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

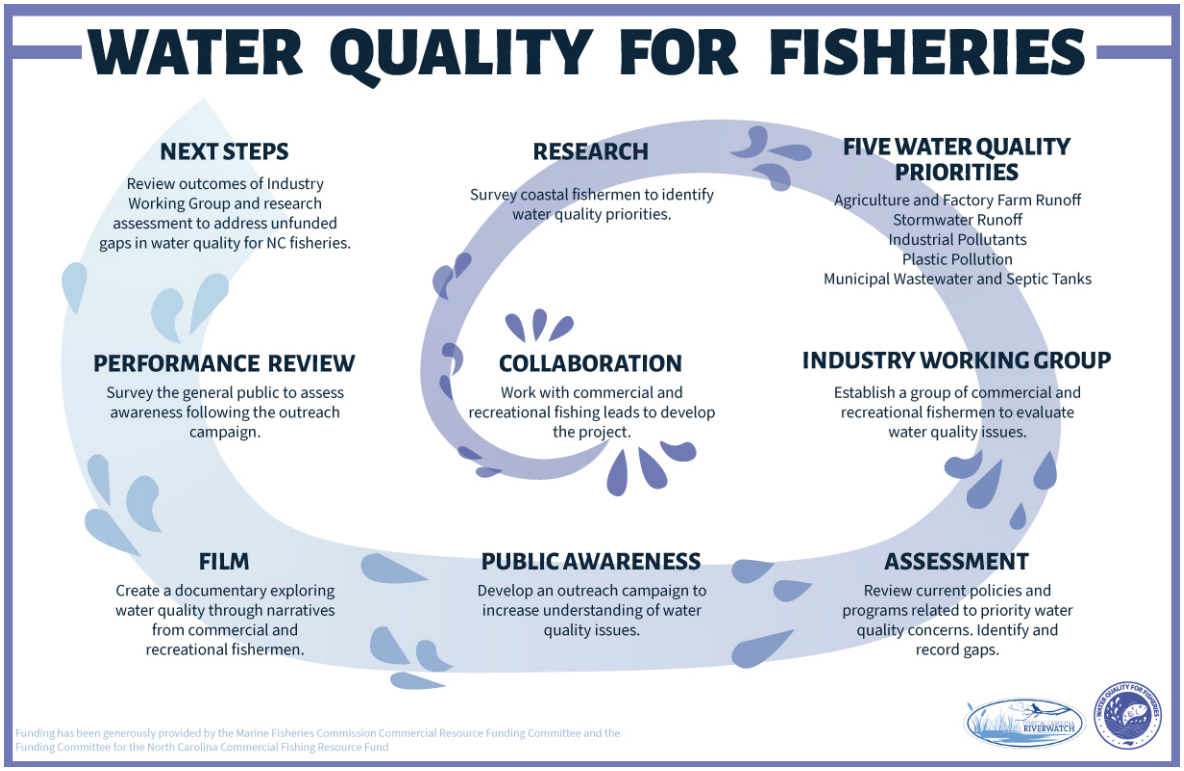
The purpose of the Water Quality for Fisheries (WQ4F) Program is to identify and address the impacts of water quality on North Carolina fisheries. This assessment is a living document that serves to address impacts on water quality that are identified by the coastal fishing community. Updates to the 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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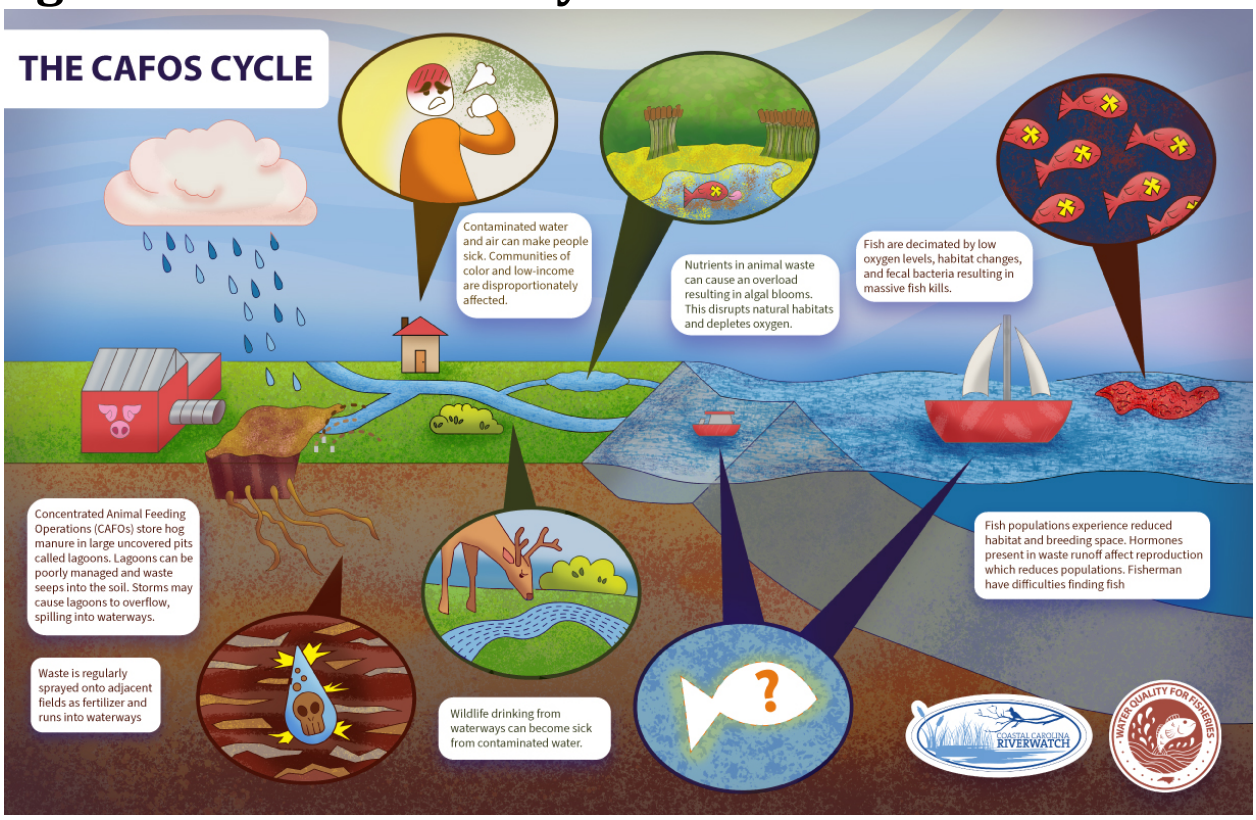
Agriculture and Factory Farm Pollution



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

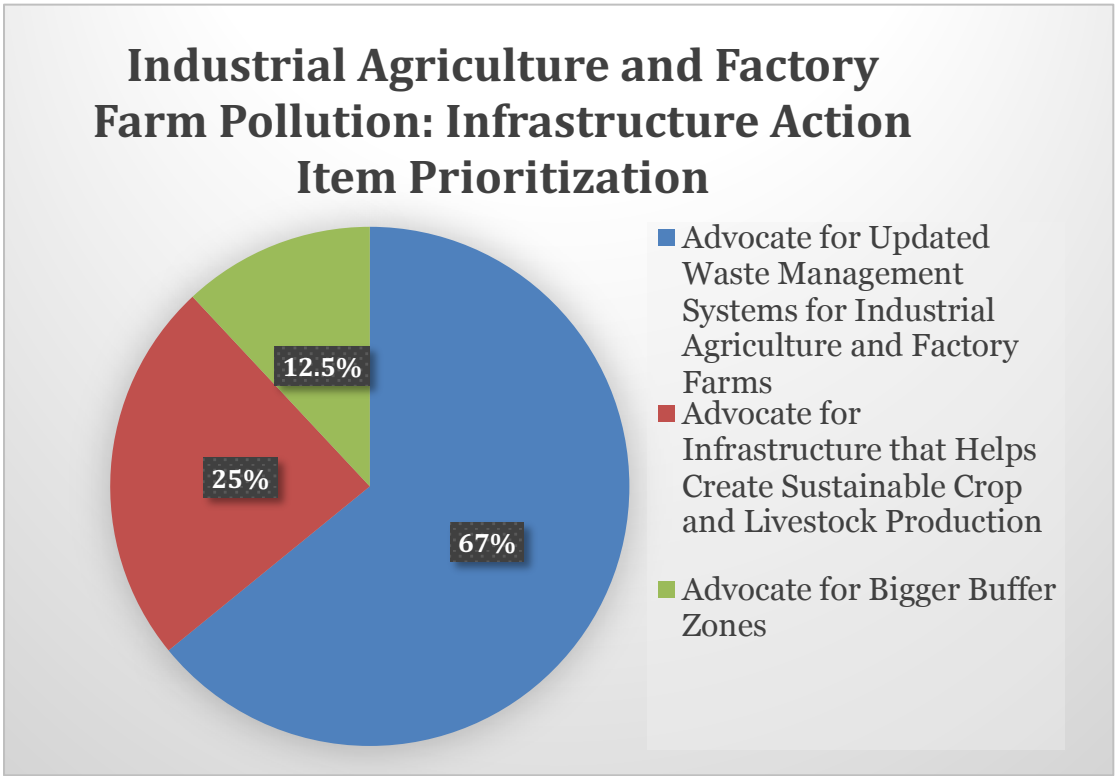


CHART 1: *Industrial Agriculture and Factory Farming Infrastructure Priorities Identified by the Industry Working Group 2021.*

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

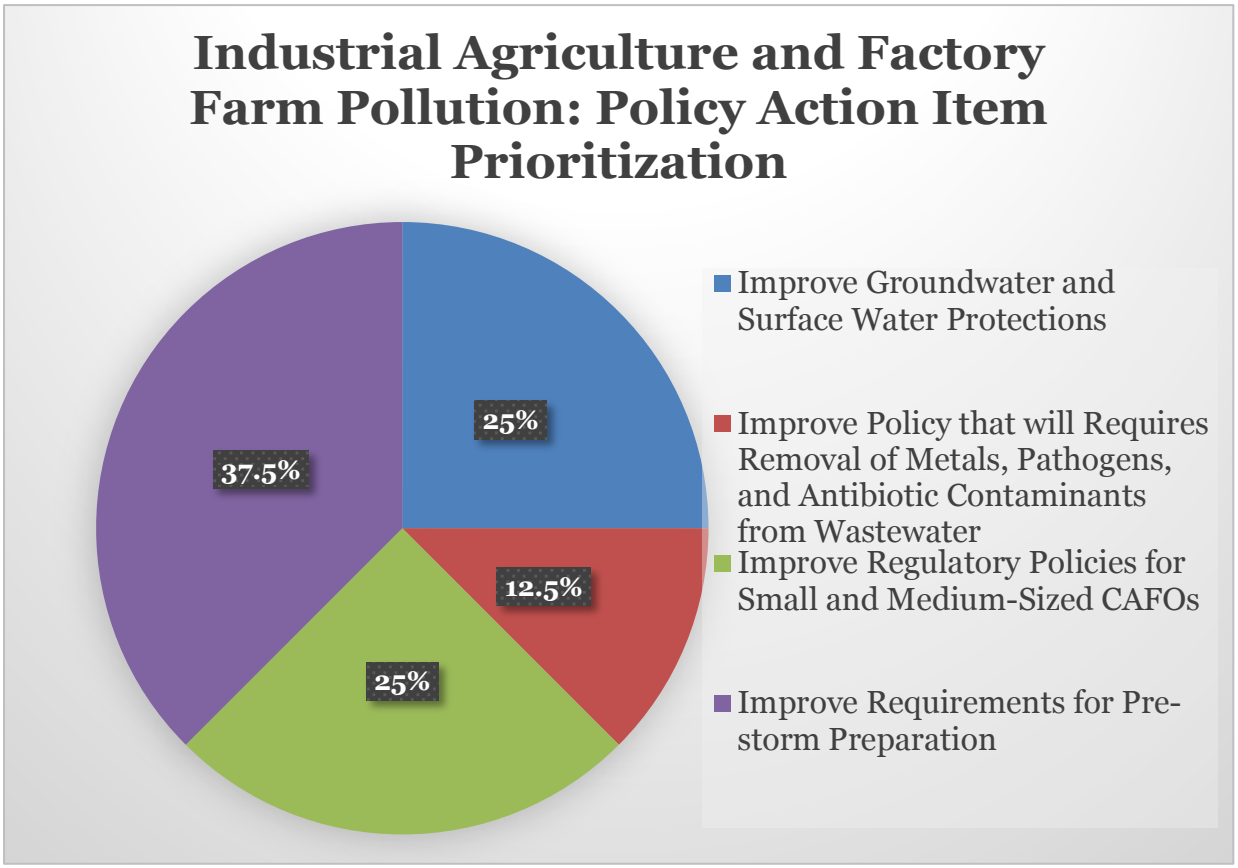


CHART 2: *Industrial Agriculture and Factory Farming Policy Priorities Identified by the Industry Working Group 2021.*

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

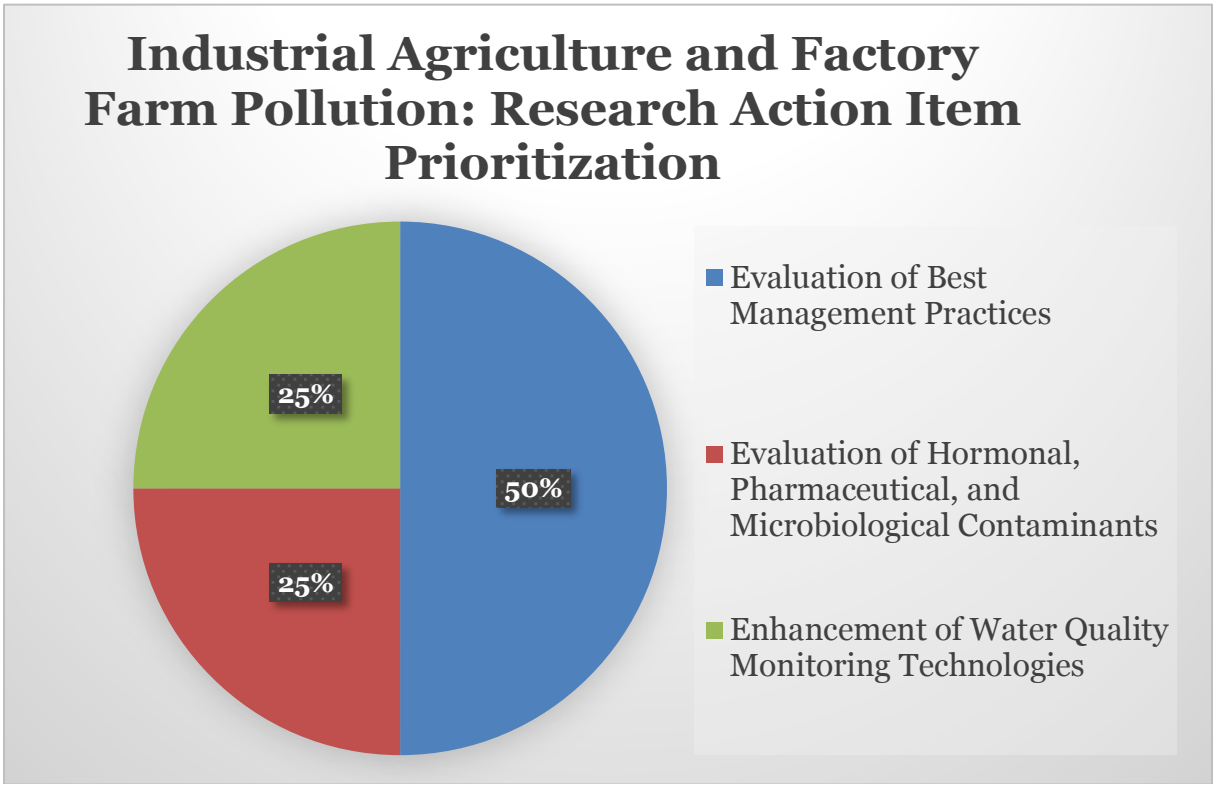


CHART 3: *Industrial Agriculture and Factory Farming Research Priorities Identified by the Industry Working Group 2021.*

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

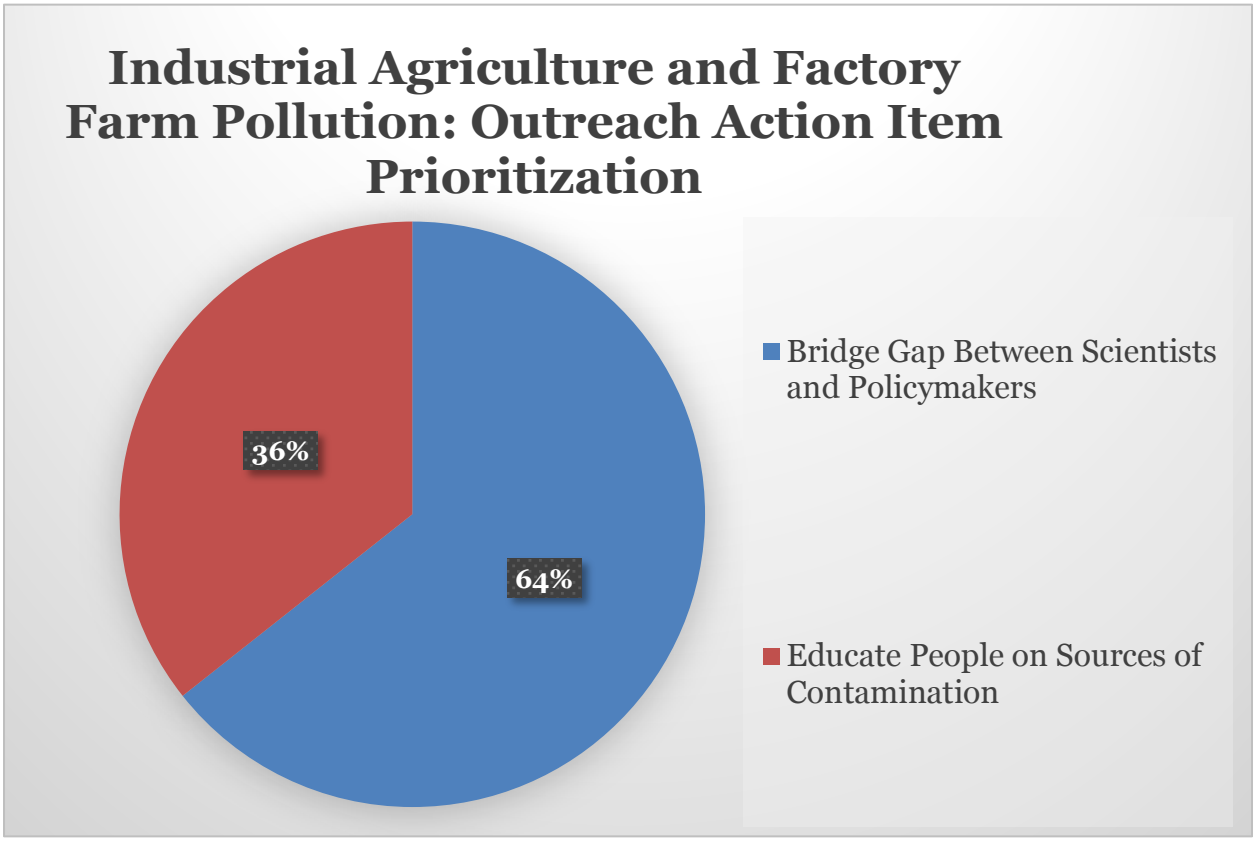


CHART 4: *Industrial Agriculture and Factory Farming Outreach Priorities Identified by the Industry Working Group 2021.*

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

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.