Coastal Carolina Riverwatch

Water Quality for Fisheries

An Assessment of Water Quality Concerns

Introduction

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

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

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Table of Contents:

Priorities Identified by Coastal North Carolina Fishermen:

Agriculture and Factory Farm Runoff
Stormwater Runoff from Roads, Highways, and Parking Lots
Industrial Pollutants

Plastic Pollution

Municipal Wastewater Treatment Plants and Septic Tanks

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Agriculture and Factory Farm Runoff

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 utilized in North Carolina. These chemicals may provide advantages to farmers because they prevent crop losses, increase food production efficiency, and they are a cost-effective method to 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 on aquatic ecosystems. Algal blooms occur as water becomes nutrient-

rich, which results in a depletion of dissolved oxygen causing massive vegetative 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 20th century, concentrated animal feeding operations (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 (Tetra Tech, 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 (Tetra Tech, 2002). Concentrated animal feeding operations (CAFOs) were initially implemented in upland areas of the midwest where the water table was below an adequate amount of soil depth. Later on, they were placed in low-lying wetlands 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 water samples (Burkholder, et al., 2006). 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 and provides more dead plant material as food for bacteria, 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 cause extreme fish kills in freshwater including species such as minnows, gar, largemouth bass, striped bass, and flounder (Burkholder, et al., 2006).

An additional negative effect of waste from factory farms entering nearby waters include the contamination of water with pathogens. This also causes human health problems and may lead to shellfish restrictions.

The animals raised in CAFOs are given hormones and antibiotics which have been found in water samples collected near the operations. Hormones found in water can affect the reproductive success and fertility of female fish (Hribar, 2010).

Infrastructure Assessment

Current Actions:

Type of Infrasture	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
Automatized 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 enhance nutrient retention in the stored water	NC State Extension 919.515.2813
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 do not effectively protect water from contamination such as excessive nutrients, pathogens, and pharmaceuticals. There are many issues associated with current CAFO infrastructure, especially the means operators use to store the animal waste.

The contaminants resulting from CAFOs may enter water sources by leaking from poorly constructed manure lagoons, overflow of pits during rain events, runoff from waste

sprayed on fields, or gases entering the air and joining the water cycle. An example of a faulty waste management system used by factory farms includes the rupturing of Oceanview Farm's lagoon in Onslow County in 1995.

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 farmers were unable to use spraying as a way for waste treatment due to the saturated soils following an extreme rain event, 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. Fortunately, 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 (Tetra Tech, 2002).

Seepage cannot total more than 1/28 inch per day. With more frequent severe weather events and hurricanes, the current CAFO infrastructure is subjected 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 such as bacteria, turbidity, and fertilizer and livestock runoff. Also, in order to decrease pollution levels in waters as well as create more cost-effective and productive farming operations, farmers may implement BMPs to reduce contaminated runoff.

North Carolina State University and government agencies have come together to collaborate on nutrient management strategies for the state, and specialists in the Division of Soil and Water Conservation in North Carolina provide technical support to farmers

upon request. The utilization of nutrient management plans will 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.

Another practice includes the implementation of riparian buffers, 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, personal communication, 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, personal communication, June 4, 2021).

During a conversation 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 best management practice utilized to decrease agricultural contamination. IPM is the implementation of a diverse range of strategies to reduce pest impacts. Some of the techniques used in this process

include crop rotation, the use of pest-resistant crops, mechanical control of insects through uproot and cultivation, biological control, pesticide use, and sanitation.

The IPM method prioritizes alternative, natural strategies to handling pest populations and resorts to pesticide use when completely necessary.

Recommended Future Actions:

Type of Infrasture Recommended	Water Quality Impacts
Updated Waste Management Systems: Dry Handling Systems	• Treats and eliminates pathogens • Reduces runoff • Stabilizes nitrogen levels • Decreases contaminants
Decommissioning flood plain CAFOs	• Decreases contamination from pathogens, nutrients, hormones, toxins, etc • Reduces algal blooms and promotes natural habitat vegetation growth
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. To begin, the current waste management processes in place for factory farms are in dire need of reconstruction. Research implies that an efficient strategy for treating and eliminating pathogens in animal waste, reducing runoff, and stabilizing nitrogen includes dry handling systems (Graham & Nachman, et al., 2010). Some alternative techniques operators can use to manage livestock waste involve air-drying, composting, anaerobic digestion, and facultative lagoons. These processes decrease the risk of water contamination from lagoons, aquatic habitat destruction, and nutrient-overload by stabilizing the nutrients in waste.

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 unique 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.

Decommission 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.

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	Environmental Protection Agency (Southeast Regional Office) 800.241.1754

	for CAFOs • Reduces contamination • Decreases nutrient-loading	
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 that 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' consequences to 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 concentrated animal feeding operation 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 Clean Water Act Amendments created in 2003 is the most influential policy addressing the regulation of CAFOs. Also known as the CAFO rules, this policy requires 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. This policy is an important advancement towards regulating the operations, but 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), created by 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 animal deaths, 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 opted to develop their own CAFO legislation with similar objectives to 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. Similarly to the requirements of the NPDES permits, North Carolina mandates all permitted AFOs to have a Certified Animal Waste Management Plan (CAWMP). The plan clearly determines which fields receive waste application, the types of crops produced, and other specifics of the facilities (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.

The Clean Water Responsibility and Environmentally Sound Policy Act (House Bill 515) set a moratorium on the construction and expansion of swine farms in North Carolina for 2 years (1997-1999) (Tetra Tech, 2002). The permit coverage under North Carolina's permitting program is stricter than the federal NPDES program standards for CAFOs. Any facility that reaches the threshold previously described for animal units, may not be constructed or expanded without a permit. Any facility under the threshold is automatically permitted and does not need to develop a waste management plan. The state does not allow any construction or operation of an animal waste management system without the administration of a permit (Tetra Tech, 2002).

As part of the enforcement process of North Carolina's permitting system for farming operations, state government agencies work together 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. Also, any newly constructed and expanded operations must have an onsite inspection to ensure their animal waste treatment systems meet environmental standards. If there is a citizen complaint or water quality problems, the North Carolina Department of Environmental Management (NCDEM) will inspect animal waste facilities.

In regard to the regulation of fertilizers and agricultural chemicals through policy, the most impactful law 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. Similarly to the NPDES program, this policy gives states

the discretion to regulate pesticides at the state level as long as the state law is as stringent as the federal standards. The agency completes cost-benefit analyses in regard to each specific pesticide. Some factors they take 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 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 United States Department of Agriculture (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

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 does 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).

Similarly, there are treatment standards established for biosolids before they can be disposed of on land. Effluent must be treated through methods that decrease pathogen levels, odor and content of waste solids, and metal levels. However, the standards lack treatment requirements for pathogens or metals for animal effluent. Therefore, pathogen and metals management can be an objective for developing environmental policies in the future.

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.

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	• Reports that	Virginia Cooperative

Pesticides on Water Quality	chemicals in water systems cause rapid fish death, changes in behavior, and reduced reproduction	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 Department of Environmental Quality, 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 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 to 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. They 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). Therefore, 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 best management practices 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 another influential NCSU researcher, Dr. Mallin, who monitored a swine waste spill in NC that caused a 29-km freshwater area to become anoxic and killed about 4000 fish by day 2 (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 amount 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. This bacteria accumulates in the sediments and presents health concerns for the public and wildlife. The pollution identified in these sediments by pathogens, nutrients, and organic materials found in swine waste, 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 (DEQ), and the Department of Coastal Management are influential in researching important water quality issues. For example, the NC Division of Water Resources (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 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 dry waste systems 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

There are still gaps in our understanding of the impacts of CAFOs on water quality. 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 are essential to our understanding of fertilizers in aquatic ecosystems. Overall, long-term research is required to assess the effectiveness of implemented best management practices and new infrastructure such as dry waste systems and wetland restoration.

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, personal communication, 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.

One limitation to current water quality monitoring is the lack of developed technology to note 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).

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	Waterkeeper Alliance www.waterkeeperalliance.org Clean Water for North Carolina 919.401.9600 Triangle Land Conservancy 919.908.8809 N.C Conservation Network 919.857.4699
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 • Create grassroots efforts for environmental and	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 N.C Conservation Network 919.857.4699

	social change • Connects participants in environmental initiatives with grants	
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

Environmental groups such as Coastal Carolina Riverwatch and the 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. Through scientific communication appropriate for a variety of audiences and lobbying policymakers, they have influence on the creation of environmental initiatives. Environmental non-governmental organizations (NGOs) build coalitions to develop community-focused projects, advocate for environmental policy, and provide communities access to resources. Some examples of environmental groups promoting water protection efforts include the various organizations aligned with the Waterkeeper Alliance, Carolina Wetlands Association, Clean Water for North Carolina, Conserving Carolina, and the Triangle Land Conservancy.

Environmental NGOs may advocate for sustainable agricultural practices and regulations through the use of petitions. For example, the Center for Food Safety along with other

organizations filed a petition to the EPA to request the regulating of CAFO methane emissions under the Clean Air Act. Meanwhile, they brought attention to the social and environmental issues associated with factory farms and water pollution (Heavican, 2021). In response to the petition, the US dairy industry is attempting to develop a sustainable industry by setting aggressive environmental targets, becoming carbon neutral, using water sustainably, and improving water quality by 2050 (Heavican, 2021). The industry also established a Net Zero Initiative in 2020 to encourage voluntary environmental action on farms by making sustainable agricultural techniques and improved technologies more affordable to dairy farmers. In order to accomplish these goals, they utilize research, technical support for farmers, and manure-based products and ecosystem markets (Heavican, 2021).

Another tactic environmental NGOs utilize to establish a public understanding of the impacts of fertilizers and CAFOs on ecosystems includes litigation. 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 stating the 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 complying with the CWA (Graham & Nachman, 2010). Court cases allow for more strict interpretations of environmental laws to protect ecosystems, meanwhile increasing public awareness of the environmental issues and rallying support among local communities.

The North Carolina State University (NCSU) Cooperative Extension plays a critical role in providing educational materials, created by professionals in the field, regarding sustainable agricultural practices. Part of their objective is to educate the public on methods to

properly handle waste management for swine and dairy operations. Also, 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 (Tetra Tech, 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 policy • Develops science-backed policies
Educate Consumers on Sustainable Product	• 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

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 efforts in educating the general public on the consequences of factory farming and fertilizer-use, but 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.

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