Cape Fear River Basin Action Plan for Migratory Fish

developed by

Cape Fear River Partnership

April 2013

The Cape Fear River Partnership

The Cape Fear River Partnership was formed in 2011 with a vision of a healthy Cape Fear River for fish and people. The partnership's mission is to restore and demonstrate the value of robust, productive, and self-sustaining stocks of migratory fish in the Cape Fear River. Building on the momentum of the newly constructed fish passage at Lock & Dam #1, this partnership of key federal, state, local, academic, and other organizations in the region is working together on this multi-year action plan. Using a broad range of tools and capabilities, we seek to provide long-term, habitat-based solutions for the most pressing challenges for migratory fish.

The partnership strives to measure achievement of our mission with the following targets: increased fish populations (as measured by catch-per-unit efforts, improved age structure, and other techniques), increased recreational fishing success for shad, striped bass, and river herring (as measured by creel surveys), and a re-opened striped bass and river herring harvest in the Cape Fear River.

The following organizations are members of the Cape Fear River Partnership:

- American Rivers (AR)
- Atlantic Coastal Fish Habitat Partnership (ACFHP)
- Cape Fear Public Utility Authority (CFPUA)
- Cape Fear River Assembly
- Cape Fear River Watch (CFRW)
- City of Wilmington
- Dial Cordy and Associates Inc. (DC&A)
- Eagles Island Coalition
- Fayetteville Public Works Commission
- Lower Cape Fear River Program (LCFRP)
- National Oceanic and Atmospheric Administration (NOAA)
- Natural Resources Conservation Service
- New Hanover County
- North Carolina Cooperative Fish and Wildlife Research Unit (NCCFWRU)
- North Carolina Department of Agriculture and Consumer Services (NCDA&CS)
    - Division of Soil & Water Conservation (NCDSWC)
    - North Carolina Forest Service
- North Carolina Department of Environment and Natural Resources (NCDENR)
    - Division of Coastal Management (NCDCM)
    - Division of Marine Fisheries (NCDMF)
    - Division of Water Quality (NCDWQ)
    - Division of Water Resources (NCDWR)
    - North Carolina Natural Heritage Program
- North Carolina State University's North Carolina Cooperative Extension (NCSU Cooperative Extension)
- North Carolina Wildlife Resources Commission (NCWRC)
- Duke Energy
- The Nature Conservancy (TNC)
- United States Army Corps of Engineers (USACE)
- United States Fish and Wildlife Service (USFWS)
- University of North Carolina Wilmington (UNCW)

Cover photo courtesy of Josh Raabe

The Cape Fear River and Migratory Fish

The Cape Fear River once supported thriving migratory fish populations including American shad, sturgeon, river herring, American eel, and striped bass. In fact, at the beginning of the 20th century, the Cape Fear River was one of the most productive rivers for American shad in North Carolina. Migratory fish populations within the Cape Fear River basin have declined substantially over the past two centuries, with current commercial landings 87 percent lower than historic estimates. State and federal agencies have limited or banned the direct harvest of many of these species to protect the diminished populations, establishing harvest moratoriums for shortnose and Atlantic sturgeon, river herring and striped bass. Harvest reductions and restrictions are in place for American shad and American eel.

These protections alone are not enough to sustain and increase the stocks of migratory fish in the Cape Fear River. Unfortunately, the river's migratory fish suffer from numerous threats that impact their numbers. There are now more than 1,100 dams in the basin, including those built to produce hydroelectric power and store drinking water, which block fish from returning to their historic spawning areas and thereby limit their abundance. Land clearing for development, industry, forestry, and agriculture can reduce riparian buffers (trees and vegetation along riverbanks) that serve to filter out excess nutrients and other pollutants from entering the river. Engineered water withdrawals, reservoirs, and inter-basin water transfers (where water is moved from one river basin to another for human use) alter the amount of water in the river—an essential aspect of migratory fish habitat health.

Managing Migratory Fish

One of the inherent challenges in managing fish, particularly migratory fish, is that they spend their lives instinctively crisscrossing our human-created, geo-political jurisdictions. In the Cape Fear River basin, species such as American shad, striped bass, and sturgeon are born in the upper reaches of the river, and then swim down to the sea where they spend several years before attempting to return upstream to spawn and begin the life cycle anew. These treks span municipal, county, and eventually state boundaries, but elsewhere in the country they span international boundaries as well.

Migratory fish and their habitat provide innumerable benefits to the human communities surrounding the river. We know that these fish are part of the national $179 billion commercial and recreational fishing industry (National Marine Fisheries Service 2012) and that the habitats in and around the river that support migratory fish are critical to the ecological health of the basin. And we know that the quality of the river affects the health of the fish and humans. The river and its inhabitants are a large part of the community's heritage and culture.

Recognizing the economic, ecological, social, and cultural importance of migratory fish in the Cape Fear River basin, and striving to create a spirit of focused collaboration that transcends political boundaries, the multiple stakeholders comprising the Cape Fear River Partnership set out to develop this *Cape Fear River Basin Action Plan for Migratory Fish*.

Cape Fear River Basin Action Plan for Migratory Fish

Using the best available information and expert knowledge, and built upon the work of other existing conservation plans, this Action Plan acknowledges several problem statements related to the health of migratory fish stocks in the Cape Fear River basin. These problem statements are nested under three goals. Sets of actions are designed to restore fish passage and improve habitat and water quality to revitalize populations of migratory fish and improve the overall condition of the river.

The specific actions developed under each of these primary goals range from: assessments that establish baseline conditions; direct conservation of habitat; development of regulatory and voluntary strategies that enhance conservation efforts; and outreach and education activities to inform the community, to identification of funding opportunities that support the work outlined in the Action Plan. These were conceived as actions that can be taken separately, yet in a parallel and coordinated fashion by a variety of federal, state, local, academic, industry, and non-governmental organizations.

Fisherman on the Cape Fear.

Cape Fear StriperFest 2012.

Action Plan Implementation

The partnership compiled a list of potential funding sources and established an Implementation Team that will track progress towards the goals established in the plan, seek solutions to obstacles, and adjust the plan as necessary. The Cape Fear River community will be able to connect to this process through the team's published annual progress reports, partnership website, and other venues such as outreach events and partner websites.

One of the first tasks of the team will be to establish a working group that will complete the development of a third goal for the Action Plan—engaging new stakeholders and increasing interest in improving fish passage and habitat conditions for migratory fish by communicating socioeconomic values associated with such improvements. A problem statement and actions related to this goal were outlined by the partnership during the process of completing the plan. These actions are designed to quantitatively and qualitatively measure the socioeconomic benefits of the conservation actions identified within this Action Plan, and to effectively communicate those benefits to the public.

We are looking forward to working together with partners and stakeholders to implement the actions in this plan. Restoration of fish access and improvement and protection of habitat and water quality will produce outcomes that benefit the fish, wildlife, and people living in the Cape Fear River basin.

Cape Fear River Partnership

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Representatives of the Cape Fear River Partnership.

Introduction

This is a voluntary Action Plan developed by the Cape Fear River Partnership. It outlines necessary and feasible actions to restore migratory fish populations in the Cape Fear River basin. The term "migratory fish" is used in the context of this plan to represent the diadromous fish species that are the focus of the plan's actions. The plan covers actions within the Cape Fear River basin from the headwaters of the Deep and Haw Rivers to the mouth of the Cape Fear River in Brunswick and New Hanover Counties (see Appendix III, Figure 1).

The partnership created four workgroups to delve into issue-areas identified as important to conserve migratory fish: fish passage, habitat, water quality and quantity, and socioeconomics. The Action Plan involved more than 18 months of planning and prioritization by the partnership and is unique for the Cape Fear River basin due to its focus on migratory fish, coastal and inland habitat, and water quality needs.

Other environment-based plans and partnerships that include the Cape Fear River basin exist in North Carolina. However, the Action Plan focuses specifically on migratory fish species in the Cape Fear River basin. Some actions in this plan are built from existing North Carolina and Cape Fear River efforts and specific species and habitat plans such as those described briefly below. Note that this Action Plan focuses on specific migratory fish goals and compliments these existing plans.

- <u>The North Carolina Coastal Habitat Protection Plan</u> (CHPP)(Deaton et al. 2010), drafted by staff from the North Carolina Divisions of Marine Fisheries (NCDMF), Coastal Management (NCDCM), and Water Quality (NCDWQ), was approved by North Carolina's environmental commissions (Marine Fisheries, Coastal Resources and Environmental Management Commissions) in 2004 with an overall goal of long-term enhancement of coastal fisheries associated with coastal habitats. The NC Wildlife Resources Commission (NCWRC) officially joined with this effort in 2010. The 1997 Fisheries Reform Act mandated that the agencies work together to complete the CHPP and implement subsequent recommendations. Every two years a Biennial Implementation Plan is developed to help achieve the goals and recommendations of the CHPP. Many of the Cape Fear River Partners have actions to complete for the CHPP. Some actions in the Action Plan are built from actions in the CHPP, but this partnership's scope is specific to migratory fish in the Cape Fear River.
- <u>The Cape Fear River Basinwide Water Quality Plan</u> (NCDWQ) was produced in 1996, 2000, and 2005 and is now updated at least every ten years by the NCDWQ. Implementation of this plan, however, is coordinated among many agencies, local governments, and stakeholders in the state. The goals of the basin-wide planning are to identify water quality problems and restore full use to Impaired Waters; to identify and protect high value resource waters; and to protect waters while allowing for reasonable economic growth. Some actions in the Action Plan are built from past basin-wide plans, and could influence the new basin-wide plan.
- <u>The North Carolina Estuarine Striped Bass Fishery Management Plan</u> was prepared and approved by North Carolina's Marine Fisheries Commission (NCMFC) and NCWRC in 2004 (as a revision to a 1994 Plan)(NCDMF and NCWRC 2004). It covers the Albemarle-Roanoke Stock and Central/Southern Management Area Stock (which includes the Cape Fear River) and contains sections on the status of the stocks, status of the fisheries, socioeconomic characteristics of the fishery, habitat, fish passage, and water quality concerns, a recommended management program, and research needs.

- Atlantic States Marine Fisheries Commission (ASMFC) Fishery Management Plan for Shad and River Herring (ASMFC 2010): In North Carolina, American shad are included in the ASMFC Shad and River Herring Fishery Management Plan. An ASMFC Plan was approved in 1985. ASMFC completed a coast-wide stock assessment for American shad in August of 2007, which indicated stocks in the Albemarle Sound and tributaries were stable, and stock status in other systems of the state was unknown. The stock assessment further concluded that most stocks along the East Coast are at all-time lows and are not recovering. ASMFC approved Amendment 3 to the Plan in February 2010; this amendment specifically addresses American shad management issues and requires states to conduct annual sampling to monitor juvenile abundance, adult stock structure, hatchery evaluations, and reporting of landings, catch, and effort for both commercial and recreational fisheries. States are also required to annually monitor bycatch and discard of American shad in fisheries that operate in state waters. Nursery and spawning habitat for American shad will be evaluated to assess habitat degradation, barriers to migration, and water quality. The Amendment also requires states to submit a sustainable fisheries management plan for all systems that will remain open to commercial or recreational fishing. NCWRC and NCDMF staff developed a statewide sustainability plan for American shad in 2011 that was updated in 2012 and has been accepted by ASMFC (NCDMF and NCWRC 2012).
- North Carolina Wildlife Action Plan (North Carolina Wildlife Resources Commission 2005): The North Carolina Wildlife Resources Commission developed the Wildlife Action Plan as a blueprint for the next half century for North Carolina fish and wildlife conservation. The plan provides guidance and assistance to other conservation-minded agencies, organizations, industries, academics, and individuals. Within the plan, priority aquatic species are listed for the Cape Fear River basin, including the migratory fish species of focus for this Action Plan. The plan points to a need to determine the vulnerability of species to threats such as dams, pollutants, and sedimentation. It supports monitoring to assess the impacts of dam removal projects and supports dam removal work.

The partnership synchronized the best available information with expert knowledge to create this Action Plan. Specific actions throughout this plan aim to gather more information about the extent of factors limiting migratory fish recovery in the Cape Fear River basin. With this document as a guide, partners can confidently move forward to address current limitations to the migratory fish stocks.

Juvenile American eels, or elvers.

Prior to this Action Plan, some beneficial actions were begun that will aid in enhancing aquatic connectivity and provide much needed access to and protect the habitat quality of migratory fish spawning and nursery grounds. These actions are described briefly below to illustrate examples of completed actions to meet Action Plan goals:

- In 2012, a rock ramp fishway was completed at the U.S. Army Corps of Engineers' (USACE) Lock and Dam #1. This structure provides for fish passage over the dam without removal of the lock and dam structure. In 2012 when about half of the fishway was completed, striped bass, American shad, and Atlantic sturgeon were tagged as part of a preliminary investigation to determine how many of them used the lock or used the partially completed rock dam to pass upstream. Formal evaluation of the ability of the completed rock arch to provide fish passage will be used to influence future priority setting for passage at USACE's Lock and Dams #2 and #3.
- In May 2012, American Rivers (AR) released a Barrier Prioritization Tool for the state of North Carolina. This tool will be refined to prioritize dam removal opportunities in the Cape Fear River basin that will benefit migratory fish (see Appendix 5).
- In summer 2012, Cape Fear River Watch (CFRW) and the University of North Carolina Wilmington (UNCW) initiated a water quality monitoring project to supplement NCDWQ regular sampling. This additional monitoring will collect biological and chemical information between Lock and Dam #1 and Lock and Dam #2 that can be used to study the recent and unprecedented blue-green algal (i.e., cyanobacterial) blooms in the middle and lower river. Data collection will frame future seasons of data collection in this reach of the river.

Aerial view of the rock arch ramp fishway under construction at Lock & Dam #1.

Some coast-wide problems that affect migratory fish populations in the Cape Fear River are beyond the scope of this Action Plan. For example, the partnership cannot address ocean factors (such as migratory fish caught as bycatch in commercial and recreational fishing), climate change, and other regional factors occurring outside of the Cape Fear basin. But bycatch concerns are being addressed by the ASMFC and regional fishery management councils.

Above: Lock & Dam #1 before construction of the rock arch ramp fishway rapids.

Right: Construction of the fishway was completed in November 2012.

Organizations and agencies are currently working with the general public to make them aware of the importance of fish passage and water quality. Outreach actions in the Action Plan build on these existing efforts, specifically

- Local soil and water conservation districts and NC Cooperative Extension offices work with a broad audience to protect and improve natural resources within their district. Both agencies work with the agricultural community, public and private landowners, and students and educators. Activities range from one-on-one training and technical assistance, to field days, to teacher workshops. Actions within the plan seek to find opportunities for synergy in outreach with the public.
- CFRW works to protect and improve the water quality of the lower Cape Fear River basin through education, advocacy, and action. Supporting migratory fish restoration efforts is a big part of that work. CFRW holds an annual "StriperFest" weekend to highlight the importance of the river's fishery and to educate the public about the environmental, economic, and recreational benefits that a strong migratory fish population would provide for the region. As part of StriperFest, CFRW funds tagging and water quality studies to help scientists better understand the life cycle of the river's migratory fish and how water quality impacts the fishery. CFRW also hosts a full day of educational activities for families centered on migratory fish and the importance of good water quality in our rivers. CFRW strongly supports making fish passage on the Cape Fear River a reality and has actively advocated for the construction of the rock arch ramp fishway at Lock and Dam #1.

About this Action Plan

The Action Plan is organized around three goals to meet the Cape Fear River Partnership's mission to restore and demonstrate the value of robust, productive, and self-sustaining stocks of migratory fish in the Cape Fear River. Actions in this plan are nested under problem statements (specific problems for migratory fish that the Action Plan aims to address) and targets (expected, measurable, ecological improvements) which fit under each of these three goals. See page 13 for a summary of the goals, problem statements, and targets of this Action Plan.

The actions are not ranked in priority order, but are listed thematically with time frames to identify which are feasible to complete when. Each action is labeled with a short, medium or long timeframe for completion. Short-term actions will be completed in year 1, by the end of 2013. Medium-term actions will be completed in 2 to 5 years, between 2014 and 2017. Long- term actions will take longer than 5 years and be completed in 2018 or beyond. Partners that will lead and assist with the implementation of the action are also identified. Applicable permits, such as USACE Section 404, USACE Section 10, and state Section 401 permits, will be pursued where necessary to implement the plan's actions.

All partners are limited to implementing actions within this plan to the extent permitted by law and subject to the availability of resources, in accordance with their respective agency missions, policies, and regulations.

Wilmington, NC.

Goal 1: Restore Access to historic migratory fish habitat.

Problem Statement 1: Obstructions block or impede migratory fish access to historic spawning and nursery habitat.

Target 1: Anadromous fish access is restored to the approximately 40% of their remaining historic habitat that is currently disrupted or blocked by dams.

Goal 2: Improve habitat conditions for migratory fish within the Cape Fear River basin.

Problem Statement 2: Spawning and nursery habitats are degraded.

Target 2: Existing riparian wetlands are maintained and restored/enhanced in areas with evidence of buffer loss and/or water quality issues.

Target 3: Reduced or eliminated future damage to instream habitat.

Problem Statement 3: The quantity and timing of flow in the Cape Fear River basin is altered compared to historical conditions. The ecological effects of these alterations to migratory fish need to be better understood.

Target 4. Seasonality and magnitude of flows support migratory fish needs at all life cycle stages.

Problem Statement 4: Degraded water quality (e.g., excess nutrients and increasing occurrences of blue green algal blooms) in the Cape Fear River and Northeast Cape Fear River is likely detrimental to migratory fish.

Target 5: Blue-green algal blooms eliminated in known locations (particularly in the regions of Lock and Dams #1 and #2 and Northeast Cape Fear) and future blooms prevented to help maintain minimum of 5 mg/L DO in spawning areas and reduce potential algal toxin formation.

Target 6: Nutrient input decreased.

Problem Statement 5: There is a need to prevent adverse chemical impacts to migratory fish.

Target 7: Inputs of toxic metals (e.g., mercury) and endocrine disrupting chemicals decreased.

Goal 3: Engage new stakeholders and increase interest in improving fish passage and habitat conditions for migratory fish through communication of socioeconomic values associated with such improvements.

Problem Statement 6: Socioeconomic benefits such as commercial and recreational fishing, tourism, recreation, water quality, and water supply are impacted by conditions that threaten migratory fish.

Target 8: Estimate socioeconomic values associated with increasing and improving fish passage and habitat conditions for migratory fish.

The Cape Fear River Basin

The 6th-order Cape Fear River is North Carolina's largest river basin that is completely contained within the state's borders, with its headwaters stretching from northwest of Greensboro to its mouth in the Atlantic Ocean at Bald Head Island. The basin covers an area of over 9,000 square miles, larger than the state of New Jersey, and there are over 6,000 miles of tributaries including four major ones: the Deep River, Haw River, Black River, and Northeast Cape Fear River (see Appendix III, Figure 1). Over one third of North Carolina's population lives within the basin. The Cape Fear is also the state's most ecologically diverse river basin, with some of the highest biodiversity on the eastern seaboard of the United States (Hall et al. 1999; Stein et al. 2000).

The Cape Fear basin is the only major river basin in North Carolina to empty directly into the Atlantic Ocean. This direct connection to the Atlantic was important for early settlers who used the Cape Fear as a way to move the natural resources found in the basin down-river, where they were loaded onto ocean-going vessels for shipment overseas. These goods included naval stores derived from the longleaf pine forests that blanketed the basin, rice from the plantations of the lower Cape Fear and timber. The port of Wilmington was a major blockade-running port during the Civil War, and later, steamboats plied the waterways of the Cape Fear connecting the many towns along its banks. As trade on the river increased so did efforts to make navigating the river easier. Over time, the river was dredged and channelized and locks and dams were constructed to facilitate navigation.

Status of Migratory Fish Stocks

The Cape Fear River once supported thriving stocks of migratory fish including American shad, sturgeon and striped bass (Earll 1887; Chestnut and Davis 1975). Migratory fish populations within the Cape Fear River have declined substantially over the past two centuries (Smith and Hightower 2012). At the beginning of the 20th century, the Cape Fear River was one of the most productive rivers in North Carolina for American shad, but current commercial landings are 87% lower than historic estimates (Smith and Hightower 2012). In the late 1800s river herring was the most economically important finfish harvested in North Carolina, and sturgeon was the most important fishery in the Cape Fear River (McDonald 1887). Yarrow (1874) reported that sturgeons were so numerous in the Cape Fear River "as almost to preclude the possibility of drift-fishing in the month of April." But by 1907, sturgeon had declined, in part due to blockages to historic spawning habitat as well as overfishing. This decline prompted concern about their future and that of other important migratory species in the river: "the history of the sturgeon is an unmistakable indication of what will eventually happen to the shad, alewives, striped bass, and other species unless ample provision is made for the survival of a sufficient percentage of the annual run until spawning has ensued" (Smith 1907).

Today, overfishing, declining water quality and habitat, and blockage of upstream spawning migrations have continued to limit these once thriving populations of migratory fish (Deaton et al. 2010; NCWRC 2005; Winslow et al. 1983). Populations have decreased greatly in North Carolina (Ashley and Rachels 2011; NCDMF 2007; NCDMF and NCWRC 2004; NCDMF and NCWRC 2012; Smith and Hightower 2012) and along the entire East Coast (ASMFC 2009; ASMFC 2010). Specific population estimates are not available for all migratory fish stocks for the Cape Fear River, but available data verify the depressed nature of these stocks (see Table 1). State and federal agencies have limited or banned the directed harvest of many of these species in the Cape Fear River to protect the diminished populations.

Atlantic sturgeon:

The Atlantic sturgeon population in the Cape Fear River is suspected to be less than 300 spawning adults (ASSRT 2007). The harvest of Atlantic sturgeon has been banned in state and federal waters since 1991. However, the ASMFC has recognized that fishery management measures alone cannot sustain stocks of migratory fish species if sufficient quantity and quality of habitat is not available (ASMFC 1999). In 2012, NOAA's National Marine Fisheries Service listed the Carolina distinct population segment of Atlantic sturgeon as endangered under the Endangered Species Act, an action that triggers several additional conservation measures by federal and state agencies, private groups, and individuals (77 FR 5914).

Tagging sturgeon for monitoring. Photo courtesy of NCDMF.

Shortnose sturgeon:

The most recent population estimate of shortnose sturgeon in the Cape Fear River is less than 50 individuals, based on analysis of tag/re-capture data by the Shortnose Sturgeon Recovery Team in 1995. (Mary Moser, personal communication, 2013). The shortnose sturgeon was listed as endangered throughout its range in 1967 under the Endangered Species Preservation Act of 1966 (a predecessor to the Endangered Species Act). NOAA's National Marine Fisheries Service later assumed jurisdiction for shortnose sturgeon under a 1974 government reorganization plan (38 FR 41370). No harvest or bycatch of shortnose sturgeon is allowed in state or federal waters. A fishing moratorium has been in place in state waters since 1991 for shortnose sturgeon.

Striped bass:

Evidence suggests that only a remnant population of striped bass remains in the Cape Fear River (NCDMF and NCWRC 2004; NCWRC 2012a). Based on catch-per-unit-effort and landings records, striped bass in the Cape Fear River have not increased in response to management efforts and are low in abundance relative to other North Carolina rivers (Patrick and Moser 2001; NCWRC 2012a). Ashley and Rachels (2011) characterized the Cape Fear River stock of striped bass as severely diminished in comparison to other North Carolina coastal rivers. Smith and Hightower (2012) collected few striped bass eggs in plankton samples taken below the three locks and dams and in the Piedmont above Lock and Dam #3, areas that are thought to be the best spawning habitat for striped bass. Striped bass have been protected by NCDMF and NCWRC through a harvest moratorium in the Cape Fear River and its tributaries since 2008. Amendments to the striped bass fishery management plan are the preferred way the two agencies can change the management of striped bass in the Cape Fear River. The striped bass plan is projected to be reviewed by NCDMF and NCWRC in 2017 or 2018.

American shad:

The population size of American shad in the Cape Fear River is unknown but considered to be well below historical levels (NCWRC 2012b). Catch-per-unit-effort from electrofishing in the Cape Fear is similar to the Neuse River and lower than estimates for the Tar and Roanoke rivers, but those comparisons may be misleading because of differences in river size and topography at survey sites. In 2012, the ASMFC required reductions in harvest for American shad in the Cape Fear River as part of North Carolina's sustainable fishing plan for this species. The status of American shad will be reviewed annually to ensure the stock is remaining sustainable based on sustainability parameters established in the North Carolina American Shad Sustainable Fishery Plan (NCDMF and NCWRC 2012).

River herring

River herring:

River herring are overfished in North Carolina (ASMFC 2009). In 2006 the NCWRC established a harvest moratorium for river herring in all inland waters. The NCDMF under NCMFC direction followed suit in 2007 and implemented a statewide moratorium on all harvest of river herring in the joint and coastal waters of North Carolina. Many other states along the mid-Atlantic have similar bans on herring possession. The ASMFC prohibited harvest of river herring in state waters along the entire East Coast beginning in January 2012, unless a given state had an approved sustainable fishing plan. Recent electrofishing sampling in the Pasquotank, Chowan, Tar, Neuse, and Cape Fear river basins (NCWRC 2012b) found that relative abundance of river herring remains low and suggests the need for continued protection through a harvest moratorium. The North Carolina River Herring Fishery Management Plan (NCDENR 2000) is currently being reviewed (2013) and could possibly be amended to better protect and restore river herring populations.

American eel:

The ASMFC's recent stock assessment for the American eel determined that the U.S. East Coast stock is depleted, but could not assess whether overfishing was occurring, based on the trend analyses conducted (ASMFC 2012). NCDMF (NCDMF 2012) has adopted the ASMFC assessment results. The status of eels within the Cape Fear River basin was recently discussed by representatives of the four fishery management agencies (NCDMF, NCWRC, NOAA and USFWS) with additional data provided by NCDWQ; they concluded that the status of eels in the Cape Fear River basin is technically unknown (W. Laney, USFWS, personal communication, July 30, 2012). Currently, there is insufficient data to conduct a basin-specific eel stock assessment. NCDMF has a minimum size limit of 6 inches and a recreational catch limit of 50 eels.

Although historic data are lacking to quantitatively determine original population sizes, rough estimates for potential population sizes can be derived based on historic landings data or historic spawning habitat in the river (see Appendix IV for methodology). Information is also available to provide estimates for current population sizes for some species, which is summarized in Table 1.

Table 1: Estimates for population potential and current population estimates for Atlantic sturgeon, shortnose sturgeon, American shad, river herring, striped bass and American eel.

Species	Population potential	Recent population estimates
Atlantic sturgeon	8,700 (based on historic landings, Earll 1887)	<300 (ASSRT 2007)
Shortnose sturgeon	31,000 (based on Kynard 1997)	<50 (based on recent estimates; Mary Moser personal communication 2013)
American shad	447,000 (based on historic habitat, St. Pierre 1979)	Not available
River herring	2,300,000 (based on historic habitat and historic landings, Chestnut and Davis 1975)	Not available
Striped bass	100,000 (based on historic landings from Chestnut and Davis 1975 and personal communication with C. Collier, NCDMF, and J. Hightower, NCCFWRU)	10,000 (based on NCDMF tagging data and personal communication with C. Collier, NCDMF)
American eel	Data is insufficient to determine population potential.	Data is insufficient to estimate current population size.

Number of Obstacles to Fish Passage

The construction of small low-head mill dams, locks and dams, and large hydroelectric dams over the past two centuries substantially limited the range of migration for fish (Walburg and Nichols 1967). For example, by 1852, 11 locks and dams had been constructed between Fayetteville, North Carolina (river kilometer 220) and the modern day site of Buckhorn Dam (river kilometer 300) to aid the passage of company ships bound for the coal fields of the Deep River Coal Company (Thompson 1852). Upstream passage was limited except during boat lockage and possibly during extended periods of high flow (Nichols and Louder 1970).

Buckhorn Dam. Photo courtesy of Lynette Batt, American Rivers.

There are currently more than 1,100 dams in the basin (North Carolina Dam Inventory 2012) (See Appendix III, Figures 2, 3 and 4 which show some of the major dams on the river. These major dams were identified from the National Inventory of Dams, the Army Corps of Engineers, dams that NOAA deems significant to diadromous fish conservation, and Google Earth). The most prominent obstructions existing today are the three locks and dams in the middle basin constructed between 1913 and 1934 and operated by USACE. These locks and dams were built for navigation purposes but now serve primarily to create pools for municipal and industrial water supply withdrawals.

Migratory Fish Habitat and Habitat Use

The Cape Fear River basin contains approximately 400 river miles and more than 14 square miles of migratory fish habitat (Joe Hightower and Fritz Rohde, pers. com., 2012). The basin contains numerous estuarine, riparian, and forested wetland areas, which are important spawning and nursery grounds for anadromous fish species (Wharton et al. 1982; NCDMF 2000).

In late winter, river herring, striped bass, Atlantic sturgeon, American shad, and others migrate from the ocean and lower estuary to spawn upstream in freshwater areas. After spawning, the surviving adults migrate downstream to the lower estuary or oceans, while the juveniles remain in nursery habitats downstream from spawning locations but still within the freshwater low-salinity system. Those juveniles spawned in spring begin their seaward migration in late fall (Sholar 1975; Marshall 1976; Sholar 1977; Fischer 1979; Hawkins 1980). American shad, striped bass, Atlantic sturgeon, and shortnose sturgeon primarily spawn in the main stem of the Cape Fear River, while river herring spawn in tributary creeks (Funderburk et al. 1991).

American eel are catadromous species that spawn in the winter and spring in the Sargasso Sea, located in the middle of the Atlantic Ocean. Larvae develop in ocean currents and by the following winter/spring migrate to freshwater for growth to maturity (Greene et al 2009). Eels may remain in freshwater and brackish systems for up to 30 years before maturing and migrating to the ocean to spawn (Greene et al. 2009).

Cape Fear River Partnership

The availability of high-quality spawning and nursery habitat for migratory fish has decreased in the basin due to a variety of fishing and non-fishing activities. To protect some of these important habitats from further degradation, the NCMFC and NCWRC have developed special designations for migratory fish spawning and nursery grounds (see Appendix III, Figure 5). Anadromous Fish Spawning Areas (AFSAs) are those areas where evidence of spawning of anadromous fish has been documented by direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae (15A NCAC 03I .0101 (b) (20) (C) and 15A NCAC 10C .0602). Primary Nursery Areas (PNAs) are those areas of the estuarine system where initial post-larval development takes place (15A NCAC 03N .0102 (b)). Inland PNAs are areas inhabited by the embryonic, larval, or juvenile life stages of marine or estuarine fish or crustaceans due to favorable physical, chemical or biological factors (15A NCAC 10C .0502). The NCMFC designates PNAs in meso-polyhaline waters utilized by estuarine species, whereas the NCWRC designates inland PNAs in oligohaline to freshwater that is used by resident freshwater and anadromous species. NCMFC-designated PNA designations are afforded some protections from pressures of fishing (i.e., no trawling) and non-fishing (i.e., no navigational dredging). AFSA designations have some restrictions on navigational dredging windows.

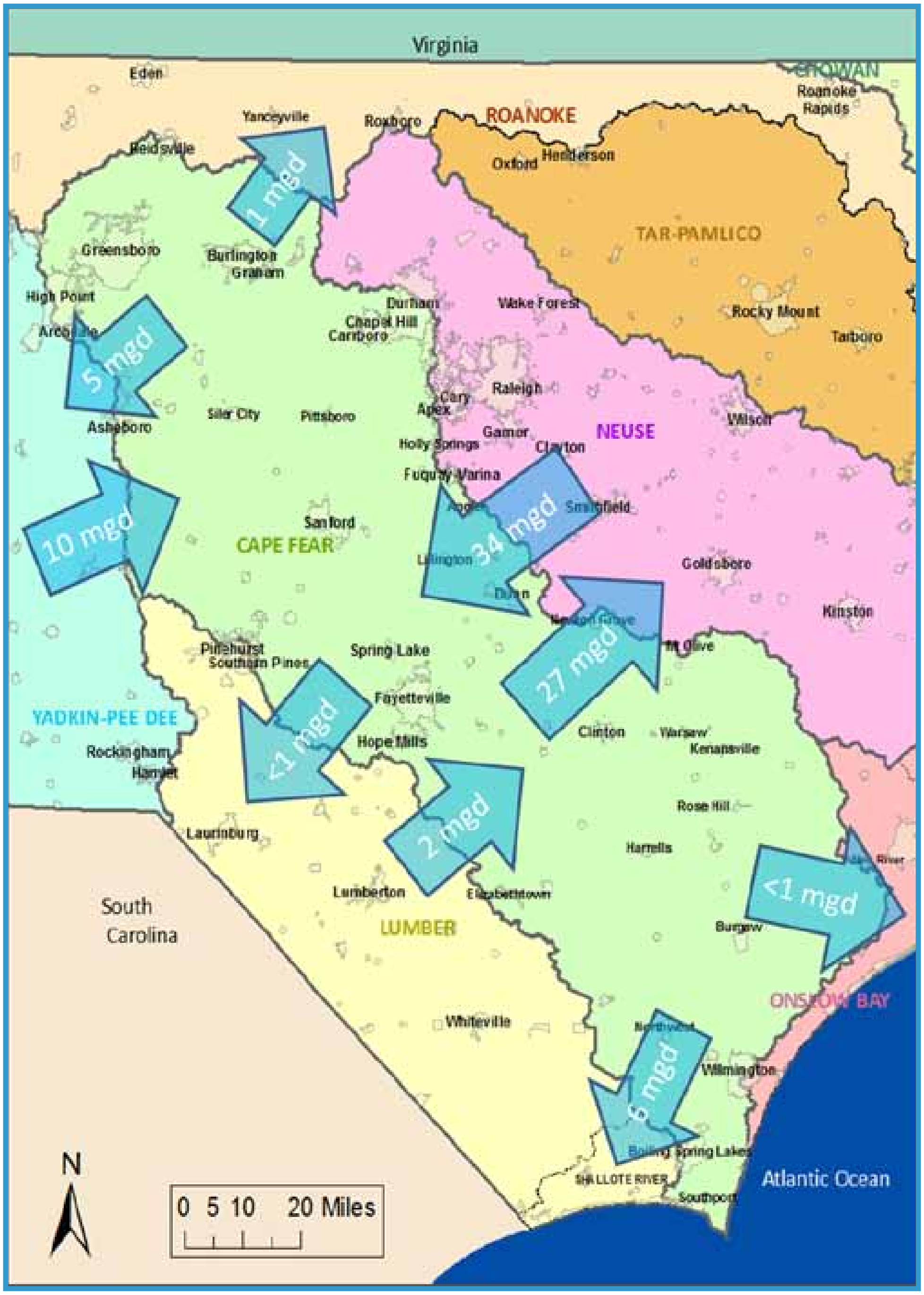
Quantity of Water

Water quantities in the Cape Fear River basin are affected by natural weather conditions, and by engineered conditions. Water quantity in the main stem of the Cape Fear River and its tributaries is an essential aspect of habitat health as migratory fish need particular flow conditions during specific seasons for passage upstream and for their water quality habitat needs. For example, striped bass successfully spawn at optimal water velocities between 3.3 and 6.6 feet per second (ft/s) and adult American shad prefer water velocities between 2 and 3 ft/s (Fay et al. 1983; Mackenzie et al. 1985; Hill et al. 1989). These are general flow requirements for these species, which need to be better clarified specific to migratory fish in the Cape Fear River basin.

Some threats to the quantity of water available for migratory fish include the engineered changes to the flows in the Cape Fear River basin due to reservoirs, water withdrawals, and interbasin water transfers. The USACE's B. Everett Jordan Dam creates the largest reservoir in the basin, capable of holding almost 69.7 million cubic feet of water (Weaver 2009). Normally, water from the reservoir is managed in a modified run-of-river mode in order to maintain normal pool elevation. The instantaneous release requirement from the dam is 40 cubic feet per second (cfs), as long as a flow target of 600 cfs is maintained at the U.S. Geological Survey (USGS) gage at Lillington, North Carolina, downstream of the reservoir. However, during serious droughts the target flow downstream at Lillington is reduced to extend the available storage in the reservoir, based on Jordan's Drought Contingency Plan. These kinds of flow alterations may be negatively affecting migratory fish.

Water withdrawals from the Cape Fear River help meet human resource needs in the river basin. Drinking water needs for residents in the basin are met in part by surface water withdrawals. In 1997, there were 78 water systems in the basin that depended on surface water withdrawals to meet some or all of their customer's drinking water needs. For example, compared to 1998 rates, withdrawals upstream of Fayetteville are projected to increase 93% by 2030 and 161% by 2050 (NCDWR 2002). Groundwater withdrawals also may threaten the quantity of water available for migratory fish, although the role of groundwater in stream flow generation is poorly understood. Groundwater is the major source of water for residents of the Black and Northeast Cape Fear sub-basins and much of the coastal region of the Cape Fear River sub-basin. Throughout the basin are 61 systems with the combined capacity to pump 64 million gallons per day (MGD) of groundwater (NCDWR 2001).

To meet water consumption needs in North Carolina, surface water is sometimes transferred from one river basin to another. By North Carolina law, interbasin transfers over a certain threshold require a certificate to mitigate the impacts of both the removal of water from the source basin, and the addition of water (growth impacts) to the receiving basin. The largest water transfers in the Cape Fear River basin are associated with the Piedmont Triad Regional Water Authority and the Town of Cary (T. Ogallo, NCDWR, personal communication, August 3, 2012). In 1991, the Piedmont Triad Regional Water Authority received a certificate to transfer 30.5 MGD from the upper Deep River to the adjoining Haw River sub-basin and to the Yadkin River basin, which is adjacent to the Cape Fear River basin (NCDWR 2002). Cary's certificate was issued in 2001 and authorizes the transfer of 24 MGD from the Haw River sub-basin to the Neuse River basin. Other sizable transfers include the Harnett County Regional Water System; the City of Wilmington and Pender and Brunswick county transfers, which are supplied in part by the Lower Cape Fear Water and Sewer Authority; and transfers of drinking water and wastewater treatment plant discharges between the Haw River sub-basin and the Neuse River basins.



Total surface water interbasin transfers between the Cape Fear River basin and adjoining basins, by public water supply systems based on 2002 or 2004 system plans are illustrated here. (NCDWR 2012).

Quality of Water

Water quality is an important component of migratory fish habitat. Fish require specific water conditions to successfully access upstream habitats. Cape Fear River water is also used directly by humans for drinking and for industrial water supplies and recreation, among other uses. Dissolved oxygen (DO), water temperature, turbidity, and water flow are important water quality characteristics that combined with nutrient inputs define water quality parameters affecting migratory fish in the Cape Fear River. Flowing water increases levels of DO as oxygen from the air mixes into the water at the surface where the water is agitated. Water temperature also affects DO levels. Increased water temperature physically reduces the capacity of water to hold DO. Elevated temperatures combined with nutrient loading creates conditions favoring algal blooms, which lead to higher biological oxygen demand (BOD) and lower DO (Mallin et al. 2006). Such conditions decrease the quality of the water migratory fish pass through and spawn in. DO concentrations below about 6 milligrams per liter (mg/l) can slow fish growth (Gray et al. 2002). Specifically, larval alewife and adult American shad and striped bass require DO levels greater than 4 mg/l (Funderburk et al. 1991). High concentrations of suspended solids have been shown to adversely affect various life stages of anadromous fish. For example, spawning adults avoid areas of extreme turbidity (Steel 1991), successful attachment and incubation of eggs are reduced due to exposed hard bottom being silted over (ASMFC 2004), and survival and feeding ability of striped bass larvae was found to be significantly reduced in some areas with high turbidity (Auld and Schubel 1978).

Inputs from the land adjacent to the Cape Fear River basin can affect nutrient levels and other water quality parameters in the Cape Fear River basin. These inputs come from a variety of land uses, including municipalities, industry, and agriculture. As of 2010, more than 2 million people lived in the Cape Fear River basin (NCDENR 2012). Approximately 12% of the land in the basin is developed and the percent impervious surface (pavement, roofs, etc.) has increased slightly in the basin between 2001 and 2006 (Fry et al. 2011). Urbanization and population pressures are concentrated in the Upper Cape Fear River Basin, in the Raleigh-Durham-Chapel Hill, Fayetteville and Greensboro areas, and along the coast in the lower portions of the river basin (see Appendix III, Figure 6). There are 203 permitted industrial and municipal wastewater dischargers into the Cape Fear River system with the total discharge quantity permitted to 429 million gallons per day (NCDENR 2012). Agricultural nutrient sources also affect the Cape Fear River's water quality. Approximately 23% of the land use in the basin is devoted to agriculture and livestock production (Xian and Homer 2010), with livestock production dominated by swine and poultry operations. Agricultural, rural, and forested land uses are concentrated in the middle Cape Fear River Basin, with many large animal farms located in the eastern portion (see Appendix III, Figure 7).

Following rain events in the Piedmont,(the plateau region upstream of the Atlantic Coastal Plain), the main stem of the lower Cape Fear River can become quite turbid. Fine silt and clay runs off from the Piedmont and upper Coastal Plain and is carried downstream to the upper estuary (Benedetti et al. 2006). Turbidity concentrations in the main river are positively correlated with river discharge, as are fecal bacteria concentrations (Mallin et al. 2000a). In the main stem of the river and its tributaries turbidity and fecal bacteria concentrations increase with local rainfall amounts (Mallin et al. 2000b) and population density and specific land uses in tributaries are positively correlated to fecal counts (Mallin et al. 2009). Rain fall over impervious surfaces can alter flow runoff into adjacent streams and may alter water temperatures. Water temperature in riverine systems is a main cue to initiate upstream migration for spawning. Spawning of striped bass in coastal rivers, for example, is triggered by increasing water temperatures in the spring (Hill et al. 1989; Funderburk et al. 1991).

Cape Fear River Partnership

Stormwater pipe. Photo courtesy of NCDWQ.

Until recently summer algal blooms (Appendix III, Figure 8), characterized by elevated densities of algae (>10,000 units/ml) or visual accumulations and surface films, were confined to the slow moving water conditions of the basin, predominating behind the USACE's three locks and dams (Kennedy and Whalen 2008). Flushing in the Cape Fear River is usually high (Ensign et al. 2004), reducing residence time for algal bloom formation. During periods of low flow (as occurred in 2008 and 2010), algal productivity and biomass increase due to the settling of suspended solids, longer residence times and better light conditions for algal growth. Periodically, major algal blooms are seen in the tributary stream stations, some of which are affected by point source discharges.

Research is ongoing to determine the suite of underlying factors behind the extent of recent algal blooms. Since 1995 the LCFRP has collected water quality data from 35 sampling locations in the lower basin on a monthly basis (Appendix III, Figure 1 delineates the lower, middle, and upper river). Two other Cape Fear Monitoring Coalitions, the Upper and Middle Cape Fear River Basins, also collect water quality data on their respective sections of the river and the NCDWQ collects basin-wide water quality data. These state data are summarized in two reports: the Cape Fear River Basinwide Water Quality Plan (NCDWQ 2005) and an Environmental Sciences Section of the Cape Fear Basin Report (NCDWQ 2009).

Healthy Ecosystems, Strong Economies

The economic strength of a community is often derived from the abundance of its natural resources and the health and well-functioning of its ecosystems. This is particularly true in coastal communities like those in the Cape Fear River basin that depend on clean water and healthy habitats to support fisheries, tourism and recreation for their livelihoods, and provide a source of clean drinking water. North Carolina recreational fishing expenditures (trip related expenditures, fishing and auxiliary equipment, membership dues, licenses and permits included) were calculated at more than $1.5 billion in 2011 (USFWS 2011). In 2010, more than 33,000 people in North Carolina were employed in the tourism and recreation industry, with their wages totaling almost $500 million (National Ocean Economics Program Database 2010). And in 2011, the total commercial fish landings in North Carolina for all species was valued at more than $71 million, $1.16 million of which was attributed to landings of striped bass alone (National Marine Fisheries Service 2011). Without conservation actions to further protect and restore habitat and improve access for migratory fish, the communities in the Cape Fear River basin stand to lose a lot.

Socioeconomic assessments conducted in other basins and watersheds begin to give us a picture of the socioeconomic benefits that we can expect from the conservation actions in this Plan. For example, the removal of the Elwha Dam in Washington State is projected to result in $138 million in aggregate benefits over 10 years (Loomis 1996). In Clallam County, Washington, the benefits from the removal of the Elwha Dam are expected to occur through an increase in sales by the fishing industry, a growth in hotel and restaurant receipts, and from sales from additional retired or commuting residents moving to the county to enjoy its amenities (Battelle 2007). The removal of four dams on the Lower Snake River was estimated to result in benefits ranging from $206 million to more than $2 billion depending on the number of visitor days in the river basin (Loomis 1999). A 2001 study of the Upper Klamath Basin in Oregon and California found the increasing salmon populations could also lead to an increase in jobs, with each additional 1,000 commercially caught salmon generating 1.5 jobs (Kruse and Scholz 2007).

Local studies also show that there is a demand for conservation activities. In the Cape Fear River basin, studies have been conducted to determine the willingness of residents in the basin to pay for improved water quality. In one study it was found that New Hanover County residents were willing to pay $175 per person per year for 5 years even if they never felt they would use the river, and up to $326 per person per year for 5 years if they did feel they would use the river (Dumas et al. 2005). In another survey, residents of Durham, Wake and Orange counties, all partly located in the Cape Fear River basin, were willing to pay between $9.36 and $10.40 per month for conservation upstream of their water intake, and were willing to pay between $6.74 and $9 per month for conservation downstream of their water intake (Jihyung Joo 2011). Thus, improved water quality is valuable to people and is an important aspect to maintaining fish habitat.

The actions in this plan are important for Cape Fear residents who rely on improved fish access, water quality and habitat to support fisheries, tourism and recreation, as well as to provide clean drinking water. Likewise, measuring the socioeconomic benefits of these actions is critical to providing land and water resource managers with the data they need to make decisions and prioritize actions.

Goal 1: Restore Access to Historic Migratory Fish Habitat in the Cape Fear River basin

Problem Statement 1: Obstructions block or impede migratory fish access to historic spawning and nursery habitat.

Restoring migratory fish access to historic spawning and nursery habitats will help rebuild currently depressed populations to support healthy ecosystems and sustainable recreational and commercial fisheries. The historic and current spawning habitats of migratory species in the Cape Fear River are known for some but not all of the species that are the focus of this Action Plan. The Smiley Falls area near Erwin, NC in the Middle Basin of the Cape Fear River may be important historic spawning grounds for many of these migratory fish species (J. Hightower, NCCFWRU, personal communication, July 31, 2012; Nichols and Louder 1970; Winslow et al. 1983). However, access to this area and to other likely historic spawning areas in the Deep River is blocked by several major dams.

Specific information about the historic and current spawning habitats of the migratory species of focus in this action plan are described below (see Appendix III, Figures 2, 3, and 4 for location references below).

- **American shad and striped bass:** The Smiley Falls area is generally considered to be the historical spawning grounds for American shad in the Cape Fear River (Nichols and Louder 1970). The Smiley Falls area could be the historical spawning grounds for striped bass as well (J. Hightower, NCCFWRU, personal communication, July 31, 2012) however the upper limit of historic spawning habitat for striped bass is generally unknown. American shad have also historically spawned in an area of the Deep River (Jackson et al. 1771).

  Smith and Hightower (2012) used egg sampling and tagging methods in 2007 and 2008 to examine the effects of the three USACE's Lock and Dams on migration and spawning of shad and striped bass. Thirty-five percent of tagged shad and 25% of striped bass migrated upstream of Lock and Dam #3. However, they found that most shad spawning took place downstream of Lock and Dam #1, and most striped bass spawning occurred between Lock and Dams #2 and #3. The study concluded that although the current locking program provides some (substantially limited) access to historical spawning habitat, further improvements in fish passage would benefit both species.

  The current extent of spawning migrations for American shad and striped bass are not known with certainty, but a reasonable estimate of the extent can be determined by taking a weighted average of the distances upstream where tagged fish were detected (based on Smith and Hightower 2012), resulting in a mean upstream distance of 109 river miles for striped bass (near Fayetteville, NC) and 122 river miles for American shad (near Wade, NC).

- **River herring:** The majority of spawning habitat for river herring lies below Lock and Dam #1 in the main stem of the Cape Fear River as well as in the Northeast Cape Fear River and other tributaries, with the historic upstream extent reaching to Smiley Falls (Winslow et al. 1983; Nichols and Louder 1970).

- **Atlantic sturgeon and shortnose sturgeon:** Smiley Falls may also be the historical spawning grounds for Atlantic sturgeon and shortnose sturgeon (J. Hightower, NCCFWRU, personal communication, July 31, 2012); however, the upper limits of historic spawning habitat for these species are generally unknown. Lock and Dam #1 is probably the current extent of Atlantic sturgeon migration in the Cape Fear River (based on Moser et al. 1998).

American eel

- **American eels:** Historical records (North Carolina Museum of Natural Sciences 2012) and stream sampling data from NCDWQ (unpublished data from Bryn Tracy, NCDWQ) suggest that dams are hindering, but not entirely blocking, eels from their upstream migrations and recruitment to the entire basin. Sites with larger numbers of eels are concentrated in the Coastal Plain region of the basin, with lower numbers from inland sites.

In 1962, through an agreement among NCWRC, USACE, and USFWS, a program was implemented in which the lock at each of USACE's three Lock and Dams was used for moving fish upstream to continue their spawning runs in the middle Cape Fear River basin (Fischer 1980; Moser et al. 2000). Nichols and Louder (1970) estimated that between 1962 and 1966, 9,770 American shad passed through Lock and Dam #1 (the lowermost structure), and only 50 passed at Lock and Dam #3 (the uppermost structure).

Although construction of the rock arch ramp fishway at Lock and Dam #1 is complete, the USACE's Lock and Dams #2 and #3 remain and continue to block spawning runs to Smiley Falls. Restoring greater fish passage beyond these two barriers is critical to rebuilding migratory fish populations in the Cape Fear River and a top priority of this Action Plan. These actions may increase the availability of spawning habitat above Lock and Dam #3. If a sufficient number of fish access habitat above Lock and Dam #3, then detailed field studies in that section of the river will be warranted in order to evaluate use of the newly available spawning habitat.

Access to the Deep River and historic spawning habitats in the upper Cape Fear River basin is currently blocked by Buckhorn Dam on the Cape Fear River and Lockville Dam near the mouth of the Deep River. Fish passage around these obstructions would allow migratory fish to reach historic spawning sites in the Deep River. Several more dams block access up the main stem of the Deep River and into its tributaries. There are no major obstructions to fish passage on the Northeast Cape Fear River or Black River in the lower Cape Fear River basin.

Target 1: Anadromous fish access is restored to the approximately 40% of their remaining historic habitat that is currently disrupted or blocked by dams.

Army Corps of Engineers' Lock and Dam #2 (above) and #3 (below).

ACTION 1: Restore fish passage in mainstem river past Lock and Dam #3	**Timeframe**	**Lead**
1.1: Pursue opportunities to obtain material to fill scour hole below Lock and Dam #2 from the North Carolina Department of Transportation projects and other sources	Short/Medium	USACE
1.2: Continue discussions with Duke Energy and the regulatory agencies about mitigation for proposed Shearon Harris nuclear plant expansion	Medium	State agencies, USFWS, and NOAA
1.3: Identify mechanism to provide funding for fish passage at Lock and Dams #2 and #3. Then approach potential funding sources for support (e.g., agency fish passage funding, non-governmental organizations, municipal)	Medium	USFWS
1.4: Examine funding options via Sections 216 and 1135 of the Water Resources Development Act of 1986 for fish passage at Locks and Dams #2 and #3	Long	USACE
1.5: Investigate mitigation opportunities raised by potential additional Wilmington dredging work (e.g., in PNAs) as a way to further incentivize installing fish passage at Lock and Dam #2	Long	NOAA, USFWS, NCDMF, and NCWRC
1.6: Construct rock arch ramp or other fish passage at Lock and Dam #2, pending appropriate authority and non-federal match	Long	USACE, Fayetteville PWC
1.7: Construct rock arch ramp or other fish passage at Lock and Dam #3, pending appropriate authority and non-federal match	Long	USACE, Fayetteville PWC
1.8: Engage in discussions with Duke Energy about fish passage at Buckhorn Dam once successful fish passage achieved past Lock and Dams #2 and #3	Long	NOAA, USFWS, NCDMF, and NCWRC
1.9: Work with industry to identify potential location of impingement/entrainment issues and reduction technologies associated with power plant National Pollutant Discharge Elimination System (NPDES) permits.	Short	NCDWQ and NCDMF

ACTION 2: Restore fish passage and habitat condition in Cape Fear River tributaries via targeted dam removals, coordinating with other aquatic species interests	Timeframe	Lead
2.1: Pursue priority dam removal projects on the Little River, including an evaluation of the breached, unnamed dam on Fort Bragg property	Short	AR and DC&A with help from NOAA
2.2: Apply prioritization tool for North Carolina to Cape Fear and barrier removal projects that will benefit migratory fish	Medium	NOAA and USFWS co-lead, with help from NCDMF and NCWRC
2.3: Continue discussions with owner of Lockville Dam about possible opportunities for future removal	Medium	AR with help from NOAA
2.4: Pursue priority dam removal projects on the Haw and Deep Rivers	Medium	AR with help from NOAA
2.5: Advance priority barrier removal projects identified through NC Barrier Prioritization Tool and on-the-ground investigation through available grant processes	Medium	NOAA, AR, DC&A ,and USFWS

ACTION 3: Protect and restore fish access to habitat in tributaries via efforts to prevent and remove lateral blockages, or if blockage removal is not feasible to otherwise provide fish passage	Timeframe	Lead
3.1: Assess impairments to floodplain connectivity using NHD Plus hydrography and identify priority sites where improvements are needed	Medium	TNC lead with help from USFWS and NOAA
3.2: Seek funding for removing priority obstructions or providing passage from above analysis (action 3.1)	Long	AR, NCDMF, NCWRC, NOAA, USFWS
3.3: Review/revise North Carolina Department of Transportation road crossing guidelines to protect migratory fish habitat from existing and future problems	Medium	NCWRC, NCDMF, NOAA,USFWS, and North Carolina Department of Transportation

ACTION 4: Gather information about population dynamics to inform future necessary management and restoration actions	**Timeframe**	**Lead**
4.1: Compile history of migratory fish and fisheries in the Northeast Cape Fear River by examining landings and other historic fisheries data, gathering existing data from state records, and speaking with fishermen	Short	NOAA
4.2: Assist NCDMF and NCWRC with future tagging and field sampling efforts for anadromous fish	Short (and ongoing)	NOAA and USFWS with help from CFRW
4.3: Compile existing survey data for American eels to determine distribution within the Cape Fear River basin, with the goal of determining where eel passage efforts are needed	Short	NOAA and USFWS
4.4: Examine archived Native American middens and archeological records for sturgeon scutes to determine historical habitat usage	Medium	USFWS
4.5: Monitor fish passage past Lock and Dam #1 (striped bass, sturgeons, shad, flathead catfish) to determine effectiveness of full rock ramp structure	Short/Medium (2013-2015)	NCDMF, USACE, and NCCFWRU with help from CFRW
4.6: Include Cape Fear fish passage and barrier removal needs (priority locations and methodology) for shad in NC's habitat plan under ASMFC Amendment 3 for shad and river herring management plan (as per the sustainable fishing plan required for shad)	Medium (due 2014)	NCDMF and NCWRC
4.7: Monitor movement of fish through the potential natural barriers between Lock and Dam #3 and Buckhorn Dam	Long	NCWRC, NCCFWRU, USFWS, and Duke Energy

ACTION 4 (continued)	Timeframe	Lead
4.8: Compile existing data on spawning and nursery areas for shad, striped bass, and Atlantic and shortnose sturgeon in the Cape Fear River	Short	NCDMF, NCWRC, and NOAA
4.9: Seek funding via Endangered Species Act Section 6 grant from NOAA or other mechanism to assess young-of-the-year Atlantic and shortnose sturgeon in the Cape Fear River	Long	NCDMF and NCWRC

Cape Fear Striped Bass. Photo courtesy of Keith Ashley.

Goal 2: Improve Habitat Conditions for Migratory Fish within the Cape Fear River basin

Problem Statement 2: Spawning and nursery habitats are degraded.

Competing uses for the resources of the Cape Fear River have led to decreasing availability of high quality habitat for its migratory fish. Alterations to riverine spawning and nursery areas and the blockage of access to habitat from dams are of significant concern and contribute to the poor status of many of the stocks that rely on the Cape Fear River. Habitat alterations may limit food availability at critical times and reduce suitable nursery habitat areas. Drainage and filling of wetlands has eliminated spawning areas in North Carolina (NCDENR 2000).

The dredging and filling of aquatic habitats is particularly damaging to migratory fish, causing the physical alteration of habitat, increasing siltation, and possibly reducing food availability. The dredging and deepening of inlets and associated channels can also increase salt water intrusion, causing a change in wetland species composition along the boundary between salt/brackish marshes and riverine swamp forests.

The historic deepening of the lower Cape Fear River caused a large conversion of tidal/riverine swamp forests to salt/brackish marsh (Hackney et al. 2007). Striped bass and sturgeon near the blasting areas of past channel deepening projects have been found to suffer from lost equilibrium, distended swim bladder, hemorrhaging, and death (Moser 1999). The Port of Wilmington is of economic importance to the area and the channel is dredged regularly for large vessels to continue to access the port. Maintenance dredging at the Port of Wilmington poses a threat to migratory fish by stirring sediments into the water column, impacting migration, and removing or burying benthic habitats. Maintenance dredging also has the potential to re-suspend contaminated sediments. The Cape Fear River channel was deepened by approximately four feet between 1999 and 2004.

Excessive sediment loading from nonpoint sources can gradually fill in creeks and small water bodies over time, reducing the depth and width of channels and covering the natural bottom (stones, aquatic macrophytes and benthic microalgae) so those habitat and food resources are not available to fish. Turbidity from sediment loading has been found to disrupt spawning migrations (Reed 1983) and results in decreased combined fish biomass (Aksnes 2007).

Target 2: Existing riparian wetlands are maintained and restored/enhanced in areas with evidence of buffer loss and/or water quality issues.

Photo courtesy of NCDWQ.

ACTION 5: Protect high quality spawning habitat	Timeframe	Lead
5.1: Continue enforcement compliance with North Carolina state rules and permit conditions for projects impacting migratory fish habitat in the Cape Fear River	Short (and ongoing)	NCDWQ
5.2: Work with NGOs and partners to explore and apply—where feasible—targeted protection actions affecting and adjacent to the priority spawning areas identified by the partnership: Smith Creek, Rice Creek, Town Creek, and Smiley Falls. Actions could include acquiring buffers, lands, and/or conservation easements, or special designations	Long	NCDMF, and NCWRC
5.3: Produce outreach materials on the value of vegetated shorelines for migratory fish habitat protection and importance of reducing non-point runoff associated with agriculture, forestry, and development land-use activities	Short	NCDMF with help from CFRW

Cape Fear wetland habitat.

Cargo ship near the mouth of the Cape Fear River.

ACTION 6: Protect river herring spawning and nursery grounds in flooded hardwood habitats	**Timeframe**	**Lead**
6.1: Create Geographic Information Systems (GIS) map of remaining inland freshwater wetlands and flooded hardwoods in the complete Cape Fear watershed (amount, location, size of stands), and provide data to the Coastal Land Trust of North Carolina, TNC, and other land trust focused NGOs	Medium	NOAA with help from NC Natural Heritage Program
6.2: Integrate Cape Fear River migratory fish data into existing spatial prioritization that directs TNC's land protection efforts	Medium	TNC
6.3: Land protection organizations and agencies, including TNC, the North Carolina Coastal Land Trust, other land trusts, and select local soil and water conservation districts, use results of GIS analysis (actions 6.1 and 6.2) to focus outreach and education activities with landowners and/or developers in promoting conservation easements, conserving hardwood habitats, and overall protection of riparian habitats	Medium	TNC
6.4: Provide educational program for landowners on river herring's need for flooded hardwood habitat	Short	CFRW

ACTION 7: Protect and restore the health of the Cape Fear River Estuary for migratory fish	TimeFrame	Lead
7.1: Determine the underlying causes of wetland loss in the coastal watershed of the Cape Fear River estuary and implement policies, programs, and /or projects to address the underlying causes identified	Medium	NOAA, with the Interagency Coastal Wetlands Work Group.

ACTION 8: Restore stream and wetland habitat in or influencing AFSAs and PNAs	Timeframe	Lead
8.1: Seek funding and partnership opportunities to restore aquatic connectivity to streams and wetlands in or influencing AFSAs and/or nursery areas, and encourage non-partner agencies to prioritize restoration actions in these habitats as well	Medium	NCDMF and NCWRC, with help from New Hanover County
8.2: Effectively manage or restore wetland areas currently conserved by TNC which are identified as priority buffers for migratory fish species	Long/ongoing	TNC

ACTION 9: Target funding opportunities to priority habitat research and restoration projects	Timeframe	Lead
9.1: Federal agencies (NOAA and NRCS) develop a better cooperative exchange of information in order to better understand any similar land based programs with funding for conservation	Medium	NOAA and NRCS
9.2: Identify specific areas within the Cape Fear River basin for the Conservation Reserve Enhancement Program (CREP) to focus on for marketing, including the impairments to flood plain connectivity sites that are identified in action 3.1	Short/Medium	NCDSWC

Cape Fear striped bass. Photo courtesy of Josh Raabe.

ACTION 10: Enhance knowledge of fish habitat use and identify high quality habitat areas in the Cape Fear River basin	Timeframe	Lead
10.1: Complete a basin-wide analysis to determine location of existing wetlands, aquatic habitats, and vegetated uplands, and determine change in land use over time that could be used by agencies for resource protection efforts	Short	TNC, Jennifer Alford, NCDMF, NCWRC, and NOAA
10.2: Compare information from action 10.1 analysis with existing anadromous fish habitat data (action 4.8) to identify important anadromous fish habitat areas in need of better protection or watershed restoration	Medium	TNC, Jennifer Alford, NCWRC, NCDMF, NOAA, NCCFWRU, and USFWS
10.3: Look at climate change and sea-level rise impacts on migratory fish habitat	Long	NCDMF, Arch, and North Carolina Natural Heritage Program
10.4: Incorporate river specific threats when developing the new Endangered Species Act recovery plans for shortnose and Atlantic sturgeon	Long	NOAA
10.5: Research possibilities and seek funding to conduct benthic surveys using side-scan sonar to assess potential Atlantic and shortnose sturgeon spawning habitat above and below existing barriers in Cape Fear River	Medium	USFWS and NCWRC co-lead, with help from NOAA, DC&A, and NCDMF

Cape Fear River habitat.

Target 3: Reduced or eliminated future damage to instream habitat.

ACTION 11: Protect instream fish habitat from in-stream impacts	Timeframe	Lead
11.1: Develop NCDMF guidelines for best practices in design and siting of energy development and infrastructure projects to minimize negative impacts to fish habitat, avoid new obstructions to fish passage, and, where possible, provide positive impacts	Medium	NCDMF with help from NCWRC, NOAA, and USFWS
11.2: Develop joint interagency recommendations that each agency would use when reviewing permit applications for dredging and filling	Medium	NCDMF and NCWRC co-lead, with help from NOAA and USFWS
11.3: Verify current instream work moratorium window is adequate for protecting Atlantic sturgeon during spawning periods and recommend changes as necessary	Short	NOAA
11.4: Review existing guidelines on snag removals	Short	NCWRC and USACE co-lead
11.5: Create outreach materials on snag removals and provide to relevant state agencies, soil and water conservation districts, and county extension agents to educate landowners	Short	CFRW (lead) with help from NOAA, NCDWR, and NCSU Cooperative Extension

Problem Statement 3: The quantity and timing of flow in the Cape Fear River basin are altered compared to historical conditions. The ecological effects of these alterations on migratory fish need to be better understood.

Flow regime is of central importance in sustaining the ecological integrity of flowing water systems (Poff et al. 1997). The five critical components of the flow regime that regulate ecological processes in river ecosystems are magnitude, frequency, duration, timing, and rate of change of hydrologic conditions. Past studies show that environmental factors such as river velocity and water temperature greatly determine the timing of upstream migration and spawning by migratory species (Dial Cordy and Associates Inc. 2006). The extent to which alterations to the flow regime of the Cape Fear River have impacted the various life stages of migratory fish species and their potential role in enhancing stocks requires additional study.

The role of groundwater in stream-flow generation is poorly understood. Groundwater discharges have large spatial and temporal variations that are highly dependent on topographic, geologic, and climatic conditions (Weaver and Pope 2001). Groundwater levels have been declining in the Cretaceous aquifers (Black Creek and Upper Cape Fear) of the central Coastal Plain for at least several decades (NCDWR 2001), which may affect base flow to streams (Bales et al. 2003) and may have serious effects on instream biological habitat and riparian wetlands. The possible reduction in stream flow from over-pumping Coastal Plain aquifers, related to population increases and agriculture activities, has not been evaluated. Discharges from water systems that pump from deep, confined aquifers may counter the groundwater withdrawals and help augment stream flows.

NCDWR has adopted a river-basin approach for the long-range planning needed to guide the sustainable use of North Carolina's water resources. As of 2010, NCDENR is required to develop hydrologic models for each of the 17 major river basins in North Carolina to determine the ecological flows needed to support and sustain the diversity of aquatic life and the functioning of ecosystems in each basin (NCDWR 2012). During this process for the Cape Fear River basin, NCDWR will evaluate the current and projected uses of surface waters against the amount of water available in the Cape Fear basin.

Jonathan Lanier shows off the day's catch. Photo courtesy of CFRW.

Earlier efforts to maintain instream flows focused on minimum releases from dams to maintain minimum flows. Stream biota have life cycles that are adapted to a flow regime, not a constant minimum flow (Poff and Allan 1995) so a minimum flow approach does not protect ecological integrity. Minimum flows lack the monthly and seasonal variability within a year, as well as the inter-annual variability between wet, dry, and average years. When this variability is reduced or lost, aquatic species diversity is often diminished and species that are most tolerant of degraded ecosystems predominate.

Target 4: Seasonality and magnitude of flows support migratory fish needs at all life cycle stages.

ACTION 12: Define existing and optimal ecological flows for the river basin for migratory fish	**Timeframe**	**Lead**
12.1: Model historic current and future flows using the WaterFALL modeling study and other available data to model flows on the Cape Fear River and its main tributaries	Short	TNC lead (with the Research Triangle Institute)
12.2: Ecological Flows Science Advisory Board determine species ecological flow needs on the Cape Fear and incorporate ecological flows into existing Neuse and Cape Fear joint River model	Medium	NCDWR and TNC, North Carolina Natural Heritage Program
12.3: Identify flow requirements for Cape Fear River that are necessary for successful spawning, egg development, and larval transport to nursery grounds	Medium	TNC, NCDMF, NCWRC, and NOAA
12.4: Supplement and refine existing habitat preference curves with expert opinion on species flow needs. Base changes on field studies and/or monitoring from action 12.3. Consult with NCDWR to provide expert opinion on species flow needs and supporting any extrapolation NCDWR does with information to make it relevant to Cape Fear	Ongoing	USFWS with help from NCCFWRU and NOAA
12.5: Identify, map and quantify all current withdrawals as a baseline to create a map format that can be easily shared with other agencies and organizations	Short	NCDWR

Problem Statement 4: Degraded water quality (e.g., excess nutrients and increasing occurrence of blue-green algal blooms) in the Cape Fear River and Northeast Cape Fear River is likely detrimental to migratory fish.

Blue-green algal bloom below Lock & Dam #1. Photo courtesy of Mike Mallin, UNCW.

In 2005, the lower Cape Fear River and estuary were included on the North Carolina 303(d) list for impaired water due to low DO, or hypoxia (NCDWQ 2012 EPA approved 303(d) list http://portal.ncdenr.org/web/wq/ps/mtu/assessment). One cause of hypoxia in the Cape Fear watershed system is algal blooms. When water temperature increases and nutrient inputs into the watershed are high, algal blooms can develop. As bacteria decompose these algal blooms, they use oxygen from the water column creating a biochemical oxygen demand (BOD), leading to hypoxic conditions. Lowered DO can stress resident and migratory fish and even pose a migratory barrier.

A major cause of algal blooms is excessive nutrient loading. Whalen and Dubbs (2005) found that a 45% dilution of instream nutrients did not decrease phytoplankton growth, indicating that the nutrients present in the Cape Fear River were well in excess of phytoplankton growth requirements. However, the Cape Fear River is not currently classified as "nutrient-sensitive waters" by the State of North Carolina. Therefore, many National Pollutant Discharge Elimination System (NPDES) dischargers do not have total nitrogen or total phosphorus limit requirements.

Total nitrogen and phosphorus concentrations in the river and upper estuary are moderate to high, and estuarine nutrient concentrations are significantly correlated with river discharge (Mallin et al. 1999). Inputs of nitrogen as ammonium, nitrate or urea have been experimentally determined to cause algal biomass increases in the blackwater streams and rivers that are present in the Cape Fear basin (Mallin et al. 2004). Between 1995 and 2006 parts of the lower Cape Fear basin experienced statistically significant increasing trends in ammonium concentrations, ranging from 100% in the main stem to 300% in the Northeast Cape Fear River (Burkholder et al. 2006). Periods of low flow, coupled with already-elevated nutrients present in the river, are likely to lead to more nuisance and toxic blooms in the future. Future development, such as the construction of additional dams and reservoirs in the river, could exacerbate these problems by creating additional areas of quiescent waters that could fuel more blooms.

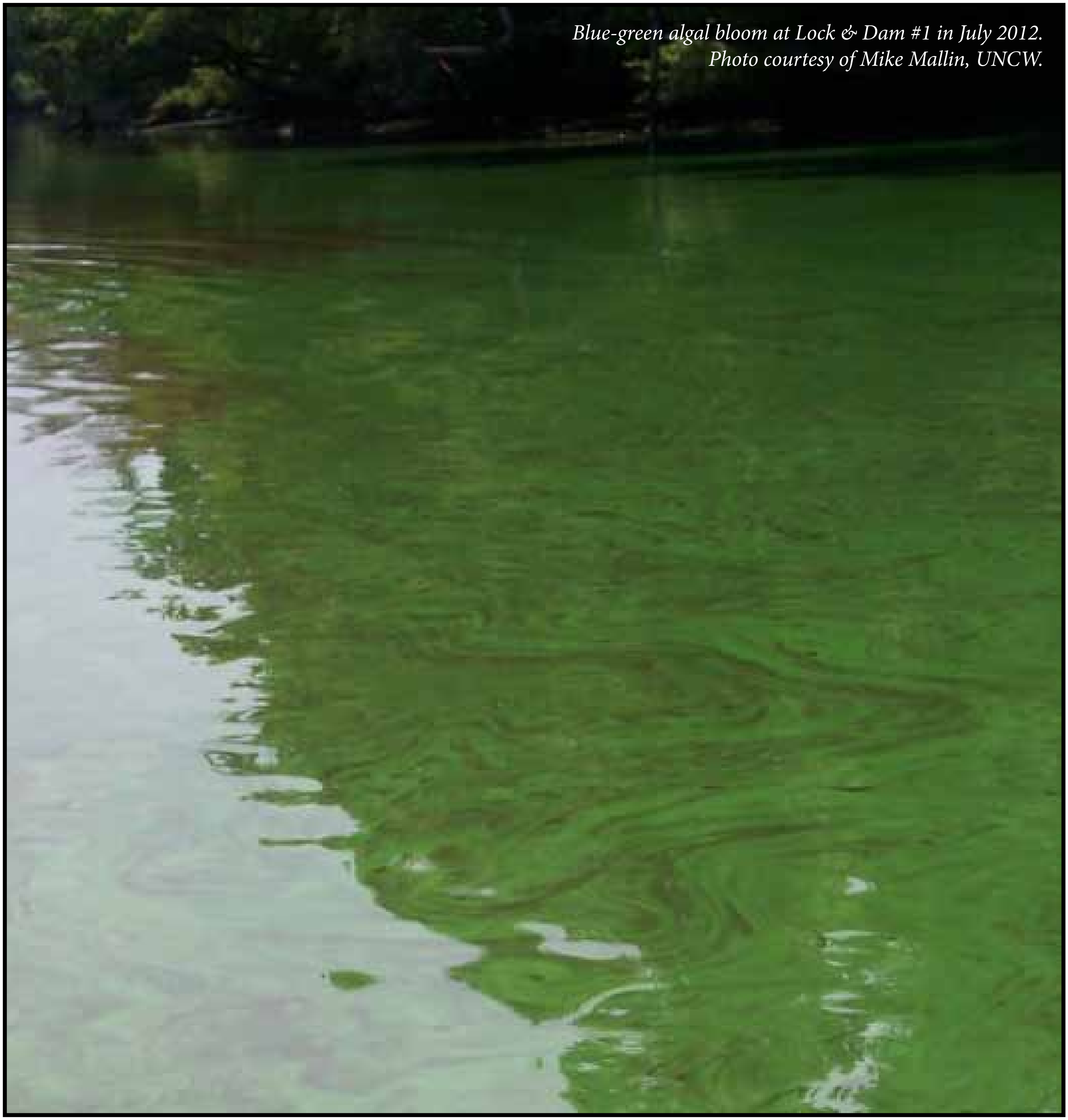
From 2009 to 2012, the Cape Fear River has been host to unprecedented cyanobacterial blooms consisting primarily, but not exclusively, of *Microcystis aeruginosa* (see Appendix III, Figure 8). *Microcystis* has been known to cause fish kills and at one point recently impacted 75 miles of the river. The blooms have occurred in the summer months and sometimes in early fall, and have centered in the reach of the river just above Lock and Dam #1 downstream to the Black River (NCDWQ 2011). This species has long been known as a toxin-producing organism (Burkholder 2002) and at least some of the blooms in the main stem of the Cape Fear have produced toxins. Specifically, two hepatotoxins—microcystin LR and microcystin RR—were isolated by UNCW in 2010 (Isaacs 2011).

The metabolites produced by the cyanobacterial blooms in 2009 forced Brunswick County to increase levels of water treatment to control the subsequent taste and odor problems arising from the cyanobacteria blooms. Exposure to toxic conditions is harmful to humans, fish, and their prey. Microalgal toxins directly damage fish by altering their internal organ function, and also affect the prey items fish consume (Burkholder, 2002).

Blooms of other species have occurred as far upstream as the upper Haw River above Buckhorn Dam during the summer and fall (NCDWQ 2011). In 2011 cyanobacterial blooms (*Anabaena planktonica* and *Microcystis*) occurred in the Northeast Cape Fear River as well, leading to strong hypoxia with DO levels falling to 0.7 mg/L (Stephanie Petter Garrett, NCDWQ, personal communication, July and August 2011). Long-term chlorophyll *a*—which is measured as a surrogate for algal biomass—and BOD data collected by researchers from UNCW have demonstrated that just downstream of Lock and Dam #1, chlorophyll *a* and BOD are strongly correlated (Mallin et al. 2006). These data were collected prior to the new set of blooms, so it is likely that additional algal biomass will create stronger summer BOD, and further lower DO in the river.

Target 5: Blue-green algal blooms eliminated in known locations (particularly in the regions of Lock and Dams #1 and #2 and Northeast Cape Fear River) and future blooms prevented to help maintain minimum of 5 mg/L DO in spawning areas and reduce potential algal toxin formation.

ACTION 13: Better define WQ in this region between Lock and Dam #1 and Buckhorn Dam	**Timeframe**	**Lead**
13.1: Increase water quality monitoring between Lock and Dams #1 and #2 to identify water quality parameters that are most stressful to migratory fish at this location	Medium	UNCW and CFRW
13.2: Seek funding for additional water quality monitoring between Lock and Dam #1 and Buckhorn Dam	Medium	UNCW
13.3: Develop a protocol to assess and monitor surface algal blooms to better document blue-green algal problems	Short	UNCW and CFPUA
13.4: Continue to assess the relationship between blue-green algal blooms and BOD downstream of Lock and Dam #1	Short	UNCW
13.5: Use all available data, including ambient monitoring and eDMR reports to assess impacts of wastewater treatment plants on the water quality in accordance with the standards between Lock and Dams #1 and #3	Short	NCDWQ and UNCW



Blue-green algal bloom at Lock & Dam #1 in July 2012. Photo courtesy of Mike Mallin, UNCW.

Target 6: Nutrient input decreased.

ACTION 14: Define nutrient inputs into the Cape Fear River basin	Timeframe	Lead
14.1: Identify chicken, turkey, and sod farm locations in the watershed	Short	CFRW
14.2: Create comprehensive map of agriculture (hog, chicken and turkey farms), forestry, and sod farms bordering the Cape Fear and its tributaries	Short	CFRW
14.3: Map wastewater land application fields (NCDWQ), septage land application fields (Division of Solid Waste) and Class B residual land application sites (NCDWQ)	Short	UNCW
14.4: Complete NCDWQ/USGS study of surface water quality associated with swine operations	Medium	NCDWQ
14.5: Correlate runoff information gathered by the NCDWQ/USGS Swine study (action 14.4) with fish habitat to determine how swine operations affect fish habitat	Medium/Long	NOAA
14.6: Correlate land-use changes throughout the basin and bordering the Cape Fear River and its tributaries to water quality parameters (DO, Nitrogen, Phosphorous, chlorophyll *a* and fecal coliform)	Long	Jennifer Alford and UNCW
14.7: Determine the severity and impact of algal blooms on the current uses of the Cape Fear River	Medium	UNCW
14.8: Meet with nutrient source permittees to pursue voluntary loading reductions	Medium	UNCW and CFRW

ACTION 15: Improve regulatory strategies to reduce point and non-point source pollution	Timeframe	Lead
15.1: NCDMF and NCWRC refine AFSAs and establish data necessary for appropriate water quality standards for these areas, particularly for nutrients and sediment	Medium-long	NCDMF and NCWRC
15.2: Work within existing joint permit and interagency policy structure to improve marina siting and marina runoff management to minimize impacts to AFSAs and nursery areas	Medium	NCDMF, NCDCM, and NCDWQ

ACTION 16: Improve voluntary strategies to reduce non-point source pollution and protect fish habitat from impacts of land-based activities	**Timeframe**	**Lead**
16.1: Increase developers participation in Wildlife Friendly Development Program in part by inviting the NCWRC to hold a workshop in Wilmington that reviews guidelines for the wildlife friendly program certification	Medium	CFRW, real estate developers, and NCWRC
16.2: Lay the groundwork for tax incentives for increasing buffers through tax credits (based on North Carolina Conservation Tax Credit handled through 'One NC Naturally Program')	Long	DENR Office of Conservation, Planning and Community Affairs
16.3: Expand Stewardship Development Awards to entire basin	Medium	Select soil and water conservation districts and New Hanover County
16.4: Reinvigorate and expand the River Friendly Farmers Program throughout the basin	Medium	Select local soil and water conservation districts
16.5: Educate County and City Planning Departments beyond the coastal plain about the Green Growth Toolbox conservation options for landowners	Long	NCWRC
16.6: Provide technical assistance in urban areas to help establish and protect buffers	Short and ongoing	Select local soil and water conservation districts, with help from local governments
16.7: Advocate and monitor for the implementation of forestry best management practices, including the establishment, management, and protection of stream and riparian buffer zones	Medium	North Carolina Forest Service
16.8: Work with private landowners to protect and restore forestry buffers through best management practices on their land	Medium	Select soil and water conservation districts
16.9: Provide technical assistance to agricultural operations that are potential sources of nutrients, specifically total nitrogen and total phosphorous.	Medium	NCDSWC, select soil and water conservation districts, NCSU Cooperative Extension, and NRCS

ACTION 16: CONTINUED	Timeframe	Lead
16.10: Work with farmers to manage fertilizer application at agronomic rates	Medium	Environmental Defense Fund (lead), NCSU Cooperative Extension, select soil and water conservation districts, and NCDSWC
16.11: Present Cape Fear Migratory Fish priorities to the NC Association of Soil and Water Conservation Districts	Medium	NCDSWC
16.12: Provide a workshop (with a focus on materials to incorporate priority areas from Action 10.2 in local program delivery, River Friendly Farmer Program, Stewardship Development Awards Program, and drug take back programs) for select soil and water conservation districts and cooperative extension to focus on setting local priorities with Cape Fear migratory fish outcomes.	Short/Medium	NCDSWC
16.13: Encourage golf course owners within targeted protection and restoration areas to pursue certification from the Audubon National Cooperative Sanctuary Program for Golf Courses	Short	CFRW
16.14: Continue promoting existing North Carolina Agriculture Cost Share Program within the basin with emphasis placed on Best Management Practices (BMPs) that can improve water quality in critical habitat areas (as identified in action 10.2)	Short (and ongoing)	NCDSWC and select soil and water conservation districts
16.15: Continue to promote funding of the existing North Carolina Community Conservation Assistance Program within the basin with emphasis placed on BMPs that can improve water quality in critical habitat areas (as identified in action 10.2)	Short (and ongoing)	NCDSWC and select soil and water conservation districts

16.16: Promote NRCS programs within the basin while continuing to provide producers with information on BMPs that can mitigate agricultural nutrient losses in critical habitat areas	Medium	NRCS and select soil and water conservation districts
16.17: Implement feasible and cost-effective storm water retrofit projects throughout the watershed to mitigate the hydrologic effects of development. Stream channel restoration activities should be implemented in target areas in order to improve aquatic habitat	Medium	NCDSWC with help from local governments, select soil and water conservation districts, and select NCSU Cooperative Extension agents
16.18: Using education materials available from NCSU Cooperative Extension, educate homeowners, commercial applicators and others regarding: proper fertilizer use specific to lawn types, fertilizer storage, and fertilizer disposal	Short (and ongoing)	Select soil and water conservation districts with help from local governments and select NCSU Cooperative Extension agents
16.19: Promote voluntary operation reviews available to farmers through NCDA&CS	Short (and ongoing)	NCDSWC
16.20: Secure additional funding for Lagoon Conversion Program to encourage use of innovative animal waste management systems	Medium/Long	NCDSWC
16.21: Secure additional funding for Swine Buyout Program to fund buyouts for swine operations in the 100-year flood plain	Medium/Long	NCDSWC

Cows in a creek. Photo courtesy of NCDWQ.

Hog farms and lagoon. Photo courtesy of NCDWQ.

Problem Statement 5: There is a need to prevent adverse chemical impacts to migratory fish.

Polluting chemicals can adversely affect the health of migratory and resident fish and of the humans who consume them (USEPA 2000a; 2000b). Waters within the Cape Fear River basin system, as well as the rest of North Carolina, are rated as impaired for fish consumption due to excessive mercury (Hg) in the flesh of several fish species, mainly piscivorous fish (NCDWQ 2005). Aside from mercury, metals and other chemical pollutant loads in fish tissue in the Cape Fear basin are understudied. One recent paper, Mallin et al. (2011), reported body burden data collected in 2005 for freshwater fish (bowfin) and clams in the Cape Fear, Black, and Northeast Cape Fear River basins. Several pollutants exceeded the Environmental Protection Agency (EPA) and North Carolina Health Director's standards for safe human consumption, including mercury, arsenic (As), selenium (Se), cadmium (Cd), polychlorinated biphenyls (PCBs), and the pesticide dieldrin. Fish tissue concentrations of Hg, Se, and PCBs were also higher than concentrations determined by researchers to be detrimental to the health of the fish themselves or their avian and mammalian predators (Lemly 1993; Kamman et al. 2000; USEPA 2000b; Evers et al. 2007). Adding more metals or chemical contaminants to the Cape Fear River basin, including waste products from industrial facilities and agricultural land uses, may result in physiological damage to fish farther down the food chain and may cause these fish to be added to non-consumption lists.

Endocrine disrupting chemicals (EDCs) are an emerging threat that is likely to become a serious threat to migratory fish that mature sexually and reproduce in rivers loaded with such compounds. EDCs enter the watershed through wastewater treatment systems and non-point sources such as runoff from agriculture and golf courses. The Cape Fear River basin, with its population centers and human impacts, is especially vulnerable based on current knowledge about EDCs. Early data from the City of Wilmington's Sweeney Water Treatment plant (CFPUA 2010) show that these EDCs are present in very small concentrations, although little is known about the full extent of their identities and essentially nothing is known about synergistic effects they may have. It is known that when these compounds act they tend to interfere with hormonal-based physiology, notably development of sexual characteristics and reproductive function. EDCs are therefore a potentially serious threat to the sexual development of fish in the Cape Fear River basin.

Target 7 Inputs of toxic metals (e.g., mercury) and endocrine disrupting chemicals decreased

ACTION 17: Better support efforts to decrease input of toxic metals and chemicals into the Cape Fear River and better understand the effects of these compounds.	**Timeframe**	**Lead**
17.1: Expand successful New Hanover County drug take-back program to other urban communities with wastewater discharging to the Cape Fear watershed.	Short -Medium	New Hanover County and CFPUA
17.2: Seek funding to initiate research on levels of EDCs and assess effects on migratory fish.	Long	USGS
17.3: Support NCDENR efforts to reduce mercury and other heavy metal inputs to the basin.	Medium	UNCW and CFRW

Sediment plume at the mouth of the Cape Fear River. Aerial photo courtesy of NASA.

Implementation Team

The working group has created an Implementation Team, whose members will work together to implement the actions in this plan. The team will hold quarterly conference calls and meet in person annually to discuss progress in implementing plan actions, find solutions to any conflicts or roadblocks that arise, and adjust plan actions through adaptive management, as necessary.

As part of a long-term adaptive-management approach, the team will develop, and revisit as needed, a list of future priority research needs that could not be committed to at the time of development of this Action Plan, which will serve to enhance habitat, water quality, and connectivity in the Cape Fear watershed. The team will also revisit and consider the need to update the Action Plan in five years (2018).

Annual progress reports will be developed by the team and made available to partner organizations and the public, through the partnership's website (www.habitat.noaa.gov/capefear) as well as other venues, including partner websites.

Refinement of Socioeconomic Actions

An essential task of the Implementation Team will be to establish a socioeconomic working group that will complete the development of supplementary actions designed to ensure that the ecosystem services provided by the conservation actions in this Plan are sustained in the Cape Fear River Basin. A problem statement and actions were preliminarily outlined by the Partnership as this Plan was completed. Additional work to be completed by the working group includes identification of action leads, and integration of these actions with the ecological actions and targets described earlier in this Plan. The Partnership's progress is outlined below.

Goal 3: Engage new stakeholders and increase interest in improving fish passage and habitat conditions for migratory fish through communication of socioeconomic values associated with such improvements.

Problem Statement 6: Socioeconomic benefits such as commercial and recreational fishing, tourism, recreation, water quality, and water supply are impacted by conditions that threaten migratory fish.

Restoring and improving access to habitat for migratory fish not only enhances the freshwater ecosystem and its biodiversity but also provides human benefits that can be described and frequently quantified. The Cape Fear River basin, including its many river tributaries, provides economic goods and services and contributes to the livelihoods, food security and safety of the residents of the area. Accounting for river ecosystem values in management decisions can help sustain the flow of goods and services in the interest of current and future generations. Additionally, quantifying the co-benefits associated with restoring habitats and fish populations helps build a broader constituency for conservation. Providing this information requires the application of scientific approaches that can utilize estimates of expected ecological changes and improvements to measure the impact on the flow of ecosystem services.

We are not fully aware of the extent of our dependence on the Cape Fear River basin and the value of commercial and recreational fisheries, tourism, recreational uses, avoided costs to water treatment, and cultural uses.

The conservation actions to be implemented under this plan are expected to result in cleaner water, more habitat and better access to habitat for migratory fish. Those ecological improvements are likely to economically benefit commercial and recreational fisheries, tourism and recreation industries; and result in avoided costs to water treatment. To better understand the relationships between humans and natural ecosystems through the services derived from them, the following actions for the Cape Fear River basin are considered:

Target 8: Estimate socioeconomic values associated with increasing and improving passage and habitat conditions for migratory fish.

ACTION 18: Identify, describe, and estimate the potential economic benefits to accrue to commercial and recreational fisheries from increasing and improving migratory fish passage and habitat.
ACTION 19: Identify, describe, and estimate the potential recreation and tourism benefits that could accrue from increasing and improving migratory fish passage and habitat.
ACTION 20: Identify, describe, and estimate the potential benefits to water users from improving migratory fish passage and habitat.

Some of the many opportunities for recreation on the Cape Fear River.

Sunset on the Cape Fear River.

Numerous existing programs may have funding that could be applied to implement the habitat, water quality, and fish passage improvement actions identified in this Action Plan. Nothing in this plan shall be construed as obligating the federal or state partners to expend, obligate, or transfer any funds, or as involving the United States in any obligation for the present or future payment of money in excess of appropriations authorized by law. Funding sources that will be investigated include, but are not limited to:

Organization	Potential Source	Type of projects/actions that would be eligible
Atlantic Coastal Fish Habitat Partnership (ACFHP)	USFWS—National Fish Habitat Partnership Grant Program	Projects that restore and conserve habitat necessary to support coastal, estuarine-dependent, and diadromous fish species.
Federal and state	Natural Resource Damage Assessment via Comprehensive Environmental Response, Compensation, and Liability Act and Oil Pollution Act	Implements habitat restoration based on previous 3rd party impacts. Kind of project depends on specific damages from that particular case; need to have nexus to damages (but can transfer mitigation to a different resource than resource damaged).
National Fish and Wildlife Foundation	Various funding opportunities	Varies by RFP.
NCDA&CS DSWC	North Carolina Agriculture Cost Share Program (ACSP)	Voluntary, incentive-based program to install agricultural best management practices to improve water quality; applicants can be reimbursed up to 75% of a predetermined average cost for each BMP installed.
NCDA&CS DSWC	NC Community Conservation Assistance Program (CCAP)	Voluntary, incentive-based program designed to improve water quality through installation of BMPs on urban, suburban and rural lands, not directly involved in agriculture production. Landowners may receive financial assistance of up to 75% of the pre-established average cost of eligible BMPs.
NCDA&CS DSWC	NC Conservation Reserve Enhancement Program (CREP)	Voluntary program using federal and state resources to achieve long-term protection of environmentally sensitive cropland and marginal pastureland. BMPs include grassed filter strips, forested riparian buffers, hardwood tree establishment, and wetland restoration. Long-term protection is achieved through voluntary 10-, 15-, 30-year or permanent easements that limit the landowner's future use of the land for activities such as farming and development; landowners receive annual rental payments and are reimbursed for establishing the conservation practices (tax incentives may be available for those that enroll in 30-year or permanent easements).

NCDMF and NCWRC	Coastal Recreational Fishing License Grants	Projects that help manage, protect, restore, develop, cultivate and enhance the state's marine resources. Obstruction removal projects qualify, as well as some types of monitoring or habitat enhancement.
NCDWQ	EPA 319 Grant Funds	Restoration of water bodies that are impaired (as listed as Integrated Report categories 4 and 5)
NCDWQ	EPA 205(j) Grant Funds	Water quality management planning efforts
NCDWR	Water Resources Development Project Grant Program	This program is designed to provide cost-share grants and technical assistance to local governments throughout the State. Applications for grants are accepted for seven purposes: General Navigation, Recreational Navigation, Water Management, Stream Restoration, Beach Protection, Land Acquisition and Facility Development for Water-Based Recreation, and Aquatic Weed Control.
NOAA	NOAA Restoration Center	Projects that benefit estuarine, riverine, or anadromous resources; fish passage, dam removal, shellfish restoration, tidal hydrology improvements, and seagrass restoration.
NOAA	Species Recovery Grants to States (under Endangered Species Act Section 6)	Management, outreach, research, and monitoring projects that direct conservation benefits for listed species, recently de-listed species, and candidate species that reside within the state. For species under NOAA jurisdiction.
Reservoir Fisheries Habitat Partnership	Grant programs	Reservoir fisheries habitat enhancement projects. Proposed projects can be based in the reservoir proper and/or in watersheds above the reservoir and/or tailwaters below.
State of North Carolina	Clean Water Management Trust Fund	Funds projects that enhance or restore degraded waters, protect unpolluted waters, and/or contribute toward a network of riparian buffers and greenways for environmental, educational, and recreational benefits.
State of North Carolina	Environmental Enhancement Grants	This program seeks to improve the air, water, and land quality of North Carolina by funding environmental projects that address the goals of the Smithfield—Attorney General Agreement. Funds environmental enhancement projects through 2025.

State of North Carolina	Natural Heritage Trust Fund	Provides supplemental funding to select state agencies for the acquisition and protection of important natural areas (and inventory of natural areas).
State of North Carolina	Parks and Recreation Trust Fund	Provides dollar-for-dollar matching grants for parks and recreational projects to serve the public.
South Atlantic Landscape Conservation Cooperative (LCC)	Science funding opportunities	Funds projects focused on filling conservation planning gaps in the South Atlantic LCC.
Southeast Aquatic Resources Partnership (SARP)	Grant programs	Funds aquatic habitat improvement projects—mostly on-the-ground aquatic habitat improvements. Proposals are submitted to SARP for scoring. Habitat and population assessments may be considered.
USFWS	National Coastal Wetlands Conservation Grant program	Focus is on long-term protection or restoration of nationally declining coastal wetlands and maritime forests on coastal barrier islands.
USFWS	North Carolina Coastal Program	Prioritized environmental restoration in North Carolina coastal area.
USFWS	North American Wetlands Conservation Act	Provides matching grants to carry out wetlands conservation projects for the benefit of wetlands-associated migratory birds and other wildlife.
USFWS	National Fish Passage Program	Funds the removal or bypass of barriers to fish movement. Non-regulatory, voluntary program to increase aquatic habitat connectivity.
USFWS	Species Recovery Grants to States (under Endangered Species Act Section 6)	Management, outreach, research, and monitoring projects that direct conservation benefits for listed species, recently de-listed species, and candidate species that reside within the state. For species under USFWS jurisdiction.
USFWS	Partners for Fish and Wildlife Program	Biologists provide technical and financial assistance to landowners who want to restore and enhance fish and wildlife habitats on their property. Partners for Fish and Wildlife projects may include restoring and improving habitat for species such as migratory birds, anadromous or migratory fish, endangered or threatened species, or other declining or imperiled species.

Migratory Fish Glossary

Anadromous fish: Fish that spend most of their lives in the ocean but migrate from the ocean to freshwater to breed/spawn (e.g., American shad, striped bass, Atlantic sturgeon, shortnose sturgeon, river herring).

Catadromous fish: Fish that spend most of their lives in freshwater but migrate from freshwater to the ocean to breed/spawn (e.g., American eel).

Diadromous fish: Fish that depend on both freshwater and ocean habitats to complete their life cycles. Collective term for anadromous and catadromous fish.

Migratory fish: Fish that move between different habitats over the course of their life cycles. Diadromous fish are a type of migratory fish. This term is used in this Action Plan to represent diadromous fish.

River herring: A term applied collectively to two similar species, alewife and blueback herring.


Release of a striped bass at StriperFest 2013. Photo courtesy of Josh Raabe.

Works Cited

Aksnes, D.L. 2007. Evidence for visual constraints in large marine fish stocks. Limnology and Oceanography 52(1):198-203.

Ashley, K. W. and R.T. Rachels. 2011. Cape Fear River American shad recreational angler creel survey 2011. North Carolina Wildlife Resources Commission, Federal Aid in Fish Restoration, Project F-22, Final Report, Raleigh.

ASMFC. 1999. Amendment 1 to the interstate fishery management plan for shad & river herring. Fishery Management Report No. 35, Washington, D.C.

ASMFC. 2004. Species habitat fact sheets for ASFMC managed species. http://www.asmfc.org/.

ASMFC. 2009. Amendment 2 to the interstate fishery management plan for shad & river herring. Washington, D.C.

ASMFC. 2010. Amendment 3 to the interstate fishery management plan for shad & river herring. Washington, D.C.

ASMFC. 2012. American Eel Stock Assessment Report for Peer Review. Atlantic States Marine Fisheries Commission, Stock Assessment Report No. 12-1 (supplement), Washington, DC. 303 p.

ASSRT. 2007. Status Review of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus). Prepared by the Atlantic Sturgeon Status Review Team for NOAA Fisheries.

Auld, A. H. and J. R. Schubel. 1978. Effects of suspended sediment on fish eggs and larvae: A laboratory assessment. Estuarine and Coastal Marine Science 6(2):153-164.

Bales, J.D., M.J. Chapman, C.J. Oblinger, and J.C. Robbins. 2003. North Carolina District Science Plan: Science Goals for 2003–2008. U.S. Geological Survey, Open-File Report 2004–1025. 31 pp. http://nc.water.usgs.gov/reports/ofr041025/pdf/report.pdf.

Battelle. 2007. Economic Support for the Elwha River Watershed: Final Economic Characterization Report with Monitoring Recommendations. Prepared for The Coastal Services Center, National Oceanic and Atmospheric Administration, August 15, 2007.

Benedetti, M.M., M.J. Raber, M.S. Smith and L.A. Leonard. 2006. Mineralogical indicators of alluvial sediment sources in the Cape Fear River basin, North Carolina. Physical Geography 27:258-281.

Burkholder. J.M. 2002. Cyanobacteria. In "Encyclopedia of Environmental Microbiology" (G. Bitton, Ed.), 952-982, pp. Wiley Publishers, NY.

Burkholder, J.M., D.A. Dickey, C. Kinder, R.E. Reed, M.A. Mallin, G. Melia, M.R. McIver, L.B. Cahoon, C. Brownie, N. Deamer, J. Springer, H.B. Glasgow, D. Toms and J. Smith. 2006. Comprehensive trend analysis of nutrients and related variables in a large eutrophic estuary: A decadal study of anthropogenic and climatic influences. Limnology and Oceanography 51:463-487.

CFPUA. 2010. 2010 Water Quality Report. 1-8, pp. Accessed at http://nc-cfwu2.civicplus.com/DocumentCenter/Home/View/1054.

Chestnut, A. and H. Davis 1975. Synopsis of Marine Fisheries of North Carolina. Part 1: Statistical Information, 1880-1973. North Carolina Sea Grant Award No. UNC-SG-75-12. 425 p.

Deaton, A.S., W.S. Chappell, K. Hart, J. O'Neal, B. Boutin. 2010. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, NC. 639 p.

Dial Cordy and Associates Inc. 2006. Cape Fear River Anadromous Fish Larvae and Egg Survey: Final Report, November 2006. U.S. Army Corps of Engineers, Wilmington District. Contract No. W912HN-05-D-0014, Task Order 0015. http://www.saw.usace.army.mil/wilmington-harbor/GRR/GRR_files/Cape%20Fear%20River%20Anadramous%20Fish%20Larvae%20and%20Egg%20Survey%20Final.pdf.

Dumas, C.F., Schuhmann, P.W., and Whitehead, J.C. 2005. Measuring the economic Benefits of Water Quality Improvement with Benefit Transfer: An Introduction for Noneconomists. American Fisheries Society Symposium: http://www.appstate.edu/~whiteheadjc/eco3660/Dumas.pdf.

Earll, E.R., 1887. North Carolina and its Fisheries. Goode, G. B. The Fisheries and Fisheries Industry of the United States. Section II, 475-497 pp. A geographical review of the fisheries industries and fishing communities for the year 1880. Volume II. United States Commission of Fish and Fisheries. Government Printing Office, Washington, D.C.

Ensign, S.H., J.N. Halls and M.A. Mallin. 2004. Application of digital bathymetry data in an analysis of flushing times of two North Carolina estuaries. Computers and Geosciences 30:501-511.

Evers, D.C., Y. Han, C.T. Driscoll, N.C. Kamman, M.W. Goodale, K.F. Lambert, T.M. Holsen, C.Y. Chen, T.A. Clair and T. Butler. 2007. Biological mercury hotspots in the Northeastern United States and Southeastern Canada. Bioscience 57:29-43.

Fay, C. W., R.J. Neves, and G.B. Pardue. 1983 Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) — striped bass. US Fish and Wildlife Service, Biological Report FWS/OBS-82/11.8 , 36 p.

Federal Register. 2012. Final Rule, Endangered and Threatened Wildlife and Plants: Final Listing Determinations for Two Distinct Population Segments of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus) in the Southeast. 50 CFR Part 224, Vol 77 (No. 24). US Government, Washington DC, 5914-5982, pp.

Works Cited

Fischer, C.A. 1979. Anadromous fisheries research program, Cape Fear River System - Phase II. North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Progress Report for Project AFCS-15-1. 70 pp.

Fischer, C.A. 1980. Anadromous fisheries research program Cape Fear River system phase II. North Carolina Department of Natural Resources and Community Development, Division of Marine Services, Completion Report for Project AFCS-15, Morehead City, NC

Fry, J., G. Xian., S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham, 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

Funderburk, S. L., J.A. Mihursky, S.J. Jordan, and D. Riley. 1991. Habitat requirements for Chesapeake Bay living resources. Habitat Objectives Workgroup, Living Resources Subcommittee and Chesapeake Research Consortium with assistance from Maryland Department of Natural Resources, Solomons, MD.

Gray, J. S., R. S. Wu, and Y.Y. Or. 2002. Effects of hypoxia and organic enrichment on the coastal marine environment. Marine Ecology Progress Series 238: 249-279.

Greene, K.E., J.L. Zimmerman, R.W. Laney, and J.C. Thomas-Blate. 2009. Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations for conservation, and research needs. Atlantic States Marine Fisheries Commission Habitat Management Series No. 9, Washington, D.C.

Hackney, C.T., G.B. Avery, L.A. Leonard, M. Posey, and T. Alphin. 2007. Biological, chemical, and physical characteristics of tidal freshwater swamp forests of the lower Cape Fear River/Estuary, North Carolina, Chapter 8, In, Conner, W.H., T.W. Doyle, and K.W. Krauss, eds. Ecology of Tidal Freshwater Forested Wetlands in the Southeastern United States. Springer, Dordrecht, The Netherlands.

Hall, Stephen P., Michael P. Schafale and John T. Finnegan. 1999. Conservation Assessment of the Southeast Coastal Plain of North Carolina, Using Site-Oriented and Landscape-Oriented Analyses. NCDENR, NC Natural Heritage Program, Raleigh, NC.

Hawkins, J.H. 1980. Investigations of anadromous fishes of the Neuse River, North Carolina. North Carolina Department of Natural Resources and Community Development, Morehead City, NC.

Hill, J., J.W. Evans, and M.J. Van Den Avyle. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic)--striped bass. Fish Wildl. Serv. / U.S. Army Corps of Engineers, Biol. Rep. 82(11.118) / TR EL-82-4, 35p.

Hoenke, K. M. 2012. A GIS Tool Prioritizing Dams for Removal within the State of North Carolina. Master's thesis. Duke University, Durham, North Carolina.

Isaacs, J.D. 2011. Chemical Investigations of the Metabolites of two strains of Toxic Cyanobacteria. Master's thesis. University of North Carolina Wilmington, Wilmington, N.C.

Jackson, Absalom et al. 1771. Petition from inhabitants of Guilford County concerning dams on Deep River to Josiah Martin (colonial governor of North Carolina). Colonial and State Records of North Carolina. Vol. 09, 87-88 pp. Documenting the American South. UNC library, Chapel Hill. 25 September 2012. http://docsouth.unc.edu/csr/index.html/document/csr09-0064.

Jihyung Joo, Ruth. 2011. Public Willingness to pay for Ecosystem Services: Water Quality in the Triangle Region NC. Duke Masters Project: http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/4654/MP_Report_RuthJoo.pdf?sequence=1.

Kamman K., A.L. Blankenship, P.D. Jones and J.P. Giesy. 2000. Toxicity reference values for the toxic effects of polychlorinated biphenyls to aquatic mammals. Human Ecological Risk Assessment 6:181-201.

Kennedy, J.T. and S.T. Whalen. 2008. Seasonality and controls of phytoplankton productivity in the middle Cape Fear River, USA. Hydrobiologia 598:203-217.

Kruse, S.A. and Scholz, A.J. 2007. Preliminary Economic Assessment of Dam Removal: The Klamath River. Ecotrust Working Paper Series No. 2.

Kynard, B.E. 1997. Life History, latitudinal patterns, and status of the shortnose sturgeon, Acipenser brevirostrum. Environmental Biology of Fishes 48:319-334.

Lemly, A.D. 1993. Guidelines for evaluating selenium data from aquatic monitoring and assessment studies. Environmental Monitoring and Assessment 28:83-100.

Loomis, J. 1996. Measuring the economic benefits of removing dams and restoring the Elwha River- Results of a contingent valuation survey. Water Resources Research, 32(2):441-447.

Loomis, J. B. 1999. Recreation and passive use values from removing the dams on the Lower Snake River to increase salmon: Walla Walla, Wash., Report from Agricultural Enterprises, Inc. for U.S. Army Corps of Engineers.

MacKenzie, C., L.S. Weiss-Glanz, and J.R. Moring. 1985. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. US Fish and Wildlife Service, Biological Report 82(11).

Mallin, M.A., L.B. Cahoon, M.R. McIver, D.C. Parsons and G.C. Shank. 1999. Alternation of factors limiting phytoplankton production in the Cape Fear Estuary. Estuaries 22:985-996.

Mallin, M.A., J.M. Burkholder, L.B. Cahoon and M.H. Posey. 2000a. The North and South Carolina coasts. Marine Pollution Bulletin 41:56-75.

Works Cited

Mallin, M.A, Williams, K. E., Esham, E. C., and Lowe, R. P. 2000b. Effects of Human Development on Bacteriological Water Quality in Coastal Watersheds. Ecological Applications 10(4):1047-1056.

Mallin, M.A., M.R. McIver, S.H. Ensign and L.B. Cahoon. 2004. Photosynthetic and heterotrophic impacts of nutrient loading to blackwater streams. Ecological Applications 14:823-838.

Mallin, M.A., V.L. Johnson, S.H. Ensign and T.A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. Limnology and Oceanography 51:690-701.

Mallin, M.A., V.L. Johnson and S.H. Ensign. 2009. Comparative impacts of stormwater runoff on water quality of an urban, a suburban, and a rural stream. Environmental Monitoring and Assessment 159:475-491.

Mallin, M.A., M.R. McIver, M. Fulton and E. Wirth. 2011. Elevated metals and organic pollutants in fish and clams in the Cape Fear River watershed. Archives of Environmental Contamination and Toxicology 61:461-471.

Marshall, M.D. 1976. Anadromous fisheries research program Tar River, Pamlico River, and Northern Pamlico River. Completion Report for Project AFCS-10. North Carolina Division of Marine Fisheries, Morehead City, NC.

McDonald, M. 1887. The rivers and sounds of North Carolina. Pages 625-637 in Goode, G. B. The Fisheries and Fisheries Industry of the United States. Section V. History and methods of the fisheries. Volume I. United States Commission of Fish and Fisheries. Government Printing Office, Washington, D.C.

Moser, M. L., J. B. Bichy, and S. B. Roberts. 1998. Sturgeon distribution in North Carolina. Final report to the U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

Moser, M.L. 1999. Wilmington Harbor blast effect mitigation tests: results of sturgeon monitoring and fish caging experiments. Final Report to: CZR, 4709 College Acres Dr., Wilmington, NC.

Moser, M. L., A. M. Darazsdi, and J. R. Hall. 2000. Improving passage efficiency of adult American shad at low-elevation dams with navigation locks. North American Journal of Fisheries Management 20:376-385.

National Marine Fisheries Service 2011. Fisheries of the United States 2011. Accessed at: http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html on December 31, 2012.

National Marine Fisheries Service. 2012. Fisheries Economics of the United States, 2011. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-F/SPO-118, 175p. Available at: https://www.st.nmfs.noaa.gov/st5/publication/index.html

National Ocean Economics Program database. 2010. http://www.oceaneconomics.org/Market/ocean/oceanEconResults.asp? IC=N&selState=37&selCounty=37000&selYears=All&selSector=6&selIndust=TO00&selValue=All&selOut=display&noepID=356A

NCDENR. 2000. North Carolina fishery management plan: Albemarle Sound area river herring. North Carolina Division of Marine Fisheries, Morehead City, NC.

NCDENR. 2012. Basinwide Information Management System (BIMS). Accessed June 2012.

NCDMF. 2007. North Carolina Fishery Management Plan, Amendment 1, River Herring. North Carolina Division of Marine Fisheries, Morehead City, NC.

NCDMF. 2000. Fish sampling for the presence or absence of disease. Interim report #2: March 1999 - January 2000. DMF, Morehead City, NC, 46 p.

NCDMF. 2012. Stock Status Report 2012. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, NC.

NCDMF and NCWRC. 2004. North Carolina Estuarine Striped Bass Fishery Management Plan for Albemarle Sound Area and Central/Southern Area. North Carolina Division of Marine Fisheries, Morehead City, NC.

NCDMF and NCWRC. 2012. North Carolina American Shad Sustainable Fishery Plan. North Carolina Division of Marine Fisheries, Morehead City, NC.

NCDWQ. 2005. Cape Fear River Basinwide Water Quality Plan. North Carolina Department of Environment and Natural Resources, Division of Water Quality/Planning, Raleigh, NC.

NCDWQ. 2009. Cape Fear River Basin Ambient Monitoring System Report January 1, 2004 through December 31, 2008. North Carolina Department of Environmental and Natural Resources, Division of Water Quality. August 2009.

NCDWQ. 2011. Algal Assemblage Assessments in the Cape Fear River in 2010. North Carolina Division of Water Quality, Environmental Science Section, Raleigh, NC; December 2011.

NCDWR. 2001. North Carolina State Water Supply Plan, January 2001. 73 p. http://www.ncwater.org/Reports_and_Publications/swsp/swsp_jan2001/swsp_j01.php.

NCDWR. 2002. Cape Fear River Basin Water Supply Plan, Second Draft. http://www.ncwater.org/Reports_and_Publications/Jordan_Lake_Cape_Fear_River_Basin/CFRBWSPdraft2.pdf.

NCDWR. 2012. Interbasin Transfer Certification web page.
Accessed at: http://www.ncwater.org/Permits_and_Registration/Interbasin_Transfer/.

Cape Fear River Partnership

Works Cited

NCWRC. 2012a. Review of Striped Bass Monitoring Programs in the Central Southern Management Area, North Carolina — 2011. Coastal Fisheries Investigations. Federal Aid in Fish Restoration Project F-22. Final Report. Raleigh, NC.

NCWRC. 2012b. American Shad and River Herring Monitoring Programs in Coastal North Carolina – 2011. Report to the Atlantic States Fisheries Commission Shad and River Herring Technical Committee. Coastal Fisheries Investigations. Federal Aid in Fish Restoration Project F-22. Final Report. Raleigh, NC.

NCWRC. 2005. North Carolina Wildlife Action Plan. Raleigh, NC.

Nichols, P. R., and D. E. Louder. 1970. Upstream passage of anadromous fish through navigation locks and use of the stream for nursery and spawning habitat, Cape Fear River, North Carolina, 1962-1966. U.S. Fish and Wildlife Service Circular 352.

North Carolina Dam Inventory 2012. http://portal.ncdenr.org/web/lr/dams.

North Carolina Museum of Natural Sciences. Fishes Database. http://collections.naturalsciences.org/resultsFishes.aspx 2012.

Patrick, W. S., and M. L. Moser. 2001. Potential competition between hybrid striped bass (Morone saxatilis x M. americana) and striped bass (M. saxatilis) in the Cape Fear River estuary, North Carolina. Estuaries 24:425-429.

Poff, N.L. and J.D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrological variability. Ecology, 76(2):606-627.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience 47(11):769-784.

Reed, J.P. 1983. The Effects of Low Level Turbidity on Fish and Their Habitat. Issue 190 of Report. Water Resources Research Institute, University of North Carolina.

Sholar, T.M. 1975. Anadromous fisheries survey of the New and White Oak River systems. Compl. Rep. Oct. 73-June 75, Proj. AFCS-9. N.C. Div. Mar. Fish, 49 p.

Sholar, T.M. 1977. Status of American shad in North Carolina. Proceedings of a workshop on American shad. 14-16 Dec. 1976. Amherst, MA. 17-32 pp.

Smith, H. M. 1907. The Fishes of North Carolina, volume 2. North Carolina Geological and Economic Survey, Raleigh, NC.

Smith, J. A., and J. E. Hightower. 2012. Effect of low-head lock and dam structures on migration and spawning of American shad and striped bass in the Cape Fear River, North Carolina. Transactions of the American Fisheries Society 141:402-413.

St. Pierre, R.S. 1979. Historical review of American shad and river herring fisheries of the Susquehanna River. Special Report to the Susquehanna River Basin Committee. U.S. Fish and Wildlife Service, Harrisburg, PA. 40 p.

Steel, J. 1991. Albemarle-Pamlico Estuarine System, technical analysis of status and trends. DENR, Raleigh, NC, APES Report No. 90-01.

Stein, B.A., L.S. Kutner, and J.S. Adams (Eds). 2000. Precious Heritage: The Status of Biodiversity in the United States. New York, NY: Oxford University Press.

Thompson, W.B. 1852. Map of the Cape Fear and Deep Rivers from Fayetteville to Hancock's Mill showing the position of the several locks and dams and canals upon the line of the company's works (drawn by Thomas F. O'Brien). Map on file at the North Carolina Archives. Raleigh, NC.

USFWS. 2011 National Survey of Fishing Hunting & Wildlife Associated Recreation. State Overview: Preliminary Estimates. U.S. Department of the Interior, U.S. Fish and Wildlife Service.

USEPA. 2000a. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1: Fish Sampling and Analysis. EPA-823-B-00-007. United States Environmental Protection Agency, Office of Water, Washington, D.C.

USEPA. 2000b. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2: Risk Assessment and Fish Consumption Limits. EPA-823-B-00-008. United States Environmental Protection Agency, Office of Water, Washington, D.C.

Walburg, C. H., and P. R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic coast of the United States, 1960. U.S. Fish and Wildlife Service Special Science Report for Fisheries Volume No. 550.

Weaver, J.C. and B.F. Pope. 2001. Low-Flow Characteristics and Discharge Profiles for Selected Streams in the Cape Fear River Basin, North Carolina, through 1998. U.S. Geological Survey Water-Resources Investigations Report 01–4094. 141 pp. http://pubs.usgs.gov/wri/wri014094/.

Weaver, J.C. 2009. Apparent Flow Losses in the Cape Fear River. U.S. Geological Survey. http://nc.water.usgs.gov/projects/capefear_flowloss/overview.html.

Works Cited

Whalen, S.C. and L.L. Dubbs. 2005. Influence of nutrient reduction, light and light-nutrient interactions on phytoplankton standing stocks, primary productivity and community composition in the Middle Cape Fear River, North Carolina. Middle Cape Fear River Basin Association, Fayetteville, NC. Technical Report.

Wharton, C. H., W.M. Kitchens, E.C. Pendleton, and T.W. Sipe. 1982. The ecology of bottomland hardwood swamps of the southeast: a community profile. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. 133 p.

Winslow, S. E., N. S. Sanderlin, G. W. Judy, J. H. Hawkins, B. F. Holland, Jr., C. A. Fischer, and R. A. Rulifson. 1983. North Carolina anadromous fisheries management program. North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Anadromous Fish Conservation Act, Completion Report AFCS-16.

Xian, G., and Homer C. 2010. Updating the 2001 National Land Cover Database impervious surface products to 2006 using Landsat imagery change detection methods. Remote Sensing of Environment, 114:1676-1686.

Yarrow, H. C. 1874. Report of a reconnaissance of the shad-rivers south of the Potomac. Report of the Commissioner for 1872 and 1873, part 2, 396-402 pp. U.S. Commissioner of Fish and Fisheries, Washington, DC.

Striped bass. Photo courtesy of Josh Raabe.

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Appendix II: List of Acronyms

ACFHP - Atlantic Coastal Fish Habitat Partnership

AFSAs – Anadromous Fish Spawning Areas

AR - American Rivers

Arch - Cape Fear Arch Conservation Collaboration

ASMFC – Atlantic States Marine Fisheries Commission

BMPs – Best management practices

BOD – Biological oxygen demand

CFPUA - Cape Fear Public Utility Authority

CFRW - Cape Fear River Watch

CFS - Cubic feet per second

DO – Dissolved oxygen

EDCs – Endocrine disrupting chemicals

FT/S – Feet per second

Fayetteville PWC – Fayetteville Public Works Commission

LCFRP - Lower Cape Fear River Program

MGD- Million gallons per day

NCCFWRU - North Carolina State University's North Carolina Cooperative Fish and Wildlife Research Unit

NCDA&CS - North Carolina Department of Agriculture and Consumer Services

NCDCM – North Carolina Department of Environment and Natural Resources Division of Coastal Management

NCDENR - North Carolina Department of Environment and Natural Resources

NCDMF – North Carolina Department of Environment and Natural Resources Division of Marine Fisheries

NCDSWC – North Carolina Department of Agriculture and Consumer Services Division of Soil & Water Conservation

NCDWQ – North Carolina Department of Environment and Natural Resources Division of Water Quality

NCDWR – North Carolina Department of Environment and Natural Resources Division of Water Resources

NCEEP – North Carolina Department of Environment and Natural Resources Ecosystem Enhancement Program

NCMFC – North Carolina Marine Fisheries Commission

NCSU Cooperative Extension - North Carolina State University's North Carolina Cooperative Extension

NCWRC - North Carolina Wildlife Resources Commission

NOAA - National Oceanic and Atmospheric Administration

PNAs – Primary Nursery Areas

TNC - The Nature Conservancy

UNCW - University of North Carolina Wilmington

USACE - United States Army Corps of Engineers

USFWS - United States Fish and Wildlife Service

USGS – United States Geological Survey

Appendix III: Cape Fear River Basin Maps

Figure 1: Cape Fear River Basin.

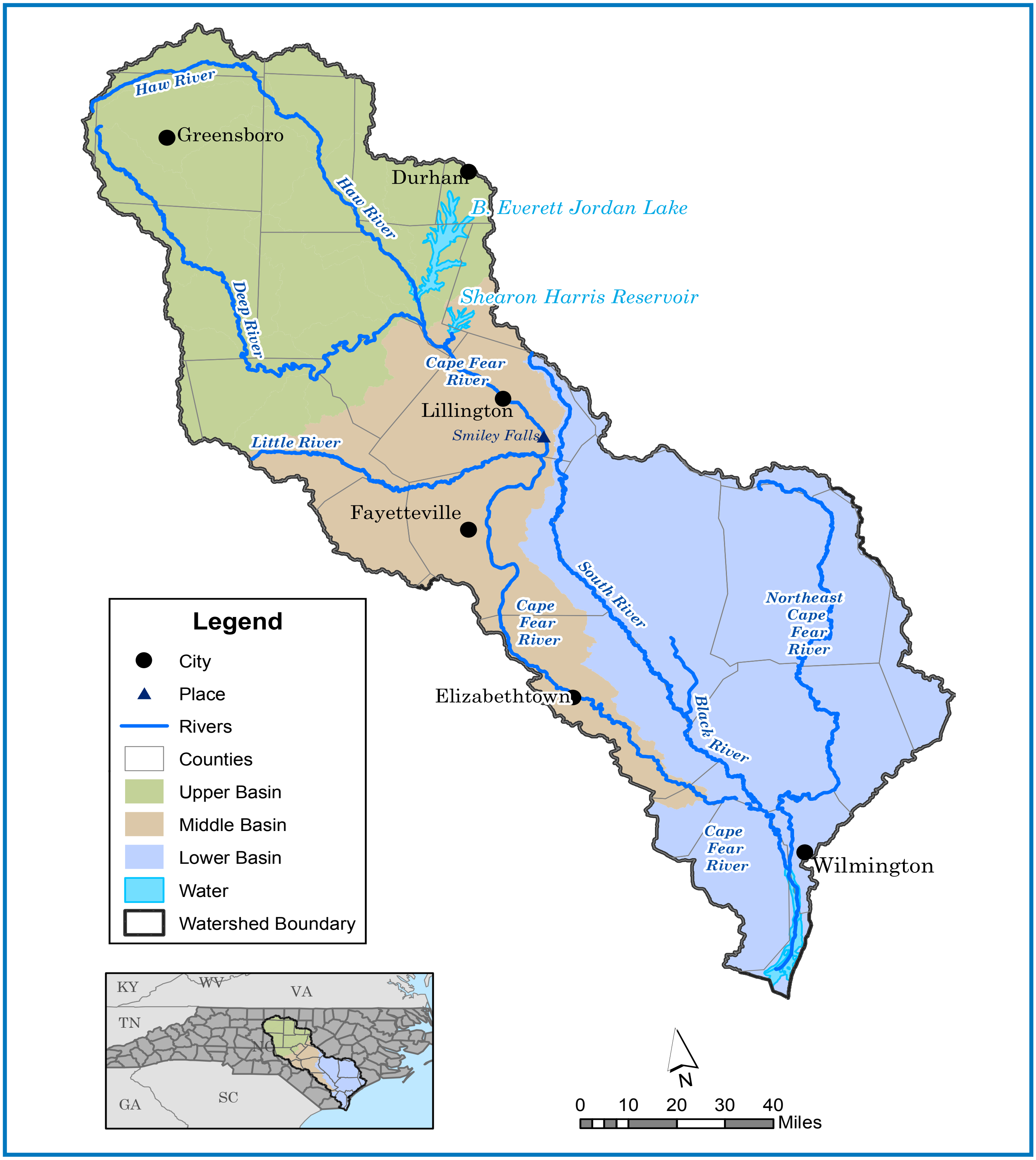

Figure 2: Major Dams in the Upper Cape Fear River Basin.

Figure 3: Major Dams in the Middle Cape Fear River Basin.

Figure 4: Major Dams in the Lower Cape Fear River Basin.

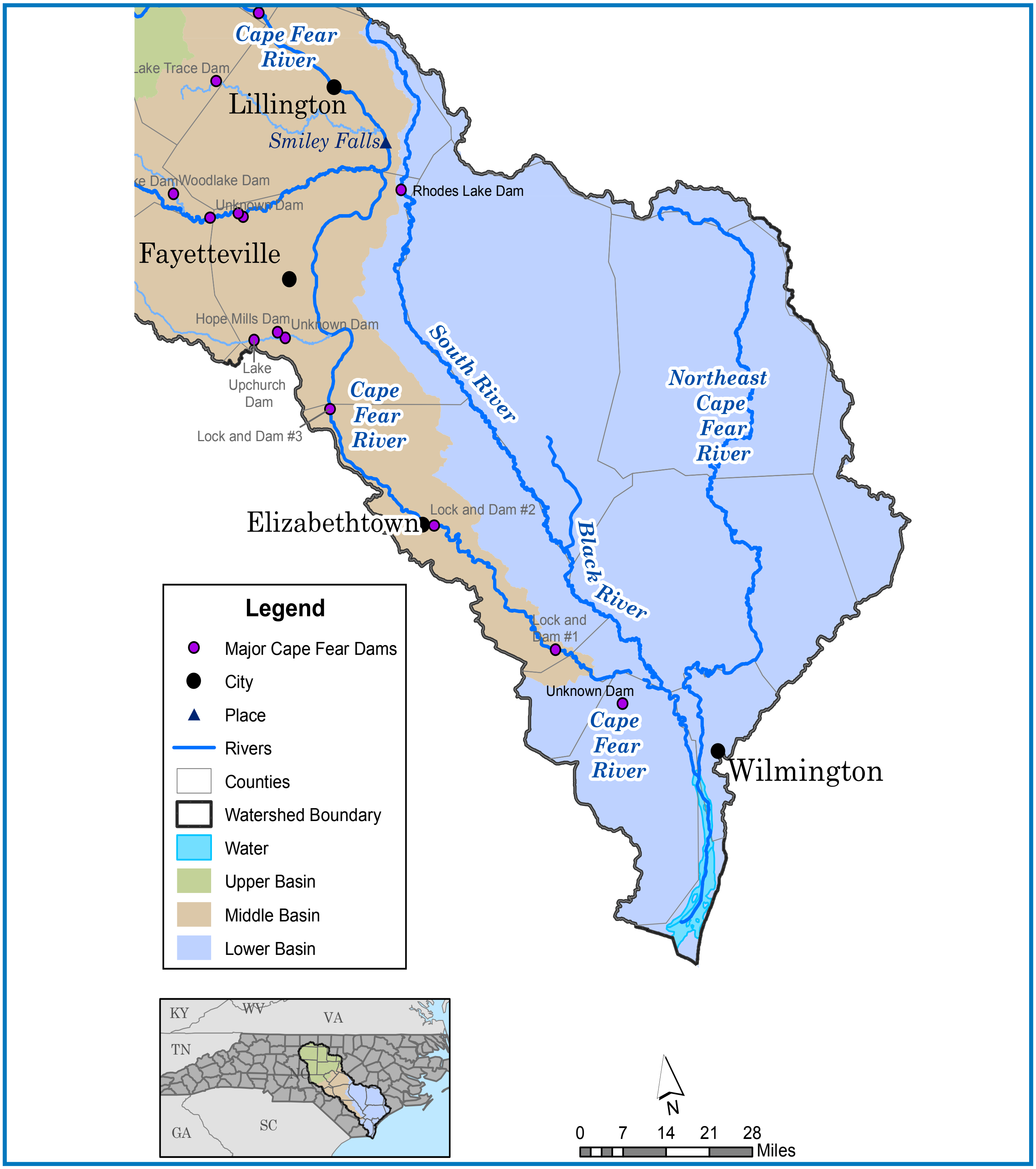

Figure 5: Anadromous fish spawning areas and primary nursery areas in the Cape Fear River basin.

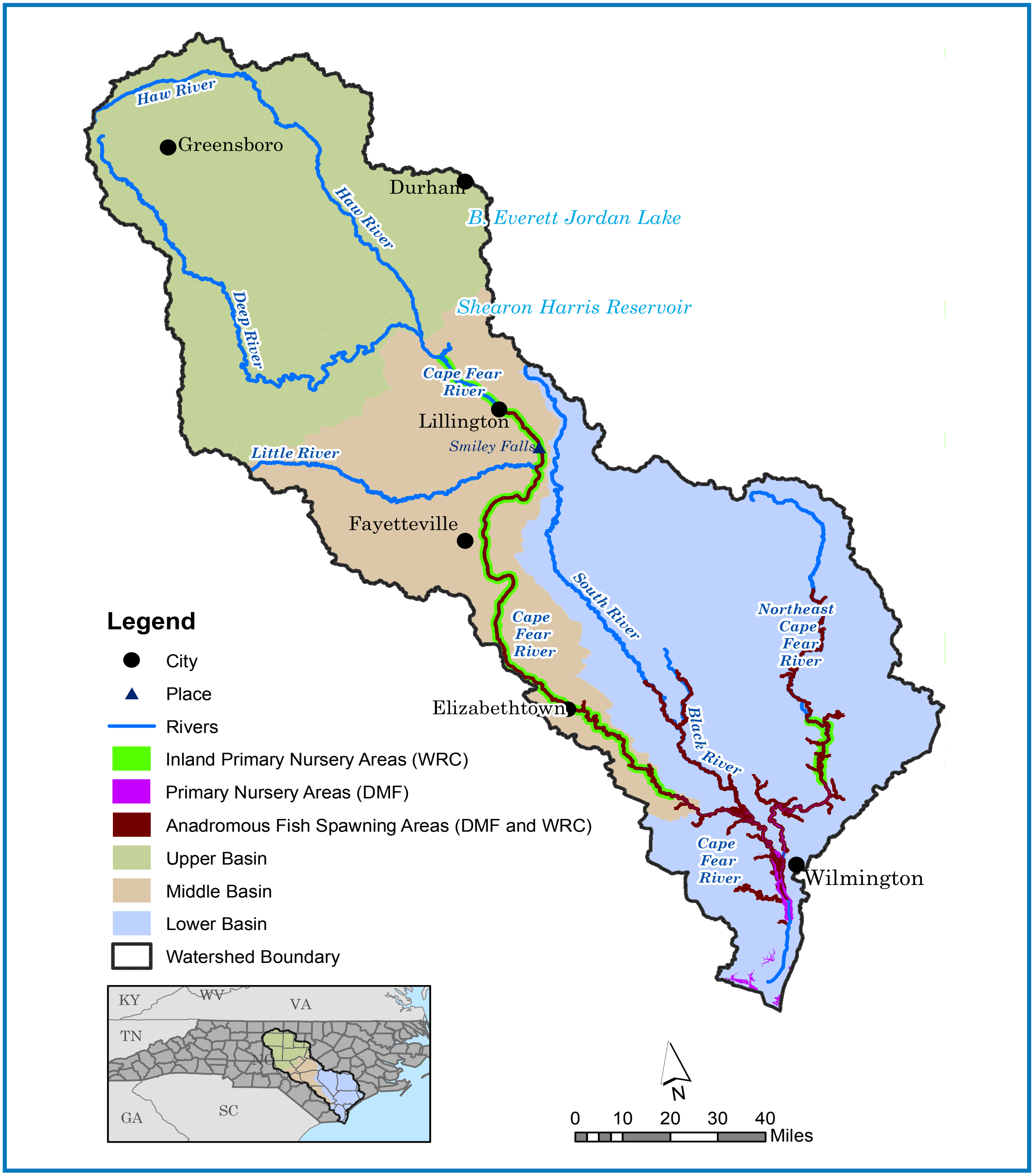

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Figure 6: Land cover in the Cape Fear River basin.

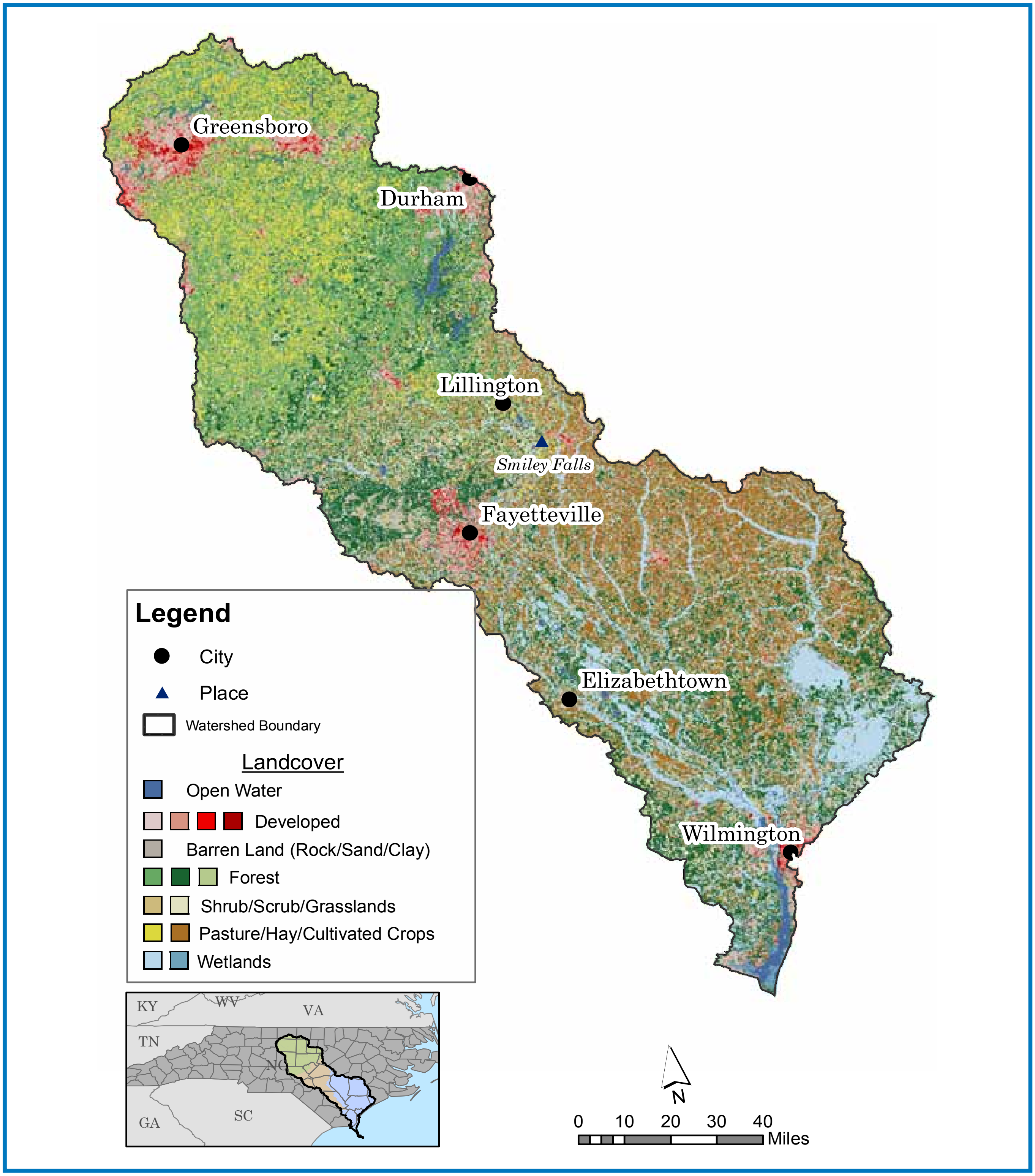


Figure 7: Permitted animal operations in the Cape Fear River basin.

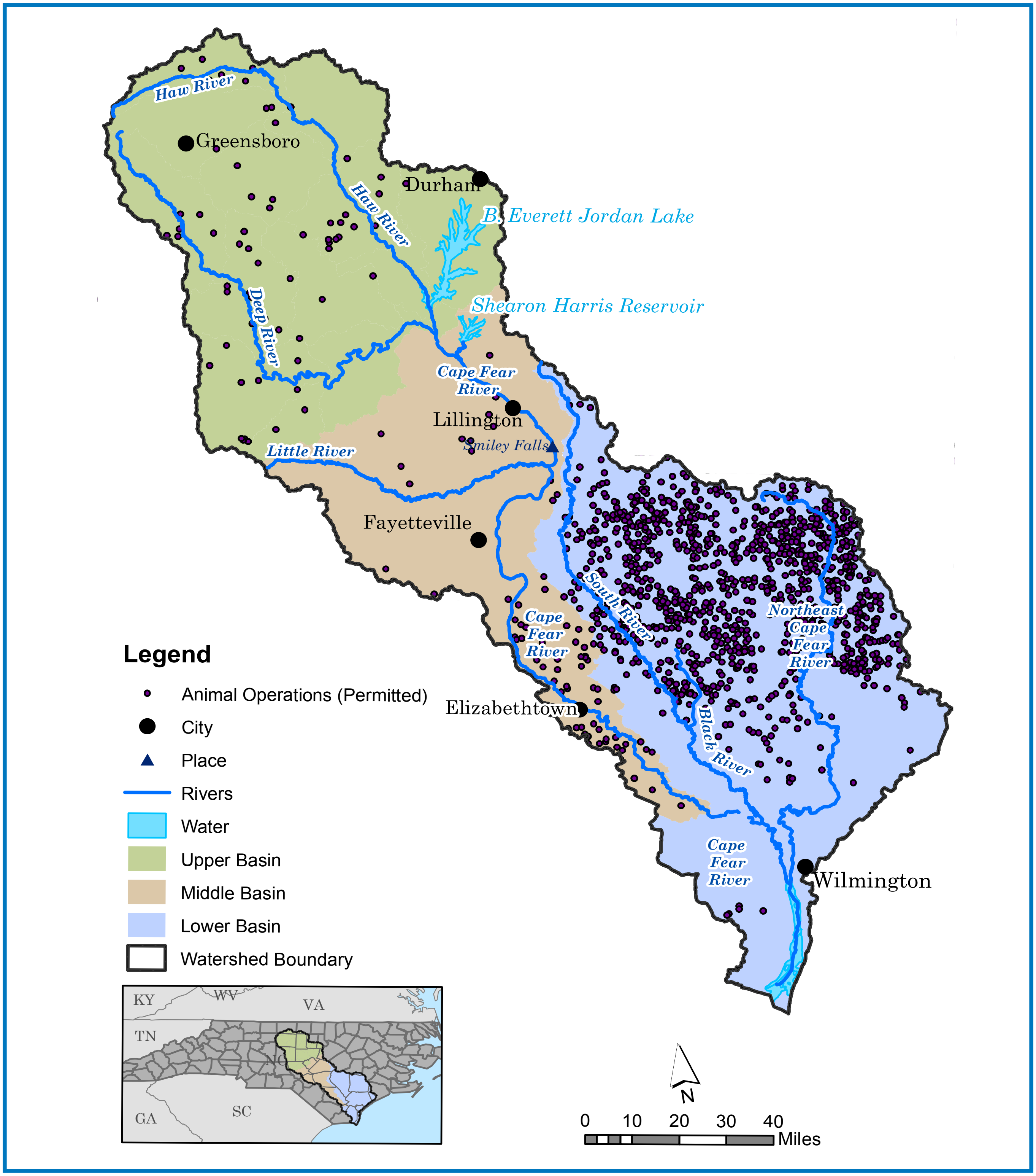
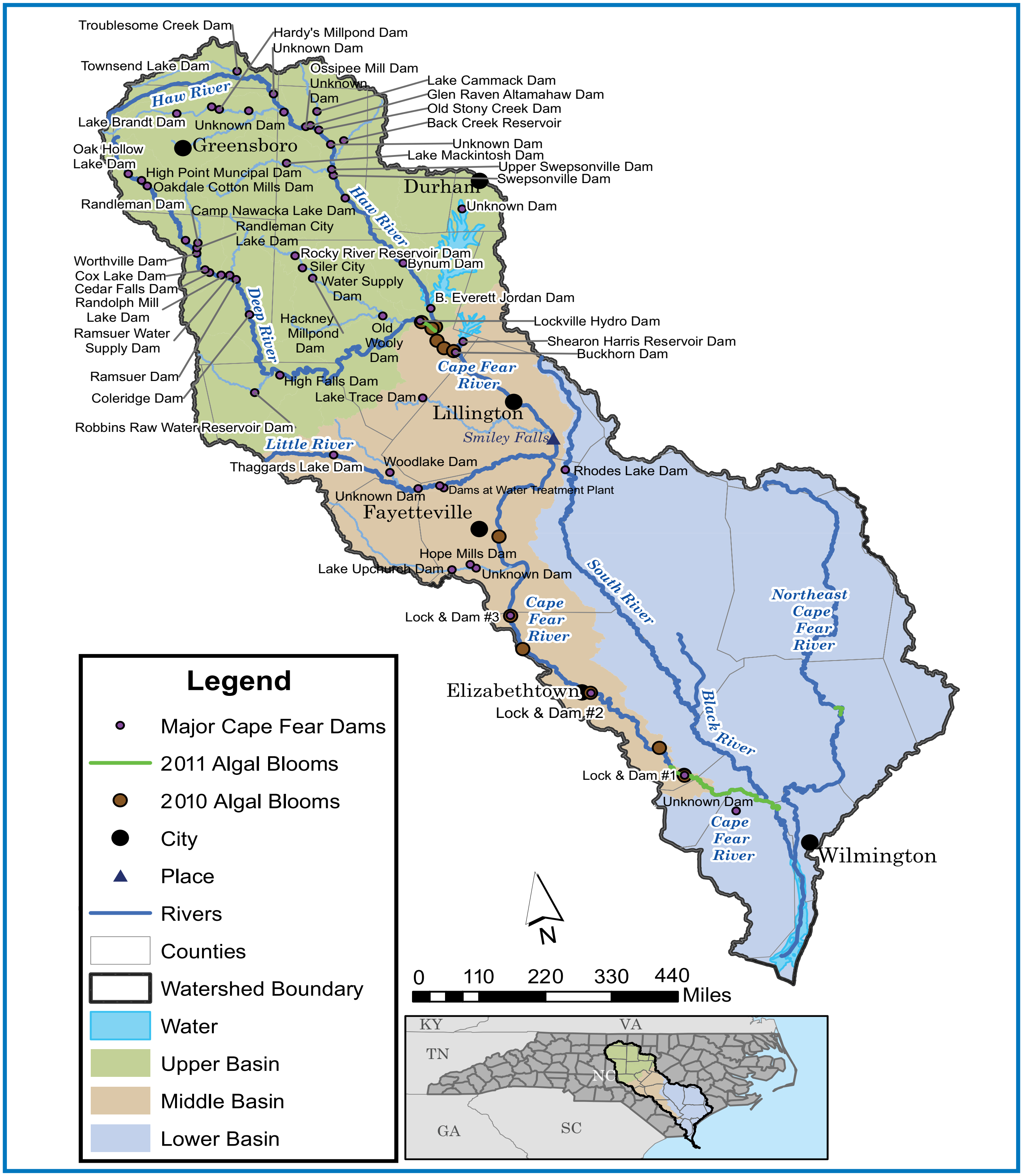


Figure 8: Documented algal blooms in the Cape Fear River basin in 2010 and 2011.



Appendix IV: Calculation Methods for Determining Estimated Original Population Sizes

Commercial landings data on sturgeons were developed by Earll (1887). The estimated harvest was 262,000 lbs in 1880 with an average size of 60 lbs. This equates to 4,367 fish harvested. Assuming that the harvest was half the spawning stock, an estimated population size was 8,700 sturgeon in the Cape Fear River.

Estimates of American shad and river herring were based on estimated acres of the Cape Fear and Northeast Cape FearRivers available for spawning. The population size of American shad was based on available habitat. Potential spawning habitat was 5,189 acres for the main stem Cape Fear River, 2,993 acres for the Northeast Cape Fear River, and 753 acres for tributaries. Using the rule-of-thumb estimate for density of 50 fish per acre for American shad (St. Pierre 1979) results in a total estimate for the Cape Fear River and its tributaries of 447,000 fish. River herring estimates were derived from the acreage and the ratio of commercial river herring harvest to American shad harvest (5:1 based on numbers of fish). The landings estimate was based on data presented in Chestnut and Davis (1975) for 1889, 1890, 1897, and 1902. The estimated run size of river herring was 2.3 million fish.

Striped bass estimates were derived from the ratio of commercial landings from the Albemarle stock with an estimated population size of 1 million fish and the Cape Fear River landings from 1889, 1890, 1897, and 1902 from Chestnut and Davis (1975). The striped bass estimate was 21,379 fish in the Cape Fear River spawning stock. Recent tagging work suggests a current population of several thousand fish (NCDMF unpublished research), so a target population size of 20,000 may be too low. The estimate of 100,000 fish was used based on best professional judgment. It would be useful to have a "rule-of-thumb" for striped bass similar to the method used to generate target run sizes for American shad.

American shad. Photo courtesy of NCWRC.

Appendix V: Results of American Rivers' North Carolina Barrier Prioritization Tool

In a recent study, Duke University Masters Student Kathleen Hoenke worked with American Rivers to develop a "North Carolina Barrier Prioritization Tool" to help inform decisions on potential dam removal projects (Hoenke 2012). Prioritizations were based on metrics that represented both social and ecological benefits of dam removals. The tool was developed using GIS, and used the following primary criteria to determine rankings: stream habitat quality, water quality, stream connectivity, stream flow, and public/social factors. This tool provides information to help identify and prioritize potential projects, but does not represent a final "ranking." Project priorities need to be determined based on ground-level investigations by interested agencies or organizations and landowner willingness. Dam removal projects are voluntary and require landowner consent.

The master barrier dataset used in the study compiled dams from the North Carolina Dam Safety Database, the Aquatic Obstruction Inventory, and the USACE's National Inventory of Dams. From this master dataset, a smaller dataset was developed for use in the prioritization tool that only included dams on perennial streams, and those with more than 1,000 feet upstream. Stream connectivity metrics, such as the distance upstream of a dam to the next dam, were calculated using TNC's Barrier Assessment Tool, and methods from The Nature Conservancy's Northeast Aquatic Connectivity Assessment Project.

Three prioritization scenarios were developed using this tool: (1) based solely on ecological criteria (e.g., water quality, connectivity, habitat, etc.); (2) including both ecological and social criteria (e.g., land ownership, use of the dam, presence of mill ponds, safety ratings); and (3) focusing on anadromous (migratory) fish (e.g., distance to spawning areas, number of downstream dams, stream flow).

Of the more than 1,100 dams in the Cape Fear River basin, 235 were prioritized for potential removal using the "anadromous fish scenario." This scenario used the following weights and criteria:

- 22.5% on the number of stream miles above the dam (connectivity rank)
- 22.5% on the total number of stream miles that would be reconnected (connectivity rank)
- 20% on stream flow / stream size (flow rank)
- 15% on distance to known Anadromous Fish Spawning Area (habitat rank)
- 10% on water quality (water quality rank)
- 5% on the number of dams downstream of the dam (connectivity rank)
- 5% on location within Historical Anadromous Fish Spawning Area (habitat rank)

These criteria were weighted and combined into four main category ranks as shown in parentheses above. It is important to note that the user of the tool may manipulate the criteria and their weights to look at specific desired factors.

Figure 9 and Table 1 show the results of the "anadromous fish scenario" described above for the Cape Fear River basin. The top 5 percent and 10 percent of priorities are shown, listed alphabetically by state ID. These results do not consider feasibility or ownership interest, and therefore do not reflect whether a dam should be removed or have fish passage. Each potential project would require additional individual investigation to determine feasibility and ownership interest in the project.

Figure 9: Results of the "Anadromous Fish Scenario" for the Cape Fear River basin (from American Rivers).

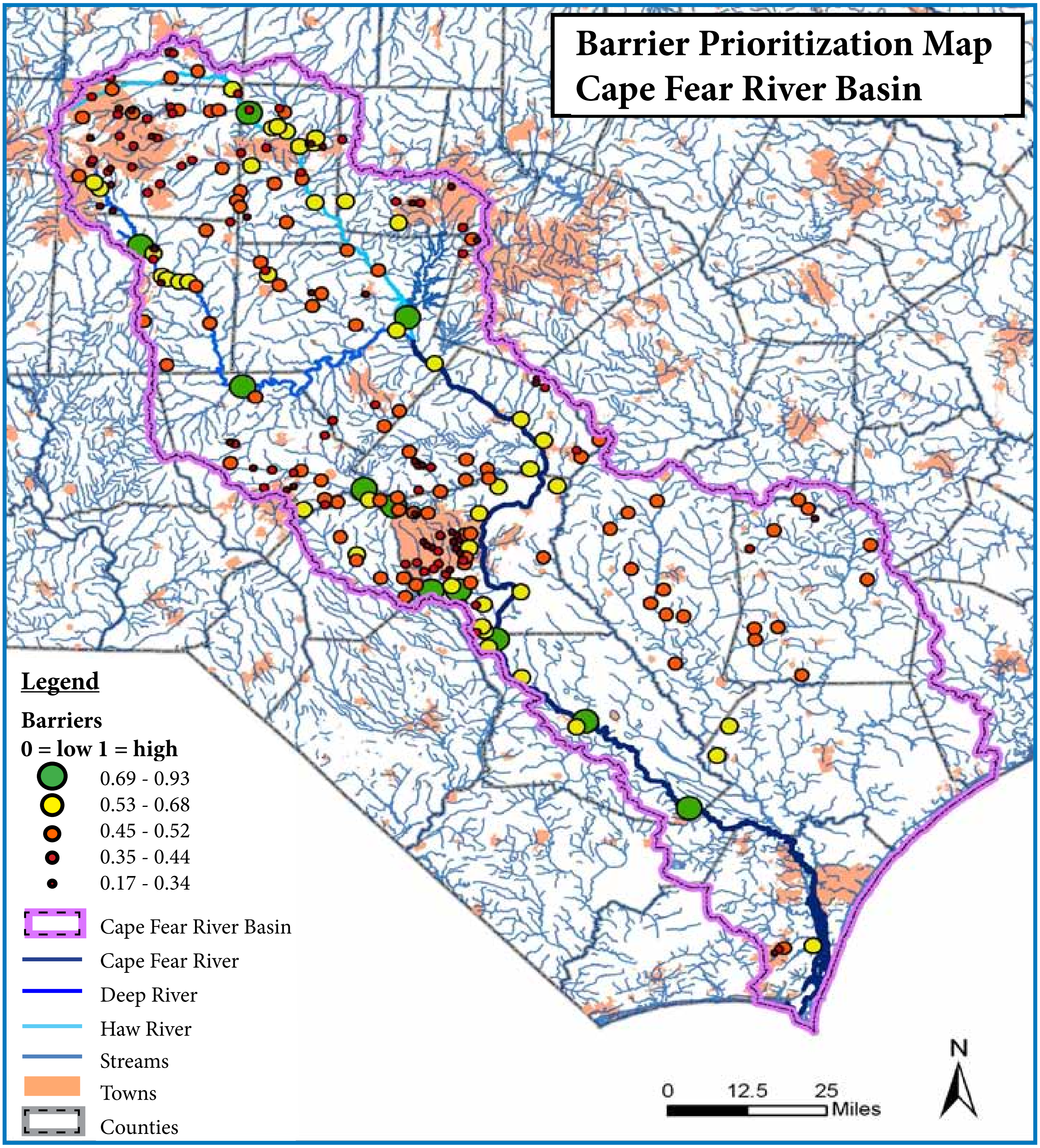


Table 1: Results of the “Anadromous Fish Scenario” for the Cape Fear River basin. Showing the top 5% and top 10% of priorities (based on American Rivers' table).

Percentile	State ID	Name	County	Hazard Rating	Stream	Owner Type
5%	ALAMA-E	UN-NAMED	Alamance	n/a	Reedy Fork	
5%	BLADE-001	Lock And Dam #1	Bladen	Low	Cape Fear River	Federal
5%	BLADE-002	Lock And Dam #2	Bladen	Low	Cape Fear River	Federal
5%	BLADE-003	Huske Lock And Dam	Bladen	Low	Cape Fear River	Private
5%	CHATH-001	B. Everett Jordan Lake	Chatham	High	Haw River	Federal
5%	CUMBE-029	Hope Mills Dam #1	Cumberland	High	Little Rockfish C	Local Gov
5%	CUMBE-063	Upchurch Lake Dam	Cumberland	High	Rockfish Creek	Private
5%	CUMBE-C	Un-named, Adjacent to 95	Cumberland	n/a	Rockfish C	
5%	MOORE-040	Woodlake Dam	Moore	High	Crains Creek	Private
5%	MOORE-A	Un-named	Moore	n/a	Little River	
5%	MOORE-C	High Falls	Moore	n/a	Deep River	
5%	RANDO-200	Randleman Dam	Randolph	High	Deep River	Private
10%	ALAMA-C	UN-NAMED	Alamance	n/a	Haw River	
10%	ALAMA-D	UN-NAMED	Alamance	n/a	Haw River	
10%	BLADE-019	Phillips Creek Dam	Bladen	High	Phillips Creek	Private
10%	BRUNS-005	Orton Lake Dam	Brunswick	Low	Orton Creek	Private
10%	CHATH-006	Charles L. Turner Reser	Chatham	High	Rocky River	Local Gov
10%	CHATH-021	Lockville Hydro Dam	Chatham	Intermediate	Deep River	Private
10%	CHATH-022	Buckhorn Lake Dam	Chatham	Low	Cape Fear River	Utility
10%	CUMBE-049	Dudley Lake Dam	Cumberland	Low	Cedar Creek	Private
10%	CUMBE-053	Rhodes Lake Dam	Cumberland	Intermediate	Black River	State

Percentile	State ID	Name	County	Hazard Rating	Stream	Owner Type
10%	CUMBE-055	Smith Lake Dam	Cumberland	Low	Cape Fear River-T	Private
10%	GUILF-096	City Lake Dam	Guilford	High	Deep River	Local Gov
10%	GUILF-158	Oakdale Cotten Mills Da	Guilford	Low	Deep River	Private
10%	HARNE-004	Elliot Sand & Gravel Pl	Harnett	Low	Little River	Private
10%	HARNE-067	Moore Dam	Harnett	High	Juniper Creek	Private
10%	HARNE-092	Keith Hills Golf Course	Harnett	Low	Buies Creek	
10%	MOORE-065	Fox Lake Dam	Moore	Low	Mill Creek-Tr	Private
10%	MOORE-B	UN-NAMED	Moore	n/a	Little River	
10%	ORANG-011	Cane Creek Resevoir Dam	Orange	High	Cane Creek	Local Gov
10%	PENDE-001	Lake Ann Dam	Pender	Low	Jones Creek	Private
10%	PENDE-003	Squires Lake Dam	Pender	Intermediate	White Oak Creek	Private
10%	RANDO-019	Randolph Mill Lake Dam	Randolph	Intermediate	Deep River	Private
10%	RANDO-038	Cox Lake Dam	Randolph	High	Deep River	Private
10%	RANDO-042	Randleman City Lake Dam	Randolph	High	Polecat Creek	Local Gov
10%	RANDO-B	Cedar Falls Upper	Randolph	n/a	Deep River	