organism and the food chain, fish continue to be exposed to pollutants for years. Therefore, industrial pollutants are considered to be a main source of fish populations' declines and pose risks to human health due to contaminated seafood consumption (Beeler, et al., 2021).

Recommended Future Actions:

Type of Research	Water Quality Impacts
Analysis of the Effects of All Heavy Metals on Aquatic Ecosystems	● Reduces heavy metal contamination ● Develops management strategies to protect aquatic ecosystems from industrial metals
Assessment of the Effectiveness of Filtration Methods	● Reduces water contamination from emerging contaminants, coal ash, and endocrine disrupting chemicals
PFAS Research Focused on Impacts on Biota	● Assists in understanding the implications of emerging contaminants on aquatic ecosystems and wildlife ● Monitors and supports fisheries conservation efforts

Researching Safe Alternatives to Industrial Pollutants	• Reduces water contamination and negative health effects on fish resulting from PFAS-containing products • Assists industries in a transition to safe alternatives to harmful chemicals

Though there has been research conducted focused on the effects of heavy metals on aquatic ecosystems, some elements have been studied more thoroughly than others. For example, there has been a significant amount of research that indicates that mercury is harmful, therefore there are more established advisories for this element (Mallin, et al., 2011). In the future, it will be beneficial to assess the impacts of other pollutants such as arsenic and cadmium on aquatic ecosystems. Then, regulatory action imposed on industrial activities may result from the scientific findings.

Additionally, analyzing the effectiveness of methods for treating water for coal ash, PFAS, and hazardous materials will greatly assist in developing support for the utilization of these methods. Currently, there are not a significant amount of widely accepted water filtration technologies that have the capacity to filter water sources. These assessments may encourage research into alternative filtration techniques.

Recently, PFAS has become a public concern leading to the allocation of financial resources to scientists studying the toxicity of these chemicals. However, experts still lack a complete understanding of how dangerous PFAS are to not only people, but aquatic ecosystems. The majority of published research focuses on the effects of PFAS on humans, but we lack information regarding their implications on fish populations. Moving forward, prioritizing the investigation of emerging contaminants on fish species and aquatic habitat will greatly assist in protecting the fisheries of the NC coast.

Finally, researching safe alternatives to products that contain emerging contaminants such as firefighting foams, water resistant materials, and non-stick coatings will significantly reduce industrial contamination in bodies of water internationally. Also, the findings may assist in gaining industrial support in the transition to materials that do not contain PFAS.

Industry Working Group Gap Analysis: Industrial Pollution Research Priorities

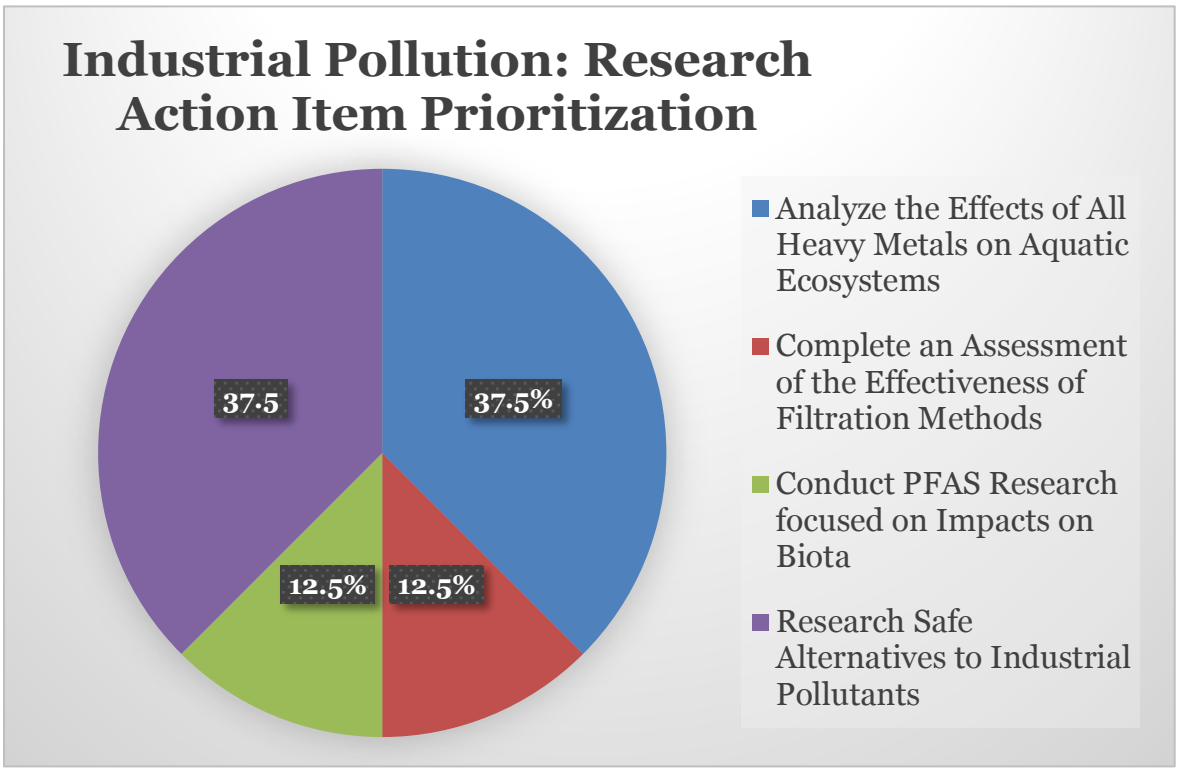


CHART 9: *Industrial Pollution Research Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Both analyzing the effects of all heavy metals on aquatic ecosystems and researching safe alternatives to industrial pollutants have been identified as the top priorities in 2021-22.

Advocacy, Outreach, and Education Assessment

Current Actions:

Type of Outreach/Advocacy	Water Quality Impacts	Lead Organization
NGOs Advocating for Communities and the Environment	• Brings attention to industrial pollution in NC • Influences political action and regulation of industrial facilities • Encourages industrial operations to cease discharge of chemicals into water resources	Clean Aire NC 704.307.9528 Cape Fear River Watch 910.762.5606 Southern Environmental Law Center 434.977.4090 Waterkeepers Carolina heather@soundrivers.org NC Conservation Network www.ncconservationnetwork.org Toxic Free NC www.toxicfreenc.org
Litigation against Polluting Industrial Facilities	• Reduces coal ash contamination in NC • Forces industries to eliminate PFAS use and pollution • Protects communities and aquatic ecosystems against health and environmental implications	Southern Environmental Law Center 434.977.4090 Cape Fear River Watch 910.762.5606 Haw River Assembly

The EPA's Toxics Release Inventory	• Increases public understanding of hazardous waste sites and impacts on health and the environment • Reduces habitat destruction and water contamination from Superfund sites	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

With the discovery of GenX in the Cape Fear River, public concern for and understanding of industrial contamination in eastern North Carolina's waterways has increased tremendously.

Environmental non-governmental organizations (NGOs) increase awareness by using their platforms and advocating for the public and wildlife. NGOs may also use litigation as a technique to address industrial pollution. The Southern Environmental Law Center (SELC) represented Cape Fear River Watch in the case against Chemours. Similarly, the SELC advocated for the communities affected by Duke Energy's coal ash spill in the Dan River.

The coal ash spill contaminated drinking water with a cancer-causing substance made of bromides. In 2020, the SELC reached an agreement with Duke that required them to remove the coal ash from the lagoon to dry, lined storage further from the river. Haw River Assembly was also represented by SELC reaching a settlement with the City of Greensboro and NC regulators to limit Greensboro's 1,4 dioxane discharge and require DEQ to investigate sources of 1,4-dioxane in the Cape Fear River Basin. (SELC, 2021).

Collaboration and coalition-building is important in bringing about noticeable changes regarding the regulation of pollutants. For example, the DEQ, Cape Fear River Watch, and the Southern Environmental Law Center are collaborating to take action against Chemours to mandate the business to remove PFAS from groundwater at the company's plant on the Cape Fear River.

The EPA assists in providing information to the public regarding hazardous releases of industrial operations through the development of the EPA's Toxics Release Inventory. The information is available by state, city, county, or Zip code. Additionally, Duke University shared maps and resources with the public in order to increase awareness of the impacts of Superfund sites and their proximity to a given community.

Recommended Future Actions:

Type of Outreach/Advocacy	Water Quality Impacts
Educating Consumers on PFAS-Containing Products	● Reduces the risk of PFAS entering bodies of water and affecting fisheries ● Decreases risks to public health ● Encourages companies to use alternative substances
Educational Information Regarding Filtration Systems	● Reduces contaminated discharge from entering nearby bodies of water ● Decreases risks to human health and the environment

Educating the public on their power as consumers will also raise awareness about the health and environmental impacts of chemicals such as PFAS on communities and aquatic ecosystems. Organizations can utilize the outreach techniques employed by groups such as Toxic Free Future, the Center for Environmental and Health Effects of PFAS, and the Superfund Center at UNC, to educate consumers on the typical products that contain PFAS such as nonstick pots, water resistant clothing items, cleaning products, and stain resistant coatings. sharing this information should greatly reduce the amount of PFAS chemicals made, used, and ultimately entering bodies of water while encouraging producers to adopt alternatives to PFAS. Already, some companies, such as IKEA and Crate and Barrel, have vowed to phase-out PFAS use in their products. There is an overall increase in demand for products that do not use hazardous chemicals in the manufacturing process (Kwiatkowski, et al., 2020).

Another important outreach initiative relating to the protection of public health from industrial contaminants includes encouraging the implementation of in-home filtration systems. Providing educational material on the advantages of these technologies could greatly increase participation. However, the cost of the systems makes them inaccessible to a large percentage of citizens. Therefore, lobbying the government to increase funding for these water supply treatment systems would greatly assist in protecting the health of low-income citizens or communities unable to install in-home filters..

Industry Working Group Gap Analysis: Industrial Pollution Outreach Priorities

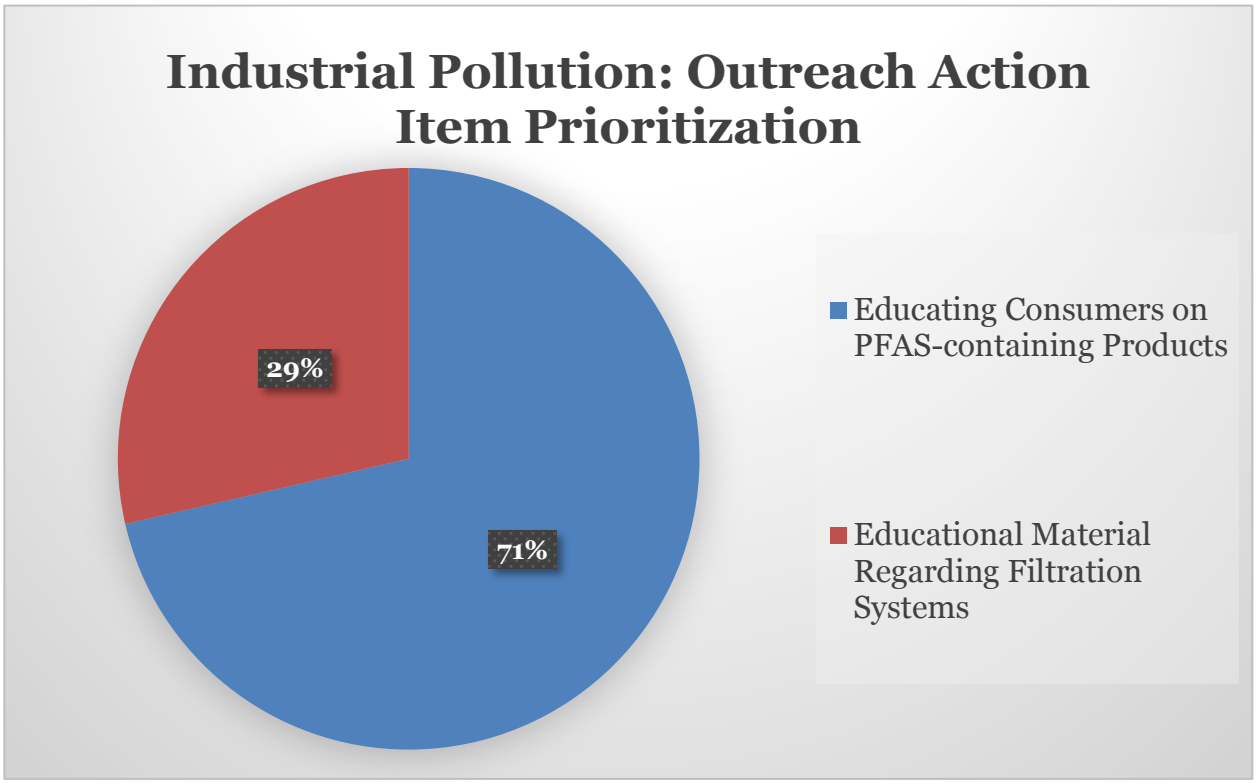


CHART 10: *Industrial Pollution Outreach Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Educating consumers on PFAS-containing products has been identified as the top priority in 2021-22.

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Industrial Pollution Assessment Revisions in 2022:

Adjusted all "Third Unregulated Contaminant Monitoring Rules" to Fifth Unregulated Contaminant Monitoring Rule to reflect most recent information. Included more info at Lee's suggestion.

Corrected sourcing of 1,4 dioxane. Corrected bioaccumulation. Expanded heavy metal info.

Included Sun et al. research at Lee's suggestion.

Added Haw River Assembly as a "lead organization" for Advocacy due to recent 1,4 dioxane settlement and involvement with PFAST Network.

Plastic Pollution

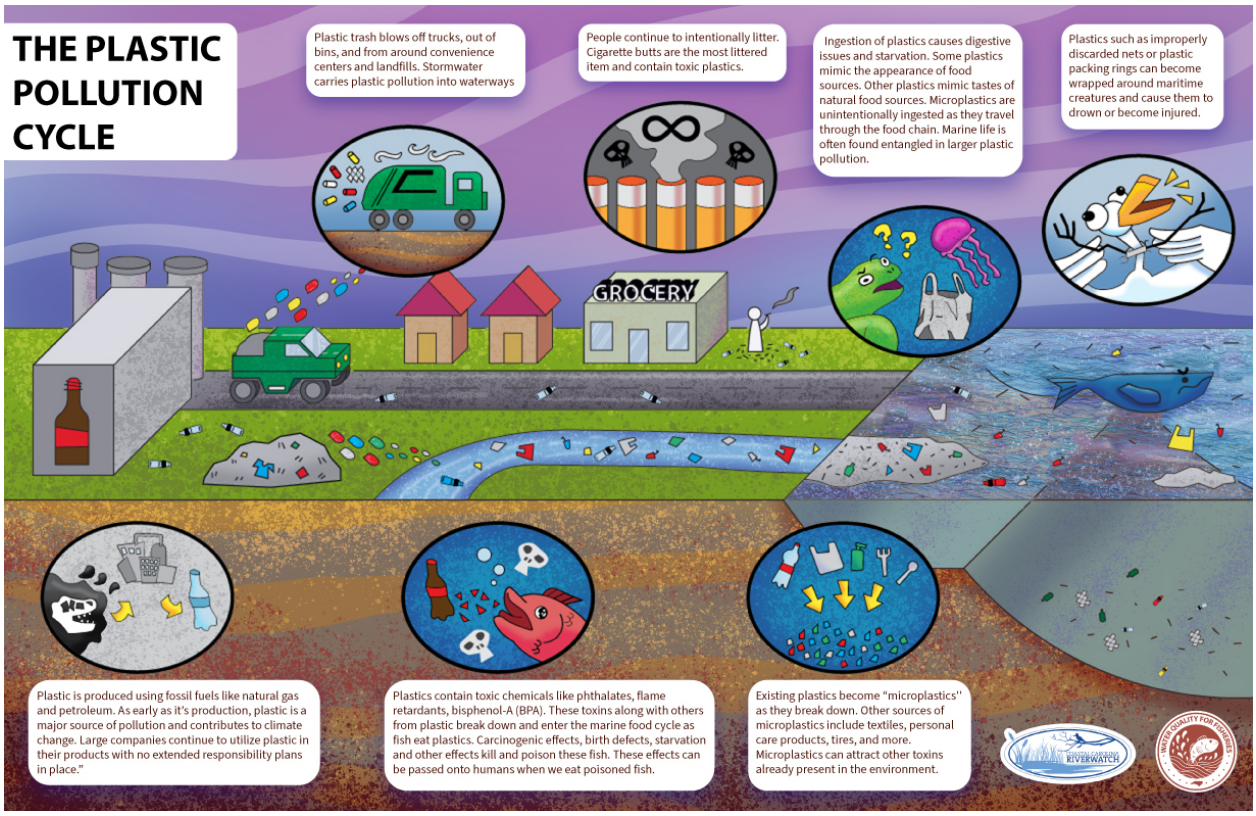

Image: Noah Weaver, *The Plastic Pollution Cycle*, 2021

Introduction

During the CCRW Water Quality for Fisheries Program initial survey, the coastal fisheries community identified plastic as one of the top five water quality impacts.

Plastic pollution has received a significant amount of media attention the last few years, but there is still a dire need to establish regulatory policies and implement effective infrastructure in order to mitigate the harmful impacts of plastics on aquatic ecosystems.

Each year, between 4.8 and 12.7 million tons of plastic ends up in the world's ocean (Michelson, 2021). Unfortunately, only 10% of plastics produced globally actually goes through the recycling process; the rest enters the environment, sits in landfills, or burns (Michelson, 2021). In fact, the United States incinerates six-fold more plastic than the amount recycled.

There are two main concerns with plastic pollution for aquatic life: entanglement and ingestion. In addition, plastics also harm wildlife due to their contribution to climate change because they are made from fossil fuel, petroleum. The plastics entering the oceans break down into smaller pieces (microplastics) that fish and birds then consume. Due to ingestion and entanglement, greater than 1,200 species are impacted by plastic pollution.

Effects of entanglement, on marine life, include injured or lost limbs or fins which impacts the individual's ability to swim, catch prey, and reproduce. Additionally, accidental ingestion of plastic is common among marine species and can affect the food chain when the prey has already ingested plastic. The consequences of ingesting plastic include throat and digestive blockages, gut damage, and malnutrition or starvation. Plastic consumption may also cause implications to marine life's nutrition, development, and immune system. Plastic products can contain harmful chemicals that are toxic when ingested.

Plastics are major contributors to municipal solid waste (MSW) with containers and packaging materials having the greatest plastic tonnage of 82.2 million tons (28.1% of total generation) according to the EPA (EPA's Containers and Packaging: Product-Specific Data, 2021). This classification of plastics includes bags, sacks, and wraps; polyethylene terephthalate (PET) bottles and jars; high-density polyethylene (HDPE) natural bottles; and other containers and packaging. Plastics can be found in durable products such as appliances, furniture, casings of batteries, and more. Some nondurable products include disposable diapers, trash bags, cups, utensils, medical devices, and shower curtains. Food containers are composed of clear or foamed polystyrene, trash bags are made of HDPE or low-density polyethylene (LDPE), and resins make up other nondurable goods.

In addition to the noticeable pieces of plastic waste we often see, microplastics are a common plastic pollutant entering bodies of water. Microplastics are tiny pieces of plastic that are used in pre-production plastic pellets, microbeads, and microfibers. These materials are used in cosmetics, microfibers from polyester, and production for larger plastic products, and they can absorb harmful pollutants and release them in the ocean like pesticides, dyes, and flame retardants (National Oceanic and Atmospheric Administration, US Department of Commerce, 2018). They also can be pieces of plastic that have broken down to less than 5 mm in diameter.

There are two main sources of plastics: land-based sources and ocean-based sources. National Oceanic and Atmospheric Administration's (NOAA) National Marine Debris Monitoring Program, completed a five-year national research project focused on monitoring debris at beaches. It was found that 49% of marine debris were identified as land-based source items, 18% were ocean-based source items, and 33% were shoreline debris and could be a result of land-based or ocean-based littering (NOAA's Administration's Programmatic Environmental Assessment, 2013).

A large proportion of plastics reach coastal waters through stormwater drains, creeks, or identified as coming from bridges, beach tourism, and recreational boating. Microplastic pollution in coastal waters is a result of runoff carrying material and the breakdown of meso- and macroplastics in the water.

Plastics are easily degradable in water due to photodegradation, thermooxidative degradation, slow oxidative breakdown, thermal degradation, and hydrolysis (Andrady, 2011). Pollution increases with the occurrence of natural events such as storm surges,

hurricanes, flooding, and high winds (NOAA's Programmatic Environmental Assessment, 2013).

Plastics can increase toxicity in water and marine life as the result of leaching of additives. During the degradation of plastics, specifically burning, harmful toxins such as styrene and other aromatics can be generated.

Microplastics absorb toxins to their surfaces which allows for biomagnification of harmful chemicals in the marine environment (Andrady, 2011). For example, toxic persistent organic pollutants (POPs) present in the ocean are absorbed and concentrated in microplastics making them bioavailable to individuals who consume the filaments.
Plastics act as a means of transport for toxic chemicals and plastics generally contain their own hazardous chemicals added during manufacturing (Campanale, 2020). Plastic molecules are able to take up toxic molecules from the environment and release them in animals after being ingested.

Plastics are able to remove iron molecules from an organism and replace it with lead. Also, plastics such as polystyrene and polyvinylchloride contain polymers such as plasticizers which are some of the greatest water polluters.

Plastic is found everywhere, including fences, house siding, and rugs and when these products are exposed to rain, these dangerous molecules are washed into nearby bodies of water.

Plastics are sources of endocrine-disrupting chemicals found in aquatic and marine ecosystems. They can cause severe reproductive issues in female and male organisms such as infertility and feminizing male fish (Harvey, 2019).
Plastics can take up harmful chemicals such as synthetic hormones found in birth control pills and cause sex morphism in male fish (Harvey, 2019).

Infrastructure Assessment

Current Actions:

Type of Infrastructure	Water Quality Impacts	Lead Organization
Plastic Waste Management: Composting, Recycling, and Combustion with Energy Recovery	• Reduces plastic pollution from disposal sites • Decreases greenhouse emissions • Limits risk of chemicals affecting fish population	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Pyrolysis	• Contains plastic waste, decreases the risk of it entering bodies of water • Produces energy	Recycle for Change 510.932.3839
Biodegradable and Compostable Plastic	• Increases rate of degradation, limiting the quantity leaving facilities and entering bodies of water • Decreases release of toxic chemicals into the environment	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

Sampling Technologies for Macroplastics: Visible Counts and Remote Sensing	• Determines levels of plastic pollution and identifies areas of concern • Locates sources of plastic pollution	Cooperation of Research Infrastructures (COOP+) Various Research Institutions
Installation of plastic collection devices in rivers (NC).	• Removes large sources of plastic pollution. • Collects data on plastic accumulation in a specific water body.	Coastal Carolina Riverwatch - New River/Jacksonville, NC Waterkeepers Carolina - Statewide

Current practices utilized to manage plastic waste include incineration, landfill use, recycling, composting, and combustion with energy recovery. The EPA is responsible for assessing the effectiveness of these processes. They found that there were 35.7 million tons of plastic produced in 2018 and 12.2% of MSW generated was plastics (Environmental Protection Agency, 2021).

The American Chemistry Council along with the National Association for PET Container Resources provides data regarding the recycling of plastic. They found that 8.7% of plastics in the US were recycled in 2018. However, 29.1% of PET bottles and jars and 29.3% of HDPE natural bottles were recycled that year. Over 15% of plastics were incinerated with energy recovery and over 75% of plastics were landfilled (Environmental Protection Agency, 2021).

Companies and industries are developing innovative ways to handle plastic waste through new infrastructure. Dow Chemical Company works with other organizations to develop the "Recycle for Change" project. The program is made up of experts that assist communities in developing a model for cooperatives. One technology utilized by Dow and its partners includes pyrolysis which allows plastics that are generally difficult to recycle to be used as fuel (Parletta, 2019).

As an attempt to reduce plastic pollution, industries have developed biodegradable and compostable plastics that microorganisms can degrade. This assists with preventing future waste, but there is an urgent need to address the plastic waste already present in the environment. The current methods of waste management are destructive to the

environment including the incineration of plastic which emits toxic chemicals into the atmosphere. Similarly, the use of landfills releases greenhouse gases and leaches contaminants into the environment. Present recycling methods are significantly inadequate as we have seen in the United States with only 9% of all recyclable plastics being recycled (Sheth, et al., 2019).

Scientists use cage-like structures to capture macroplastics in bodies of water, visual counts, and remote sensing to define an amount of visible plastics (Conchubhair, et al., 2019).

Measuring the quantity of microplastics is more difficult. A common sampling process includes the collection of water samples from the field, filtration, separation, and finally quantification in a lab setting (NOAA, 2016).

"Improving Human and Ecosystem Health through Microplastic Reduction" is a two-year (2020-2022) microplasic program by Waterkeepers Carolina. 15 Waterkeepers in various geographic regions across North Carolina will collect regular surface water samples to be analyzed for microplastic content by partners at Plastic Ocean Project. This data will help to characterize statewide microplastic pollution in NC. A second component of this program is the installation of trash collecting devices in each of the water bodies being studied. These devices will be monitored and emptied by Waterkeepers. Trash will be categorized and recorded using survey materials prepared by Duke Policy and Law Clinic. The results from the microplastic analysis and the trash surveys will be utilized to inform decision makers, researchers, and the public of needs for future policies, advocacy, and further study on plastic reduction. Coastal Carolina Riverwatch is partnering with the City of Jacksonville, NC to install a litter collection device in Sandy Branch Run, a tributary of the New River. Local education and advocacy efforts will be expanded through this partnership.

Recommended Future Actions:

Type of Infrastructure	Water Quality Impacts
Restructuring Manufacturing Process of Plastics: Changing Chemical Composition and Product Design	• Decreases excess plastic production and contamination • Increases chemical stability of plastics and reduces toxin levels • Reduces marine life entanglement and ingestion of plastics
Microplastic Filtration Technologies	• Decreases microplastic contamination • Reduces toxic impacts on aquatic life
Updated Wastewater Treatment and Waste Management Infrastructure	• Filters microplastics from wastewater • Reduces the amount of plastics exiting waste facilities and entering the environment
Bioengineering Technologies: Plastic-Degrading Organisms	• Degrades plastics and reduces the amount of plastics entering bodies of water • Decreases leaching of chemicals into the environment
Improving Plastic Disposal Bins (Recycling Bins)	• Increases amount of plastic recycled • Decreases plastic pollution resulting from litter
Develop Marine-based Research Infrastructures (RIs)	• Allows for microplastic contamination assessment and identification of problem areas

Addressing the over-production of plastic is an essential step in reducing the pollution of coastal waters. A key point is the need to eliminate, substitute, or improve what is necessary to be plastic.

Some ways to combat the excessive manufacturing of plastic includes restructuring plastic chemistry, product design, recycling techniques, and consumer habits (Parker, 2018). Changing the toxic chemical makeup of plastics will allow for safer chemical composition of materials and reduce the amount of dangerous waste entering landfills and the environment. Developing alternatives to plastic is necessary to eliminate plastic pollution because plastic can only be recycled once, meaning it eventually ends up in a landfill or the environment.

Microplastics easily enter bodies of water due to their prevalence in a significant amount of products as well as their small size. Due to the lack of technology available to filter microplastics from wastewater, hundreds of thousands of clothing fibers are released in one load of laundry (Hallas, et al., 2018). Strategies to reduce the amount of microplastics leaving individual homes include the installation of laundry and sink filters and the overall improvement of wastewater treatment plants.

In the future, there is a need for updated wastewater treatment infrastructure that has the ability to filter out the microplastics currently polluting waters worldwide. Urgent development of successful waste collection, management, and recycling processes proves to be necessary in order to prevent plastic disposal into the environment.
Improving waste management technologies and avoiding incineration as a means to get rid of waste will greatly aid in reducing the amount of toxins entering the environment (Gallo, et al., 2018).

In order to increase the amount of material recycled requires an improvement of the sorting process for plastic waste. Currently, there are many difficulties associated with sorting out the various types of plastics received by facilities and removing materials that are contaminated by non-recyclable waste.

Research is currently underway to identify other means to break down plastic waste without harming the environment. Recently, an investigation of fungi and bacteria that have enzymes with the ability to degrade the polymers in plastic waste has been initiated. However, scientists have only found a few populations of these species in India and Japan. Therefore, we need more research to locate potential plastic-degrading organisms and develop the infrastructure to utilize these species. This method and other bioengineering technologies as a plastic waste reduction strategy could greatly reduce the harmful impacts of microplastics and macroplastics on aquatic ecosystems.

In order to reduce plastic litter and encourage plastic disposal and recycling in public places at the coast, municipalities should provide appropriate and adequate waste disposal and recycle bins with proper labeling, lids that eliminate wind-blown litter, and consistent collection services to prevent overflow. Furthermore, local governments should support public outreach efforts that encourage pack-in, pack-out programs, waste reduction alternatives, and economic impacts of litter at the coast. (Rider, 2021)

One technology utilized in many European research institutions, marine-based Research Infrastructure (RI), assesses different environmental factors, but they do not evaluate

plastics in the water column (Conchubhair, et al., 2019). Scientists have been researching technologies that can be utilized to assess plastic levels.

Researchers can use remote sensing to evaluate the amount of plastics in water, but they do not have the technology to assess microplastics on site due to their small size (Conchubhair, et al., 2019). Moving forward, developing a technology to precisely evaluate microplastic contamination in water samples is essential.

Industry Working Group Gap Analysis: Plastic Pollution Infrastructure Priorities

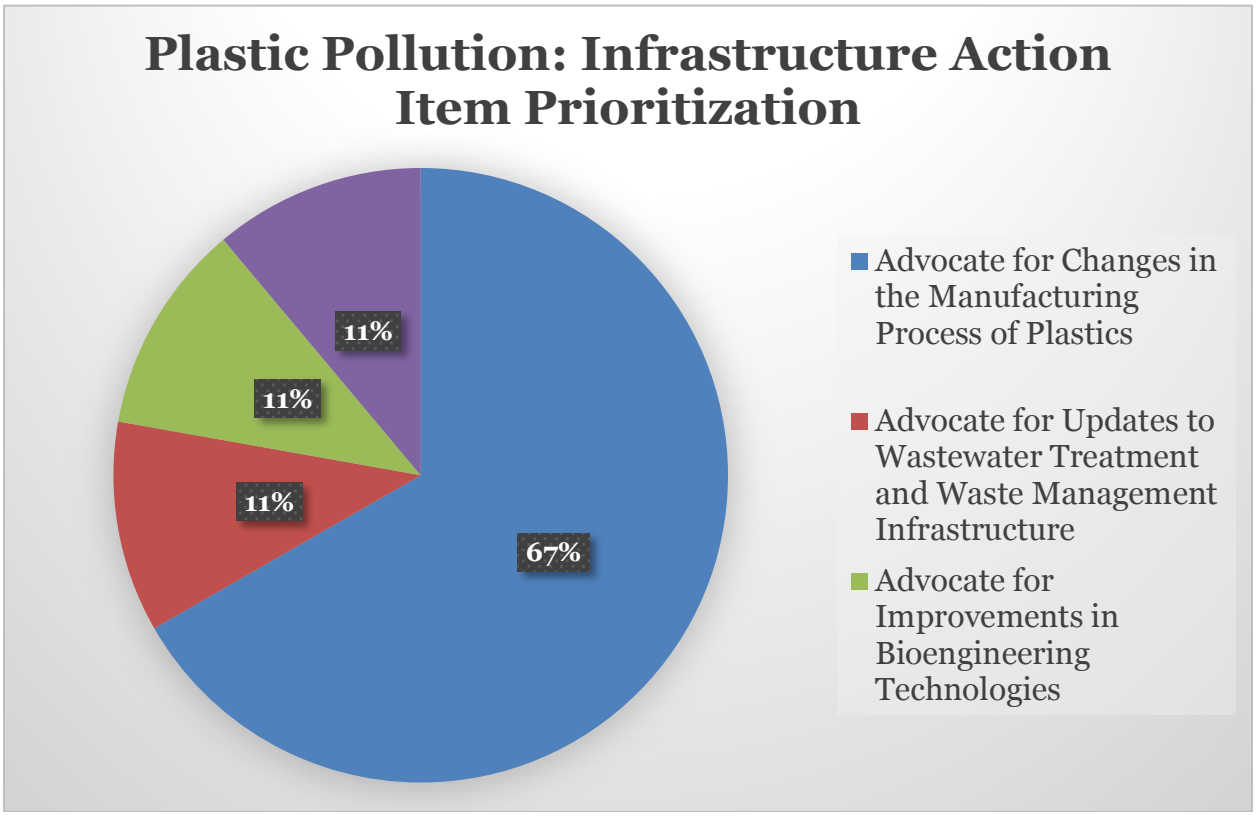

CHART 11: *Plastic Pollution Infrastructure Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Advocating for changes in the manufacturing process of plastics that prevent plastic pollution has been identified as the top priority in 2021-22.

Policy and Enforcement Assessment

Current Actions:

Type of Policy	Water Quality Impacts	Lead Organization
The UNEA Resolutions	• Addresses marine litter, microplastic, and waste management issues • Reduces plastic consumption and pollution	United Nations Environment Assembly
Marine Debris Research, Prevention, and Reduction Act	• Identifies sources of marine debris and reduces contributions to plastic pollution • Protects marine habitat	National Oceanic and Atmospheric Administration (Marine Debris Program) marinedebris.web@noaa.gov
Microbead-Free Waters Act	• Reduces micro-bead contamination in aquatic ecosystems	US Food and Drug Administration 888.INFO.FDA (1-888.463.6332)

Act to Prevent Pollution from Ships	• Limits ship emissions and pollution of marine waters	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
North Carolina Littering Policies	• Reduce debris from entering coastal waters • Monitor plastic pollution	North Carolina Division of Marine Fisheries 877.623.6748
NC Managing Environmental Waste Act of 2021	• Decreases plastic waste from food packaging • Reduces plastic pollution from facilities	Agriculture and Natural and Economic Resources Committee 919.715.3021

Some global policies that establish plastic pollution regulation include the international UNEA Resolutions used to address marine litter, microplastics, and waste management; the G20 countries', which includes the United States, implementation of actions to reduce marine plastic litter; and the Basel Convention's legislative objectives to address plastic waste (Plastics Policy Inventory, 2020). Additionally, the Convention on Migratory Species has developed resolutions to address environmental issues associated with marine debris.

There are policies developed to decrease plastic debris. For example, the Marine Debris Research, Prevention, and Reduction Act aims to identify sources of debris, and assess, reduce, and prevent marine debris from negatively affecting the marine environment (Hallas, et al., 2018). The act is not specific to plastic pollution, but includes these materials in the reduction efforts.

The International Fisheries Regulations, aims to regulate fisheries management within and outside of US jurisdictions; the Microbead-Free Waters Act, prohibits the production, packaging, and distribution of rinse-off cosmetics that contain plastic microbeads; and the Act to Prevent Pollution from Ships (Plastics Policy Inventory, 2020). This act includes an international treaty that is enforced by the EPA with severe penalties for ships that do not comply.

The State of North Carolina has implemented policies in order to manage the release of debris into bodies of water. For example, there are laws stating that a watercraft or vehicle must have appropriately secured any load they are carrying (NC General Statute 14-399). The North Carolina Division of Marine Fisheries and Wildlife Resources Commission are responsible for regulating littering policies on the waterways.

In 2009, the North Carolina General Assembly banned plastic bags on the Outer Banks which mandated establishments replace disposable plastics with paper bags. Unfortunately, in 2017 the bill was repealed and some stores resorted to plastic bag usage.

In April of 2021, the NC House passed the NC Managing Environmental Waste Act of 2021 which aims to address plastic waste issues by increasing city and county funding for plastic reduction programs, developing a pilot program to reduce plastic waste at food service facilities ran by the state, and mandates the Agriculture and Natural and Economic Resources Committee to research plastic pollution (National Caucus of Environmental Legislators, 2021). At the time of this publication, the bill was still being reviewed by the NC Senate. In May of 2021, a bill enacting a ban on single-use and non-recyclable products was proposed in the North Carolina General Assembly. There have not been any votes or advancements with the potential legislation (National Caucus of Environmental Legislators, 2021).

There has, however, been progress in managing litter in coastal waters. At the national level, NOAA has developed a Marine Debris Program under the Marine Debris Act that funds marine debris management and research across the country. Another contributor to plastic pollution in the oceans and coastal rivers includes derelict fishing materials including monofilament fishing line, plastic mesh, ropes, and bags from shellfish farms.

Funding from NOAA and the North Carolina Sea Grant has been provided to implement the North Carolina Coastal Federation's Lost Fishing Gear Recovery Project. Fishermen are funded to recover derelict crab pots and fishing gear (Hallas, et al., 2018).

Recommended Future Actions:

Type of Policy	Water Quality Impacts
Plastic Bag, Styrofoam, Single-Use Plastic, and Straw Bans	• Eliminates plastic contamination from these sources • Protects fish populations and habitat
Plastic Bag Tax	• Reduces plastic bag usage and pollution • Decreases risk of entanglement, ingestion, and poisoning for aquatic life
Extended Producer Responsibility Policies	• Increases recycling and composting of plastic products, reducing the amount of plastic entering water systems • Decreases implications of plastic pollution on fisheries
Implementation of a State-Wide Plastic Pollution Program	• Encourages collaboration among municipalities, greatly reducing plastic pollution and consumption • Holds polluters responsible • Establishes water quality standards for plastic pollutants
Government Funded Debris Clean-Up Initiatives	• Improves beach and river conditions through clean-ups • Protects aquatic habitat and populations
International Treaty Setting Measurable Plastic Reduction Targets	• Holds countries accountable for plastic pollution • Reduces plastic pollution in the oceans and protect marine life
Microplastic Regulatory Policy	• Decreases microplastic pollution in the nation's bodies of waters

	• Protects aquatic life from entanglement, ingestion, and poisoning due to plastic pollution

Several states have passed legislation to assist in regulating plastic production, consumption, and disposal. Currently, 12 states have passed legislation that reduces single-use plastic production and 10 states have legislation in progress (Environment America, 2019). However, North Carolina has not passed more stringent plastic regulations. There are several policy options currently being utilized that could assist in decreasing plastic pollution and increasing recycling practices. For example, bans on plastic bags, polystyrene (expanded and rigid), single-use plastic, and straws are already being implemented by some US states (National Caucus of Environmental Legislators, 2021). The City of Roanoke, Virginia passed a 5-cent tax on plastic bags that allocates the revenue to environmental efforts, waste reduction programs, pollution mitigation initiatives, and SNAP recipients (Mahoney, 2021).

Extended producer responsibility policies require producers to make single-use products recyclable or compostable. State commissions and councils can assist in completing research and defining the severity of plastic pollutants in the environment, create management recommendations, and develop policy to address these issues (National Caucus of Environmental Legislators, 2021). Another common way states have attempted to reduce plastic consumption is passing legislation that supports the use of reusable bottles in business establishments and installing beverage container deposit systems (or refill stations).

One limitation to the management of marine debris on the coast includes the lack of collaboration between municipalities (Hallas, et al., 2018). One way to remedy this problem would be to implement coordination by the state as a whole. Having a state-wide plastic pollution reduction program could assist in reducing the contamination.
Another option in place of developing a new pollution-control program for plastics is to incorporate plastic reduction efforts into existing policies and programs such as the Stormwater Program.

These exiting programs could take on plastic and debris pollution, identify sources, and hold polluters accountable. The NCDEQ could increase the enforcement of littering laws and develop water quality standards for plastic pollutants. Additionally, it is important for the EPA to establish criteria for plastic pollution levels in order for states to enforce these programs.

Increasing government funding for coastal cleanups could greatly assist in reducing the amount of plastics carried by runoff to the estuaries and ocean. The Department of Transportation allocates millions of dollars per year to fund litter pickup and cleanup work.

However, even $19 million spent for trash pickup does not provide enough funding to clean 40% of primary roads and 90% of secondary roads in the state (Hallas, et al., 2018). Establishing a binding, international treaty that sets specific and measurable targets for plastic reduction efforts could greatly assist in reducing plastic pollution in the ocean. Due to plastics' ability to float and travel long distances easily, it is important to address contamination sources globally to reduce marine plastic.

Finally, creating policies that aim to regulate microplastic production and pollution is essential in protecting aquatic life. With microplastics being a relatively recent area of study, there has not been political action relative to its management in marine and freshwaters. As scientists' research confirms the significant harmful effects of microplastics on marine mammals and fish, the next step would be to establish standards and criteria for microplastics.

Industry Working Group Gap Analysis: Plastic Pollution Policy Priorities

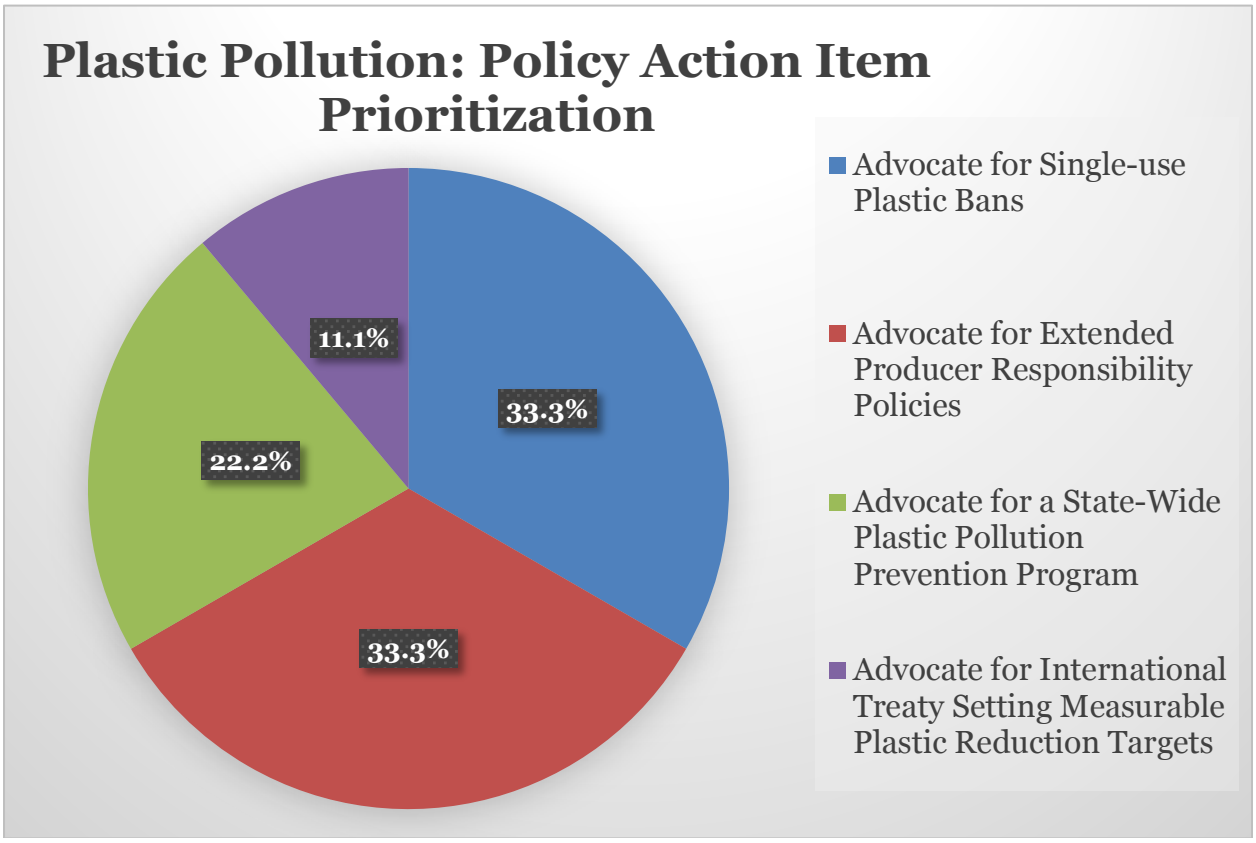

CHART 12: *Plastic Pollution Policy Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Both advocating for single-use plastic-bans and extended producer responsibility have been identified as the top priority in 2021-22.

Research Assessment

Current Actions:

Type of Research	Water Quality Impacts	Lead Organization
First Global Analysis of Plastic Pollution	• Quantifies the amount of plastic in the ocean • Identifies greatest sources of pollution, assisting in the mitigation of their contamination	
Assessment of Plastic Pollution Levels in North Carolina	• Provides data that can be utilized in the development of regulatory actions • Reduces plastic pollution from identified sources	North Carolina Marine Debris Symposium LisaR@coastalcarolinariverwatch.org National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program sarah.latshaw@noaa.gov North Carolina Coastal Federation 252.393.8185 Duke University (Plastic Pollution Working Group) plastics@duke.edu

Research on the Impacts of Plastic Ingestion on Aquatic Life	• Determines the extent of effects of plastic ingestion on aquatic life and methods to mitigate the occurrence • Provides estimates for percentage of aquatic life ingesting plastics	North Carolina Marine Mammal Stranding Network https://www.marinemammalsnccnc.com/information-and-resources.html Duke University Marine Laboratory 252.504.7503
Evaluation of Toxicity of Plastics and Related Impacts	• Limits the amount of toxic chemicals leaching into the environment • Provides information about the implications of chemicals on aquatic life	Duke University: Various Scientists Plastic Ocean Project Bonnie@plasticoceanproject.org
Studies Focused on Heavy Metal Contamination	• Provides data regarding the utilization of heavy metals in plastics and their effects on aquatic species	Environmental Protection Agency (Southeast Regional Office) 800.241.1754
Analyzing Plastics' Impacts on Local Water Temperatures	• Assesses the extent of influence plastic has on coastal waters • Analyzes the impacts of warmer temperatures on aquatic life	University of Tasmania's Institute for Marine and Antarctic Studies

Studies on the Trophic Transfer of Plastics and Long-Term Effects on Aquatic Species	• Increases our understanding of the transfer of plastic toxins from prey to predator • Develops knowledge base to assist in protecting fish species	Bonnie Monteleone, Plastic Ocean Project bonnie@plasticoceanproject.org
Generating Estimates of Plastic Loadings in Water Bodies across North Carolina	• Establishes linkages between the presence of macroplastics and levels of microplastics • Creates a sampling protocol for plastics • Protects rivers feeding into estuaries from plastic pollution	Dr. Barbara Doll at North Carolina University bdoll@ncsu.edu Waterkeepers Carolina - Several Participating Waterkeeper Organizations in North Carolina Heather@soundrivers.org

The first global analysis of all the plastics in existence was conducted to assess production and consumption levels. The researchers found that 8.3 billion metric tons have been produced with 6.3 billion tons consisting of plastic waste and only 9% of the waste being recycled (Parker, 2018). The United States shares the same value of 9% for the amount of plastic recycled each year. Furthermore, the study estimated that 8 million metric tons of plastic are produced each year (Parker, 2018). They also discovered that plastic packaging makes up greater than 40% of non-fiber plastics, meaning it is the greatest contributor to non-fiber plastic pollution (Parker, 2018).

The North Carolina Coastal Federation and experts from the NC Marine Debris Symposium network (including Coastal Carolina Riverwatch, Duke University, NC Sea Grant, National Estuarine Research Reserve, and state and local government agencies) completed an assessment of marine debris, including plastic pollution, to provide information that will be utilized in future policy development. The data was sourced from the Ocean Conservancy's International Coastal Cleanup data and the Marine Debris Tracker App. They found that consumer plastics are the greatest source of debris in the state (Hallas, et al., 2018). Additionally, fishing gear, abandoned vessels, and infrastructure remains broken by storms were identified in the state's coastal waters, all of which further damage habitat and impact fish populations.

According to the National Oceanic and Atmospheric Administration (NOAA), marine debris is considered to be any "persistent manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment" (National Oceanic and

Atmospheric Marine Debris Program, 2014). Researchers have identified the main contributors to marine debris as retailers, the agricultural sector, shellfish mariculture, fisheries industry, commercial transporters, recreational boaters, coastal municipalities, tourists, and emergency rescue operations (Newman, et al., 2015).

Research has also been conducted to assist in understanding the impacts of plastic ingestion on marine life. The North Carolina Marine Mammal Stranding Network (NCMMSN) and the North Carolina Sea Turtle Stranding Network conduct necropsies which assist in determining if plastic ingestion was the cause of death for the individual and create a database of every studied stranded marine organism (NCMMSN of the North Carolina Central Coast, n.d.).

The Duke University Marine Laboratory in Beaufort, North Carolina researches the effects of plastic ingestion on marine life as well. Additionally, when studies assess the amount of plastic ingested by specific fish species, and they have found resin pellets in 33-63% of individuals sampled (Miranda, Carvalho-Souza, 2016).

The Nicholas Institute for Environmental Policy Solutions at Duke University has developed a Plastic Pollution Working Group in order to promote collaboration among students and faculty. They aim to share their research with the goal of identifying solutions to the issues presented by plastic pollution. The interdisciplinary group includes professionals in engineering, chemistry, policy, corporate strategy and entrepreneurship, environmental toxicology, marine conservation, and emerging technologies and bioinformatics.

Researchers from Duke University found that sea anemones tend to consume available polyethylene due to the “tastiness” of additives found in plastics. After feeding the anemones pellets of polyethylene, they found that the concentration of most elements was similar to the control group, but the lead concentrations were significantly greater for the experimental group (Diana, 2020).

Microplastics' ability to carry microorganisms and contaminants when ingested has been named the Trojan Horse effect. One group of scientists at Duke University studied if the effect would impact the toxicity of nano plastics and evaluated whether it had an effect on the biodistribution of the contaminants (Trevisan, et al., 2020). Finally, they investigated whether the effect influenced the mitochondrial toxicity of nano plastics. They dosed zebrafish embryos with nano plastics and found they did cause changes in embryonic and larval development. However, they did find nano plastic particles have varying negative effects on mitochondrial energy metabolism. This study found that early development zebrafish experienced high percentages of pericardial edemas (98%) and curved tails (34%).

The two main concerns with microplastic pollution are the physical and chemical impacts on organisms. One study completed by the Water Research Institute in Italy published significant findings relative to the chemical effects of plastic pollution on aquatic life. Microplastics obtain toxic chemicals by absorbing them from the environment or containing additives like monomers or oligomers from manufacturing (Campanale, et al,.

2020). The additives are used to increase the plastic products' resistance to temperature, mold, bacteria, fire, and electricity (Campanale, et al., 2020).

Many of these toxic chemicals such as BPA, phthalates, and brominated flame retardants are classified as endocrine disruptors. These chemicals impact the development of the endocrine system and the functioning of organs that are responsive to hormonal signals (Campanale, et al., 2020). They can be linked to hormonal cancers, reproductive problems, metabolic disorders, asthma, and impaired neurological development. One study published in Environmental Health Perspectives placed broken up pieces of plastic products in saltwater or alcohol and found that over 70% of the products released chemicals similar to estrogen (Hamilton, 2011). Scientists have found links to certain plastic chemicals such as BPA to cancer, diabetes, heart disease, and other illnesses.

Additionally, heavy metals including antimony oxide, aluminum oxide, and zinc borate are used in polymer products such as flame retardants, fillers, and stabilizers (Campanale, et al., 2020). Zinc, lead, chromium, and cadmium are utilized as colorants. The EPA has identified some of these heavy metals as "known" or "probable" human carcinogens. High levels of heavy metals can cause cellular and tissue damage, mimic estrogen activation, and breast cancer (Campanale, et al., 2020). With plastics acting as vectors for the heavy metals and entering bodies of water at a rapid rate, aquatic organisms are exposed to these harmful substances.

Not only does plastic pollution poison and trap marine life, researchers have found that plastic causes increased water temperatures. The accumulation of material on the surface develops an insulation layer that can lead to an unsuitable environment for wildlife (Rosane, 2021). Researchers from the University of Tasmania's Institute for Marine and Antarctic Studies (IMAS) studied two remote islands' beaches, Henderson Island and the Cocos Islands. They discovered a large quantity of debris on the islands and determined that the plastic elevated daily maximum water temperatures by 2.45 degrees Celsius and decreased daily minimum temperatures by 1.5 degrees Celsius (Rosane, 2021). Ectotherms such as crab and sea turtles are especially vulnerable to the fluctuations in water temperatures because they rely on external temperatures to regulate their body temperature (Rosane, 2021). Ad indirect observation noted in this study was that plastic is often mistaken for shells by hermit crabs causing deaths by the hundred and even thousands on the two islands.

One specific study completed with larval and juvenile Black Sea Bass discovered that there was trophic transfer from the microzooplankton exposed to microplastics when they were consumed by the Black Sea Bass. The scientists also found that the immune response of the fish decreased with an increased concentration of microplastics in the organisms (Steinbarger, et al., 2021). The larval fish did not prefer the non-exposed microzooplankton over the microzooplankton containing microplastics (B. Monteleone, personal communication, July 27, 2021).

Similarly, some of the same researchers in the Black Sea Bass study found that trophic transfer of microplastics can be documented in larval inland silversides who eat microzooplankton. They noted significantly lower weight values of larvae exposed to

microplastics in comparison to the unexposed organisms after 16 days (Athey, et al., 2020). Also, they found individuals were more susceptible to predation when exposed to DDT, a contaminant associated with microplastics, because the chemical affects locomotion and predator escape response (Athey, et al., 2020).

Finally, researchers at North Carolina State University, including Dr. Barbara Doll, are generating estimates of loadings of macroplastics and microplastics coming from rivers and entering sounds. Studies are focused on linkages between trash and the amount of microplastics found at a given site. The most common items contributing to microplastic pollution in the Neuse River Basin are polystyrene foam, plastic bottles, plastic bags, plastic films (polystyrene) (B. Doll, personal communication, July 9, 2021).

Recommended Future Actions:

Type of Research	Water Quality Impacts
Green Chemistry Research	• Protects aquatic ecosystem from harmful effects of toxins found in plastics • Reduces plastic pollution
Studies Focused on the Interactions of Molecules in the Environment and the Physiological Effects on Fish	• Defines the implications of chemicals on wildlife, fish, and flora • Assists in creating regulations and criteria levels for chemicals • Protects aquatic populations from toxins and plastics
Developing Technologies to Identify Plastics in Aquatic Organisms	• Increases our understanding of how prevalent plastics are inside aquatic organisms • Improves technologies and necropsy techniques to identify causes of death in organisms due to plastics, therefore preventing other deaths
Research Focused on Identifying Endocrine-Disrupting Chemicals	• Develops a greater scientific understanding of chemicals interactions with fisheries • Assists in identifying specific chemicals that are endocrine-disrupting in order to create regulations

Overall, plastics research, particularly its effects on the environment, is fairly new and limited. Dedicating more time and resources to green chemistry research could assist in the development of alternatives to plastic products. It is essential to study the lifecycle of new biodegradable polymers and their impacts on marine organisms (Gallo, et al., 2018). Evaluating the chemical makeup of products before they are widely produced will prevent the over-production of toxic materials that tend to end up in landfills and the environment.

While scientists have begun to study the interactions of molecules found in plastics with the environment, there is still a significant lack in understanding of the extent of plastic molecules leaching into water. In the future, discovering the quantity of molecules entering aquatic ecosystems when plastics pollute the environment will assist in developing regulations and criteria for chemical levels. Specific elements such as mercury and silicone have been investigated, but broadening the research will greatly contribute to plastics research.

Research published in the journal, Environmental Sciences Europe found an association between the exposure of microplastics to negative effects on marine populations (Gallo, et al., 2018). Specifically, they discovered micro- and nano-plastics decrease zooplankton species' ability to survive and increases their mortality rate (Gallo, et al., 2018). Also, crustaceans had decreased survival and fecundity when exposed to plastics. Overall, the Joint Research Centre of the EC, found that plastic ingestion negatively affects reproductive capacity and survival of marine life from lower trophic levels (Gallo, et al., 2018).

The authors of this research acknowledge a knowledge gap in our understanding of the extent these chemicals have on marine species as a result of plastic ingestion. This study is one of a few that evaluates the impacts of toxics from plastics on marine life, and there is a need to further investigate the chemical implications of plastic pollution. Additionally, the physiological effects of microplastics on fish and marine life are not well understood and require increased laboratory studies (Baechler, et al., 2019).

Though Duke has begun research on the effects of plastic ingestion on marine life through necropsies, it is difficult to identify microplastic pieces inside the animal. Moving forward, developing and improving the technologies to locate microplastics inside of organisms will greatly assist in improving our understanding of how their prevalence in the marine environment contributes to deaths.

There are relevant studies that identify endocrine-disrupting chemicals (EDCs) in fish and other marine life. However, we still do not know what proportion of chemicals act as EDCs. Also, there is a need for more research regarding the interactions these chemicals have with the environment, with specific attention paid to their impacts on fisheries.

Industry Working Group Gap Analysis: Plastic Pollution Research Priorities

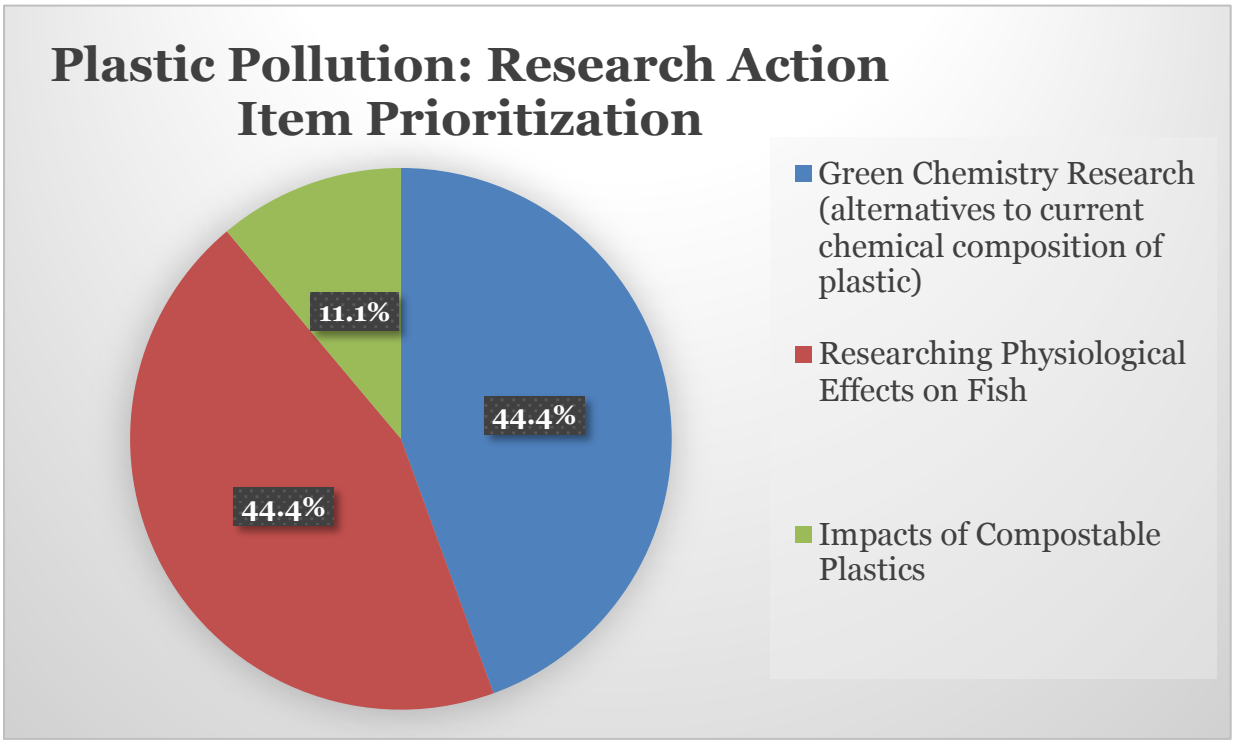

CHART 13: *Plastic Pollution Research Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Both researching green chemistry (alternatives to current chemical composition of plastic) and researching the physiological effects of plastic on fish have been identified as the top priorities in 2021-22.

Advocacy, Outreach, and Education Assessment

Current Actions:

Type of Advocacy, Education	Water Quality Impacts	Lead Organization
Public Educational Material Developed by Environmental NGOs	• Decreases plastic consumption and pollution • Teaches proper plastic disposal techniques	North Carolina Marine Debris Symposium www.ncmarinedebrissymposium.com / Coastal Carolina Riverwatch www.coastalcarolinariverwatch.org NC Division of Environmental Assistance and Customer Service NCDEACS https://deq.nc.gov/about/divisions/environmental-assistance-customer-service Carolina Recycling Association http://www.cra-recycle.org North Carolina Solid Waste Association of North America NCSWANA https://ncswana.org Plastic Ocean Project https://www.plasticoceanproject.org Wrap Recycling Action Program

		https://www.plasticfilmrecycling.org/about/ North Carolina Stream Watch: NCDEQ 919.707.9009 North Carolina Aquariums' Initiative: In Our Hands 1-800.406.FISH (3474) NC Marine Debris Action Plan https://www.nccoast.org/wp-content/uploads/2020/01/N.C.-Marine-Debris-Action-Plan.pdf
Advocating for Plastic Regulations	• Eliminates use of polystyrene foam and other products that break down easily and pollute aquatic ecosystems • Encourages plastic reduction efforts	Environment America https://environmentamerica.org/feature/ame/wildlife-over-waste
Companies Publicizing Plastic Reduction Efforts	• Reduces plastic consumption, waste, and pollution • Addresses social, environmental, and economic impacts of plastic production and pollution • Encourages other companies to	Ocean Friendly Establishments https://www.oceanfriendlyest.com NC Green Travel https://deq.nc.gov/about/divisions/environmental-assistance-customer-service/nc-green-travel-program

	participate in plastic reduction initiatives	
Ocean Friendly Establishments Certification	• Decreases plastic consumption and waste in local communities • Advocates for alternatives to plastics, therefore reducing pollution	Ocean Friendly Establishments https://www.oceanfriendlyest.com Oceanfriendlyestablishments@gmail.com
Plastics Policy Inventory	• Identifies policy gaps in plastic regulatory actions • Promotes sustainable policy development and aquatic ecosystem protection	Duke University (Plastic Pollution Working Group) plastics@duke.edu
National Caucus of Environmental Legislators' Initiatives	• Provides the public with information and data related to plastic pollution and its effects on health • Provides educational information about current policy initiatives	National Caucus of Environmental Legislators' Initiatives (202) 744-1006

Beach and River Clean-ups	• Creates concern for local recreational and fishing sites and their protection • Reduces amount of plastic currently in bodies of water • Encourages decreased consumption of plastics	NC Marine Debris Symposium www.ncmarinedebrissymposium.com Check out local environmental organizations!

In North Carolina, non-government organizations have fervently championed the cause of reducing plastic consumption and production reduction. Programs that consistently provide and promote educational material in regard to the appropriate plastic disposal and strategies to reduce consumption patterns include the annual North Carolina Marine Debris Symposium hosted by Coastal Carolina Riverwatch, the Carolina Recycling Association and NC Solid Waste Association conferences, and workshops provided by the NOAA Marine Debris Program, (Rider, 2021).

Environment America is advocating for a ban on polystyrene foam take-out cups and containers. Polystyrene foam is particularly dangerous because it breaks apart easily, and it persists in the environment as extremely small particles. Environment America has had success in advocating for plastic reduction efforts through the passing of statewide laws encouraging recycling and a plastic bag ban in the whole state of California (Environment America, 2019).

Some companies are resisting the transition from plastics, but others are actively contributing to the initiative. For example, McDonald's has committed to phasing out foam cups and containers across the globe and replacing them with 100% recycled products (Environment America, 2019). Locally, retailers who decide to use alternatives to single-use plastics may receive the *Ocean Friendly Establishment* certification. This program was developed by two non-profit organizations located in Wilmington, Plastic Ocean Project and the Cape Fear Surfrider Foundation Chapter (Hallas, et al., 2018).

Duke University Marine Laboratory is at the forefront of outreach regarding this issue with the development of their community science program. Fourth grade classes in Carteret County participate in beach cleanups and learn about using marine debris in art, the recycling process, and scientific data collection. Also, the Nicholas Institute for Environmental Policy Solutions at Duke created a database of public policies that regulate plastic pollution around the world since 2000 called the Plastics Policy Inventory. The inventory includes over 310 policies that anyone can download to learn more information about the legislation. The goal of the database is to identify where there are policy gaps,

analyze the policies' effectiveness, and determine ways current legislation can be improved or new legislation can be developed (Plastics Policy Inventory, 2020).

In 2020, Coastal Carolina Riverwatch launched a pilot environmental equity program to engage local youth in advocacy and award scholarship funds. CCRW worked with local school officials to prioritize students identifying as Black, Indigenous, People of Color, and/or low income. This program serves to empower new, diverse, and inclusive environmental leaders. Through an application process, a student was selected to participate in a mentorship with Coastal Carolina Riverwatch staff . The student researched local litter issues and organized a community litter cleanup. Following, the student participated in advocacy and civic engagement with Town of Beaufort officials on litter issues and waste reduction. Upon completion, the student received a $1,000 college scholarship.

At the federal level, the National Caucus of Environmental Legislators (NCEL) provides substantial information regarding the environmental and public health implications of plastics to the public (NCEL 2021). Also, they describe policy options for managing plastic waste and details regarding current bills and enacted legislation.

Finally, involving community members in ocean and river cleanups assists with raising awareness of the issue. The public visualizes the extent of plastic contamination in their community when participating in trash cleanup activities. Creating the connection between their favorite fishing or recreational sites and the quantity of plastic entering the system. Therefore, participants are developing a concern and encouraging involvement in plastic reduction initiatives.

Recommended Future Actions:

Type of Advocacy, Education	Water Quality Impacts
Educational Material Regarding Alternatives to Plastics	• Decreases plastic consumption and a market for those products • Reduces amount of plastics entering aquatic ecosystems
Writing, Calling, and Lobbying Legislators	• Increases protection of water quality and aquatic habitats • Informs politicians on local environmental issues
Public Outreach regarding Human Contribution to Aquatic Plastic Pollution from Land Sources	• Educates public on strategies to reduce littering and improper plastic disposal • Reduces quantity of plastics entering streams and estuaries

Increasing Corporate Transparency	• Reduces consumption of harmful plastic products • Decreases plastic pollution and protects the aquatic environment from toxins and entanglement

Working with producers and providing educational material regarding the use of plastic packaging in their production processes could assist in encouraging alternatives to plastics. Another method to assist in reducing marine litter would be to provide technical assistance and waste management techniques to stakeholders and provide methods to reduce our individual plastic consumption (Gallo, et al., 2018).

The translation from the science of chemistry to policy development is complex because political decisions are not always driven by scientific data. Making chemistry more approachable and educating political leaders and the public on the chemical makeup of our products and their impact on the environment and public health may encourage regulatory action.

Additionally, NGOs, environmental groups, and stakeholders can express concerns to our legislators in order to inform leaders about current, local water quality issues. Lobbying, writing, and calling representatives and discussing fishermen's worries related to the implications of increased plastic pollution could influence policy-makers. The fishing industry, tourism, and aquaculture are economically significant to North Carolina, but they are extremely vulnerable to the effects of plastic contamination on the fish and shellfish populations. Therefore, the public can push for initiatives such as plastic bag bans or a plastic bottle bill to decrease the production and consumption of plastic in the state, and protect the economic and ecological integrity of NC fisheries.

Also, providing educational material about the sources of plastic pollution in marine and freshwater ecosystems will help to decrease littering. 90% of plastic debris comes from terrestrial sources such as littering when plastics are thrown on the ground and then washed through storm drains to local waters. Making the connection between our actions on land and their effects on aquatic environments will help persuade the general public to participate in proper plastic disposal practices.

The public should be made more aware of the prevalence of plastics containing dangerous toxins in our products. For example, the rain that falls on a plastic fence or garbage can every week in the spring eventually breaks down the plastics and carries dangerous chemicals with it to local streams and rivers. Informing the public on sources of plastic pollution on their own property as well as the public health risks associated with exposure to these products. Also, increasing corporate transparency will allow the public to understand what kind of dangerous additives are used in plastics. Then, they can make a decision about what type of products they want to buy and keep in their households.

Industry Working Group Gap Analysis: Plastic Pollution Outreach Priorities

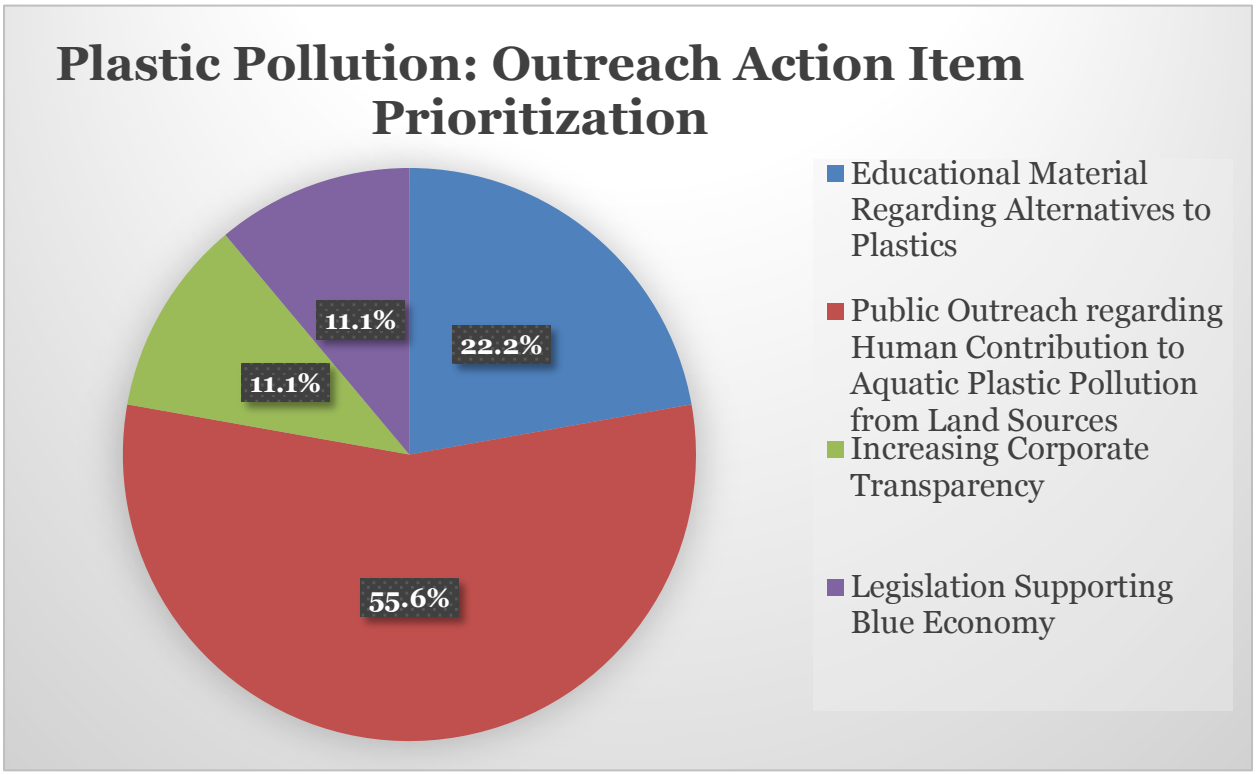

CHART 14: *Plastic Pollution Outreach Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Public outreach regarding human contributions to aquatic plastic pollution from land sources has been identified as the top priority in 2021-22.

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Municipal Wastewater and Sewage

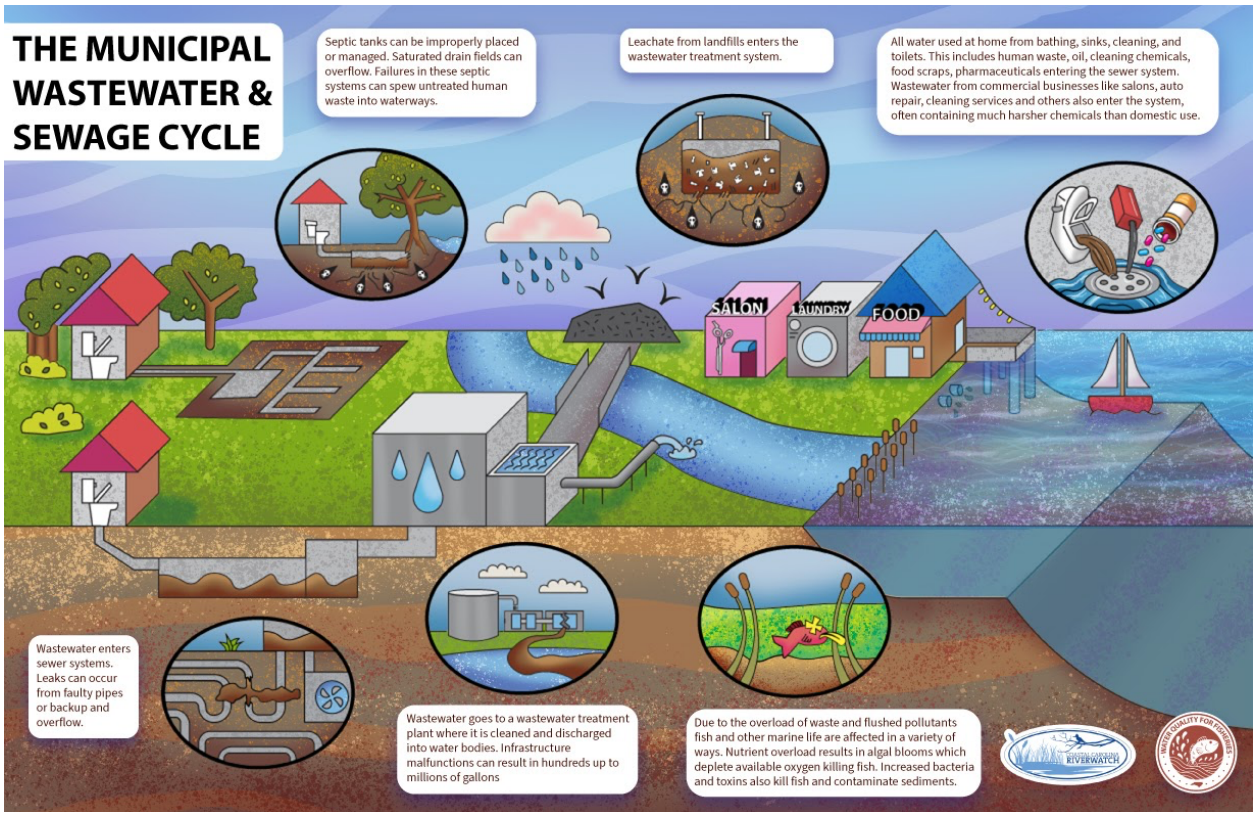

Image: Noah Weaver, *The Wastewater Pollution Cycle*, 2021

Introduction

Wastewater treatment systems are one of the US's most widely-used pollution control technologies in the US. 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.

Differing from municipal wastewater treatment facilities, about 50% of homes in North Carolina use on-site wastewater systems, or 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 an SSO, the spill may consist of hundreds to millions of gallons of sewage overflow that contain dangerous 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 blooms can lead to the release of hydrogen sulphide and ammonia, both potentially toxic to aquatic life in low concentrations. (Shahidul, 2004).

Sewage waste 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 sanitary sewer 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 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	System owner and operators
Septic Systems	• Treats wastewater from individual households for bacteria and suspended solids • Reduces water and soil contamination near households	System owners
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. These collection systems obtain wastewater from individual sources through gravity flow. Then, the water is sent to a central treatment system. Pipes 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 resistant to corrosion, all types of mains 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 addresses dissolved 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 drain field 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).

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 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.

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 to 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 micro sieves; 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 excessive out 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 installed 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).

Industry Working Group Gap Analysis: Wastewater Pollution Infrastructure Priorities

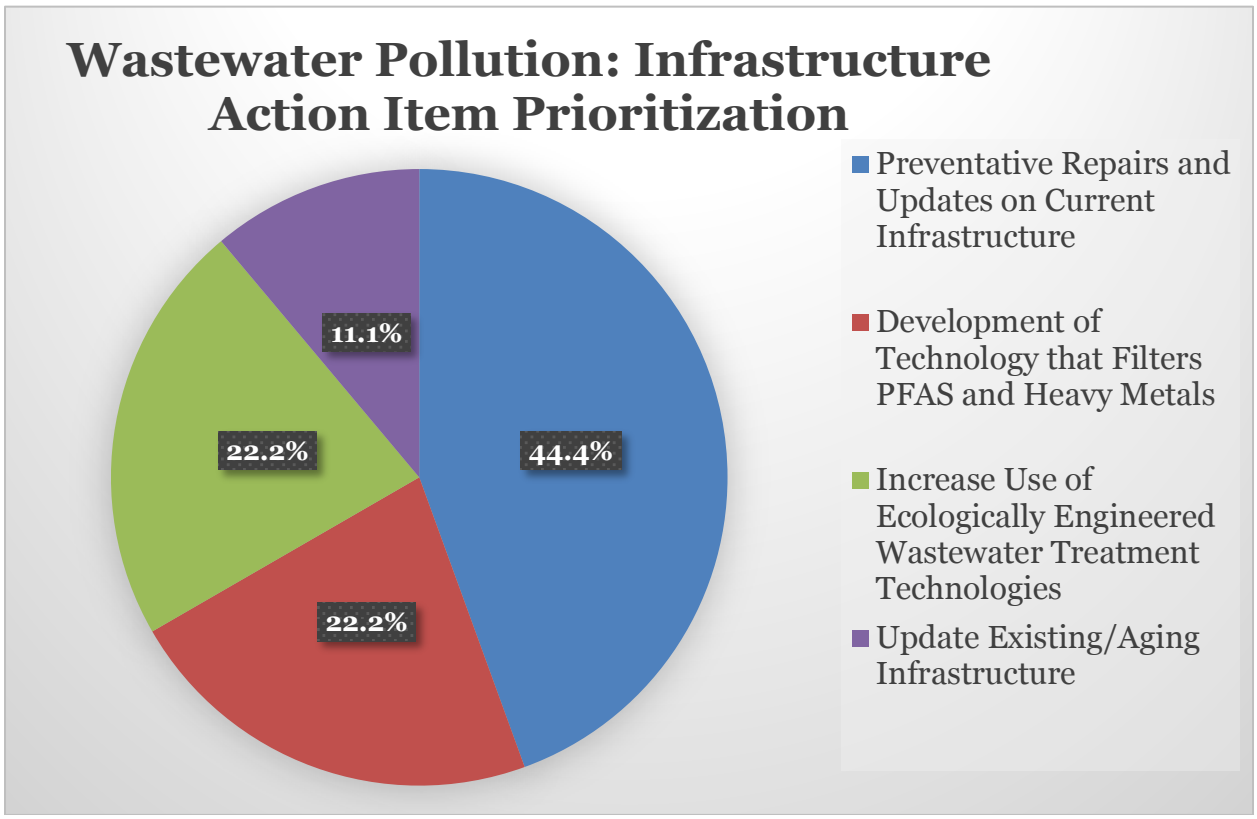

CHART 15: *Wastewater Pollution Infrastructure Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Advocating for preventative repairs and updates on current infrastructure has been identified as the top priority in 2021-22.

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 permit must 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 DWR the 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.

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 SSO 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 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 this 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 collaborate with the NC General Assembly in order to help secure adequate funding for wastewater infrastructure.

Experts have shown that the vulnerability of municipal sewage systems is due to their inability to handle large rain events, hurricanes, and high-water tables associated with 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-income citizens or located in rural areas in order for them to successfully implement new technologies.

Industry Working Group Gap Analysis: Wastewater Pollution Policy Priorities

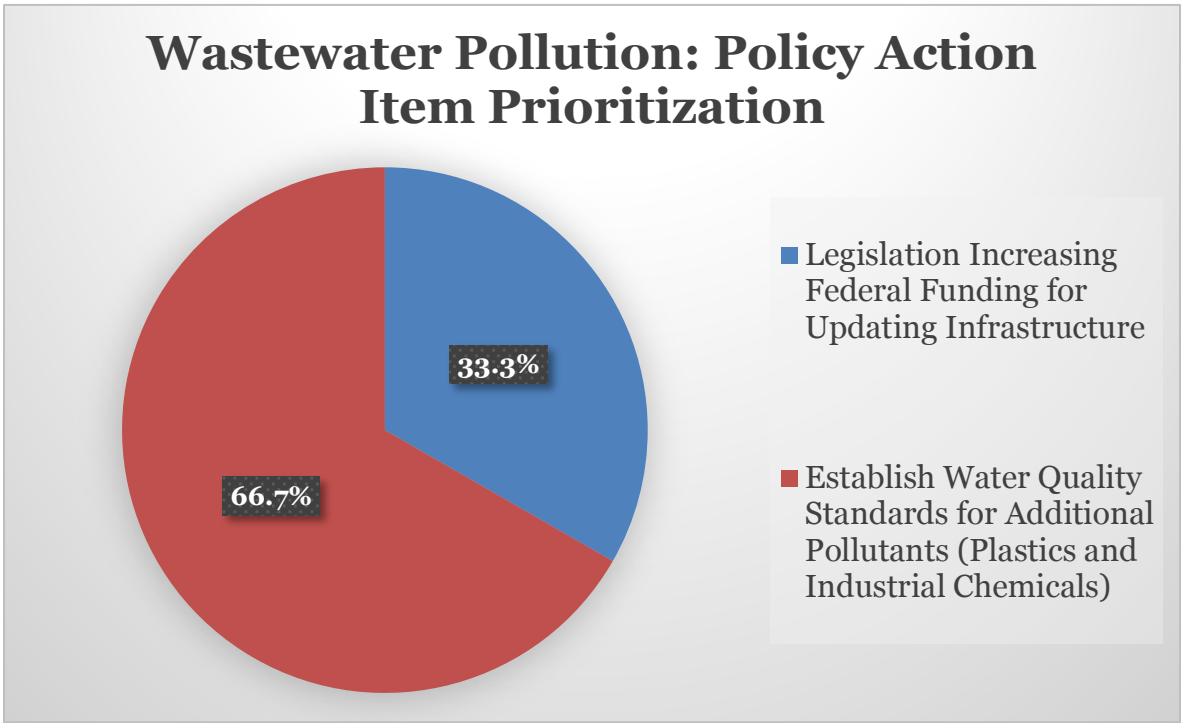

CHART 16: *Wastewater Pollution Policy Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Establishing water quality standards for additional wastewater pollutants, including plastics and industrial chemicals, has been identified as the top priority in 2021-22.

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 risk of polluting surface waters	NC Division of Marine Fisheries, Anne Deaton Anne.Deaton@ncdenr.gov
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. 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 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. 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 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 of the infrastructure from 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.

Looking at 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 that, 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 remain in the water after treatment due to 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 because they lack the ability to eliminate them efficiently (Kostich, et al., 2021). This may lead to antimicrobial resistance which means bacteria no longer respond 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 (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 and improve water quality.

Pharmaceuticals and other toxins enter water bodies 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 is considered landfill leachate. The resulting substance is dangerous because it can have very high concentrations of ammonia and organic nitrogen that negatively affect aquatic organisms.

Some wastewater treatment plants receive landfill leachate and researchers are studying the effectiveness of the facilities in filtering 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 treatment process 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.

Industry Working Group Gap Analysis: Wastewater Pollution Research Priorities

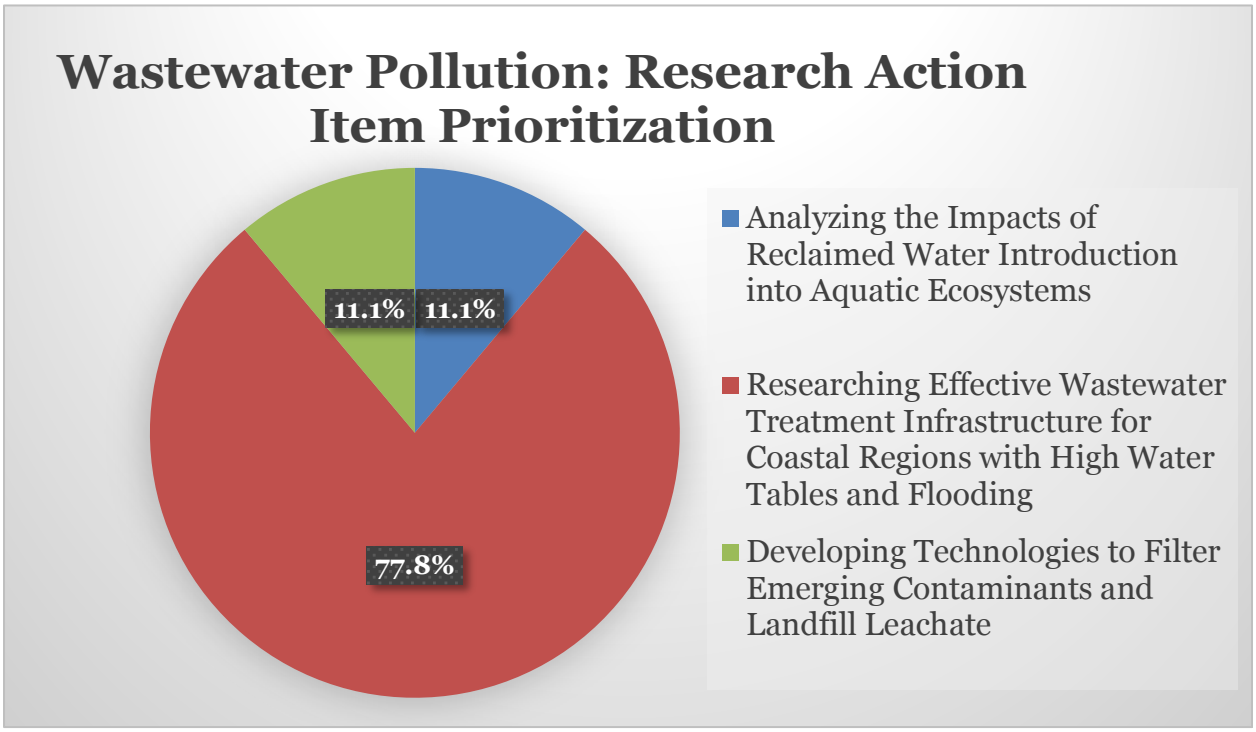

CHART 17: *Wastewater Pollution Research Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Researching wastewater treatment infrastructure for coastal regions, with high water tables and flooding, to determine effective best management practices for reducing wastewater pollution has been identified as the top priority in 2021-22.

Advocacy, Outreach, and Education Assessment

Current Actions:

Type of Outreach	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 • Reduces water contamination including bacteria, suspended solids, and chemicals resulting from wastewater discharge	On-Site Water Protection (OSWP) Branch 919.707.5854
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	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

	untreated wastewater contamination	
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 promote 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 for all sectors of the industry. 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 POTWs. 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. In the past, 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 stressed 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.

Industry Working Group Gap Analysis: Wastewater Pollution Outreach Priorities

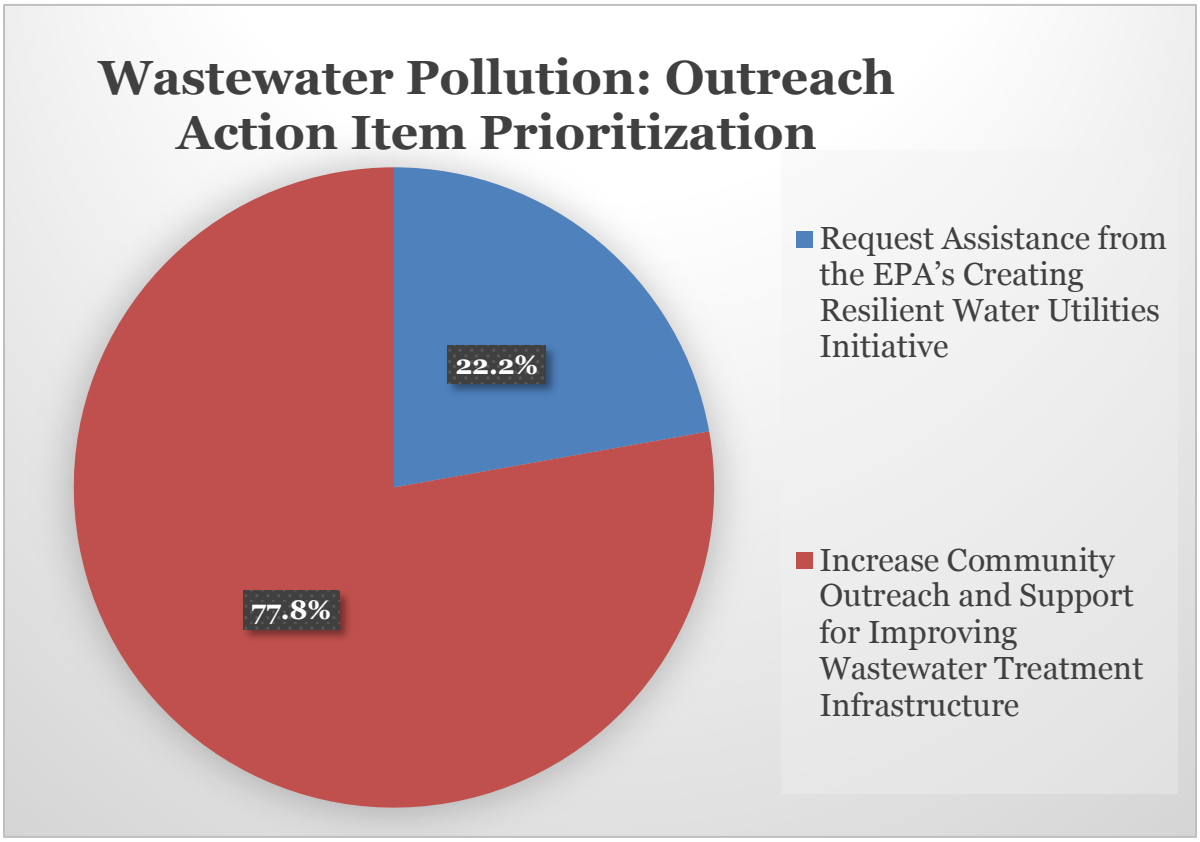

CHART 18: *Wastewater Pollution Outreach Priorities Identified by the Industry Working Group 2021.*

The Industry Working Group met and voted to prioritize action items identified by the Water Quality for Fisheries Research and Assessment Team. Increasing community outreach support for improving wastewater treatment infrastructure has been identified as the top priority in 2021-22.

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Wastewater Pollution Assessment Revisions in 2022:

Meteorological Influences on Nitrogen Dynamics of a Coastal Onsite Wastewater Treatment System

Wetter periods appear to affect nitrogen transport from OWTS. "…found that DON originating from the OWTS was mobile and contributed to elevate TDN concentrations along the groundwater flow path to the estuary. Elevated concentrations of DON in groundwater were more common during wet periods. These results suggest that if future sea level rise results in shallower groundwater tables in coastal settings, there may be an increase in OWTS DON transport." (p 1883)

Onsite Wastewater System Nitrogen Contributions to Groundwater in Coastal North Carolina

Discussing the potential impact to environmental and public health should contributions from OWS enter shallow groundwater. "Nitrogen derived from OWS can impact shallow groundwater beneath OWS and adjacent surface waters…levels of NO_3^--N beyond state setback regulations can be higher than background levels." (p 6)

Wastewater Nitrogen Contributions to Coastal Plain Watersheds, NC, USA

Discussion that nitrogen inputs from OWS need to be considered in nutrient management strategies. "Nitrogen concentrations and mass exports were greater in groundwater and surface water served by septic systems compared to water bodies served by the sewer system. Additionally, effluent from septic systems discharging to the groundwater increased water quantity in the form of elevated baseflow at septic sites, which translated to greater baseflow discharge in watersheds served by septic systems. (p 14-15)

Is on-site wastewater a significant source of phosphorus to coastal plain streams?

Discussion that phosphorus inputs from OSW need to be considered in nutrient management strategies. "…watersheds served by OSW had significantly larger concentrations and watershed loads of TP and TDP relative to adjacent watersheds that do not receive wastewater discharges. Streamflow and water quality with regard to phosphorus were influenced by OSW in these coastal plain watersheds." (conclusion)

Detection of pharmaceuticals and other personal care products in groundwater beneath and adjacent to onsite wastewater treatment systems in a coastal plain shallow aquifer

OWTS appear to contribute non-point source nutrients and pharmaceutical pollutants and current setback distances may not be sufficient to prevent entry into waterways. "The high volume of wastewater discharged to the subsurface by OWTS in Eastern NC, USA, as well as in other coastal areas, has been shown to be contributing to non-point source nutrients such as TDN, DOC, and PPCPs into the nutrient sensitive rivers, estuaries, and ocean…domestic wastewater may not be fully treated as I flows along groundwater flow

paths and discharges to surface waters…the results of our study indicate that current horizontal setback distances of OWTS to surface water bodies may be adequate to control for some trace organic contaminants originating from OWTS."(p 222-223)

Fate and Transport of Enteric Microbes from Septic Systems in a Coastal Watershed

Study indicates that current setbacks of OWTS may not be enough to prevent fecal microbe entry into waterways. "…OWTS at both sites contributed to significantly elevated concentrations of E.coli and enterococci in groundwater beneath the drain fields relative to background groundwater concentrations…since the study sites were adjacent to an estuary, results suggest that current OWTS setbacks of 15-30 m may not be sufficiently protective to prevent elevated microbial concentrations in shallow groundwater from reaching nearby surface water and adjacent waterways (e.g., shellfish harvesting areas)." (p 28-29)

Groundwater and stream *E. coli* concentrations in coastal plain watersheds served by onsite wastewater and a municipal sewer treatment system

Discusses pollutant input of *E. coli* from OWS to groundwater. "…effluent discharged to the subsurface via some OWS can increase the concentration of *E. coli* and SC (specific conductivity) of groundwater adjacent to and down gradient (15-22m) from the systems relative to groundwater up-gradient from the OWS, and relative to groundwater in watersheds served by MWS. Groundwater with elevated *E. coli* concentrations can contribute to elevated concentrations of *E. coli* in streams. The OWS that were installed with the largest vertical separation distances to groundwater (both more than 45 cm) had *E. coli* concentrations in groundwater similar to what was observed in groundwater at the MWS (municipal wastewater treatment system) sites." (p. 1859)

Influence of Sewered Versus Septic Systems on Watershed Exports of *E. coli*

Discussion of storms and seasonality effects on elevated *E. coli* levels in watersheds containing sewered or septic systems. "(1) during baseflow conditions, septic watersheds contained elevated stream discharge and *E. coli* concentrations and exports as compared to sewer watersheds; (2) warmer months had elevated *E. coli* watershed exports compared to colder months in both septic and sewer watersheds; and (3) …storms significantly increased watershed *E. coli* exports in both septic and sewered watersheds, but *E. coli* counts in sewered watersheds were considerably greater likely due to greater impervious surface coverage and or leaky sewer infrastructure." (p. 228)

Water Quality for Fisheries
2021-22 Prioritized Action Items

The Industry Working Group goals are to address water quality impacts on fisheries and recommend action items. The Industry Working Group has prioritized the following action items in 2021-22:

Industrial Agriculture and Factory Farming Pollution:

- Advocate for updated waste management systems for industrial agriculture and factory farming practices.
- Improve the requirements for pre-storm preparation.
- Conduct a thorough evaluation of best management practices that reduce or eliminate agriculture and factory farming pollution.
- Bridge the gap between scientists and policymakers.

Stormwater Pollution:

- Implement sustainable development techniques (wetland and forest protection, permeable surfaces, increased vegetated areas, on-site runoff treatment technologies).
- Advocate for green infrastructure policy development (standardize the use of permeable pavement, green streets, filtration systems, and nature-based infrastructure).
- Enhance the monitoring of stormwater runoff.
- Publicize successful stormwater control efforts.

Industrial Pollution:

- Reduce industrial activities that utilize harmful industrial chemicals in their process and the development of new filtration technologies.
- Advocate for policy that enforces the maximum contaminant levels for municipal water treatment facilities.
- Analyze the effects of all heavy metals on aquatic ecosystems and research safe alternatives to industrial pollutants.
- Increase education efforts providing information to consumers on PFAS-containing products.

Plastic Pollution:

- Advocate for changes in the manufacturing process of plastics that prevent plastic pollution.
- Advocate for single-use plastic-bans and extended producer responsibility.
- Research green chemistry (alternatives to current chemical composition of plastic) and research the physiological effects of plastic on fish.

- Develop and support public outreach regarding human contributions to aquatic plastic pollution from land sources.

Wastewater Pollution:

- Advocate for preventative repairs and updates on current infrastructure.
- Establish water quality standards for additional wastewater pollutants, including plastics and industrial chemicals.
- Research wastewater treatment infrastructure for coastal regions, with high water tables and flooding, to determine effective best management practices for reducing wastewater pollution.
- Increase community outreach support for improving wastewater treatment infrastructure.