Environmental Assessment of the Lower Cape Fear River System, 2009

By

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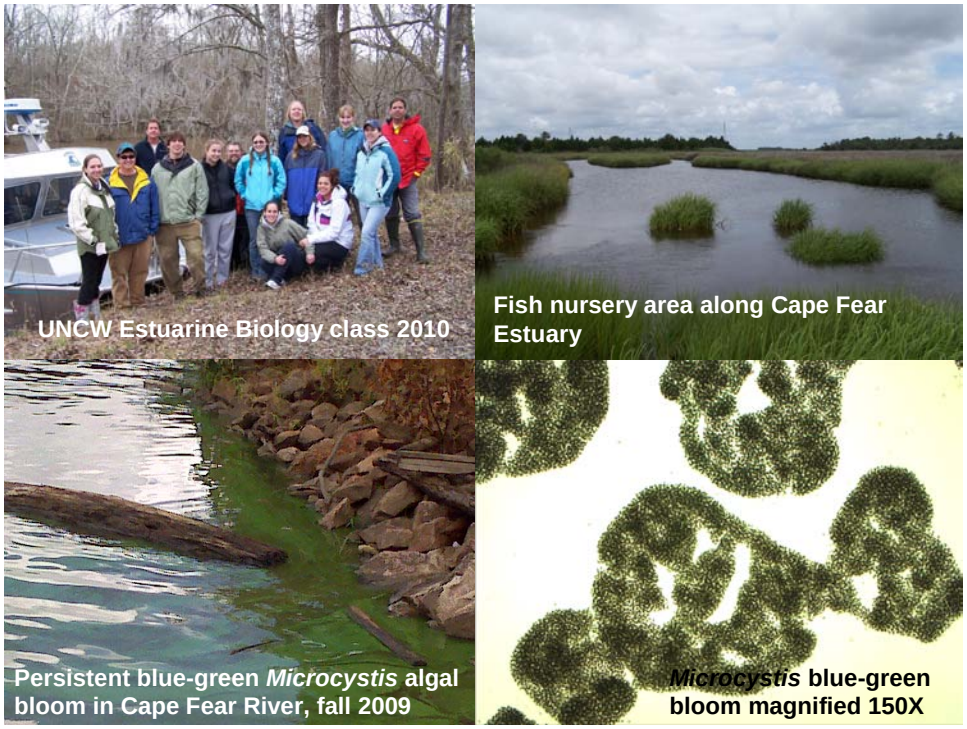

UNCW Estuarine Biology class 2010

Fish nursery area along Cape Fear Estuary

Persistent blue-green *Microcystis* algal bloom in Cape Fear River, fall 2009

Microcystis blue-green bloom magnified 150X

Executive Summary

Multiparameter water sampling for the Lower Cape Fear River Program (LCFRP) has been ongoing since June 1995. Scientists from the University of North Carolina Wilmington's (UNCW) Aquatic Ecology Laboratory perform the sampling effort. The LCFRP currently encompasses 36 water sampling stations throughout the Cape Fear, Black, and Northeast Cape Fear River watersheds. The LCFRP sampling program includes physical, chemical, and biological water quality measurements and analyses of the benthic and epibenthic macroinvertebrate communities, and has in the past included assessment of the fish communities. Principal conclusions of the UNCW researchers conducting these analyses are presented below, with emphasis on water quality of the period January - December 2009. The opinions expressed are those of UNCW scientists and do not necessarily reflect viewpoints of individual contributors to the Lower Cape Fear River Program.

The mainstem lower Cape Fear River is a 6th order stream characterized by periodically turbid water containing moderate to high levels of inorganic nutrients. It is fed by two large 5th order blackwater rivers (the Black and Northeast Cape Fear Rivers) that have low levels of turbidity, but highly colored water with less inorganic nutrient content than the mainstem. While nutrients are reasonably high in the river channels, major algal blooms have until recently been rare because light is attenuated by water color or turbidity, and flushing is usually high (Ensign et al. 2004). During periods of low flow (as in 2008) algal biomass as chlorophyll *a* increases in the river because lower flow causes settling of more solids and improves light conditions for algal growth. Periodically major algal blooms are seen in the tributary stream stations, some of which are impacted by point source discharges. Below some point sources, nutrient loading can be high and fecal coliform contamination occurs. Other stream stations drain blackwater swamps or agricultural areas, some of which periodically show elevated pollutant loads or effects (Mallin et al. 2001).

Average annual dissolved oxygen (DO) levels at the river channel stations for 2009 were similar to the average for 1996-2008. Dissolved oxygen levels were lowest during the summer, often falling below the state standard of 5.0 mg/L at several river and upper estuary stations. There is a dissolved oxygen sag in the main river channel that begins at Station DP below a paper mill discharge and near the Black River input, and persists into the mesohaline portion of the estuary. Mean oxygen levels were highest at the upper river stations NC11 and AC and in the middle to lower estuary at stations M42 to M18. Lowest mainstem average 2009 DO levels occurred at the lower river and upper estuary stations DP, BBT, IC, NAV, HB, BRR and M61 (6.6-6.9 mg/L). As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River. These rivers are classified as blackwater systems because of their tea colored water. The Northeast Cape Fear River often seems to be more oxygen stressed than the Black River; as such, in 2009 Stations NCF117 and B210,

representing those rivers, had average DO concentrations of 6.2 and 7.2 mg/L, respectively. Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2009. Station BCRR (upper Burgaw Creek) and SR (South River) had DO levels below 4.0 mg/L 58% of the occasions sampled, with NC403 (Northeast Cape Fear River headwaters) and GS (Goshen Swamp) 50%, and LVC2 (Livingston Creek) below standard 33% of occasions sampled. Considering all sites sampled in 2009, we rated 19% as poor for dissolved oxygen, 11% as fair, and 69% as good.

Annual mean turbidity levels for 2009 were generally similar to the long-term average. Highest mean turbidities were at the upper estuary sites NAV (27 NTU), HB (26 NTU) and BRR (25 NTU) with turbidities gradually decreasing downstream through the estuary. Turbidity was much lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river, and were low in general in the lower order streams.

Regarding stream stations, chronic or periodic high nitrate levels were found at a number of sites, including BC117 (Burgaw Creek below Burgaw), ROC (Rockfish Creek), 6RC (Six Runs Creek), NC403, and PB (Panther Branch). Average chlorophyll *a* concentrations were larger than usual, particularly from June through August 2009; during this same period river flow as measured by USGS at Lock and Dam #1 was lower for 2009 compared with the 1995-2009 long-term average (1,898 CFS compared with 3,704 CFS). In the estuary blooms occurred from M61 through M35, and stream stations that hosted algal blooms included GS, NC403, PB and SR, but this represented fewer blooms than in 2008. The most troublesome occurrence was the presence of cyanobacteria (i.e. blue-green algal blooms) in the Cape Fear River during autumn near and upstream of NC11. These consisted of *Microcystis aeruginosa*, which can produce toxins, and their persistence and concentrations was the greatest seen in this section of the river during the length of the Lower Cape Fear River Program. We note that fish kills did not occur related to the blooms.

Several stream stations, particularly BC117, BCRR, ROC, PB, BRN (Browns Creek), HAM, SAR (Northeast Cape Fear River near Sarecta), LVC2 and LRC showed high fecal coliform bacteria counts on a number of occasions. Periodically biochemical oxygen demand (BOD) concentrations in several Northeast Cape Fear River watershed stream stations (especially AC, N403, GS, ANC) and Station LVC2 in the Cape Fear Watershed were elevated (BOD5 3.0 mg/L or greater). Collection of water column metals was suspended in early 2007 as they are no longer required by NC DWQ.

This report also includes an in-depth look at each subbasin, providing information regarding the results of the North Carolina Division of Water Quality's 2005 Basinwide Management Plan, and providing the UNCW-Aquatic Ecology Laboratory's (AEL) assessments of the 2009 sampling year. The UNCW-AEL utilizes ratings that consider a water body to be of poor quality if the water quality standard for a given parameter is in violation > 25% of the time, of fair quality if the standard is in violation between 11 and 25% of the time, and good quality if the standard is violated no more than 10% of

the time. UNCW also considerers nutrient loading in water quality assessments, based on published experimental and field scientific findings.

For the 2009 period UNCW rated 100% of the stations as good in terms of chlorophyll *a*, likely due to increased river flows and light attenuation compared with the lower water period of 2008. For turbidity 86% of the sites were rated good, 11% fair, and 3% (one station) poor, all located in the upper estuary. Fecal coliform bacteria counts showed better water quality in 2009 compared to 2008, with 40% of the sites rated as good to fair compared with 52% in 2008. Using the 5.0 mg/L DO standard for the mainstem river stations, and the 4.0 mg/L "swamp water" DO standard for the stream stations and blackwater river stations, 39% of the sites were rated poor or fair for dissolved oxygen, somewhat less than in 2008. In addition, by our UNCW standards excessive nitrate and phosphorus concentrations were problematic at a number of stations (Chapter 3).

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1.0 Introduction

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The Lower Cape Fear River Program is a unique science and education program that has a mission to develop an understanding of processes that control and influence the ecology of the Cape Fear River, and to provide a mechanism for information exchange and public education. This program provides a forum for dialogue among the various Cape Fear River user groups and encourages interaction among them. Overall policy is set by an Advisory Board consisting of representatives from citizen's groups, local government, industries, academia, the business community, and regulatory agencies. This report represents the scientific conclusions of the UNCW researchers participating in this program and does not necessarily reflect opinions of all other program participants. This report focuses on the period January through December 2009.

The scientific basis of the LCFRP consists of the implementation of an ongoing comprehensive physical, chemical, and biological monitoring program. Another part of the mission is to develop and maintain a data base on the Cape Fear basin and make use of this data to develop management plans. Presently the program has amassed a 14-year (1995-2009) data base that is available to the public. Using this monitoring data as a framework the program goals also include focused scientific projects and investigation of pollution episodes. The scientific aspects of the program are carried out by investigators from the University of North Carolina Wilmington Center for Marine Science. The monitoring program was developed by the Lower Cape Fear River Program Technical Committee, which consists of representatives from UNCW, the North Carolina Division of Water Quality, The NC Division of Marine Fisheries, the US Army Corps of Engineers, technical representatives from streamside industries, the City of Wilmington Wastewater Treatment Plants, Cape Fear Community College, Cape Fear River Watch, the North Carolina Cooperative Extension Service, the US Geological Survey, forestry and agriculture organizations, and others. This integrated and cooperative program was the first of its kind in North Carolina.

Broad-scale monthly water quality sampling at 16 stations in the estuary and lower river system began in June 1995 (directed by Dr. Michael Mallin). Sampling was increased to 34 stations in February of 1996, 35 stations in February 1998, and 36 stations in 2005. The Lower Cape Fear River Program added another component concerned with studying the benthic macrofauna of the system in 1996. This component is directed by Dr. Martin Posey and Mr. Troy Alphin of the UNCW Biology Department and includes the benefit of additional data collected by the Benthic Ecology Laboratory under Sea Grant and NSF sponsored projects in the Cape Fear Estuary. The third major biotic component (added in January 1996) was an extensive fisheries program directed by Dr. Mary Moser of the UNCW Center for Marine Science Research, with subsequent (1999) overseeing by Mr. Michael Williams and Dr. Thomas Lankford of UNCW-CMS. This

program involved cooperative sampling with the North Carolina Division of Marine Fisheries and the North Carolina Wildlife Resources Commission. The fisheries program ended in December 1999, but was renewed with additional funds from the Z. Smith Reynolds Foundation from spring – winter 2000. The regular sampling that was conducted by UNCW biologists was assumed by the North Carolina Division of Marine Fisheries.

1.1. Site Description

The mainstem of the Cape Fear River is formed by the merging of the Haw and the Deep Rivers in Chatham County in the North Carolina Piedmont. However, its drainage basin reaches as far upstream as the Greensboro area (Fig. 1.1). The mainstem of the river has been altered by the construction of several dams and water control structures. In the coastal plain, the river is joined by two major tributaries, the Black and the Northeast Cape Fear Rivers (Fig. 1.1). These 5th order blackwater streams drain extensive riverine swamp forests and add organic color to the mainstem. The watershed (about 9,149 square miles) is the most heavily industrialized in North Carolina with 244 permitted wastewater discharges with a permitted flow of approximately 425 million gallons per day, and (as of 2000) over 1.83 million people residing in the basin (NCDENR 2005). Approximately 24% of the land use in the watershed is devoted to agriculture and livestock production (NCDENR 2005), with livestock production dominated by swine and poultry operations. Thus, the watershed receives considerable point and non-point source loading of pollutants. However, the estuary is a well-flushed system, with flushing time ranging from 1 to 22 days with a median flushing time of about seven days, much shorter than the other large N.C. estuaries to the north (Ensign et al. 2004).

Water quality is monitored by boat at nine stations in the Cape Fear Estuary (from Navassa to Southport) and one station in the Northeast Cape Fear Estuary (Table 1.1; Fig. 1.1). Riverine stations sampled by boat include NC11, AC, DP, IC, and BBT (Table 1.1; Fig. 1.1). NC11 is located upstream of any major point source discharges in the lower river and estuary system, and is considered to be representative of water quality entering the lower system (we note that the City of Wilmington and portions of Brunswick County get their drinking water from the river just upstream of Lock and Dan #1). Station BBT is located on the Black River between Thoroughfare (a stream connecting the Cape Fear and Black Rivers) and the mainstem Cape Fear, and is influenced by both rivers. We consider B210 and NCF117 to represent water quality entering the lower Black and Northeast Cape Fear Rivers, respectively. Data has also been collected at stream and river stations throughout the Cape Fear, Northeast Cape Fear, and Black River watersheds (Table 1.1; Fig. 1.1; Mallin et al. 2001). Data collection at a station in the Atlantic Intracoastal Waterway was initiated in February 1998 to obtain water quality information near the Southport Wastewater Treatment Plant discharge, and there is one station, SC-CH, sampled for selected parameters on Smith Creek at Castle Hayne Road (Table 1.1).

1.2. Report Organization

This report contains two sections assessing LCFRP data. Section 2 presents an overview of physical, chemical, and biological water quality data from the 36 individual stations, and provides tables of raw data as well as figures showing spatial or temporal trends. In Section 3 we analyze our data by sub-basin, give information regarding the NC DWQ's 2005 Basinwide Plan, and make UNCW-based water quality ratings for dissolved oxygen, turbidity, chlorophyll *a*, and fecal coliform bacterial abundance. We also utilize other relevant parameters such as nutrient concentrations to aid in these assessments. This section is designed so that residents of a particular sub-basin can see what the water quality is like in his or her area based on LCFRP data collections.

The LCFRP has a website that contains maps and an extensive amount of past water quality, benthos, and fisheries data gathered by the Program available at: www.uncw.edu/cmsr/aquaticecology/lcfrp/

References Cited

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.

Mallin, M.A., S.H. Ensign, M.R. McIver, G.C. Shank and P.K. Fowler. 2001. Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. *Hydrobiologia* 460:185-193.

NCDENR. 2005. Cape Fear River Basinwide Water Quality Plan. North Carolina Department of Environment and Natural Resources, Division of Water Quality/Planning, Raleigh, NC, 27699-1617.

Table 1.1. Description of sampling locations in the Cape Fear Watershed, 2009, including UNCW designation and NCDWQ station designation number.

UNCW St.	DWQ No.	Location	
High order river and estuary stations			
NC11	B8360000	At NC 11 bridge on Cape Fear River (CFR)	
GPS		N 34.39663	W 78.26785
AC	B8450000	5 km downstream from International Paper on CFR	
GPS		N 34.35547	W 78.17942
DP	B8460000	At DAK America's Intake above Black River	
GPS		N 34.33595	W 78.05337
IC	B9030000	Cluster of dischargers upstream of Indian Cr. on CFR	
GPS		N 34.30207	W 78.01372
B210	B9000000	Black River at Highway 210 bridge	
GPS		N 34.43138	W 78.14462
BBT	none	Black River between Thoroughfare and Cape Fear River	
GPS		N 34.35092	W 78.04857
NCF117	B9580000	Northeast Cape Fear River at Highway 117, Castle Hayne	
GPS		N 34.36342	W 77.89678
NCF6	B9670000	Northeast Cape Fear River near GE dock	
GPS		N 34.31710	W 77.95383
NAV	B9050000	Railroad bridge over Cape Fear River at Navassa	
GPS		N 34.25943	W 77.98767
HB	B9050100	Cape Fear River at Horseshoe Bend	
GPS		N 34.24372	W 77.96980
BRR	B9790000	Brunswick River at John Long Park in Belville	
GPS		N 34.22138	W 77.97868
M61	B9750000	Channel Marker 61, downtown at N.C. State Port	
GPS		N 34.19377	W 77.95725

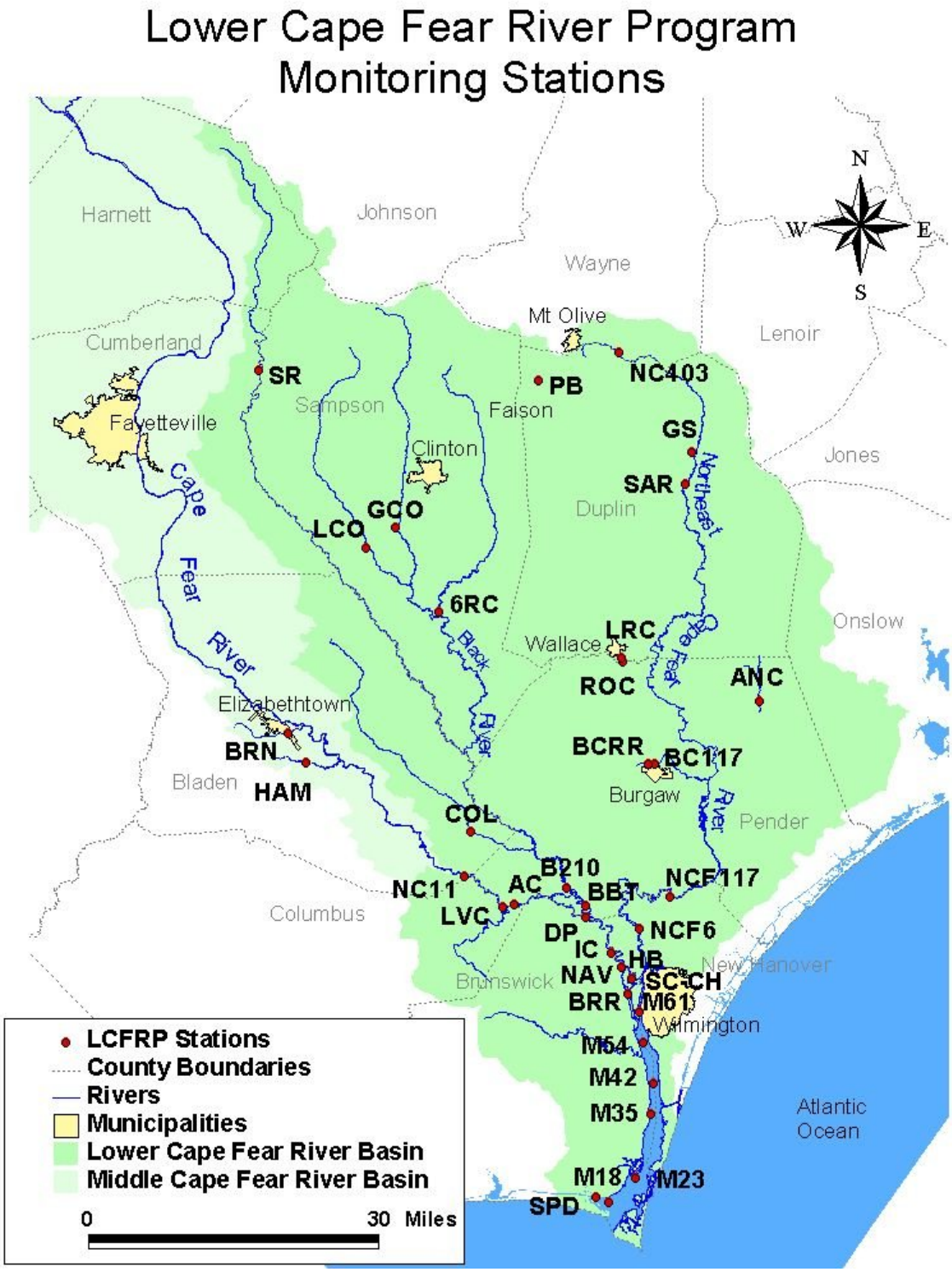
M54	B7950000	Channel Marker 54, 5 km downstream of Wilmington	
GPS		N 34.13933	W 77.94595
M42	B9845100	Channel Marker 42 near Keg Island	
GPS		N 34.09017	W 77.93355
M35	B9850100	Channel Marker 35 near Olde Brunswick Towne	
GPS		N 34.03408	W 77.93943
M23	B9910000	Channel Marker 23 near CP&L intake canal	
GPS		N 33.94560	W 77.96958
M18	B9921000	Channel Marker 18 near Southport	
GPS		N 33.91297	W 78.01697
SPD	B9980000	1000 ft W of Southport WWT plant discharge on ICW	
GPS		N 33.91708	W 78.03717

Stream stations collected from land

SR	B8470000	South River at US 13, below Dunn	
GPS		N 35.15600	W 78.64013
GCO	B8604000	Great Coharie Creek at SR 1214	
GPS		N 34.91857	W 78.38873
LCO	B8610001	Little Coharie Creek at SR 1207	
GPS		N 34.83473	W 78.37087
6RC	B8740000	Six Runs Creek at SR 1003 (Lisbon Rd.)	
GPS		N 34.79357	W 78.31192
BRN	B8340050	Browns Creek at NC 87	
GPS		N 34.61360	W 78.58462
HAM	B8340200	Hammonds Creek at SR 1704	
GPS		N 34.56853	W 78.55147
LVC2	B8441000	on Livingston Creek near Acme	
GPS		N 34.33530	W 78.2011
COL	B8981000	Colly Creek at NC 53	
GPS		N 34.46500	W 78.26553

ANC	B9490000	Angola Creek at NC 53	
GPS		N 34.65705	W 77.73485
NC403	B9090000	Northeast Cape Fear below Mt. Olive Pickle at NC403	
GPS		N 35.17838	W 77.98028
PB	B9130000	Panther Branch below Bay Valley Foods	
GPS		N 35.13445	W 78.13630
GS	B9191000	Goshen Swamp at NC 11	
GPS		N 35.02923	W 77.85143
SAR	B9191500	Northeast Cape Fear River near Sarecta	
GPS		N 34.97970	W 77.86251
LRC	B9460000	Little Rockfish Creek at NC 11	
GPS		N 34.72247	W 77.98145
ROC	B9430000	Rockfish Creek at US 117	
GPS		N 34.71689	W 77.97961
BCRR	B9500000	Burgaw Canal at Wright St., above WWTP	
GPS		N 34.56334	W 77.93481
BC117	B9520000	Burgaw Canal at US 117, below WWTP	
GPS		N 34.56391	W 77.92210
SC-CH	B9720000	Smith Creek at Castle Hayne Rd.	
GPS		N 34.25897	W 77.93872

Figure 1.1 Map of the Lower Cape Fear River system and the LCFRP sampling stations.



2.0 Physical, Chemical, and Biological Characteristics of the Lower Cape Fear River and Estuary

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2.1 - Introduction

This section of the report includes a discussion of the physical, chemical, and biological water quality parameters, concentrating on the January-December 2009 Lower Cape Fear River Program monitoring period. These parameters are interdependent and define the overall condition of the river. Physical parameters measured during this study included water temperature, dissolved oxygen, field turbidity and laboratory turbidity, total suspended solids (TSS), salinity, conductivity, pH and light attenuation. The chemical makeup of the Cape Fear River was investigated by measuring the magnitude and composition of nitrogen and phosphorus in the water. Three biological parameters including fecal coliform bacteria, chlorophyll *a* and biochemical oxygen demand were examined.

2.2 - Materials and Methods

All samples and field parameters collected for the estuarine stations of the Cape Fear River (NAV down through M18) were gathered on an ebb tide. This was done so that the data better represented the river water flowing downstream through the system rather than the tidal influx of coastal ocean water. Sample collection and analyses were conducted according to the procedures in the Lower Cape Fear River Program Quality Assurance/Quality Control (QA/QC) manual. Technical Representatives from the LCFRP Technical Committee and representatives from the NC Division of Water Quality inspect UNCW laboratory procedures and periodically accompany field teams to verify proper procedures are followed. We note that our previous Livingston Creek station (LVC) has been discontinued and a new station sampled from the dock of Hexion Specialty Chemicals near Acme (LVC2) was put into operation in 2005.

Physical Parameters

Water Temperature, pH, Dissolved Oxygen, Turbidity, Salinity, Conductivity

Field parameters were measured at each site using a YSI 6920 (or 6820) multi-parameter water quality sonde displayed on a YSI 650 MDS. Each parameter is measured with individual probes on the sonde. At stations sampled by boat (see Table 1.1) physical parameters were measured at 0.1 m, the middle of the water column, and at the bottom (up to 12 m). Occasionally, high flow prohibited the sonde from reaching the actual bottom and measurements were taken as deep as possible. At the terrestrially sampled stations the physical parameters were measured at a depth of 0.1 m. The Aquatic Ecology

Laboratory at the UNCW CMS is State-certified by the N.C. Division of Water Quality to perform field parameter measurements.

Chemical Parameters

Nutrients

All nutrient analyses were performed at the UNCW Center for Marine Science (CMS) for samples collected prior to January 1996. A local State-certified analytical laboratory was contracted to conduct all subsequent analyses except for orthophosphate, which is performed at CMS. The following methods detail the techniques used by CMS personnel for orthophosphate analysis.

Orthophosphate (PO_4^{-3})

Water samples were collected ca. 0.1 m below the surface in triplicate in amber 125 mL Nalgene plastic bottles and placed on ice. In the laboratory 50 mL of each triplicate was filtered through separate1.0 micron pre-combusted glass fiber filters, which were frozen and later analyzed for chlorophyll *a*. The triplicate filtrates were pooled in a glass flask, mixed thoroughly, and approximately 100 mL was poured into a 125 mL plastic bottle to be analyzed for orthophosphate. Samples were frozen until analysis.

Orthophosphate analyses were performed in duplicate using an approved US EPA method for the Bran-Lubbe AutoAnalyzer (Method 365.5). In this technique the orthophosphate in each sample reacts with ammonium molybdate and anitmony potassium tartrate in an acidic medium (sulfuric acid) to form an anitmony-phospho-molybdate complex. The complex is then reacted with ascorbic acid and forms a deep blue color. The intensity of the color is measured at a wavelength of 880 nm by a colorimeter and displayed on a chart recorder. Standards and spiked samples were analyzed for quality assurance.

Biological Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria were analyzed at a State-certified laboratory contracted by the LCFRP. Samples were collected approximately 0.1 m below the surface in sterile plastic bottles provided by the contract laboratory and placed on ice for no more than six hours before analysis.

Chlorophyll a

The analytical method used to measure chlorophyll *a* is described in Welschmeyer (1994) and US EPA (1997) and was performed by CMS personnel. Chlorophyll *a* concentrations were determined utilizing the 1.0 micron filters used for filtering samples for orthophosphate analysis. All filters were wrapped individually in foil, placed in airtight containers and stored in the freezer. During analysis each filter was immersed in 10 mL of

90% acetone for 24 hours, which extracts the chlorophyll *a* into solution. Chlorophyll *a* concentration of each solution was measured on a Turner 10-AU fluorometer. The fluorometer uses an optimal combination of excitation and emission bandwidth filters which reduces the errors inherent in the acidification technique. The Aquatic Ecology Laboratory at the CMS is State-certified by the N.C. Division of Water Quality for the analysis of chlorophyll *a*.

Biochemical Oxygen Demand (BOD)

Five sites were originally chosen for BOD analysis. One site was located at NC11, upstream of International Paper, and a second site was at AC, about 3 miles downstream of International Paper (Fig.1.1). Two sites were located in blackwater rivers (NCF117 and B210) and one site (BBT) was situated in an area influenced by both the mainstem Cape Fear River and the Black River. For the sampling period May 2000-April 2004 additional BOD data were collected at stream stations 6RC, LCO, GCO, BRN, HAM and COL in the Cape Fear and Black River watersheds. In May 2004 those stations were dropped and sampling commenced at ANC, SAR, GS, N403, ROC and BC117 in the Northeast Cape Fear River watershed. The procedure used for BOD analysis was Method 5210 in Standard Methods (APHA 1995). Samples were analyzed for both 5-day and 20-day BOD. During the analytical period, samples were kept in airtight bottles and placed in an incubator at 20^{o} C. All experiments were initiated within 6 hours of sample collection. Samples were analyzed in duplicate. Dissolved oxygen measurements were made using a YSI Model 5000 meter that was air-calibrated. No adjustments were made for pH since most samples exhibited pH values within or very close to the desired 6.5-7.5 range (pH is monitored during the analysis as well); a few sites have naturally low pH and there was no adjustment for these samples because it would alter the natural water chemistry and affect true BOD.

2.3 - Results and Discussion

This section includes results from monitoring of the physical, biological, and chemical parameters at all stations for the time period January-December 2009. Discussion of the data focuses both on the river channel stations and stream stations, which sometimes reflect poorer water quality than mainstem stations. The contributions of the two large blackwater tributaries, the Northeast Cape Fear River and the Black River, are represented by conditions at NCF117 and B210, respectively. The Cape Fear Region did not experience any significant hurricane activity during this monitoring period (after major hurricanes in 1996, 1998, and 1999). Therefore this report reflects low to medium flow conditions for the Cape Fear River and Estuary.

Physical Parameters

Water temperature

Water temperatures at all stations ranged from 4.0 to 30.8^{o}C, and individual station annual averages ranged from 16.7 to 20.8^{o}C (Table 2.1). Highest temperatures occurred during July and August and lowest temperatures during February. Stream stations were generally cooler than river stations, most likely because of shading and lower nighttime air temperatures affecting the shallower waters.

Salinity

Salinity at the estuarine stations (NAV through SPD) ranged from 0.1 to 34.2 practical salinity units (psu) and station annual means ranged from 1.3 to 28.4 psu (Table 2.2), somewhat lower than in 2008. Lowest salinities occurred in December and highest salinities occurred in July. In the upper estuary the annual mean salinity for 2009 was lower than that of the twelve-year average for 1996-2008 for all stations (Figure 2.1), approximately equal to the long-term mean in mid-estuary, and higher in the lowest portions of the estuary. Two stream stations, NC403 and PB, had occasional oligohaline conditions due to discharges from pickle production facilities.

Conductivity

Conductivity at the estuarine stations ranged from 0.10 to 52.01 mS/cm and from 0.06 to 12.33 mS/cm at the freshwater stations (Table 2.3). Temporal conductivity patterns followed those of salinity. Dissolved ionic compounds increase the conductance of water, therefore, conductance increases and decreases with salinity, often reflecting river flow conditions due to rainfall. Conductivity may also reveal point source pollution sources, as is seen at BC117, which is below a municipal wastewater discharge. Stations PB and NC403 are below industrial discharges, and often have elevated conductivity. Smith Creek (SC-CH) is an estuarine tidal creek and the conductivity values reflect this (Table 2.3).

pH

pH values ranged from 3.8 to 8.1 and station annual means ranged from 4.1 to 7.9 (Table 2.4). pH was typically lowest upstream due to acidic swamp water inputs and highest downstream as alkaline seawater mixes with the river water. Low pH values at COL predominate because of naturally acidic blackwater inputs at this near-pristine stream station.

Dissolved Oxygen

Dissolved oxygen (DO) problems are a major water quality concern in the lower Cape Fear River and its estuary, and several of the tributary streams (Mallin et al. 1999; 2000; 2001a; 2001b; 2002a; 2002b; 2003; 2004; 2005a; 2006a; 2006b; 2007; 2008). Surface concentrations for all sites in 2009 ranged from 0.6 to 12.2 mg/L and station annual means

ranged from 4.2 to 9.3 mg/L (Table 2.5). Average annual DO levels at the river channel and estuarine stations for 2009 were very similar to the average for 1996-2008 (Figure 2.2). River dissolved oxygen levels were lowest during the summer and early fall (Table 2.5), often falling below the state standard of 5.0 mg/L at several river and upper estuary stations. Working synergistically to lower oxygen levels are two factors: lower oxygen carrying capacity in warmer water and increased bacterial respiration (or biochemical oxygen demand, BOD), due to higher temperatures in summer. Unlike other large North Carolina estuaries (the Neuse, Pamlico and New River) the Cape Fear estuary rarely suffers from dissolved oxygen stratification. This is because despite salinity stratification the oxygen remains well mixed due to strong estuarine gravitational circulation and high freshwater inputs (Lin et al. 2006). Thus, hypoxia in the Cape Fear is present throughout the water column.

There is a dissolved oxygen sag in the main river channel that begins at DP below a paper mill discharge and persists into the mesohaline portion of the estuary (Fig. 2.2). Mean oxygen levels were highest at the upper river stations NC11 and AC and in the low-to-middle estuary at stations M23 and M35. Lowest mainstem mean 2009 DO levels occurred at the river and upper estuary stations IC, NAV, HB, BRR and M61 (6.6-6.9 mg/L). NAV and HB were both below 5.0 mg/L on 42% of occasions sampled and BRR was below on 33%. All river stations upstream (NC11, AC, DP, BBT, and IC) were below 4.0 mg/L on 9% of occasions sampled or less, and rated as Good. Discharge of high BOD waste from the paper/pulp mill just above the AC station (Mallin et al. 2003), as well as inflow of blackwater from the Northeast Cape Fear and Black Rivers, has in other years helped to diminish oxygen in the upper estuary. Additionally, algal blooms periodically form behind Lock and Dam #1, and the chlorophyll *a* they produce is strongly correlated with BOD at Station NC11 (Mallin et al. 2006b); thus the blooms do contribute to lower DO in the river. As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River (NCF117 2009 mean = 6.2, NCF6 = 6.5, B210 2009 mean = 7.2). These rivers are classified as blackwater systems because of their tea colored water. As the water passes through swamps en route to the river channel, tannins from decaying vegetation leach into the water, resulting in the observed color. Decaying vegetation on the swamp floor has an elevated biochemical oxygen demand and usurps oxygen from the water, leading to naturally low dissolved oxygen levels. Runoff from concentrated animal feeding operations (CAFOs) may also contribute to chronic low dissolved oxygen levels in these blackwater rivers (Mallin et al. 1998; 1999; 2006; Mallin 2000). We note that phosphorus and nitrogen (components of animal manure) levels are positively correlated with BOD in the blackwater rivers and their major tributaries (Mallin et al. 2006b).

In the past the Northeast Cape Fear River has often been more oxygen stressed than the Black River, and in 2009 Stations NCF117 DO concentrations were again somewhat lower than at B210 (means 6.2 and 7.2 mg/L, respectively). Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2009. Stations SR had DO levels below 4.0 mg/L 58% of the occasions sampled, with NC403 and GS 50%, and

LVC2 33%, and BCRR 25% (Table 2.5). Some of this can be attributed to low summer water conditions and some potentially to CAFO runoff; however point-source discharges also likely contribute to low dissolved oxygen levels at NC403 and possibly SR, especially via nutrient loading (Mallin et al. 2001a; 2002a; 2004). Hypoxia is thus a widespread problem, with 39% of the sites impacted in 2008.

Field Turbidity

Field turbidity levels ranged from 0 to 167 Nephelometric turbidity units (NTU) and station annual means ranged from 3 to 27 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Annual mean turbidity levels for 2009 were lower than the long-term average in the river stations, higher in the upper estuary, then lower in the mid-to-lower estuary (Fig. 2.3). Highest mean turbidities were at NAV, HB and BRR (25-27 NTU) with turbidities generally low in the middle to lower estuary (Figure 2.3). Turbidity was considerably lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river. Average turbidity levels were low in the freshwater streams, with the exception of BC117 and to a lesser extent BCRR, PB and LRC. The State standard for freshwater turbidity is 50 NTU.

Note: In addition to the laboratory-analyzed turbidity that are required my NCDWQ for seven locations, the LCFRP uses nephelometers designed for field use, which allows us to acquire in situ turbidity from a natural situation. North Carolina regulatory agencies are required to use turbidity values from water samples removed from the natural system, put on ice until arrival at a State-certified laboratory, and analyzed using laboratory nephelometers. Standard Methods notes that transport of samples and temperature change alters true turbidity readings. Our analysis of samples using both methods shows that lab turbidity is nearly always lower than field turbidity; thus we do not discuss lab turbidity in this report.

Total Suspended Solids

Total suspended solid (TSS) values system wide ranged from 1 to 110 mg/L with station annual means from 1 to 24 mg/L (Table 2.7). The overall highest values were at NAV and NCF6. In the stream stations TSS was generally considerably lower than the river and estuary, except for Station PB. Although total suspended solids (TSS) and turbidity both quantify suspended material in the water column, they do not always go hand in hand. High TSS does not mean high turbidity and vice versa. This anomaly may be explained by the fact that fine clay particles are effective at dispersing light and causing high turbidity readings, while not resulting in high TSS. On the other hand, large organic or inorganic particles may be less effective at dispersing light, yet their greater mass results in high TSS levels. While there is no NC ambient standard for TSS, many years of data from the lower Cape Fear watershed indicates that 25 mg/L can be considered elevated.

Light Attenuation

The attenuation of solar irradiance through the water column is measured by a logarithmic function (k) per meter. The higher this light attenuation coefficient is the more strongly light is attenuated (through absorbance or reflection) in the water column. River and estuary light attenuation coefficients ranged from 0.97 to 6.63/m and station annual means ranged from 1.84 at M23 to 4.49 /m at NCF6 (Table 2.8). In the Cape Fear system, light is attenuated by both turbidity and water color.

High light attenuation did not always coincide with high turbidity. Blackwater, though low in turbidity, will attenuate light through absorption of solar irradiance. At NCF6 and BBT, blackwater stations with moderate turbidity levels, light attenuation was high. Compared to other North Carolina estuaries the Cape Fear has high average light attenuation. The high average light attenuation is a major reason why phytoplankton production in the major rivers and the estuary of the LCFR is generally low. Whether caused by turbidity or water color this attenuation tends to limit light availability to the phytoplankton (Mallin et al. 1997; 1999; 2004).

Chemical Parameters – Nutrients

Total Nitrogen

Total nitrogen (TN) is calculated from TKN (see below) plus nitrate; it is not analyzed in the laboratory. TN ranged from 60 to 14,900 μg/L and station annual means ranged from 474 to 7,920 μg/L (Table 2.9). Mean total nitrogen in 2009 was slightly higher than the fourteen-year mean at most river stations, but equivalent to the mean in the mid-to-lower estuary (Figure 2.4). Previous research (Mallin et al. 1999) has shown a positive correlation between river flow and TN in the Cape Fear system. In the main river total nitrogen concentrations were highest between NC11 and AC, entering the system, then remained fairly constant down the river and declined from mid-estuary into the lower estuary, most likely reflecting uptake of nitrogen into the food chain through algal productivity and subsequent grazing by planktivores as well as through dilution and marsh denitrification. The blackwater rivers maintained TN concentrations considerably lower than those found in the mainstem Cape Fear River. One stream station, BC117, had a very high mean of 7,920 μg/L, likely from the upstream Town of Burgaw wastewater discharge. PB, ROC, NC403 and ANC also had comparatively high TN values among the stream stations. Temporal patterns for TN were not evident.

Nitrate+Nitrite

Nitrate+nitrite (henceforth referred to as nitrate) is the main species of inorganic nitrogen in the Lower Cape Fear River. Concentrations system wide ranged from 10 (detection limit) to 14,100 μg/L and station annual means ranged from 67 to 7,166 μg/L (Table 2.10). The highest average riverine nitrate levels were at NC11 and AC (both 773 μg/L) indicating that much of this nutrient is imported from upstream. Moving downstream, nitrate levels

decrease most likely as a result of uptake by primary producers, microbial denitrification in riparian marshes and tidal dilution. Despite this, the rapid flushing of the estuary (Ensign et al. 2004) permits sufficient nitrate to enter the coastal ocean in the plume and contribute to offshore productivity (Mallin et al. 2005b). Nitrate can limit phytoplankton production in the lower estuary in summer (Mallin et al. 1999). The blackwater rivers carried lower loads of nitrate compared to the mainstem Cape Fear stations; i.e. the Northeast Cape Fear River (NCF117 mean = 253 μg/L) and the Black River (B210 = 225 μg/L). No clear temporal pattern was observable for nitrate.

Several stream stations showed high levels of nitrate on occasion including BC117, ROC, 6RC, NC403, PB and LCO. PB and NC403 are downstream of industrial wastewater discharges and ROC and 6RC primarily receive non-point agricultural or animal waste drainage. BC117 always showed very high nitrate levels. The Town of Burgaw wastewater plant, upstream of BC117, has no nitrate discharge limits. Over the past several years a considerable number of experiments have been carried out by UNCW researchers to assess the effects of nutrient additions to water collected from blackwater streams and rivers (i.e. the Black and Northeast Cape Fear Rivers, and Colly and Great Coharie Creeks). These experiments have collectively found that additions of nitrogen (as either nitrate, ammonium, or urea) significantly stimulate phytoplankton production and BOD increases. Critical levels of these nutrients were in the range of 0.2 to 0.5 mg/L as N (Mallin et al. 1998; Mallin et al. 2001a; Mallin et al. 2002a, Mallin et al. 2004). Thus, we conservatively consider nitrate concentrations exceeding 0.5 mg/L as N in Cape Fear watershed streams to be potentially problematic to the stream's environmental health.

Ammonium

Ammonium concentrations ranged from 5 (detection limit) to 1,710 μg/L and station annual means ranged from 15 to 391 μg/L (Table 2.11). River areas with the highest mean ammonium levels this monitoring period included AC, which is below a pulp mill discharge, and M54, located downstream of the Wilmington South Side Wastewater Treatment Plant discharge. Ocean dilution and biological uptake accounts for decreasing levels in the lower estuary. At the stream stations, areas with periodic high levels of ammonium include BCRR, BC117, LRC, NC403 and especially PB (below a point source), which had the highest mean and median ammonium concentrations in the system (Table 2.11).

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of the total concentration of organic nitrogen plus ammonium. TKN ranged from 50 to 4,900 μg/L and station annual means ranged from 400 to 1,575 μg/L (Table 2.12). TKN concentration decreases ocean-ward through the estuary, likely due to ocean dilution and food chain uptake of nitrogen. One notably elevated peak of 4,900 μg/L of TN was seen at PB in July; this station was located downstream of an industrial point source discharge and had the highest mean concentrations for the system. Station ANC also had high mean and median concentrations. No other unusual peaks in TKN were seen in the data.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from below detection limit to 2,950 μg/L and station annual means ranged from 38 to 915 μg/L (Table 2.13). Mean TP for 2009 was approximately equal to the fourteen-year mean in most areas (Figure 2.5). In the river TP is highest at the upper riverine channel stations and declines downstream into the estuary. Some of this decline is attributable to the settling of phosphorus-bearing suspended sediments, yet incorporation of phosphorus into bacteria and algae is also responsible. A temporal pattern of higher summer TP is a result of increasing orthophosphate during the summer.

The experiments discussed above in the nitrate subsection also involved additions of phosphorus, either as inorganic orthophosphate or a combination of inorganic plus organic P. The experiments showed that additions of P exceeding 0.5 mg/L led to significant increases in bacterial counts, as well as significant increases in BOD over control. Thus, we consider concentrations of phosphorus above 0.5 mg/L (500 μg/L) to be potentially problematic to blackwater streams. Streams periodically exceeding this critical concentration included BC117, GCO, ROC, PB and NC403. Some of these stations (BC117, NC403, PB) are downstream of industrial or wastewater discharges, while GCO and ROC are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from undetectable to 1,720 μg/L and station annual means ranged from 8 to 702 μg/L (Table 2.14). Much of the orthophosphate load is imported into the Lower Cape Fear system from upstream areas, as NC11 or AC typically has the highest levels. The Northeast Cape Fear River had higher orthophosphate levels than the Black River. Orthophosphate can bind to suspended materials and is transported downstream via particle attachment; thus high levels of turbidity at the uppermost river stations may be an important factor in the high orthophosphate levels. Turbidity declines toward the lower estuary because of settling, and orthophosphate concentration also declines. In the estuary, primary productivity helps reduce orthophosphate concentrations by assimilation into biomass. Orthophosphate levels typically reach maximum concentrations during summertime, when anoxic sediment releases bound phosphorus. Also, in the Cape Fear Estuary, summer algal productivity is limited by nitrogen, thereby allowing the accumulation of orthophosphate (Mallin et al. 1997; 1999). In spring, productivity in the estuary is usually limited by phosphorus (Mallin et al. 1997; 1999).

The stream station BC117 had very high orthophosphate levels, and ROC, GCO and ANC had comparatively high levels. BC117 is below a municipal wastewater discharge, and ROC, GCO and ANC are impacted by agriculture/animal waste runoff.

Chemical Parameters - EPA Priority Pollutant Metals

The LCFRP had previously sampled for water column metals (EPA Priority Pollutant Metals) on a bimonthly basis. However, as of 2007 this requirement was suspended by the NC Division of Water Quality and these data are no longer collected by the LCFRP.

Biological Parameters

Chlorophyll a

During this monitoring period in most locations chlorophyll *a* was low, except for elevated concentrations in July and August at many locations (Table 2.15). At many of the river and estuarine stations chlorophyll *a* for 2009 was considerably higher than the fourteen-year mean for those sites (Figure 2.6). However, an unusual and important algal bloom occurred in September at Station NC11, with chlorophyll *a* levels of 61 μg/L, the highest we have ever recorded in riverine or estuarine sampling on the Cape Fear. We note that at this site it has been demonstrated that chlorophyll *a* biomass is significantly correlated with biochemical oxygen demand (BOD5 – Mallin et al. 2006b). High chlorophyll at NC11 may represent remnants of algal blooms forming in the more lentic (lake-like) conditions found above Lock and Dam #1. What was even more important was that this was a bloom of cyanobacteria (blue-green algae) called *Microcystis aeruginosa*. Significant concentrations of toxin (72.94 μg/L of microcystin, a liver toxin) were detected in the bloom as well by the North Carolina Department of health and Human Services (NCDHHS memo dated September 25, 2010). The World Health Organization has recommended a limit of 1 μg/L of microcystins for drinking water to protect human health (Burkholder 2002). The bloom persisted for a number of weeks before dissipating. The presence of the bloom affected Brunswick County water treatment in that county and they contracted with UNCW LCFRP to collect additional water samples to keep them informed of chlorophyll *a* concentrations. We note that the City of Wilmington also receives their drinking water from the river above Lock and Dam #1.

System wide, chlorophyll *a* ranged from undetectable to 438 μg/L and station annual means ranged from 1–45 μg/L. Production of chlorophyll *a* biomass is usually low to moderate in the rivers and estuary primarily because of light limitation by turbidity in the mainstem and high organic color and low inorganic nutrients in the blackwater rivers.

Spatially, highest values are normally found in the mid-to-lower estuary stations because light becomes more available downstream of the estuarine turbidity maximum (Table 2.6). On average, flushing time of the Cape Fear estuary is rapid, ranging from 1-22 days with a median of 6.7 days (Ensign et al. 2004). This does not allow for much settling of suspended materials, leading to light limitation of phytoplankton production. However, under lower-than-average flows there is generally clearer water through less suspended material and less blackwater swamp inputs. For the growing season May-September, long-term (1995-2009) average monthly flow at Lock and Dam #1 was 3,704 CFS (USGS data; http://nc.water.usgs.gov/realtime/real_time_cape_fear.html), whereas for 2009 it was

1,898 CFS. Thus, chlorophyll *a* concentrations in the estuary were larger than the average for the preceding eleven years (Figure 2.6).

Substantial phytoplankton blooms occasionally occur at the stream stations, with a few occurring June through August in 2009 (Table 2.15). These streams are generally shallow, so vertical mixing does not carry phytoplankton cells down below the critical depth where respiration exceeds photosynthesis. Thus, when lower flow conditions prevail, elevated nutrient conditions (such as are periodically found in these stream stations) can lead to algal blooms. In areas where the forest canopy opens up large blooms can occur. When blooms occur in blackwater streams they can become sources of BOD upon death and decay, reducing further the low summer dissolved oxygen conditions common to these waters (Mallin et al. 2001a; 2002a; 2004; 2006b). Stream algal blooms exceeding the State standard of 40 µg/L in 2009 occurred at GS, PB, NC403 and SR (Table 2.15).

Biochemical Oxygen Demand

For the mainstem river, median annual five-day biochemical oxygen demand (BOD5) concentrations were approximately equivalent between NC11 and AC, suggesting that in 2009 (as was the case with 2007 and 2008) there as little discernable effect of BOD loading from the nearby pulp/paper mill inputs (Table 2.16). BOD was somewhat lower during the winter than summer at most (but not all) sites.

Results of 2009 BOD analyses from several stream stations in the Northeast Cape Fear River watershed can be seen in Table 2.16. LVC2, GS, BC117 and N403 all showed large (> 3.5 mg/L) individual BOD5 measurements during 2009, particularly during summer. Stations BC117, LVC2 and N403 are below point sources, but GS is a non-point runoff area.

Fecal Coliform Bacteria

Fecal coliform (FC) bacterial counts ranged from 1 to >20,000 CFU/100 mL and station annual geometric means ranged from 8 to 492 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded at the mainstem sites only rarely in 2009, in July and November. Geometric mean fecal coliform counts in 2009 in the Cape Fear, Black, and Northeast Cape Fear Rivers as well as the estuary were high compared with the fourteen-year average (Figure 2.7).

During 2009 BCRR exceeded the state standard 83% of the time; PB 75%, BC117 and BRN 58%, LRC, ROC and HAM 50%, SAR 42%, LVC2 33%, 6RC and SR 25% of the time. BC117, LVC2 and PB are located below point source discharges and the other sites are primarily influenced by non-point source pollution. Overall, elevated fecal coliform counts are problematic in this system, with 40% of the stations impacted in 2009, an improvement from the previous year 2008.

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Table 2.1 Water temperature (°C) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	10.2	10.6	10.7	11.3	11.0	11.6	12.2	12.1	12.3	12.1
FEB	10.0	10.4	10.6	9.9	10.6	10.7	10.7	10.9	10.6	10.5
MAR	16.9	16.9	16.1	16.5	16.0	15.9	16.0	16.6	16.9	16.4
APR	18.5	18.5	18.5	18.4	18.4	18.5	18.6	18.3	17.8	19.4
MAY	25.3	25.1	25.0	24.9	24.7	24.8	24.9	24.7	23.7	24.9
JUN	26.0	26.4	26.5	26.4	26.5	26.3	26.9	26.5	26.3	27.6
JUL	28.6	28.7	29.2	28.9	28.7	28.8	28.9	28.1	28.0	28.1
AUG	29.6	29.6	29.6	29.4	29.2	29.0	28.9	29.0	28.6	29.1
SEP	27.7	28.0	27.8	28.3	27.9	27.4	27.4	27.3	27.1	27.5
OCT	23.1	23.1	22.9	23.3	23.4	23.2	23.7	23.8	24.3	24.0
NOV	13.9	14.0	14.0	14.9	15.2	15.7	16.4	16.9	17.0	16.7
DEC	12.3	12.4	12.5	13.5	13.5	13.5	13.9	14.0	14.4	13.8
mean	**20.2**	**20.3**	**20.3**	**20.5**	**20.4**	**20.5**	**20.7**	**20.7**	**20.6**	**20.8**
std dev	7.4	7.3	7.4	7.2	7.1	6.9	6.8	6.6	6.5	6.8
max	29.6	29.6	29.6	29.4	29.2	29.0	28.9	29.0	28.6	29.1
min	10.0	10.4	10.6	9.9	10.6	10.7	10.7	10.9	10.6	10.5

month	NC11	AC	DP	BBT	IC	NCF6
JAN	10.4	10.8	11.2	11.6	11.4	13.2
FEB	7.7	7.8	7.7	7.7	7.8	8.5
MAR	10.8	11.0	11.3	12.1	12.0	13.8
APR	16.1	16.2	16.1	16.1	16.2	16.9
MAY	23.8	23.9	23.7	23.7	23.7	24.0
JUN	26.2	26.0	26.0	26.0	26.2	25.6
JUL	30.8	29.4	28.4	28.5	29.9	29.0
AUG	30.1	30.7	30.0	30.7	29.8	30.0
SEP	27.1	27.6	27.0	26.5	26.9	27.2
OCT	23.0	23.0	21.8	21.8	22.4	22.9
NOV	18.5	18.9	18.8	18.8	19.1	19.4
DEC	10.8	10.9	11.3	12.1	11.8	12.6
mean	**19.6**	**19.7**	**19.4**	**19.6**	**19.8**	**20.3**
std dev	8.3	8.2	7.8	7.6	7.8	7.2
max	30.8	30.7	30.0	30.7	29.9	30.0
min	7.7	7.8	7.7	7.7	7.8	8.5

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	11.2	10.0	9.9	9.6	8.5	9.4	12.3	11.2	12.4
FEB	15.5	14.6	16.2	14.3	14.6	13.9	13.2	13.8	12.8
MAR	8.4	5.7	7.2	7.2	5.5	6.0	5.9	5.8	4.3
APR	16.1	16.5	17.2	16.7	16.1	16.9	16.6	15.9	15.4
MAY	23.3	22.4	22.6	22.5	21.6	22.3	23.1	22.3	22.2
JUN	24.9	26.6	26.4	26.9	27.4	24.5	24.4	22.4	22.8
JUL	25.7	25.3	25.2	25.5	25.9	24.0	25.5	24.1	23.6
AUG	26.5	26.8	26.2	27.2	27.5	26.7	25.9	25.6	25.1
SEP	22.6	21.6	22.5	22.9	22.4	22.9	22.1	22.8	21.9
OCT	19.6	19.5	18.8	19.2	20.8	18.5	18.5	18.9	18.9
NOV	15.7	14.6	15.0	14.4	14.5	15.5	14.7	15.1	14.1
DEC	14.7	13.7	13.0	13.5	12.7	13.9	14.3	14.8	14.5
mean	**18.7**	**18.1**	**18.4**	**18.3**	**18.1**	**17.9**	**18.0**	**17.7**	**17.3**
std dev	6.0	6.7	6.4	6.7	7.3	6.4	6.3	6.0	6.1
max	26.5	26.8	26.4	27.2	27.5	26.7	25.9	25.6	25.1
min	8.4	5.7	7.2	7.2	5.5	6.0	5.9	5.8	4.3

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	9.5	9.2	10.0	8.9	12.3	11.1
FEB	7.0	6.5	6.8	6.7	8.0	7.3
MAR	4.6	4.0	4.2	5.1	5.5	5.3
APR	18.8	18.8	19.7	19.4	19.5	18.9
MAY	22.5	23.1	23.6	21.9	22.1	21.5
JUN	23.6	24.0	25.1	23.5	23.7	23.0
JUL	24.7	24.7	25.7	24.4	24.1	23.2
AUG	26.6	26.6	26.1	25.1	25.8	25.5
SEP	21.8	22.4	22.6	22.1	22.1	21.3
OCT	19.1	18.9	19.0	18.4	18.2	17.4
NOV	16.8	17.0	17.0	16.3	16.4	16.3
DEC	8.6	8.4	7.9	8.1	9.3	9.2
mean	**17.0**	**17.0**	**17.3**	**16.7**	**17.3**	**16.7**
std dev	7.6	7.9	8.0	7.5	6.9	6.8
max	26.6	26.6	26.1	25.1	25.8	25.5
min	4.6	4.0	4.2	5.1	5.5	5.3

month	NCF117	B210	COL	LVC2	SC-CH
JAN	11.9	10.9	10.9	11.0	13.0
FEB	8.1	5.7	5.7	4.0	7.7
MAR	7.8	6.1	6.1	5.1	8.8
APR	16.8	16.7	16.7	15.4	16.7
MAY	23.8	23.5	23.5	20.7	23.7
JUN	25.8	25.8	25.8	21.9	26.2
JUL	29.3	27.7	27.7	23.6	28.0
AUG	29.2	29.2	29.2	26.8	29.2
SEP	24.4	23.8		23.7	25.3
OCT	20.6	20.0	20.0	18.6	22.7
NOV	18.6	16.3	16.3	14.2	19.0
DEC	11.7	11.3	11.3	11.7	12.8
mean	**19.0**	**18.1**	**17.6**	**16.4**	**19.4**
std dev	7.8	8.2	8.4	7.4	7.5
max	29.3	29.2	29.2	26.8	29.2
min	7.8	5.7	5.7	4.0	7.7

Table 2.2 Salinity (psu) during 2009 at the Lower Cape Fear River Program estuarine stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD	NCF6	SC-CH
JAN	0.1	0.1	0.1	0.6	1.2	4.4	13.2	17.8	29.5	21.5	0.3	0.7
FEB	2.5	3.6	2.8	5.6	9.2	16.9	21.0	26.6	31.4	26.6	1.1	0.5
MAR	0.1	0.1	0.1	0.7	2.5	5.8	9.9	25.6	28.5	21.6	0.1	0.5
APR	0.1	0.1	0.2	3.5	4.1	6.0	9.7	21.6	26.3	26.4	0.1	0.2
MAY	0.1	0.6	0.9	4.4	8.6	12.2	18.3	27.7	32.0	26.8	0.6	3.7
JUN	0.1	0.1	2.4	6.1	7.3	10.3	12.5	21.7	24.5	29.4	0.1	2.1
JUL	4.2	7.9	9.4	11.4	15.4	19.0	23.1	28.6	32.5	31.3	9.8	10.9
AUG	2.3	4.1	7.7	10.3	13.6	15.9	18.5	26.3	32.2	33.6	1.0	5.9
SEP	0.4	3.3	6.1	10.5	12.8	14.2	16.6	23.7	27.4	30.0	4.1	11.0
OCT	5.6	5.4	5.4	7.5	10.7	13.3	21.4	26.9	34.2	31.0	6.1	4.1
NOV	0.1	0.1	0.1	0.6	1.9	3.8	10.1	14.7	20.7	21.7	14.5	13.8
DEC	0.1	0.2	0.3	3.1	4.9	6.5	9.7	15.2	21.4	21.6	0.1	0.1
mean	**1.3**	**2.1**	**3.0**	**5.4**	**7.7**	**10.7**	**15.3**	**23.0**	**28.4**	**26.8**	**3.2**	**4.5**
std dev	1.9	2.7	3.4	3.9	4.8	5.3	5.1	4.9	4.4	4.4	4.7	4.9
max	5.6	7.9	9.4	11.4	15.4	19.0	23.1	28.6	34.2	33.6	14.5	13.8
min	0.1	0.1	0.1	0.6	1.2	3.8	9.7	14.7	20.7	21.5	0.1	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations, 1995-2008 versus 2009.

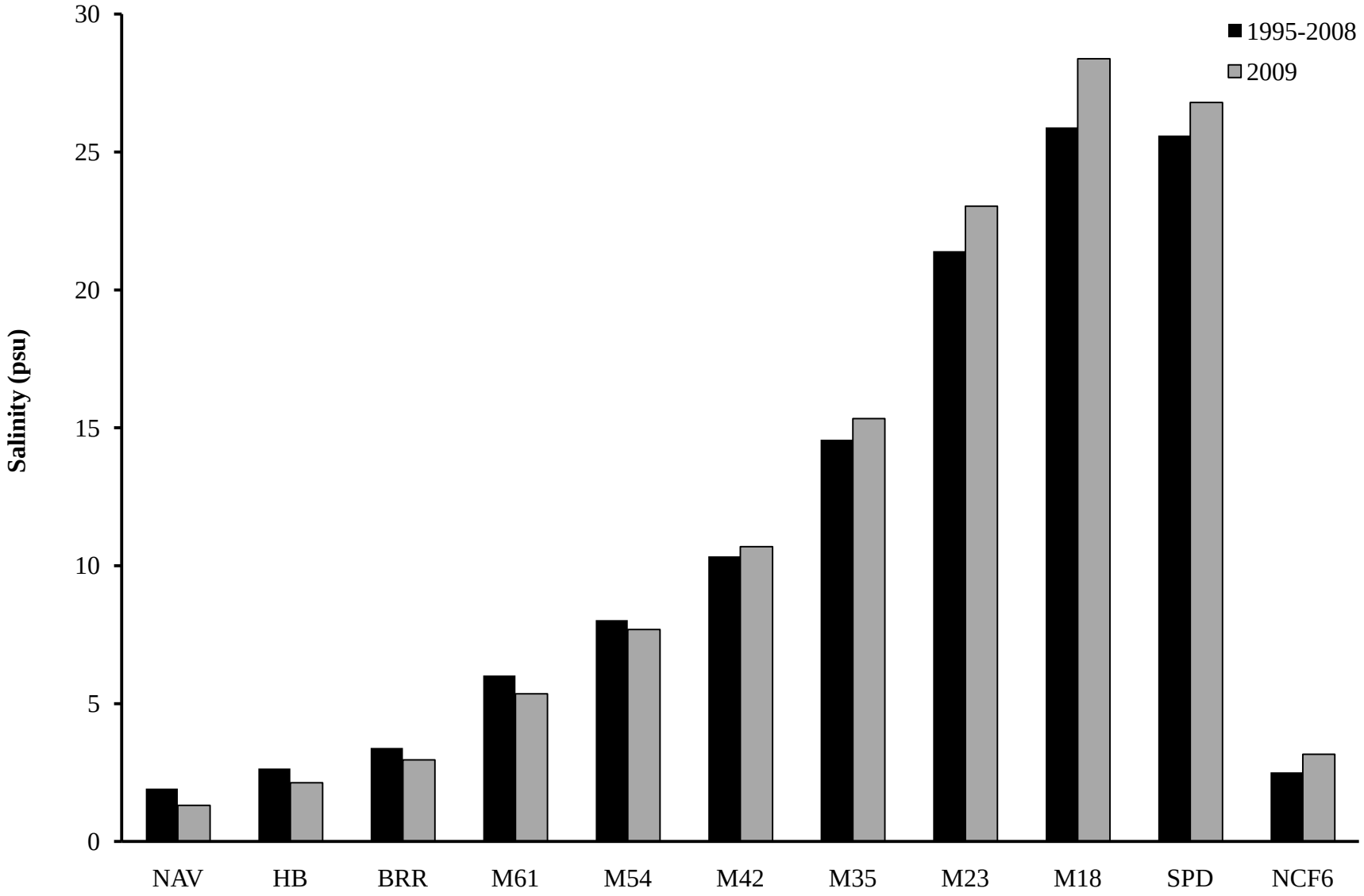


Table 2.3 Conductivity (mS/cm) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	0.10	0.11	0.15	1.14	2.37	8.02	21.89	28.86	45.59	34.22
FEB	4.66	6.63	5.21	9.83	15.74	27.54	33.51	41.58	48.43	41.67
MAR	0.12	0.14	0.18	1.31	4.65	9.97	16.71	39.83	44.14	34.35
APR	0.12	0.14	0.51	6.38	7.55	10.60	16.44	34.32	41.03	41.06
MAY	0.24	1.22	1.81	7.98	14.76	20.52	29.64	42.99	49.08	41.76
JUN	0.18	0.30	4.56	10.70	12.73	17.54	20.88	34.63	38.63	45.59
JUL	7.72	13.69	16.13	19.27	25.41	30.77	36.63	44.24	49.75	48.11
AUG	4.39	7.52	13.43	17.61	22.66	26.15	30.02	41.26	49.34	51.24
SEP	0.86	6.11	10.89	17.85	21.48	23.47	27.06	37.48	42.66	46.48
OCT	9.85	9.39	9.52	12.95	18.01	21.97	34.15	41.92	52.01	47.58
NOV	0.12	0.13	0.18	1.24	3.55	6.95	17.14	24.14	32.93	34.50
DEC	0.16	0.31	0.66	5.74	8.68	11.33	16.41	24.90	34.05	34.38
mean	**2.38**	**3.81**	**5.27**	**9.33**	**13.13**	**17.90**	**25.04**	**36.35**	**43.97**	**41.75**
std dev	3.45	4.68	5.79	6.57	7.83	8.30	7.67	7.04	6.29	6.18
max	9.85	13.69	16.13	19.27	25.41	30.77	36.63	44.24	52.01	51.24
min	0.10	0.11	0.15	1.14	2.37	6.95	16.41	24.14	32.93	34.22

month	NC11	AC	DP	BBT	IC	NCF6
JAN	0.11	0.21	0.13	0.13	0.13	0.60
FEB	0.12	0.12	0.13	0.12	0.14	2.16
MAR	0.11	0.12	0.13	0.11	0.11	0.19
APR	0.11	0.12	0.12	0.09	0.11	0.22
MAY	0.11	0.12	0.18	0.16	0.17	1.19
JUN	0.12	0.30	0.18	0.12	0.16	0.20
JUL	0.11	0.26	0.20	0.20	0.26	16.71
AUG	0.14	0.15	0.20	0.19	0.23	1.98
SEP	0.11	0.13	0.18	0.16	0.18	7.45
OCT	0.13	0.36	0.20	0.20	0.21	10.55
NOV	0.17	0.30	0.28	0.28	5.63	23.65
DEC	0.09	0.10	0.10	0.09	0.09	0.09
mean	**0.12**	**0.19**	**0.17**	**0.15**	**0.62**	**5.41**
std dev	0.02	0.09	0.05	0.06	1.58	7.77
max	0.17	0.36	0.28	0.28	5.63	23.65
min	0.09	0.10	0.10	0.09	0.09	0.09

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	0.14	0.17	0.16	0.34	1.01	0.15	0.16	0.42	0.26
FEB	0.11	0.18	0.16	0.38	2.04	0.16	0.15	0.50	0.29
MAR	0.13	0.14	0.14	0.23	0.90	0.14	0.12	0.28	0.16
APR	0.13	0.15	0.16	0.32	1.03	0.17	0.07	0.48	0.18
MAY	0.10	0.17	0.18	0.50	1.87	0.14	0.13	0.28	0.19
JUN	0.11	0.19	0.23	0.94	9.74	0.17	0.17	0.57	0.23
JUL	0.15	0.31	0.24	1.17	12.33	0.27	0.29	0.63	0.21
AUG	0.11	0.29	0.22	0.68	1.26	0.18	0.10	0.47	0.24
SEP	0.11	0.11	0.21	0.52	2.23	0.10	0.13	0.86	0.25
OCT	0.11	0.28	0.26	0.75	6.96	0.13	0.19	0.57	0.26
NOV	0.12	0.21	0.20	0.29	1.23	0.13	0.14	0.31	0.13
DEC	0.10	0.13	0.14	0.13	0.55	0.05	0.12	0.21	0.12
mean	**0.12**	**0.19**	**0.19**	**0.52**	**3.43**	**0.15**	**0.15**	**0.46**	**0.21**
std dev	0.02	0.06	0.04	0.31	3.97	0.05	0.05	0.18	0.05
max	0.15	0.31	0.26	1.17	12.33	0.27	0.29	0.86	0.29
min	0.10	0.11	0.14	0.13	0.55	0.05	0.07	0.21	0.12

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.13	0.09	0.11	0.08	0.11	0.14
FEB	0.13	0.09	0.13	0.08	0.11	0.14
MAR	0.10	0.07	0.09	0.06	0.09	0.10
APR	0.12	0.07	0.10	0.07	0.09	0.13
MAY	0.13	0.16	0.17	0.10	0.11	0.16
JUN	0.13	0.09	0.17	0.09	0.09	0.09
JUL	0.14	0.09	0.32	0.13	0.12	0.20
AUG	0.12	0.09	0.15	0.06	0.13	0.22
SEP	0.14	0.09	0.17	0.09	0.13	0.25
OCT	0.13	0.08	0.10	0.08	0.11	0.22
NOV	0.16	0.10	0.20	0.10	0.14	0.24
DEC	0.15	0.10	0.11	0.08	0.15	0.13
mean	**0.13**	**0.09**	**0.15**	**0.09**	**0.12**	**0.17**
std dev	0.02	0.02	0.06	0.02	0.02	0.05
max	0.16	0.16	0.32	0.13	0.15	0.25
min	0.10	0.07	0.09	0.06	0.09	0.09

month	NCF117	B210	COL	LVC2	SC-CH
JAN	0.16	0.09	0.08	0.13	1.36
FEB	0.16	0.09	0.08	0.12	0.92
MAR	0.16	0.09	0.08	0.16	1.02
APR	0.14	0.08	0.07	0.14	0.43
MAY	0.15	0.08	0.07	0.16	6.79
JUN	0.12	0.08	0.07	0.10	3.97
JUL	0.17	0.09	0.07	0.12	18.52
AUG	0.15	0.14	0.07	0.13	10.47
SEP	0.13	0.09		0.17	18.61
OCT	0.10	0.09	0.06	0.11	7.38
NOV	0.15	0.12	0.08	0.16	22.72
DEC	0.10	0.10	0.11	0.08	0.19
mean	**0.14**	**0.10**	**0.08**	**0.13**	**7.70**
std dev	0.02	0.02	0.01	0.03	8.11
max	0.17	0.14	0.11	0.17	22.72
min	0.10	0.08	0.06	0.08	0.19

Table 2.4 pH during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	6.9	7.0	7.4	7.5	8.1	8.0	7.9	8.0	8.0	7.8
FEB	7.2	7.2	7.6	7.4	7.8	7.9	8.0	8.0	7.9	7.9
MAR	6.9	7.0	7.2	7.1	7.4	7.6	7.8	8.0	8.0	7.9
APR	7.9	7.1	7.2	7.2	7.7	7.6	7.9	7.9	7.9	7.7
MAY	7.0	7.0	7.3	7.3	7.4	7.7	7.9	8.0	8.0	7.9
JUN	6.7	6.7	6.7	6.9	7.1	7.2	7.4	7.8	7.9	7.5
JUL	7.0	7.1	7.1	7.4	7.5	7.7	7.9	7.9	8.0	7.8
AUG	7.0	7.1	7.1	7.2	7.3	7.5	7.8	7.9	7.9	7.8
SEP	6.7	6.8	7.0	7.1	7.2	7.4	7.5	7.8	7.8	7.6
OCT	6.9	7.0	7.1	7.2	7.4	7.5	7.7	7.8	8.0	7.8
NOV	6.7	6.8	7.1	6.8	7.5	7.7	7.6	7.7	7.8	7.7
DEC	7.0	7.0	7.4	6.9	7.6	7.6	7.7	8.0	7.9	7.7
mean	**7.0**	**7.0**	**7.2**	**7.2**	**7.5**	**7.6**	**7.8**	**7.9**	**7.9**	**7.8**
std dev	0.3	0.1	0.2	0.2	0.3	0.2	0.2	0.1	0.1	0.1
max	7.9	7.2	7.6	7.5	8.1	8.0	8.0	8.0	8.0	7.9
min	6.7	6.7	6.7	6.8	7.1	7.2	7.4	7.7	7.8	7.5

month	NC11	AC	DP	BBT	IC	NCF6
JAN	6.6	7.1	6.9	6.7	6.8	6.7
FEB	6.6	6.9	6.9	6.8	6.9	6.8
MAR	7.1	7.1	7.1	6.9	6.9	6.6
APR	6.9	7.0	7.0	6.4	6.7	6.8
MAY	6.8	6.8	6.8	6.7	6.8	6.8
JUN	6.7	7.1	6.8	6.5	6.7	6.5
JUL	6.9	7.0	6.8	6.8	6.9	7.1
AUG	6.9	7.0	6.9	6.9	6.9	6.8
SEP	6.6	6.8	6.7	6.6	6.7	6.7
OCT	6.7	7.2	6.8	6.7	6.8	6.7
NOV	6.7	7.1	6.9	6.9	6.9	7.2
DEC	6.6	6.7	6.7	6.3	6.5	6.1
mean	**6.8**	**7.0**	**6.9**	**6.7**	**6.8**	**6.7**
std dev	0.2	0.2	0.1	0.2	0.1	0.3
max	7.1	7.2	7.1	6.9	6.9	7.2
min	6.6	6.7	6.7	6.3	6.5	6.1

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	6.2	6.6	6.6	6.9	6.7	7.2	7.0	7.0	6.4
FEB	5.8	6.6	6.7	6.8	6.8	7.2	7.1	7.3	7.3
MAR	5.5	6.5	6.7	6.5	6.4	6.9	6.6	7.2	7.5
APR	6.3	6.7	6.7	6.5	6.7	7.3	6.9	7.4	6.8
MAY	5.8	6.6	6.6	6.4	6.6	7.1	6.8	7.3	7.3
JUN	6.2	6.9	6.5	6.5	7.3	7.4	7.1	7.4	6.8
JUL	6.5	7.1	6.6	6.5	7.5	7.7	7.1	7.4	6.7
AUG	6.2	7.0	6.3	6.4	6.8	7.1	6.6	7.4	6.7
SEP	5.6	6.3	6.4	6.3	6.7	6.9	6.8	7.7	6.7
OCT	5.2	6.9	6.5	6.4	7.1	7.4	7.2	7.5	6.7
NOV	5.8	6.4	6.5	6.4	6.6	6.7	6.8	6.8	6.2
DEC	5.4	6.3	6.6	6.1	6.5	6.6	6.5	6.7	6.1
mean	**5.9**	**6.7**	**6.6**	**6.5**	**6.8**	**7.1**	**6.9**	**7.3**	**6.8**
std dev	0.4	0.3	0.1	0.2	0.3	0.3	0.2	0.3	0.4
max	6.5	7.1	6.7	6.9	7.5	7.7	7.2	7.7	7.5
min	5.2	6.3	6.3	6.1	6.4	6.6	6.5	6.7	6.1

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	6.6	6.3	6.4	5.9	6.5	6.6
FEB	6.4	6.3	6.4	6.0	6.5	6.7
MAR	6.2	5.5	6.4	6.2	6.4	6.5
APR	6.8	6.1	6.4	6.1	6.7	6.8
MAY	7.0	7.1	6.9	6.4	7.0	7.0
JUN	7.0	6.8	6.9	6.1	6.6	6.5
JUL	7.0	6.8	7.1	6.4	7.1	7.3
AUG	7.1	6.7	6.4	5.9	7.0	7.4
SEP	7.0	6.9	6.7	6.1	7.0	7.2
OCT	7.2	6.7	6.2	6.1	6.8	7.1
NOV	6.6	6.7	6.7	6.3	6.8	6.9
DEC	6.1	5.9	6.2	6.2	6.5	6.5
mean	**6.8**	**6.5**	**6.6**	**6.1**	**6.7**	**6.9**
std dev	0.4	0.5	0.3	0.2	0.2	0.3
max	7.2	7.1	7.1	6.4	7.1	7.4
min	6.1	5.5	6.2	5.9	6.4	6.5

month	NCF117	B210	COL	LVC2	SC-CH
JAN	6.0	5.7	3.9	6.7	6.0
FEB	6.4	6.1	3.9	7.4	7.4
MAR	6.7	6.2	3.8	6.6	7.2
APR	6.5	6.2	4.0	6.6	6.8
MAY	6.7	6.3	4.2	6.9	7.0
JUN	6.3	6.0	4.0	6.8	6.7
JUL	6.6	6.3	4.0	6.8	7.0
AUG	6.7	6.5	4.5	6.8	6.7
SEP	6.2	6.4		7.0	6.9
OCT	5.8	6.4	4.3	6.6	6.6
NOV	6.3	6.3	4.4	6.9	7.1
DEC	5.9	5.9	3.8	6.5	6.7
mean	**6.3**	**6.2**	**4.1**	**6.8**	**6.8**
std dev	0.3	0.2	0.2	0.2	0.4
max	6.7	6.5	4.5	7.4	7.4
min	5.8	5.7	3.8	6.5	6.0

Table 2.5 Dissolved Oxygen (mg/l) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	10.1	10.0	10.1	10.1	10.4	10.3	9.7	9.7	9.1	9.3
FEB	10.8	10.7	10.6	10.5	10.5	10.5	10.4	10.0	9.5	10.0
MAR	8.4	9.0	8.4	8.2	8.7	8.5	8.4	7.8	7.8	8.2
APR	7.8	7.9	7.8	7.8	8.2	8.1	8.2	7.9	8.0	7.2
MAY	5.5	5.9	6.2	6.1	6.4	7.4	7.6	7.4	7.0	7.2
JUN	4.9	4.9	4.9	5.0	5.2	5.6	6.3	6.7	6.7	5.0
JUL	4.2	4.6	5.6	5.3	5.6	6.3	7.1	6.4	6.3	5.2
AUG	3.9	4.0	4.2	4.3	4.9	5.7	6.9	6.6	6.1	5.2
SEP	4.0	3.8	3.8	3.6	4.2	4.7	5.8	6.0	5.9	4.6
OCT	4.4	4.4	4.7	4.9	5.0	5.9	6.0	6.4	6.2	6.2
NOV	7.7	8.2	7.6	6.9	6.4	5.7	5.7	6.0	7.1	7.6
DEC	8.4	7.9	8.3	7.0	7.5	8.0	8.1	8.5	8.3	7.7
mean	**6.7**	**6.8**	**6.9**	**6.6**	**6.9**	**7.2**	**7.5**	**7.5**	**7.3**	**7.0**
std dev	2.5	2.5	2.3	2.2	2.1	1.9	1.5	1.4	1.2	1.7
max	10.8	10.7	10.6	10.5	10.5	10.5	10.4	10.0	9.5	10.0
min	3.9	3.8	3.8	3.6	4.2	4.7	5.7	6.0	5.9	4.6

month	NC11	AC	DP	BBT	IC	NCF6
JAN	11.0	10.6	10.4	9.6	9.9	8.9
FEB	12.1	11.7	11.4	11.4	11.1	10.5
MAR	11.4	11.3	11.2	9.9	9.9	8.1
APR	9.3	9.0	9.0	7.1	7.8	7.6
MAY	7.5	6.7	5.8	5.5	5.9	6.6
JUN	7.0	5.7	5.5	4.5	4.9	4.3
JUL	8.7	4.2	3.5	3.5	3.7	4.6
AUG	7.3	7.3	4.7	5.1	4.3	5.1
SEP	6.1	6.0	4.6	4.4	4.3	4.0
OCT	6.6	6.7	5.2	5.3	5.0	4.4
NOV	8.8	8.0	5.7	5.7	5.6	6.3
DEC	10.2	9.8	9.5	7.4	8.5	7.2
mean	**8.8**	**8.1**	**7.2**	**6.6**	**6.7**	**6.5**
std dev	2.0	2.4	2.9	2.5	2.6	2.1
max	12.1	11.7	11.4	11.4	11.1	10.5
min	6.1	4.2	3.5	3.5	3.7	4.0

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	8.0	7.8	7.5	7.2	8.3	11.6	9.1	9.2	4.3
FEB	8.1	7.9	10.0	7.5	8.7	11.0	9.5	9.5	6.8
MAR	11.6	11.3	12.2	10.6	9.9	11.8	11.0	11.8	10.6
APR	8.5	6.6	6.8	5.2	7.4	9.4	8.3	8.0	6.7
MAY	3.3	5.0	2.8	2.4	1.2	7.3	6.5	6.1	4.7
JUN	4.5	5.7	1.6	1.7	8.2	8.9	5.9	5.6	1.1
JUL	1.6	5.0	2.5	1.1	6.1	7.8	6.5	4.6	1.2
AUG	4.2	5.9	0.6	1.1	4.3	7.1	4.8	5.1	1.8
SEP	4.5	4.9	2.5	1.9	4.7	7.7	7.1	5.9	7.4
OCT	5.1	7.2	3.0	1.1	5.1	9.0	8.0	6.7	6.3
NOV	5.9	6.6	6.8	4.0	5.4	9.9	8.2	9.3	8.9
DEC	6.8	7.0	8.8	6.8	7.0	9.8	7.9	8.1	8.3
mean	**6.0**	**6.7**	**5.4**	**4.2**	**6.4**	**9.3**	**7.7**	**7.5**	**5.7**
std dev	2.7	1.8	3.7	3.2	2.4	1.6	1.7	2.2	3.1
max	11.6	11.3	12.2	10.6	9.9	11.8	11.0	11.8	10.6
min	1.6	4.9	0.6	1.1	1.2	7.1	4.8	4.6	1.1

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	10.7	10.8	8.7	7.3	10.3	9.9
FEB	12.0	12.2	10.6	9.8	12.0	12.2
MAR	11.7	11.7	11.7	10.5	10.4	10.8
APR	7.7	7.0	5.0	4.2	8.0	7.3
MAY	7.2	7.1	6.3	1.0	8.1	6.2
JUN	6.7	7.0	5.8	2.5	7.1	6.8
JUL	6.2	5.6	4.6	1.2	7.9	7.0
AUG	6.0	6.3	3.9	2.5	7.2	6.2
SEP	7.1	7.4	8.3	0.9	8.0	4.5
OCT	9.4	8.3	5.5	1.5	7.9	7.5
NOV	8.6	8.5	7.0	2.0	8.9	4.7
DEC	9.9	9.9	9.9	9.2	10.8	10.6
mean	**8.6**	**8.5**	**7.3**	**4.4**	**8.9**	**7.8**
std dev	2.1	2.2	2.5	3.7	1.6	2.5
max	12.0	12.2	11.7	10.5	12.0	12.2
min	6.0	5.6	3.9	0.9	7.1	4.5

month	NCF117	B210	COL	LVC2	SC-CH
JAN	8.9	8.6	7.0	8.7	8.9
FEB	9.7	10.5	9.7	9.8	9.8
MAR	11.1	11.5	10.7	9.8	10.5
APR	6.6	7.2	6.2	4.6	8.3
MAY	6.5	5.7	5.9	1.4	7.1
JUN	4.4	5.7	6.3	5.8	4.8
JUL	4.0	4.6	5.4	3.5	4.4
AUG	4.3	4.9	4.8	3.5	4.8
SEP	3.3	4.8		2.9	4.3
OCT	4.0	5.9	6.2	6.2	4.4
NOV	4.5	8.3	4.6	4.5	6.3
DEC	7.0	8.6	7.3	8.2	7.6
mean	**6.2**	**7.2**	**6.7**	**5.7**	**6.8**
std dev	2.6	2.3	1.9	2.8	2.3
max	11.1	11.5	10.7	9.8	10.5
min	3.3	4.6	4.6	1.4	4.3

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations, 1995-2008 versus 2009.

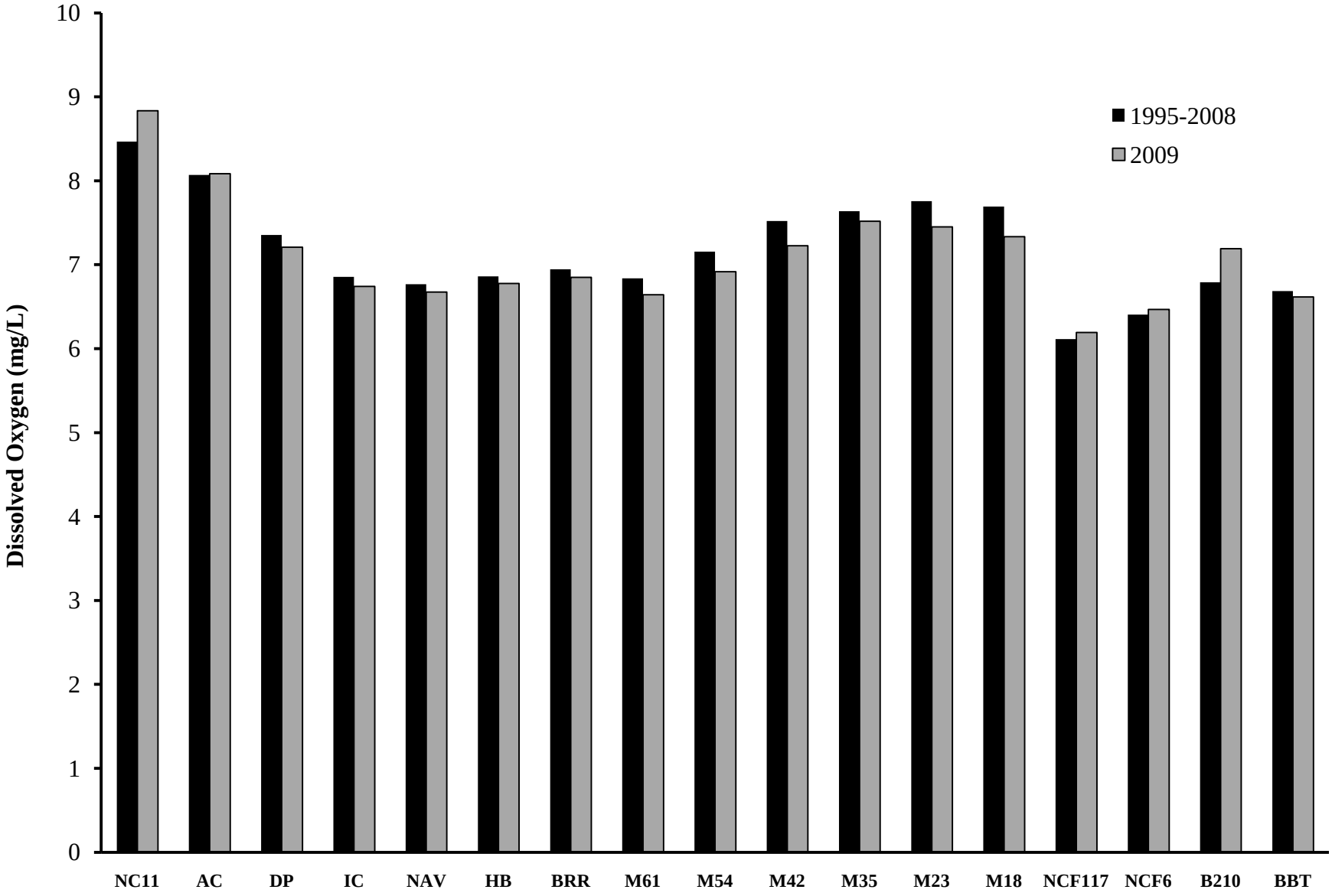


Table 2.6 Field Turbidity (NTU) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	89	72	81	60	61	23	21	18	27	36
FEB	18	17	19	12	15	9	10	7	10	11
MAR	8	9	12	16	16	11	7	16	19	10
APR	14	16	14	9	11	8	14	17	22	15
MAY	7	9	8	7	9	8	6	5	8	6
JUN	13	19	9	5	5	4	3	4	6	8
JUL	14	12	10	8	10	8	5	5	3	9
AUG	26	15	17	9	8	9	7	3	7	8
SEP	37	9	8	3	4	7	8	5	7	6
OCT	19	36	14	9	9	9	6	8	9	12
NOV	59	78	82	40	51	33	16	12	6	15
DEC	18	17	22	25	20	14	10	13	25	15
mean	**27**	**26**	**25**	**17**	**18**	**12**	**9**	**9**	**12**	**13**
std dev	24	24	27	17	18	8	5	5	8	8
max	89	78	82	60	61	33	21	18	27	36
min	7	9	8	3	4	4	3	3	3	6

month	NC11	AC	DP	BBT	IC	NCF6
JAN	16	21	19	12	16	26
FEB	12	11	14	14	17	32
MAR	40	38	32	16	30	4
APR	26	23	21	7	12	13
MAY	13	17	18	17	20	51
JUN	9	15	13	8	9	17
JUL	6	9	10	12	9	9
AUG	7	7	8	6	11	11
SEP	8	6	10	6	8	8
OCT	18	11	11	8	12	18
NOV	8	11	11	10	21	13
DEC	56	50	47	21	33	6
mean	**18**	**18**	**18**	**11**	**17**	**17**
std dev	15	13	11	5	8	13
max	56	50	47	21	33	51
min	6	6	8	6	8	4

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	4	5	4	2	6	4	5	11	10
FEB	4	3	3	2	6	3	5	9	15
MAR	6	2	1	1	7	11	5	8	8
APR	1	4	1	0	3	13	6	11	10
MAY	7	13	7	4	32	90	31	167	81
JUN	2	7	8	3	23	1	4	12	8
JUL	1	1	28	7	13	5	4	13	11
AUG	3	2	15	14	16	3	8	13	8
SEP	13	3	3	0	6	8	11	16	7
OCT	6	4	3	4	6	5	7	12	19
NOV	6	3	2	1	6	10	8	16	15
DEC	6	8	2	18	60	12	10	15	13
mean	**5**	**5**	**6**	**5**	**15**	**14**	**9**	**25**	**17**
std dev	3	3	8	6	16	24	7	45	20
max	13	13	28	18	60	90	31	167	81
min	1	1	1	0	3	1	4	8	7

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	5	5	2	1	6	7
FEB	4	5	2	1	5	5
MAR	8	5	3	4	8	9
APR	3	0	0	0	8	5
MAY	4	6	3	4	5	6
JUN	5	5	3	12	14	18
JUL	2	2	4	26	4	5
AUG	8	7	9	19	7	6
SEP	6	6	13	8	3	8
OCT	5	4	6	3	38	7
NOV	3	2	4	3	3	7
DEC	5	3	1	1	6	11
mean	**5**	**4**	**4**	**7**	**9**	**8**
std dev	2	2	4	8	10	4
max	8	7	13	26	38	18
min	2	0	0	0	3	5

month	NCF117	B210	COL	LVC2	SC-CH
JAN	5	1	0	3	12
FEB	4	2	3	3	22
MAR	3	6	6	7	21
APR	2	1	0	2	15
MAY	2	1	1	2	8
JUN	7	4	3	7	21
JUL	2	3	4	24	19
AUG	3	4	7	9	19
SEP	2	3		5	10
OCT	1	3	4	7	12
NOV	3	4	1	4	25
DEC	7	4	2	4	18
mean	**3**	**3**	**3**	**6**	**17**
std dev	2	2	2	6	5
max	7	6	7	24	25
min	1	1	0	2	8

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2008 versus 2009.

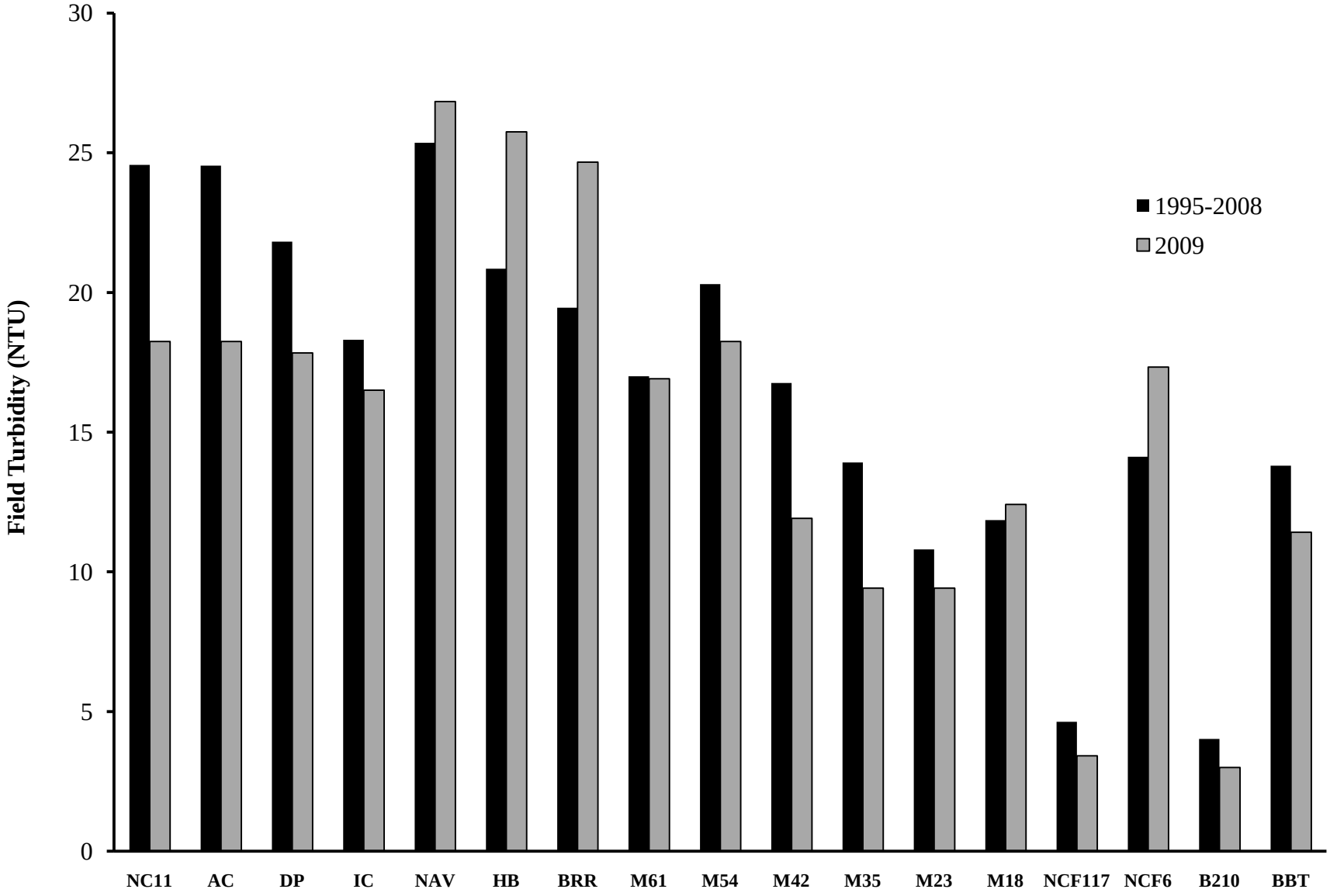


Table 2.7 Total Suspended Solids (mg/L) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	59	30	34	25	42	16	22	24	35	42
FEB	12	11	11	9	10	10	18	8	8	18
MAR	7	8	11	17	17	14	12	35	33	20
APR	14	15	19	13	11	12	12	28	53	22
MAY	6	9	9	8	15	13	14	9	19	18
JUN	15	17	7	9	8	11	10	11	9	21
JUL	18	15	12	9	16	10	8	10	8	26
AUG	29	16	21	11	13	15	13	8	11	21
SEP	47	12	17	7	10	13	19	13	20	12
OCT	22	25	10	7	8	8	7	8	10	21
NOV	45	44	35	14	34	20	11	11	6	23
DEC	15	15	9	13	15	14	11	10	19	16
mean	**24**	**18**	**16**	**12**	**17**	**13**	**13**	**15**	**19**	**22**
std dev	17	10	10	5	11	3	5	9	14	7
max	59	44	35	25	42	20	22	35	53	42
min	6	8	7	7	8	8	7	8	6	12

month	NC11	AC	DP	IC	NCF6
JAN	7	8	9	10	29
FEB	5	5	8	7	24
MAR	54	46	45	27	3
APR	27	29	24	12	16
MAY	9	8	13	18	86
JUN	8	9	15	10	20
JUL	7	8	7	5	9
AUG	4	2	4	5	15
SEP	7	5	7	9	20
OCT	8	7	6	10	17
NOV	3	6	6	16	9
DEC	56	57	54	32	3
mean	**16**	**16**	**17**	**13**	**21**
std dev	19	18	16	9	22
max	56	57	54	32	86
min	3	2	4	5	3

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	2	2	1	1	5	1	2	4	4
FEB	3	2	2	1	4	1	3	5	7
MAR	3	2	1	1	6	11	6	6	4
APR	3	6	3	2	8	16	9	12	6
MAY	5	10	8	4	25	101	28	110	28
JUN	4	10	13	7	13	2	4	12	7
JUL	8	16	28	9	73	3	1	8	10
AUG	5	3	14	12	27	2	13	6	8
SEP	4	7	4	4	8	9	14	12	7
OCT	3	3	3	13	4	3	3	7	8
NOV	1	1	1	1	2	5	6	7	7
DEC	3	4	2	5	16	10	6	9	6
mean	**4**	**6**	**7**	**5**	**16**	**14**	**8**	**17**	**9**
std dev	2	5	8	4	20	28	8	30	6
max	8	16	28	13	73	101	28	110	28
min	1	1	1	1	2	1	1	4	4

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	3	3	1	1	5	3
FEB	2	4	1	1	2	1
MAR	5	3	3	2	17	6
APR	5	2	3	2	19	5
MAY	1	3	2	11	3	3
JUN	1	4	2	10	13	8
JUL	2	1	3	23	1	4
AUG	4	6	8	9	3	4
SEP	1	3	6	6	1	2
OCT	2	4	4	4	27	4
NOV	1	1	3	4	1	4
DEC	3	1	1	1	4	4
mean	**3**	**3**	**3**	**6**	**8**	**4**
std dev	2	2	2	6	9	2
max	5	6	8	23	27	8
min	1	1	1	1	1	1

month	NCF117	B210	COL	LVC2
JAN	4	1	1	1
FEB	3	1	1	1
MAR	2	2	2	4
APR	3	1	1	3
MAY	6	2	3	3
JUN	5	1	1	4
JUL	2	1	3	13
AUG	3	1	13	8
SEP	3	1		4
OCT	3	4	2	2
NOV	4	1	2	2
DEC	4	1	1	1
mean	**4**	**1**	**3**	**4**
std dev	1	1	3	3
max	6	4	13	13
min	2	1	1	1

Table 2.8 Light Attenuation (k) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	5.84	5.62	5.79	5.82	6.10	3.24	3.01	2.41	3.21	3.34
FEB	2.52	2.80	2.95	2.26	2.66	1.41	1.15	1.11	0.97	2.19
MAR	2.85	2.65	3.02	3.40	3.40	2.72	2.50	2.50	3.10	1.56
APR	3.51							1.89	2.78	2.57
MAY	2.83	3.09	3.19	2.57	2.59	2.55	1.73	1.23		1.72
JUN	3.32	3.83	3.62	2.78	2.76	2.46	2.13	1.74	1.47	2.10
JUL	3.40	3.53	3.27	3.03	2.47	2.04	1.58	1.02	1.00	1.83
AUG	4.30	3.72	3.91	2.79	2.40		2.36	1.27	1.21	1.86
SEP	6.30	4.29	3.68	3.42	2.66	2.64	2.03	1.89	1.94	1.69
OCT	4.96	4.74	3.96	3.68	3.43	3.00	2.29	1.71	1.14	1.69
NOV	6.63	6.04	6.17	6.04	5.60	4.54	2.89	2.34	1.70	2.27
DEC	3.32	4.18	4.22	4.62	4.16	3.71	3.05	2.98	3.04	2.61
mean	**4.15**	**4.04**	**3.98**	**3.67**	**3.48**	**2.83**	**2.25**	**1.84**	**1.96**	**2.12**
std dev	1.44	1.09	1.07	1.28	1.29	0.87	0.61	0.62	0.90	0.52
max	6.63	6.04	6.17	6.04	6.10	4.54	3.05	2.98	3.21	3.34
min	2.52	2.65	2.95	2.26	2.40	1.41	1.15	1.02	0.97	1.56
median	3.46	3.83	3.68	3.40	2.76	2.68	2.29	1.82	1.70	1.98

month	NC11	AC	DP	BBT	IC	NCF6
JAN	2.07	3.29	2.59	3.04	3.11	
FEB	1.92	2.17	2.49	2.43	2.57	4.62
MAR	4.63	4.38	4.10	3.26	3.64	3.11
APR	3.11	3.17	3.06	3.13	2.95	4.14
MAY	2.51	2.46	3.20	2.82	4.34	5.76
JUN	2.55	3.79	2.55	3.50	2.93	5.86
JUL	2.77	3.24	3.36	3.28	3.49	2.77
AUG						
SEP	2.34	1.84	3.63	3.87	4.13	4.31
OCT	2.35	2.36	3.26	3.20	3.30	5.85
NOV	1.69	2.88	4.03	3.96	4.69	3.63
DEC	6.00	5.77	5.72	4.67	4.97	4.88
mean	**2.90**	**3.21**	**3.45**	**3.38**	**3.65**	**4.49**
std dev	1.29	1.12	0.93	0.61	0.78	1.12
max	6.00	5.77	5.72	4.67	4.97	5.86
min	1.69	1.84	2.49	2.43	2.57	2.77
median	2.51	3.17	3.26	3.26	3.49	4.47

Table 2.9 Total Nitrogen (µg/l) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	1,920	1,460	1,660	1,400	1,620	1,960	1,260	1,470	940	600
FEB	1,430	1,290	720	1,320	1,370	940	890	490	430	510
MAR	990	930	900	1,050	1,090	1,080	950	530	770	680
APR	1,560	1,290	1,010	830	900	1,030	890	730	230	500
MAY	1,320	1,430	1,400	1,300	1,050	910	410	330	100	340
JUN	1,630	1,900	1,370	1,260	1,130	1,170	1,210	430	340	300
JUL	1,190	920	850	720	700	680	530	300	600	600
AUG	1,410	1,680	1,120	1,060	1,060	960	880	550	500	600
SEP	1,370	1,050	1,100	860	900	710	860	740	860	640
OCT	1,030	960	830	1,330	700	580	190	320	100	60
NOV	1,340	1,220	1,300	980	1,240	960	800	590	570	410
DEC	1,240	940	1,080	1,030	1,130	1,020	990	640	560	450
mean	**1,369**	**1,256**	**1,112**	**1,095**	**1,074**	**1,000**	**822**	**593**	**500**	**474**
std dev	246	305	265	215	252	334	297	301	264	169
max	1,920	1,900	1,660	1,400	1,620	1,960	1,260	1,470	940	680
min	990	920	720	720	700	580	190	300	100	60
median	1,355	1,255	1,090	1,055	1,075	960	885	540	530	505

month	NC11	AC	DP	IC	NCF6
JAN	1,350	1,580	1,340	1,360	1,360
FEB	1,380	1,570	1,400	1,600	1,600
MAR	1,280	1,300	1,360	970	970
APR	1,190	1,290	1,220	1,230	1,230
MAY	1,130	1,290	1,090	1,190	1,190
JUN	1,750	1,860	1,910	1,660	1,660
JUL	2,360	2,210	1,660	1,420	1,420
AUG	1,810	2,000	1,920	1,860	1,860
SEP	1,640	1,450	1,660	1,920	1,920
OCT	1,150	1,290	910	1,120	1,120
NOV	1,920	2,260	1,580	1,240	1,240
DEC	1,010	1,070	840	910	910
mean	**1,498**	**1,598**	**1,408**	**1,373**	**1,373**
std dev	385	378	340	314	314
max	2,360	2,260	1,920	1,920	1,920
min	1,010	1,070	840	910	910
median	1,365	1,510	1,380	1,300	1,300

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1,300	1,460	840	1,400	1,720	880	1,690	5,970	830
FEB	1,100	1,340	700	2,000	930	660	2,450	7,150	790
MAR	3,940	1,690	1,780	3,510	5,060	2,770	2,240	4,760	1,050
APR	980	1,060	630	1,300	1,180	860	1,280	7,720	270
MAY	980	1,120	800	620	1,080	1,240	1,420	3,840	1,650
JUN	1,400	1,240	1,120	1,080	2,300	830	1,890	9,710	1,220
JUL	1,500	1,240	1,820	1,300	4,940	1,010	4,940	13,800	1,380
AUG	1,640	980	1,700	1,520	2,940	1,450	1,790	9,610	1,360
SEP	1,710	1,460	1,220	1,200	1,480	1,080	2,050	14,900	1,270
OCT	1,520	910	900	1,740	1,620	970	2,710	10,200	760
NOV	2,300	1,790	1,010	1,980	3,110	1,900	1,710	4,600	1,400
DEC	1,500	1,500	1,100	2,250	3,240	2,070	1,850	2,780	640
mean	**1,656**	**1,316**	**1,135**	**1,658**	**2,467**	**1,310**	**2,168**	**7,920**	**1,052**
std dev	770	264	401	705	1,363	604	921	3,686	381
max	3,940	1,790	1,820	3,510	5,060	2,770	4,940	14,900	1,650
min	980	910	630	620	930	660	1,280	2,780	270
median	1,500	1,290	1,055	1,460	2,010	1,045	1,870	7,435	1,135

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,680	1,330	1,280	680	1,160	1,180
FEB	1,520	1,650	1,130	710	990	750
MAR	2,180	1,780	1,750	1,030	1,630	2,070
APR	1,340	890	890	890	940	970
MAY	1,300	920	1,020	950	630	560
JUN	1,550	1,220	1,210	1,100	1,290	950
JUL	720	720	1,530	1,700	980	470
AUG	1,250	1,390	1,530	1,110	750	460
SEP	1,410	1,150	680	650	550	200
OCT	930	600	540	900	1,010	400
NOV	880	410	1,190	640	710	100
DEC	1,440	730	100	100	1,420	1,640
mean	**1,350**	**1,066**	**1,071**	**872**	**1,005**	**813**
std dev	375	407	445	364	313	563
max	2,180	1,780	1,750	1,700	1,630	2,070
min	720	410	100	100	550	100
median	1,375	1,035	1,160	895	985	655

month	NCF117	B210	COL	LVC2
JAN	1,050	980	800	820
FEB	1,330	980	600	760
MAR	1,160	1,240	820	2,000
APR	1,090	1,260	1,100	970
MAY	990	840	730	3,330
JUN	1,120	1,000	1,140	650
JUL	1,180	1,150	1,730	1,140
AUG	1,180	1,130	1,830	1,090
SEP	1,020	1,100		1,380
OCT	900	780	740	710
NOV	980	500	700	1,090
DEC	1,040	540	810	1,040
mean	**1,087**	**958**	**1,000**	**1,248**
std dev	111	240	399	717
max	1,330	1,260	1,830	3,330
min	900	500	600	650
median	1,070	990	810	1,065

Figure 2.4 Total Nitrogen at the Lower Cape Fear River Program mainstem stations, 1995-2008 versus 2009.

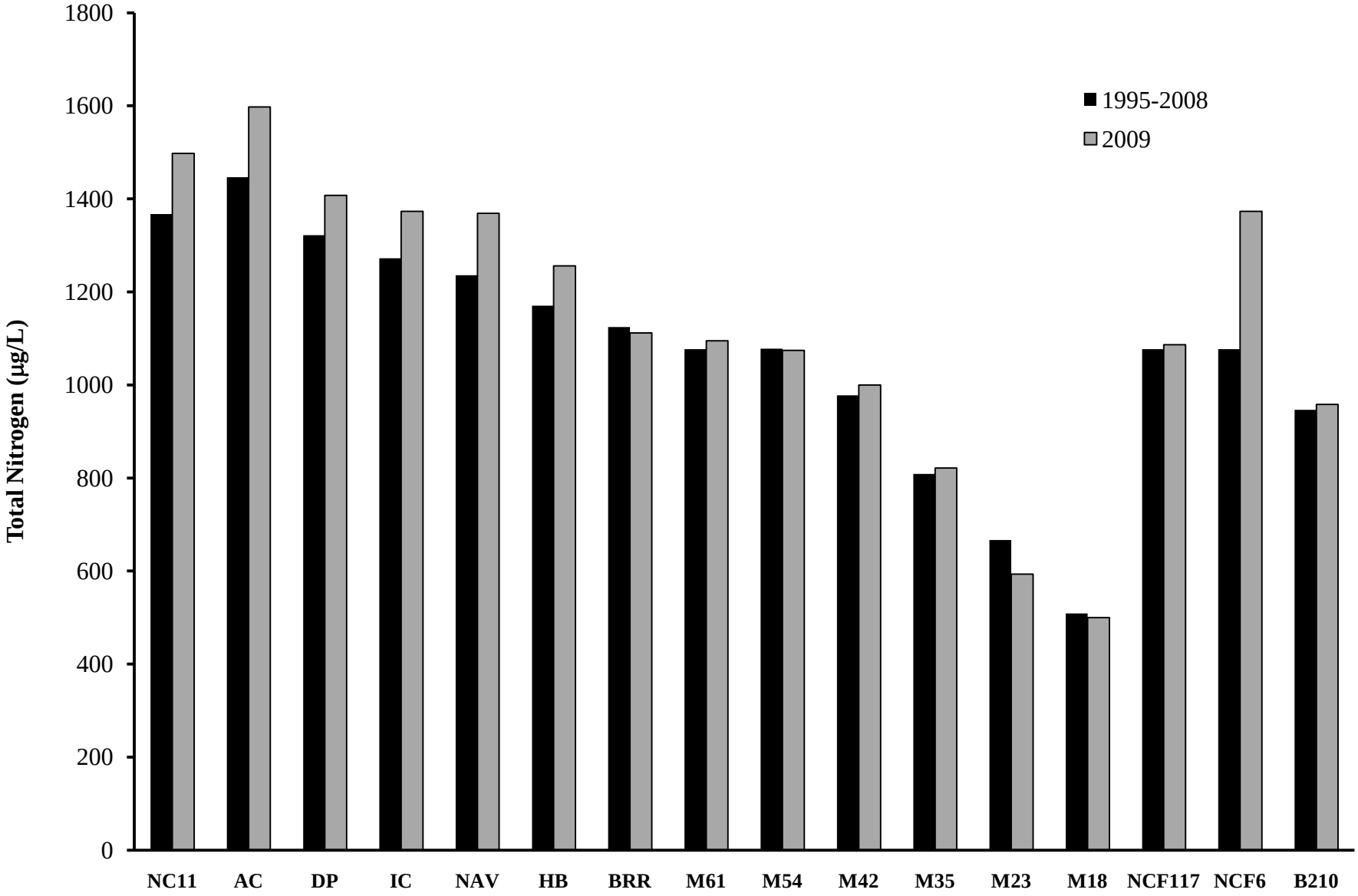


Table 2.10 Nitrate/Nitrite (µg/l) during 2009 at the Lower Cape Fear River stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	720	660	660	600	620	560	360	270	40	200
FEB	730	690	720	630	570	340	290	90	30	110
MAR	290	330	300	350	390	380	350	130	70	180
APR	560	590	510	130	400	330	290	130	30	10
MAY	620	630	600	500	450	310	210	30	10	40
JUN	730	700	570	460	430	370	310	130	40	10
JUL	390	320	250	220	200	80	30	10	10	10
AUG	910	880	720	560	460	360	180	50	10	10
SEP	470	450	400	360	300	310	260	140	160	40
OCT	330	360	430	330	300	280	190	120	10	60
NOV	540	620	600	380	440	460	400	390	270	210
DEC	440	340	380	330	330	320	290	240	160	150
mean	**561**	**548**	**512**	**404**	**408**	**342**	**263**	**144**	**70**	**86**
std dev	180	175	152	145	112	108	96	104	79	76
max	910	880	720	630	620	560	400	390	270	210
min	290	320	250	130	200	80	30	10	10	10
median	550	605	540	370	415	335	290	130	35	50

month	NC11	AC	DP	IC	NCF6
JAN	750	680	640	560	250
FEB	880	870	800	800	610
MAR	580	600	660	470	680
APR	590	590	520	430	230
MAY	730	790	490	590	420
JUN	950	760	910	760	410
JUL	660	610	460	520	220
AUG	910	1000	820	760	270
SEP	640	750	560	520	320
OCT	650	590	410	520	270
NOV	1320	1460	880	540	180
DEC	610	570	540	510	520
mean	**773**	**773**	**641**	**582**	**365**
std dev	205	243	165	117	157
max	1,320	1,460	910	800	680
min	580	570	410	430	180
median	695	715	600	530	295

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	300	460	40	800	820	180	990	5370	130
FEB	100	540	10	1200	330	260	1450	6950	90
MAR	1840	990	980	2710	3460	1570	1440	4160	550
APR	80	160	30	700	480	160	580	6820	70
MAY	80	320	10	120	80	140	520	2740	850
JUN	100	240	20	80	10	130	990	9510	120
JUL	10	40	20	10	40	110	3740	13200	180
AUG	140	80	10	20	440	350	590	7810	160
SEP	110	60	20	100	80	80	650	14100	70
OCT	120	110	10	40	220	170	1710	9450	160
NOV	900	190	110	1280	2210	1000	810	3600	700
DEC	600	1100	700	1750	2540	1470	1350	2280	640
mean	**365**	**358**	**163**	**734**	**893**	**468**	**1,235**	**7,166**	**310**
std dev	510	342	309	826	1,119	526	847	3,699	274
max	1,840	1,100	980	2,710	3,460	1,570	3,740	14,100	850
min	10	40	10	10	10	80	520	2,280	70
median	115	215	20	410	385	175	990	6,885	160

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	1080	630	580	180	360	380
FEB	1120	950	630	210	490	350
MAR	1080	780	950	330	730	670
APR	540	190	90	90	140	170
MAY	800	320	220	50	230	160
JUN	650	320	210	10	90	250
JUL	220	120	730	10	380	70
AUG	250	190	30	110	250	60
SEP	310	150	80	50	250	10
OCT	230	100	40	10	310	10
NOV	380	110	390	40	210	10
DEC	940	430	40	60	920	740
mean	**633**	**358**	**333**	**96**	**363**	**240**
std dev	343	273	303	94	234	241
max	1,120	950	950	330	920	740
min	220	100	30	10	90	10
median	595	255	215	55	280	165

month	NCF117	B210	COL	LVC2
JAN	350	380	10	220
FEB	630	480	10	160
MAR	360	440	20	300
APR	190	260	10	170
MAY	290	240	30	730
JUN	220	200	40	150
JUL	180	150	30	140
AUG	180	230	30	190
SEP	20	100		580
OCT	100	80	40	110
NOV	180	100	10	290
DEC	340	40	510	640
mean	**253**	**225**	**67**	**307**
std dev	150	138	140	208
max	630	480	510	730
min	20	40	10	110
median	205	215	30	205

Table 2.11 Ammonium (µg/l) during 2009 at the Lower Cape Fear River stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	80	40	60	70	140	60	50	20	5	10
FEB	50	60	60	60	90	10	10	5	5	10
MAR	20	5	10	40	100	40	50	5	5	20
APR	60	60	60	80	60	70	40	5	5	5
MAY	100	100	90	80	60	30	10	5	5	5
JUN	100	100	90	100	5	60	5	5	5	5
JUL	90	100	70	80	130	10	20	5	5	5
AUG	40	50	20	20	20	10	5	5	5	5
SEP	70	40	40	10	10	20	5	5	5	10
OCT	40	30	40	30	30	20	20	20	10	10
NOV	80	70	80	60	130	80	100	100	90	80
DEC	50	40	40	60	80	100	60	50	30	60
mean	**65**	**58**	**55**	**58**	**71**	**43**	**31**	**19**	**15**	**19**
std dev	25	29	25	26	46	29	28	28	24	24
max	100	100	90	100	140	100	100	100	90	80
min	20	5	10	10	5	10	5	5	5	5
median	65	55	60	60	70	35	20	5	5	10

month	NC11	AC	DP	IC	NCF6
JAN	40	180	70	50	10
FEB	5	20	30	30	50
MAR	10	10	5	20	30
APR	10	20	30	40	20
MAY	130	90	140	130	60
JUN	90	220	90	80	60
JUL	20	460	90	80	10
AUG	10	50	140	130	5
SEP	90	60	100	80	10
OCT	50	90	70	50	40
NOV	20	100	50	40	50
DEC	60	60	60	40	30
mean	**45**	**113**	**73**	**64**	**31**
std dev	39	121	40	35	20
max	130	460	140	130	60
min	5	10	5	20	5
median	30	75	70	50	30

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	20	60	30	10	160	60	40	10	20
FEB	30	30	5	10	100	70	20	20	40
MAR	50	5	5	5	5	220	50	80	30
APR	40	50	20	50	190	70	30	80	40
MAY	200	120	250	140	160	320	130	280	400
JUN	190	100	10	140	440	10	10	120	240
JUL	90	5	200	150	1710	90	70	170	190
AUG	60	40	80	200	470	130	110	120	160
SEP	30	40	20	10	420	90	30	60	150
OCT	40	20	5	280	660	80	20	70	100
NOV	80	20	70	70	280	140	100	90	110
DEC	320	30	20	20	100	70	30	50	20
mean	**96**	**43**	**60**	**90**	**391**	**113**	**53**	**96**	**125**
std dev	89	34	78	87	438	80	38	70	109
max	320	120	250	280	1,710	320	130	280	400
min	20	5	5	5	5	10	10	10	20
median	55	35	20	60	235	85	35	80	105

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	20	20	20	10	30	30
FEB	20	10	10	20	40	50
MAR	70	20	20	10	50	370
APR	5	5	10	10	10	30
MAY	50	60	60	120	60	110
JUN	20	40	40	50	30	90
JUL	10	30	70	5	30	80
AUG	50	40	70	40	30	50
SEP	30	20	90	90	40	20
OCT	20	10	5	50	30	30
NOV	20	20	40	30	20	10
DEC	40	10	20	20	40	40
mean	**30**	**24**	**38**	**38**	**34**	**76**
std dev	18	15	27	34	13	93
max	70	60	90	120	60	370
min	5	5	5	5	10	10
median	20	20	30	25	30	45

month	NCF117	B210	COL	LVC2
JAN	10	5	5	5
FEB	5	10	10	10
MAR	30	20	20	30
APR	5	5	5	5
MAY	110	160	160	60
JUN	100	100	100	150
JUL	5	40	40	150
AUG	20	30	30	300
SEP	10	20		20
OCT	20	20	20	110
NOV	30	30	30	20
DEC	20	20	20	20
mean	**30**	**38**	**40**	**73**
std dev	34	44	45	86
max	110	160	160	300
min	5	5	5	5
median	20	20	20	25

Table 2.12 Total Kjeldahl Nitrogen (µg/l) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	1200	800	1000	800	1000	1400	900	1200	900	400
FEB	700	600	50	700	800	600	600	400	400	400
MAR	700	600	600	700	700	700	600	400	700	500
APR	1000	700	500	700	500	700	600	600	200	500
MAY	700	800	800	800	600	600	200	300	100	300
JUN	900	1200	800	800	700	800	900	300	300	300
JUL	800	600	600	500	500	600	500	300	600	600
AUG	500	800	400	500	600	600	700	500	500	600
SEP	900	600	700	500	600	400	600	600	700	600
OCT	700	600	400	1000	400	300	100	200	100	100
NOV	800	600	700	600	800	500	400	200	300	200
DEC	800	600	700	700	800	700	700	400	400	300
mean	**808**	**708**	**604**	**692**	**667**	**658**	**567**	**450**	**433**	**400**
std dev	171	171	235	144	160	260	232	260	243	158
max	1,200	1,200	1,000	1,000	1,000	1,400	900	1,200	900	600
min	500	600	50	500	400	300	100	200	100	100
median	800	600	650	700	650	600	600	400	400	400

month	NC11	AC	DP	IC	NCF6
JAN	600	900	700	800	1100
FEB	500	700	600	800	700
MAR	700	700	700	500	800
APR	600	700	700	800	800
MAY	400	500	600	600	900
JUN	800	1100	1000	900	900
JUL	1700	1600	1200	900	1100
AUG	900	1000	1100	1100	1000
SEP	1000	700	1100	1400	1000
OCT	500	700	500	600	600
NOV	600	800	700	700	700
DEC	400	500	300	400	500
mean	**725**	**825**	**767**	**792**	**842**
std dev	344	289	262	260	185
max	1,700	1,600	1,200	1,400	1,100
min	400	500	300	400	500
median	600	700	700	800	850

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1000	1000	800	600	900	700	700	600	700
FEB	1000	800	700	800	600	400	1000	200	700
MAR	2100	700	800	800	1600	1200	800	600	500
APR	900	900	600	600	700	700	700	900	200
MAY	900	800	800	500	1000	1100	900	1100	800
JUN	1300	1000	1100	1000	2300	700	900	200	1100
JUL	1500	1200	1800	1300	4900	900	1200	600	1200
AUG	1500	900	1700	1500	2500	1100	1200	1800	1200
SEP	1600	1400	1200	1100	1400	1000	1400	800	1200
OCT	1400	800	900	1700	1400	800	1000	800	600
NOV	1400	1600	900	700	900	900	900	1000	700
DEC	900	400	400	500	700	600	500	500	100
mean	**1,292**	**958**	**975**	**925**	**1,575**	**842**	**933**	**758**	**750**
std dev	352	307	400	383	1,163	225	239	413	359
max	2,100	1,600	1,800	1,700	4,900	1,200	1,400	1,800	1,200
min	900	400	400	500	600	400	500	200	100
median	1,350	900	850	800	1,200	850	900	700	700

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	600	700	700	500	800	800
FEB	400	700	500	500	500	400
MAR	1100	1000	800	700	900	1400
APR	800	700	800	800	800	800
MAY	500	600	800	900	400	400
JUN	900	900	1000	1100	1200	700
JUL	500	600	800	1700	600	400
AUG	1000	1200	1500	1000	500	400
SEP	1100	1000	600	600	300	200
OCT	700	500	500	900	700	400
NOV	500	300	800	600	500	100
DEC	500	300	100	100	500	900
mean	**717**	**708**	**742**	**783**	**642**	**575**
std dev	244	266	317	378	240	344
max	1,100	1,200	1,500	1,700	1,200	1,400
min	400	300	100	100	300	100
median	650	700	800	750	550	400

month	NCF117	B210	COL	LVC2
JAN	700	600	800	600
FEB	700	500	600	600
MAR	800	800	800	1700
APR	900	1000	1100	800
MAY	700	600	700	2600
JUN	900	800	1100	500
JUL	1000	1000	1700	1000
AUG	1000	900	1800	900
SEP	1000	1000		800
OCT	800	700	700	600
NOV	800	400	700	800
DEC	700	500	300	400
mean	**833**	**733**	**936**	**942**
std dev	118	205	437	594
max	1,000	1,000	1,800	2,600
min	700	400	300	400
median	800	750	800	800

Table 2.13 Total Phosphorus (µg/l) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	270	180	190	150	180	80	70	40	70	70
FEB	90	90	140	80	70	50	70	20	20	40
MAR	70	80	90	100	110	70	60	50	80	40
APR	110	120	120	90	80	80	60	60	80	70
MAY	110	120	130	100	90	90	50	30	20	30
JUN	140	130	90	100	70	70	60	30	40	10
JUL	150	110	110	90	100	120	80	40	30	50
AUG	210	170	140	110	110	110	80	40	40	50
SEP	260	150	140	110	110	110	110	90	70	50
OCT	130	120	140	90	100	70	60	50	40	50
NOV	180	170	170	130	140	100	70	70	50	40
DEC	80	80	80	90	70	60	60	40	50	40
mean	**150**	**127**	**128**	**103**	**103**	**84**	**69**	**47**	**49**	**45**
std dev	64	33	31	19	31	21	15	18	21	16
max	270	180	190	150	180	120	110	90	80	70
min	70	80	80	80	70	50	50	20	20	10
median	135	120	135	100	100	80	65	40	45	45

month	NC11	AC	DP	IC	NCF6
JAN	90	180	90	90	120
FEB	90	90	100	100	100
MAR	170	180	160	120	60
APR	150	130	120	100	80
MAY	120	110	130	150	230
JUN	170	210	170	140	130
JUL	200	200	140	140	120
AUG	170	170	150	180	130
SEP	170	150	180	180	130
OCT	150	150	120	140	120
NOV	200	260	170	130	60
DEC	170	140	130	120	80
mean	**154**	**164**	**138**	**133**	**133**
std dev	35	44	27	28	28
max	200	260	180	180	180
min	90	90	90	90	90
median	170	160	135	135	120

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	110	90	110	110	160	30	210	530	100
FEB	70	60	60	90	160	20	230	740	70
MAR	140	50	40	60	100	60	90	210	50
APR	80	110	110	150	190	70	170	820	90
MAY	190	180	240	270	580	300	310	750	300
JUN	160	170	270	330	360	40	300	1,180	220
JUL	130	130	480	370	2,950	70	560	1,690	160
AUG	200	150	370	650	840	90	380	1,280	260
SEP	240	160	150	260	350	100	310	1,990	180
OCT	160	140	80	540	250	100	500	1,240	170
NOV	200	60	60	70	140	60	130	350	70
DEC	210	50	40	80	140	50	100	200	30
mean	**158**	**113**	**168**	**248**	**518**	**83**	**274**	**915**	**142**
std dev	51	47	137	187	762	70	144	548	83
max	240	180	480	650	2,950	300	560	1,990	300
min	70	50	40	60	100	20	90	200	30
median	160	120	110	205	220	65	265	785	130

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	50	30	110	20	80	70
FEB	30	20	60	10	40	50
MAR	90	40	60	30	60	70
APR	70	30	160	50	110	140
MAY	110	260	310	110	100	170
JUN	80	60	290	130	100	100
JUL	180	100	460	220	110	170
AUG	200	100	530	130	90	180
SEP	140	70	250	100	80	200
OCT	120	60	120	70	190	190
NOV	120	40	300	70	80	90
DEC	50	10	50	10	40	50
mean	**103**	**68**	**225**	**79**	**90**	**123**
std dev	50	64	153	60	38	55
max	200	260	530	220	190	200
min	30	10	50	10	40	50
median	100	50	205	70	85	120

month	NCF117	B210	COL	LVC2
JAN	70	30	10	30
FEB	40	30	10	30
MAR	60	40	50	30
APR	60	40	10	30
MAY	80	100	30	40
JUN	60	100	10	50
JUL	80	130	50	70
AUG	120	120	100	50
SEP	90	120		60
OCT	80	100	390	20
NOV	70	80	70	30
DEC	80	40	10	10
mean	**74**	**78**	**67**	**38**
std dev	19	37	106	16
max	120	130	390	70
min	40	30	10	10
median	75	90	30	30

Figure 2.5 Total Phosphorus at the Lower Cape Fear River program manistem stations, 1995-2008 versus 2009.

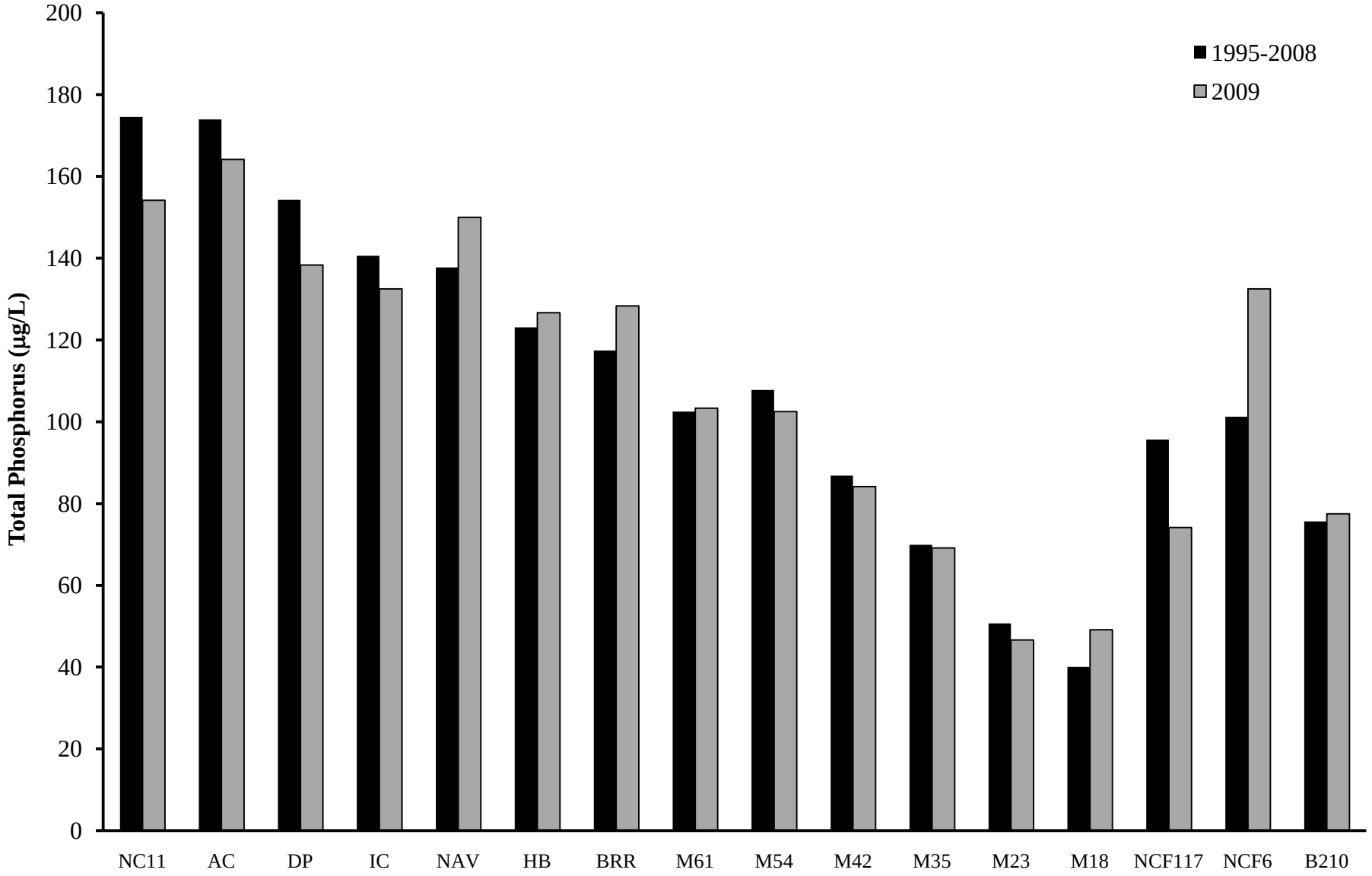


Table 2.14 Orthophosphate (µg/l) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	80	70	60	40	40	30	10	10	10	10
FEB	30	30	30	30	10	10	10	0	0	0
MAR	10	20	20	23	30	30	20	10	10	10
APR	30	30	30	30	30	30	20	10	0	0
MAY	60	50	50	50	40	30	10	0	0	0
JUN	60	60	60	40	40	30	20	10	0	10
JUL	50	40	30	30	40	20	10	20	10	10
AUG	110	60	50	70	60	50	20	10	10	10
SEP	100	60	50	60	40	40	30	30	20	20
OCT	40	50	50	30	40	30	20	20	10	20
NOV	30	30	30	40	50	40	40	40	30	30
DEC	40	40	30	40	40	40	30	30	20	20
mean	**53**	**45**	**41**	**40**	**38**	**32**	**20**	**16**	**10**	**12**
std dev	30	16	14	14	12	10	10	12	10	9
max	110	70	60	70	60	50	40	40	30	30
min	10	20	20	23	10	10	10	0	0	0
median	45	45	40	40	40	30	20	10	10	10

month	NC11	AC	DP	BBT	IC	NCF6
JAN	40	50	40	30	30	30
FEB	40	40	30	30	30	20
MAR	20	20	30	20	20	20
APR	30	30	30	10	20	10
MAY	50	50	50	50	50	40
JUN	70	100	90	40	70	40
JUL	70	90	70	60	80	40
AUG	110	130	110	100	110	60
SEP	50	160	90	70	100	40
OCT	90	100	60	50	70	40
NOV	150	160	100	70	60	30
DEC	40	30	30	20	40	40
mean	**63**	**80**	**61**	**46**	**57**	**34**
std dev	37	51	30	26	30	13
max	150	160	110	100	110	60
min	20	20	30	10	20	10
median	50	70	55	45	55	40

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	60	20	20	50	60	0	130	330	10
FEB	30	10	10	40	30	20	160	610	10
MAR	70	0	0	20	20	0	20	100	10
APR	20	20	20	80	40	0	60	550	20
MAY	100	50	50	90	70	10	80	260	80
JUN	110	50	40	70	20	10	170	1,000	70
JUL	50	60	20	60	80	20	340	1,380	50
AUG	140	60	80	260	280	20	200	1,120	80
SEP	190	50	40	150	110	20	20	1,720	40
OCT	110	30	30	70	50	20	160	1,030	40
NOV	160	30	30	40	60	20	80	300	10
DEC	20	30	20	50	40	10	50	20	60
mean	**88**	**34**	**30**	**82**	**72**	**13**	**123**	**702**	**40**
std dev	56	20	21	65	71	9	92	541	28
max	190	60	80	260	280	20	340	1,720	80
min	20	0	0	20	20	0	20	20	10
median	85	30	25	65	55	15	105	580	40

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	10	10	60	0	20	20
FEB	10	0	40	0	10	10
MAR	20	0	20	0	10	10
APR	10	0	70	0	20	30
MAY	40	140	110	20	30	50
JUN	50	30	160	10	30	50
JUL	50	40	340	20	30	60
AUG	80	50	290	30	40	90
SEP	50	20	130	20	40	140
OCT	60	50	10	10	40	80
NOV	50	20	180	10	40	90
DEC	20	10	30	0	20	20
mean	**38**	**31**	**120**	**10**	**28**	**54**
std dev	23	39	107	10	11	40
max	80	140	340	30	40	140
min	10	0	10	0	10	10
median	45	20	90	10	30	50

month	NCF117	B210	COL	LVC2
JAN	40	10	10	10
FEB	10	0	0	10
MAR	10	0	0	30
APR	10	10	10	0
MAY	40	30	10	0
JUN	40	30	10	0
JUL	50	30	20	0
AUG	50	74	30	10
SEP	40	40		20
OCT	40	30	320	0
NOV	30	30	40	10
DEC	60	30	10	0
mean	**35**	**26**	**42**	**8**
std dev	17	20	93	10
max	60	74	320	30
min	10	0	0	0
median	40	30	10	5

Table 2.15 Chlorophyll *a* (µg/l) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	3	2	3	3	4	4	4	5	9	6
FEB	5	6	12	6	7	10	9	6	5	10
MAR	11	16	11	8	8	6	3	6	6	5
APR	3	3	4	3	4	5	6	7	8	6
MAY	3	3	15	7	7	31	12	6	5	10
JUN	1	1	1	2	1	3	2	3	2	6
JUL	5	20	25	24	18	30	21	13	8	7
AUG	6	5	10	10	12	20	26	10	8	8
SEP	3	2	4	3	4	7	19	13	9	5
OCT	2	3	3	5	3	7	3	5	6	5
NOV	4	4	3	2	2	2	2	3	3	3
DEC	2	2	2	1	1	1	2	3	4	2
mean	**4**	**6**	**8**	**6**	**6**	**10**	**9**	**7**	**6**	**6**
std dev	3	6	7	6	5	10	8	3	2	2
max	11	20	25	24	18	31	26	13	9	10
min	1	1	1	1	1	1	2	3	2	2

month	NC11	AC	DP	BBT	IC	NCF6
JAN	3	2	2	1	1	2
FEB	10	7	5	4	4	3
MAR	16	19	20	12	13	1
APR	7	7	8	2	4	5
MAY	6	4	3	2	2	7
JUN	5	3	3	1	2	2
JUL	61	11	2	2	6	10
AUG	22	15	10	11	7	4
SEP	5	5	2	2	1	2
OCT	6	4	1	1	1	2
NOV	10	6	5	4	5	2
DEC	4	3	3	1	2	0
mean	**13**	**7**	**5**	**4**	**4**	**3**
std dev	15	5	5	4	3	3
max	61	19	20	12	13	10
min	3	2	1	1	1	0

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	2	2	2	4	5	1	1	1	1
FEB	2	1	2	3	6	1	6	4	2
MAR	3	3	2	3	2	2	2	1	1
APR	6	4	4	3	10	2	2	8	2
MAY	2	4	7	5	23	35	5	10	3
JUN	8	3	13	42	16	1	1	2	1
JUL	11	1	60	17	438	1	2	1	7
AUG	7	4	19	11	23	4	3	4	1
SEP	4	2	3	5	5	11	2	1	1
OCT	1	1	3	11	6	1	1	1	0
NOV	1	1	1	3	2	3	1	1	0
DEC	1	3	6	5	6	2	1	1	1
mean	**4**	**2**	**10**	**9**	**45**	**5**	**2**	**3**	**2**
std dev	3	1	16	11	119	9	2	3	2
max	11	4	60	42	438	35	6	10	7
min	1	1	1	3	2	1	1	1	0

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	1	1	1	1	1	1
FEB	1	1	1	1	1	1
MAR	2	1	3	4	2	2
APR	1	1	2	4	2	2
MAY	0	0	1	2	0	1
JUN	0	0	0	1	1	1
JUL	1	1	1	60	5	2
AUG	1	1	3	3	11	2
SEP	1	2	2	4	1	2
OCT	1	0	1	2	2	1
NOV	1	0	1	2	1	1
DEC	1	1	1	1	1	1
mean	**1**	**1**	**1**	**7**	**2**	**1**
std dev	0	1	1	16	3	1
max	2	2	3	60	11	2
min	0	0	0	1	0	1

month	NCF117	B210	COL	LVC2
JAN	1	0	0	1
FEB	1	1	0	1
MAR	1	1	1	3
APR	1	1	4	6
MAY	2	1	1	3
JUN	1	1	1	1
JUL	2	2	2	7
AUG	2	2	28	3
SEP	1	1		2
OCT	0	1	3	1
NOV	0	0	4	4
DEC	0	0	0	0
mean	**1**	**1**	**4**	**3**
std dev	1	1	8	2
max	2	2	28	7
min	0	0	0	0

Figure 2.6 Chlorophyll *a* at the Lower Cape Fear River program mainstem stations, 1995-2008 versus 2009.

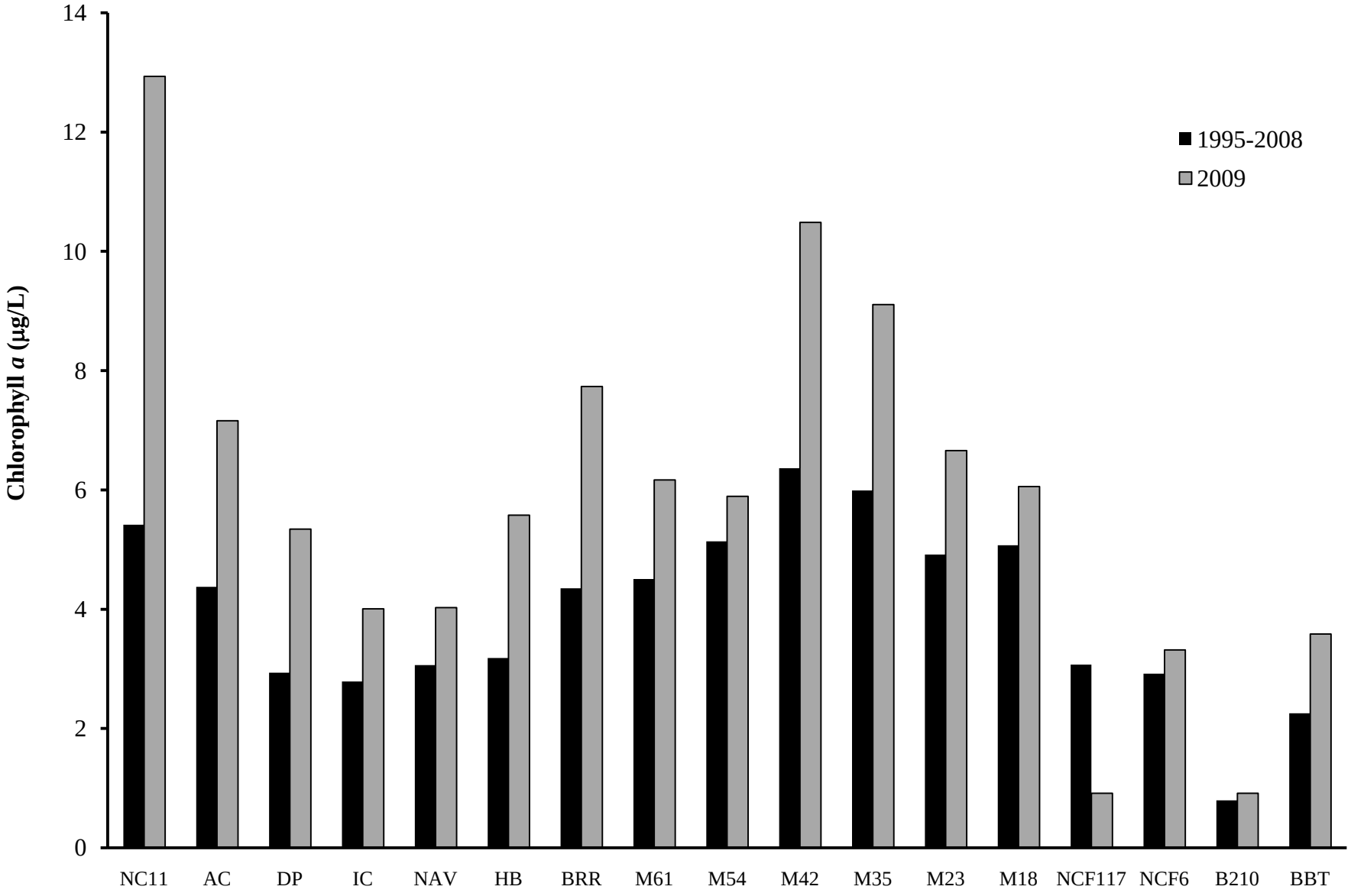


Table 2.16 Biochemical Oxygen Demand (mg/l) during 2009 at the Lower Cape Fear River Program stations.

5-Day Biochemical Oxygen Demand

month	NC11	AC	ANC	SAR	GS	N403	ROC	BC117	NCF117	B210	LVC2	BBT
JAN	0.9	8.3	0.9	1.5	1.0	0.9	0.9	0.8	0.6	0.5	1.1	2.4
FEB	0.2	0.3	2.1	1.5	1.7	1.1	1.3	1.6	1.7	1.8	1.5	0.0
MAR			1.5	1.6	1.5	1.2	1.9	1.7				
APR	1.7	1.4	3.1	2.0	1.9	1.7	2.2	2.9				1.2
MAY	1.9	1.5	3.4	2.8	3.0	3.7	2.4	5.6	3.0	2.5	4.2	1.5
JUN	1.5	2.7							1.7	1.9	1.8	1.4
JUL	6.9	3.4	3.0	1.0	4.7	3.0	1.5	1.1	1.2	1.8	3.5	2.3
AUG	1.8	1.8							1.7	1.8	1.4	1.7
SEP	1.3	1.0	1.4	2.0	1.5	1.6	1.5	1.5	1.2	1.4	1.5	0.9
OCT	1.0	1.8	1.2	1.0	1.0	1.2	1.1	1.4	0.8	1.1	0.9	1.2
NOV	1.7	1.2							1.1	0.8	1.3	2.0
DEC	2.2	2.1	1.1	1.3	1.4	1.8	1.6	1.6	1.3	1.1	1.3	2.0
median	1.7	1.8	1.5	1.5	1.5	1.6	1.5	1.6	1.3	1.6	1.5	1.5
mean	1.9	2.3	2.0	1.6	2.0	1.8	1.6	2.0	1.4	1.5	1.9	1.5
stdev	1.7	2.2	1.0	0.6	1.2	0.9	0.5	1.5	0.7	0.6	1.1	0.7
max	6.9	8.3	3.4	2.8	4.7	3.7	2.4	5.6	3.0	2.5	4.2	2.4
min	0.2	0.3	0.9	1.0	1.0	0.9	0.9	0.8	0.6	0.5	0.9	0.0

20-Day Biochemical Oxygen Demand

month	NC11	AC	ANC	SAR	GS	N403	ROC	BC117	NCF117	B210	LVC2	BBT
JAN	2.9	16.0	3.1	4.0	3.2	2.6	2.8	2.6	2.5	1.7	3.1	5.6
FEB	2.7	2.7	4.7	4.0	4.1	2.6	3.4	2.0	3.8	3.5	3.8	2.4
MAR			4.1	3.8	3.2	2.5	4.2	3.0				
APR	4.1	3.7	6.6	5.4	4.8	4.2	5.7	7.2				3.2
MAY	4.7	3.8	8.1	6.7	7.2	8.1	6.1	11.6	6.6	5.3	9.4	4.3
JUN	3.4	7.3							4.5	3.7	4.4	3.6
JUL	10.6	8.4	7.5	3.1	8.2	8.3	4.5	3.2	2.8	3.1	7.4	4.3
AUG	4.2	4.3							3.1	2.6	4.2	4.4
SEP	3.2	2.8	4.0	5.6	3.6	4.6	4.5	3.7	3.2	3.2	3.4	3.3
OCT	2.7	5.2	3.4	3.0	2.7	3.6	3.2	3.6	3.3	3.6	3.7	3.2
NOV	3.5	3.3							3.1	2.0	3.7	5.6
DEC	4.7	4.6	3.1	3.3	3.5	3.9	3.8	3.7	3.5	2.6	2.9	4.3
median	3.5	4.3	4.1	4.0	3.6	3.9	4.2	3.6	3.3	3.2	3.8	4.3
mean	4.2	5.6	5.0	4.3	4.5	4.5	4.2	4.5	3.6	3.1	4.6	4.0
stdev	2.2	3.9	1.9	1.3	1.9	2.2	1.1	3.0	1.2	1.0	2.1	1.0
max	10.6	16.0	8.1	6.7	8.2	8.3	6.1	11.6	6.6	5.3	9.4	5.6
min	2.7	2.7	3.1	3.0	2.7	2.5	2.8	2.0	2.5	1.7	2.9	2.4

Table 2.17 Fecal Coliform Bacteria (cfu/100 ml) during 2009 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	519	149	149	176	108	51	22	8	8	2
FEB	11	11	22	8	11	2	4	2	4	2
MAR	28	10	37	82	46	10	10	10	10	10
APR	64	64	19	10	37	5	2	12	8	15
MAY	10	32	64	23	10	5	3	3	3	3
JUN	50	23	23	19	5	10	5	5	5	5
JUL	118	330	163	1,350	228	10	10	32	10	5
AUG	17	11	35	28	38	9	1	2	6	2
SEP	37	46	91	91	73	64	19	28	19	19
OCT	127	145	82	10	10	19	10	10	10	19
NOV	290	330	455	82	127	100	118	19	10	28
DEC	19	181	154	73	46	37	37	10	10	55
mean	**108**	**111**	**108**	**163**	**62**	**27**	**20**	**12**	**9**	**14**
std dev	146	113	117	361	63	29	31	9	4	15
max	519	330	455	1,350	228	100	118	32	19	55
min	10	10	19	8	5	2	1	2	3	2
Geomean	50	57	68	47	35	15	9	8	8	8

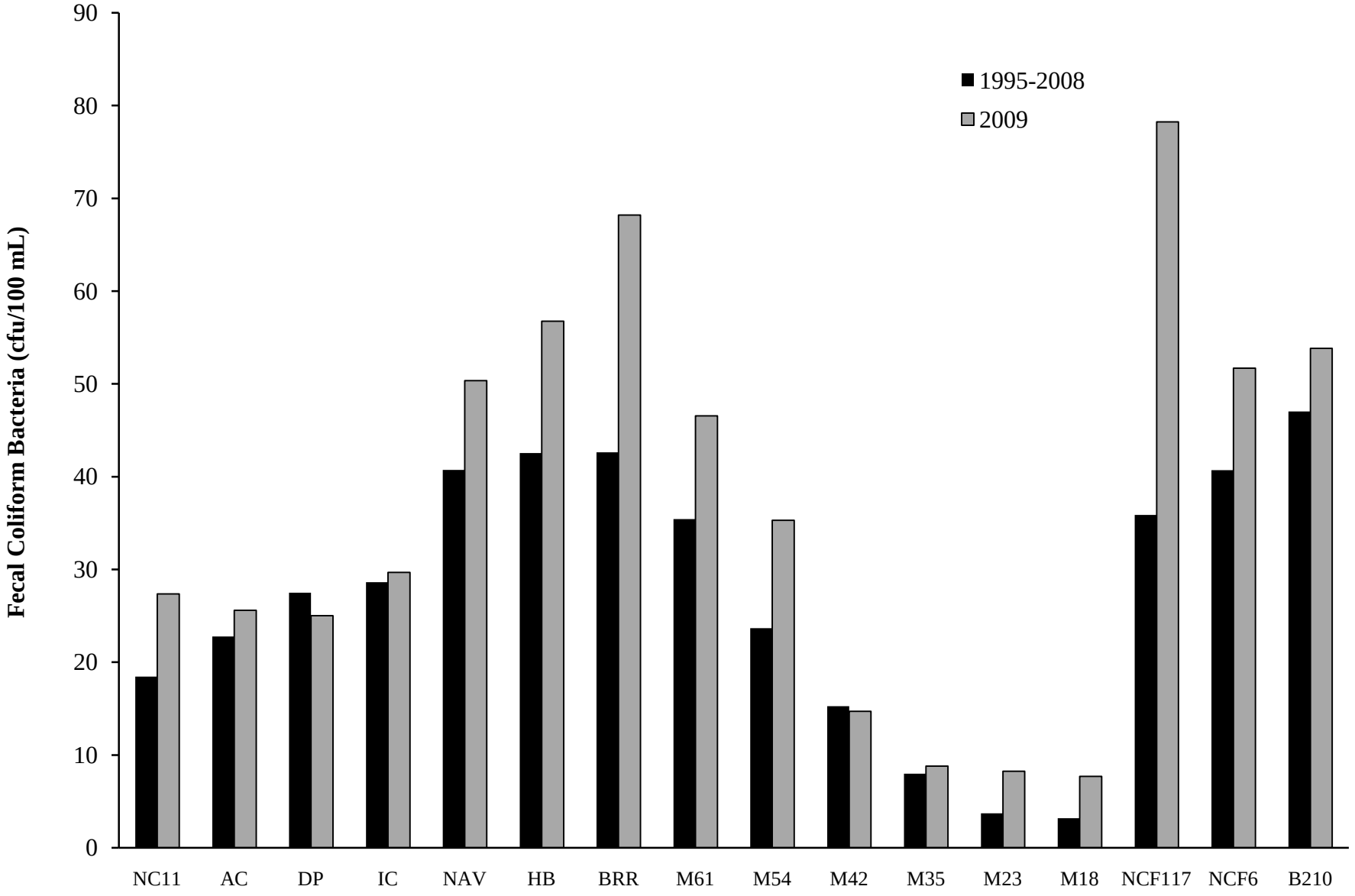
month	NC11	AC	DP	IC	NCF6
JAN	40	55	29	64	164
FEB	29	11	4	8	19
MAR	84	27	27	43	33
APR	10	28	10	10	10
MAY	5	3	28	28	110
JUN	5	10	10	50	64
JUL	135	46	14	3	64
AUG	6	11	33	35	31
SEP	64	37	55	37	55
OCT	37	19	28	46	37
NOV	19	46	37	55	226
DEC	199	352	260	154	55
mean	**53**	**54**	**45**	**44**	**72**
std dev	58	91	66	38	62
max	199	352	260	154	226
min	5	3	4	3	10
Geomean	27	26	25	30	52

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	46	591	55	73	470	96	130	100	210
FEB	17	38	15	8	110	40	114	118	1,200
MAR	100	64	19	33	46	41	77	37	91
APR	37	28	14	37	37	228	64	195	115
MAY	120	450	195	182	546	3,500	319	10,000	12,000
JUN	108	144	192	88	204	109	410	1,364	208
JUL	64	91	1,546	208	290	830	55	530	637
AUG	58	52	116	66	6,000	35	82	1,000	328
SEP	728	728	118	181	3,700	364	11,000	1,546	637
OCT	64	172	118	181	819	37	440	136	520
NOV	154	310	46	28	580	290	360	410	637
DEC	55	380	200	586	910	350	270	240	685
mean	**129**	**254**	**220**	**139**	**1,143**	**493**	**1,110**	**1,306**	**1,439**
std dev	184	227	406	151	1,744	933	2,985	2,667	3,198
max	728	728	1,546	586	6,000	3,500	11,000	10,000	12,000
min	17	28	14	8	37	35	55	37	91
Geomean	79	154	87	81	417	169	229	391	492

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	136	58	73	40	390	310
FEB	22	19	26	40	73	186
MAR	1,140	257	17	40	28	82
APR	46	28	28	14	91	250
MAY	46	46	37	140	37	100
JUN	41	14	19	160	145	320
JUL	19	10	55	455	280	109
AUG	46	40	100	11,200	400	182
SEP	127	19	46	154	230	46
OCT	1,455	82	127	190	12,000	820
NOV	109	55	136	220	637	280
DEC	330	91	118	37	300	424
mean	**293**	**60**	**65**	**1,058**	**1,218**	**259**
std dev	461	64	42	3,060	3,256	201
max	1,455	257	136	11,200	12,000	820
min	19	10	17	14	28	46
Geomean	105	40	51	130	231	197

month	NCF117	B210	COL	LVC2	SC-CH
JAN	65	104	37	188	172
FEB	26	50	17	17	82
MAR	51	28	19	28	73
APR	145	64	28	55	109
MAY	91	10	86	41	32
JUN	32	32	23	37	28
JUL	82	118	46	20,000	109
AUG	88	74	284	600	27
SEP	181	64		127	10
OCT	64	19	55	64	82
NOV	127	172	109	230	145
DEC	136	109	73	334	91
mean	**91**	**70**	**71**	**1,810**	**80**
std dev	46	46	73	5,487	48
max	181	172	284	20,000	172
min	26	10	17	17	10
Geomean	78	54	49	140	62

Figure 2.7 Fecal Coliform Bacteria at the Lower Cape Fear River program mainstem stations, 1996-2008 versus 2009 using geometric mean.



3.0 Water Quality Evaluation by Subbasin in the Lower Cape Fear River System

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3.0 Water Quality Evaluation by Subbasin

This section details an evaluation of water quality within each subbasin for dissolved oxygen, turbidity, chlorophyll *a*, fecal coliform bacteria, nitrate+nitrite and total phosphorus at the LCFRP sampling sites. Monthly data from January to December 2009 are used in these comparisons.

3.1 Introduction

The NC Division of Water Quality prepares a basinwide water quality plan for each of the seventeen major river basins in the state every five years (NCDENR, DWQ Cape Fear River Basinwide Water Quality Plan October 2005). The basinwide approach is a non-regulatory watershed based approach to restoring and protecting the quality of North Carolina's surface waters. The first basinwide plan for the Cape Fear River was completed in 1996 and five-year interval updates have been completed in 2000 and 2005.

The goals of the basinwide program are to:

-Identify water quality problems and restore full use to impaired waters.
-Identify and protect high value resource waters.
-Protect unimpaired waters while allowing for reasonable economic growth.

DWQ accomplishes these goals through the following objectives:

-Collaborate with other agencies to develop appropriate management strategies.
-Assure equitable distribution of waste assimilative capacity.
-Better evaluate cumulative effects of pollution.
-Improve public awareness and involvement.

The US Geological Survey (USGS) identifies 6 major hydrological areas in the Cape Fear River Basin. Each of these hydrologic areas is further divided into subbasins by DWQ. There are 24 subbasins within the Cape Fear River basin, each denoted by six digit numbers, 03-06-01 to 03-06-24 (NCDENR-DWQ, October 2005).

All surface waters in the state are assigned a *primary* classification that is appropriate to

the best uses of that water. North Carolina's Water Quality Standards Program adopted classifications and water quality standards for all the state's river basins by 1963. The program remains consistent with the Federal Clean Water Act and its amendments. DWQ assesses ecosystem health and human health risk through the use of five use support categories: aquatic life, recreation, fish consumption, water supply and shellfish harvesting. These categories are tied to the uses associated with the primary classifications applied to NC rivers and streams. Waters are supporting if data and information used to assign a use support rating meet the criteria for that use category. If these criteria are not met then the waters are Impaired. Waters with inconclusive data and information are Not Rated. Waters with insufficient data or information are rated No Data. Because of state wide fish consumption advisories for several fishes, all waters in the basin are impaired on an evaluated basis.

For ambient water quality monitoring criteria DWQ uses water quality data collected by both their own monitoring system as well as several NPDES discharger coalitions including the Lower Cape Fear River Program. The parameters used to assess water quality in the aquatic life category include dissolved oxygen (DO), pH, chlorophyll *a* and turbidity as well as benthos and fish data. DWQ rates use support based on whether the NC State Water Quality Standard is exceeded as listed below:

Numerical standard exceeded in ≤ 10% of samples	=	Supporting
Numerical standard exceeded in > 10% of samples	=	Impaired
Less than 10 samples collected	=	Not Rated
DO and pH standard exceeded in swamp streams	=	Not Rated

*Some of the NC State Water Quality standards are written with more specific criteria and the reader should refer to http://h2o.enr.state.nc.us/csu/index.htm for complete details about the use of the standards.

3.2 Methods

The UNCW Aquatic Ecology Laboratory (AEL) has developed an evaluation system that incorporates some of the guidelines used by DWQ and utilizes data collected by the Lower Cape Fear River Program. This approach determines a water quality "rating" for the parameters dissolved oxygen, chlorophyll *a*, fecal coliform bacteria, field turbidity and the nutrient species nitrate-nitrite (referred to as nitrate) and total phosphorus. For dissolved oxygen, chlorophyll *a*, and fecal coliform bacteria we compare LCFRP data to the N.C. State Water Quality Standards (http://h2o.enr.state.nc.us/csu/index.htm). Fecal coliform bacteria data is analyzed considering human contact standards, not shellfishing standards.

The NC DWQ does not have surface water quality standards for nitrate and total phosphorus. The AEL water quality standard is based on levels noted to be problematic in the scientific literature and our own published research. Based on data from four years of nutrient addition bioassay experiments using water from the Black and Northeast Cape

Fear Rivers, Colly Creek and Great Coharie Creek, the UNCW-AEL considers total phophorus levels of 500 µg/L or greater potentially harmful to water quality in all the waters of the Cape Fear River watershed. Nitrate levels of 200 µg/L, 500 µg/L and 1,000 µg/L in small streams, mainstem blackwater stations (NCF117, NCF6, B210) and mainstem Cape Fear River stations, respectively, are considered harmful to water quality. These nutrient levels may lead to algal blooms, high bacteria levels and high biochemical oxygen demand (BOD) in blackwater streams (Mallin et al., 2001; 2002; 2004). Water quality status for nutrient species at the mainstem Cape Fear River stations was evaluated with a higher standard for nutrients because its waters are quite different (greater discharge and turbidity concentrations) than the blackwater areas and are able to better assimilate higher nutrient levels.

AEL rates use support based on whether the NC State Water Quality Standard is exceeded as listed below:

Good = Standard is exceeded in 0 or 1 of 12 measurements ($\leq$10%)
Fair = Standard is exceeded in 2 or 3 of 12 measurements (11-25%)
Poor = Standard is exceeded in 4-12 out of 12 measurements (>25%)

The 36 stations monitored by the LCFRP by subbasin:

Subbasin #	**LCFRP Stations**
03-06-16	BRN, HAM, NC11
03-06-17	LVC2, AC, DP, IC, NAV, HB, BRR, M61, M54, M42, M35, M23, M18, SPD
03-06-18	SR
03-06-19	6RC, LCO, GCO
03-06-20	COL, B210, BBT
03-06-21	N403
03-06-22	SAR, GS, PB, LRC, ROC
03-06-23	ANC, BC117, BCRR, NCF6, NCF117, SC-CH

Each subbasin is addressed separately with a description and map showing the LCFRP stations. This will be followed by a summary of the information published in the October 2005 Cape Fear River Basinwide Water Quality Plan and water quality status discussion using the UNCW-AEL approach for the 2009 LCFRP data.

3.3 Cape Fear River Subbasin 03-06-16

Location: Cape Fear River upstream and downstream of Elizabethtown
Counties: Bladen, Columbus, Cumberland, Pender
Water bodies: Cape Fear River
Municipalities: Elizabethtown, Dublin, White Lake, East Arcadia, Tar Heel
NPDES Dischargers: 7 @ 13.7 million gallons per day
Concentrated Swine Operations: 50

LCFRP monitoring stations (DWQ #):

BRN (B8340050), HAM (B8340200), NC11 (B8360000)

NC DWQ monitoring stations (DWQ #):

Six ambient monitoring stations Subbasin 03-06-16 includes the Cape Fear River and many streams that drain coastal plain wetlands and bay lakes. Most of the watershed is forested with some agriculture

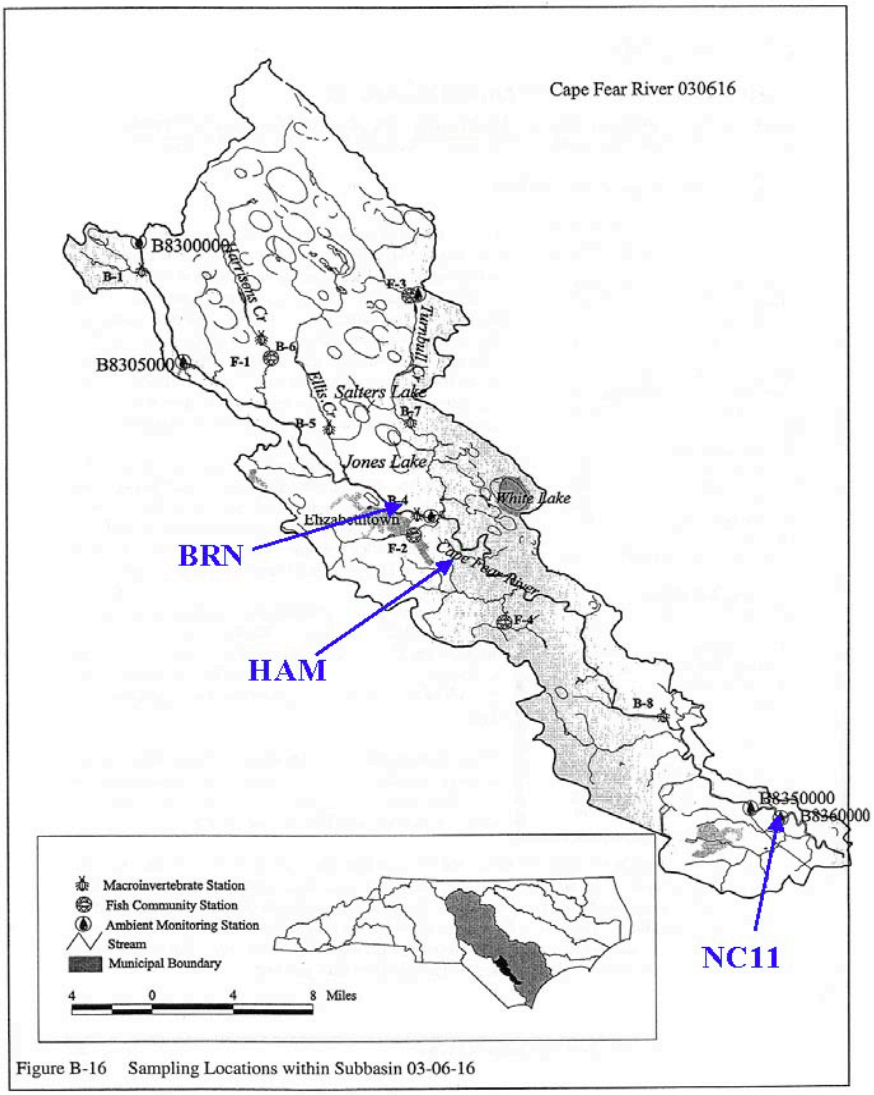


Figure B-16 Sampling Locations within Subbasin 03-06-16

pres

The CFR Basinwide Water Quality Plan lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Supporting	101.5 freshwater miles	Supporting	115.1 freshwater miles
Not Rated	40.1 freshwater miles	Not Rated	4.8 freshwater miles
Not Rated	1,593.2 freshwater acres	No Data	153.1 freshwater miles
No Data	131.4 freshwater miles	No Data	2,510.8 freshwater acres
No Data	917.6 freshwater acres		

*Brown's Creek, rated as impaired in the 2000 CFRBWQP, was upgraded in the 2005 plan (NCDENR DWQ CFRWQBP, July 2000 and NCDENR DWQ CFRWQBP, October 2005).

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: NC11 since June 1995, BRN & HAM since February 1996
Sampling relevance: Represents water entering the Lower Cape Fear River watershed from the middle basin (NC11). There are also concentrated animal operations within the area (BRN and HAM).


BRN **-** representative of small tributaries. NC11 – Main stem of the Cape Fear River has a deep channel, is freshwater with minor tidal influence.

Dissolved Oxygen ratings for BRN and NC11 were both good. At HAM the rating was fair, with values exceeding the NC State standard 17% of the time (Table 3.3.1).

All sites within this subbasin had a good rating for chlorophyll *a* concentrations (Table 3.3.1). The North Carolina State standard for chlorophyll *a*, 40 µg/L, was exceeded only once which was at NC11 in July 2010. We do note that blue-green algal blooms occurred

in the NC11 area late summer through fall 2009 (see Chapter 2).

For fecal coliform bacteria concentrations NC11 had a good rating (Table 3.3.1). BRN and HAM received poor ratings exceeding the standard 58% and 50% of the time, respectively.

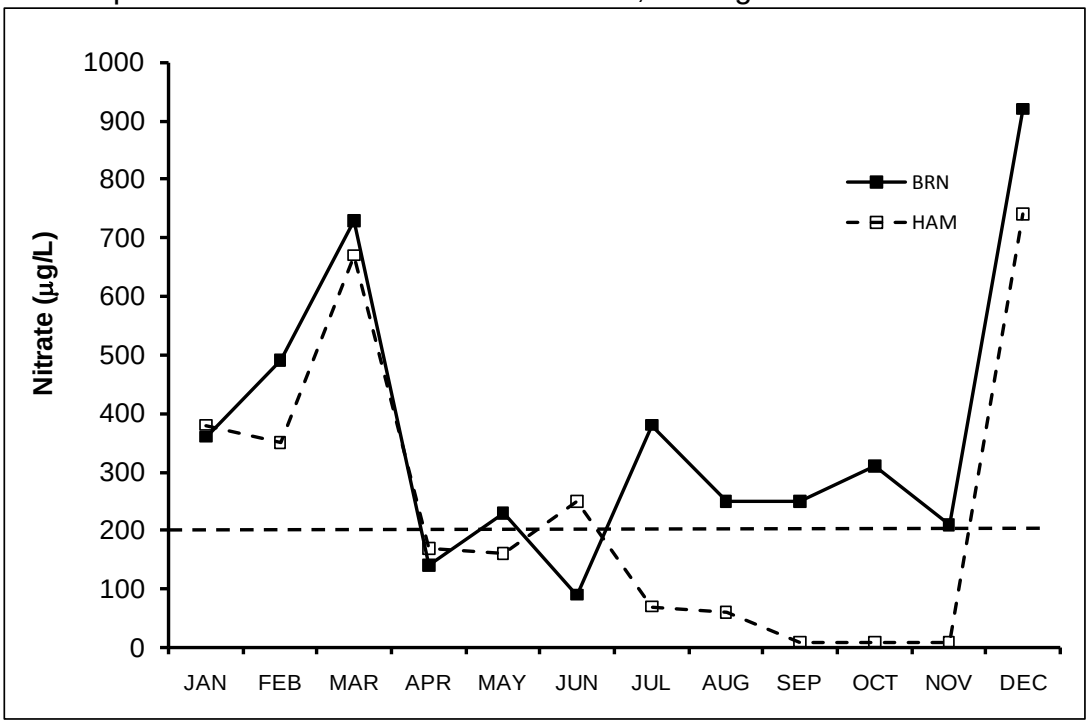
For field turbidity all stations were rated good (Table 3.3.1). The NC State Standard of 50 NTU was exceeded once at NC11 in December.

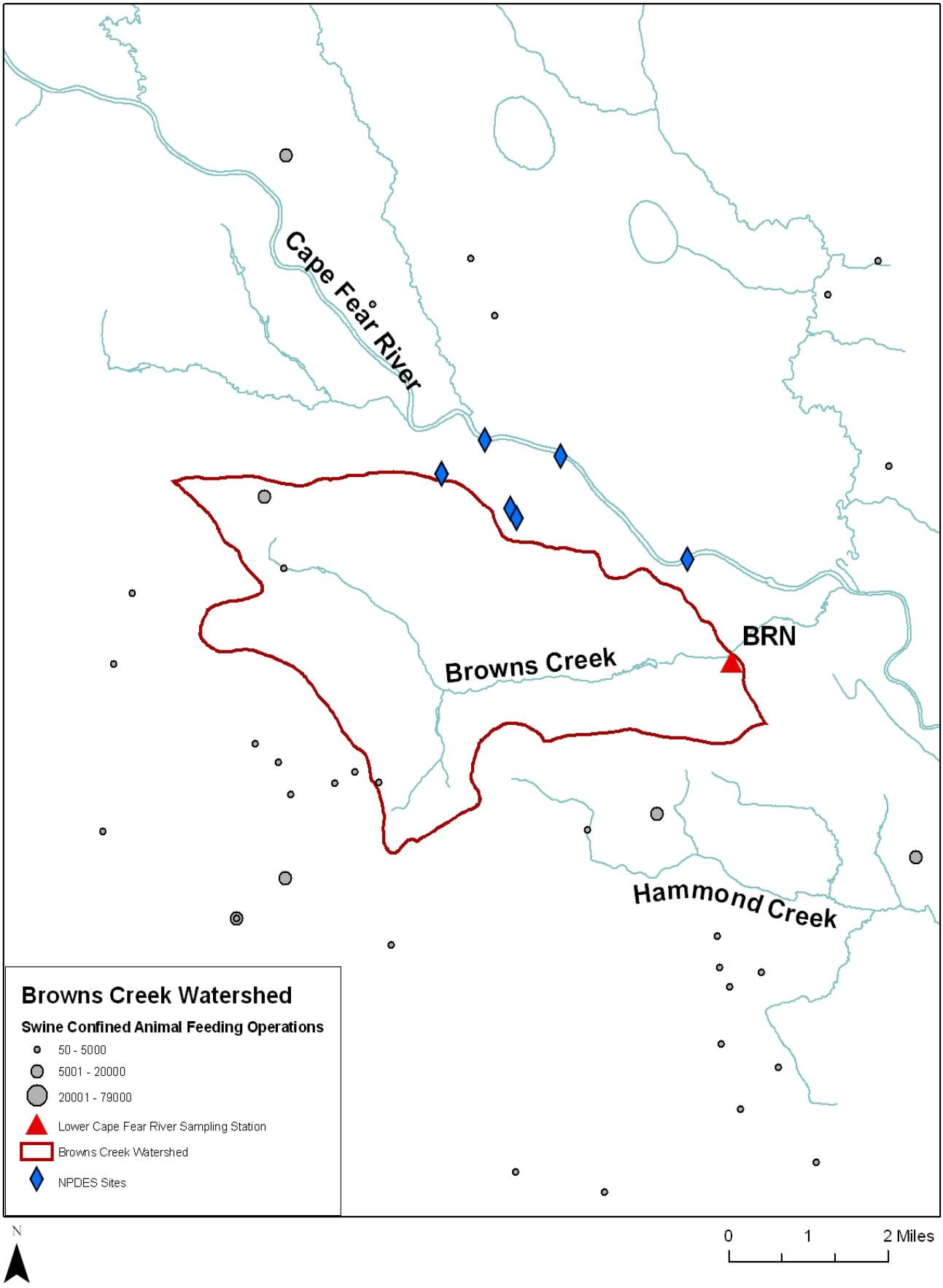
For nitrate BRN and HAM received a poor rating exceeding the standard 83% and 42% of the time, respectively (Table, 3.3.1, Figure 3.3.1). A good rating was found at NC11 for both nutrient species and for total phosphorus at BRN and HAM.

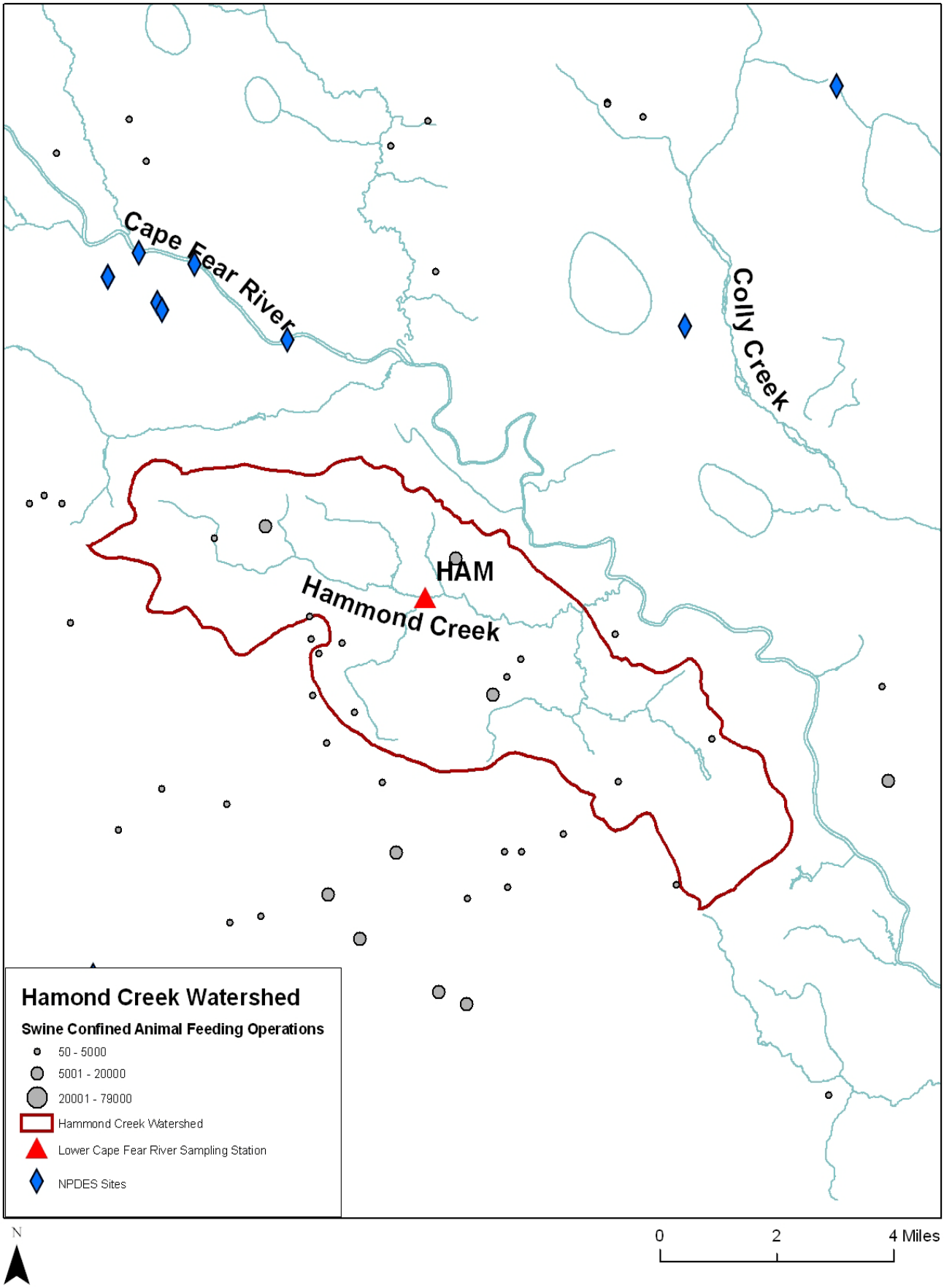
Table 3.3.1 UNCW AEL 2009 evaluation for subbasin 03-06-16

Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
BRN	G	G	P	G	P	G
HAM	F	G	P	G	P	G
NC11	G	G	G	G	G	G

Figure 3.3.1 Nitrate concentrations at the LCFRP stations BRN and HAM for 2009. The dashed line represents the AEL standard for nitrate, 200 ug/L.




Cape Fear River
BRN
Browns Creek
Hammond Creek
Browns Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Lower Cape Fear River Sampling Station
Browns Creek Watershed
NPDES Sites
N
0
1
2 Miles


Cape Fear River
Colly Creek
HAM
Hammond Creek
Hamond Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Hammond Creek Watershed
Lower Cape Fear River Sampling Station
NPDES Sites
N
0
2
4 Miles

3.4 Cape Fear River Subbasin 03-06-17

Location: Cape Fear River near Riegelwood, downstream to estuarine area near Southport
Counties: Columbus, Pender, Brunswick, New Hanover
Waterbodies: Cape Fear River and Estuary
Municipalities: Wilmington, Southport
NPDES Dischargers: 41 @ 99.9 million gallons per day
Concentrated Swine Operations: 7

LCFRP monitoring stations (DWQ #):
LVC2 (B8445000), AC (B8450000), DP (B8460000), IC (B9030000), NAV (B9050000), HB (B9050100), BRR (B9790000), M61 (B9750000), M54 (B9795000), M42 (B9845100), M35 (B9850100), M23 (B9910000), M18 (B9921000), SPD (B9980000)

DWQ monitoring stations:
NAV (B9050000), M61 (B9750000), M54(B9795000)

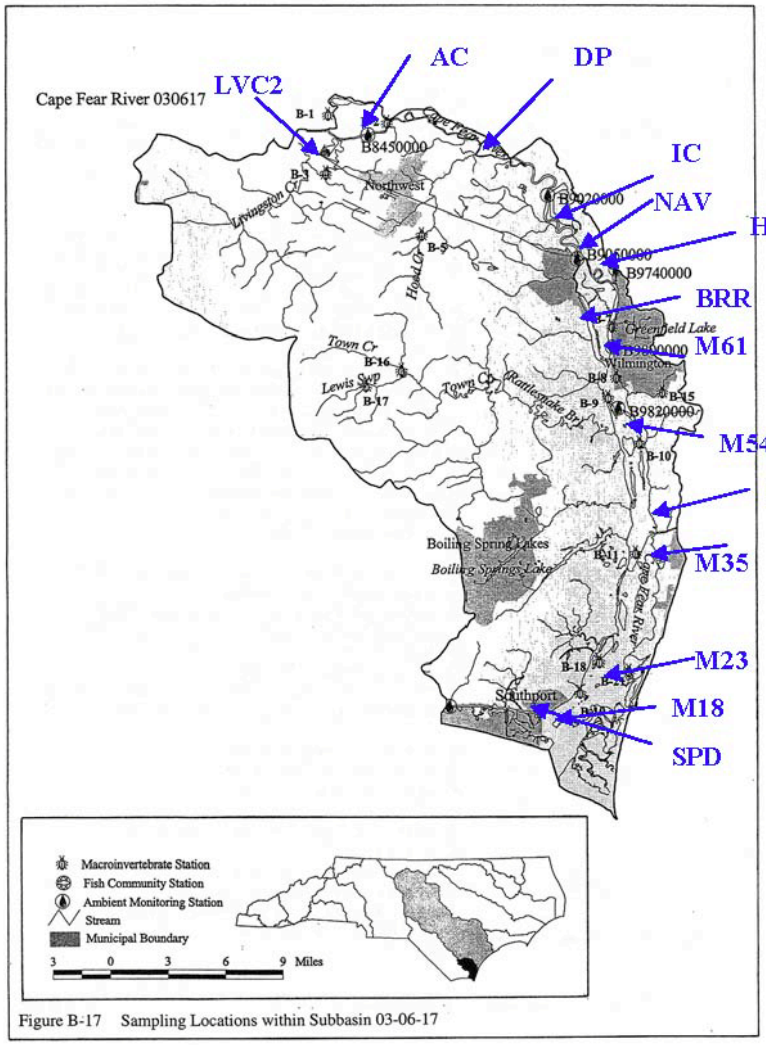


Figure B-17 Sampling Locations within Subbasin 03-06-17

Subbason 03-06-17 includes the mainstem of the Cape Fear River, the Cape Fear River Estuary and many streams that drain the areas west of the River. Most of the watershed is forested with some urban areas including Wilmington and Southport.

The CFR Basinwide Water Quality Plan lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Supporting	14,125.4 saltwater acres	Supporting	21,092.3 saltwater acres
Not Rated	2.0 saltwater acres	Impaired	96.6 saltwater acres
Impaired	6,457.0 saltwater acres	Supporting	44.1 freshwater miles
Supporting	75.4 freshwater miles	Not Rated	5.6 coast miles
Not Rated	22.3 freshwater miles	Impaired	4.7 coast miles
Not Rated	406.9 freshwater acres	No Data	2,254.6 saltwater acres
No Data	2,859.2 saltwater acres	No Data	269.1 freshwater miles
No Data	215.4 freshwater miles	No Data	1,251.5 freshwater acres
No Data	844.5 freshwater acres	No Data	12.5 coast miles
No Data	22.8 coast miles		

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: Most stations since 1995, all sampled since 1998
Sampling relevance: Highly important estuary for fisheries productivity. Also receives point source discharge and non-point source pollution.

AC – representative of riverine system channel

HB- upper estuary, upstream of Wilmington


M35 – represents wide estuary

Sites given a good rating for dissolved oxygen include AC, DP, IC, NAV, M42, M35, M23, M18 and SPD (Table 3.4.1). Sites having a fair rating for dissolved oxygen, with the percentage of samples not meeting the standard shown in parentheses, are M61 (33%) and M54 (17%) (Figure 3.4.1). LVC2, HB and BRR were rated poor with samples below the standard 33%, 42% and 33% of the time, respectively (Figure 3.4.2).

All sites within this subbasin had a good rating in terms of chlorophyll *a* concentrations (Table 3.4.1). None of the sampled locations exceeded the 40 µg/L North Carolina State standard on any sample occasion during 2009.

Eleven of the fourteen sites within this subbasin had a good rating for fecal coliform bacteria concentrations (Table 3.4.1). NAV and HB both had a fair rating with 17% of samples exceeding the state human contact standard of 200 cfu/100 mL. LVC2 had a poor rating with 33% of samples exceeding the standard.

Nine of the fourteen sites within this subbasin had a good rating for field turbidity (Table 3.4.1). Five stations were rated fair including NAV, HB, BRR, M61 and M54 with 17%, 25%, 17%, 17% and 17% of samples exceeding the NC state standard for brackish waters of 25 NTU, respectively.

All sites in this subbasin rated good for nitrate except LVC2 which was rated poor for nitrate, exceeding the UNCW-AEL recommended standard (200 mg/L for stream stations) 50% of the time (Table 3.4.1). All stations rated good for total phosphorus.

Table 3.4.1 UNCW AEL 2009 evaluation for subbasin 03-06-17

Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
LVC2	P	G	P	G	P	G
AC	G	G	G	G	G	G
DP	G	G	G	G	G	G
IC	G	G	G	G	G	G
NAV	G	G	F	F	G	G
HB	P	G	F	F	G	G
BRR	P	G	G	F	G	G
M61	F	G	G	F	G	G
M54	F	G	G	F	G	G
M42	G	G	G	G	G	G
M35	G	G	G	G	G	G
M23	G	G	G	G	G	G
M18	G	G	G	G	G	G
SPD	G	G	G	G	G	G

Figure 3.4.1 Dissolved oxygen concentrations at M61 and M54, rated fair for 2009. The dashed line shows the NC State Standard of 5.0 mg/L.

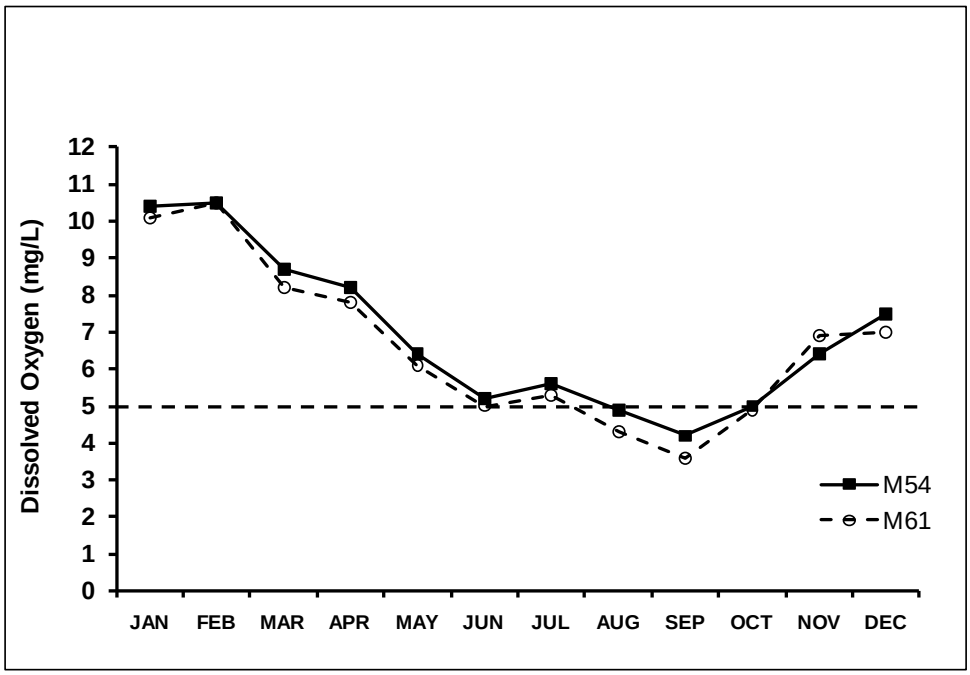
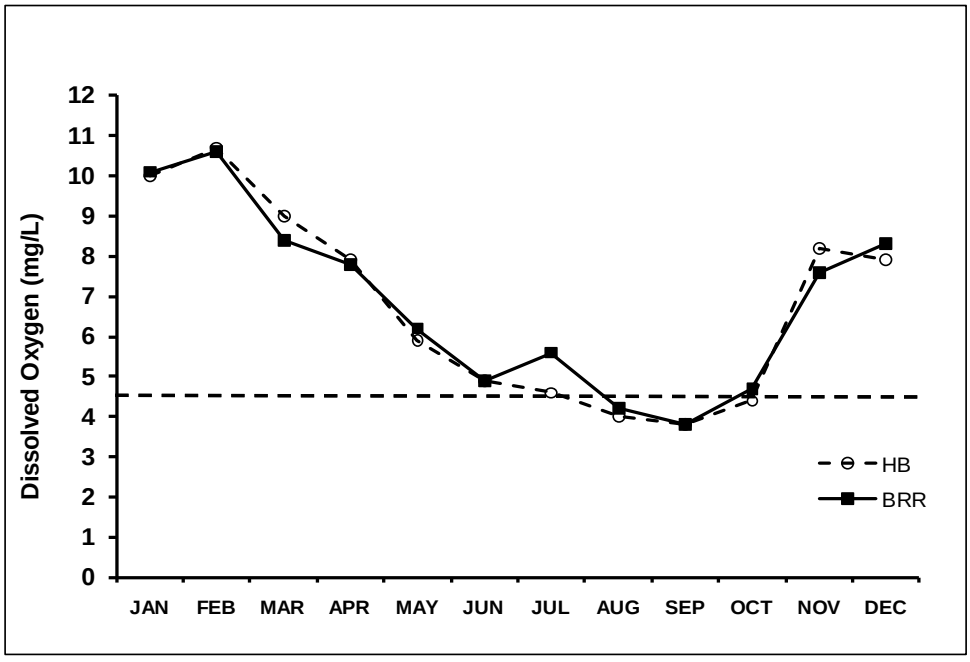


Figure 3.4.2 Dissolved oxygen concentrations at HB and BRR, rated poor for 2009. The dashed line shows the NC State Standard of 5.0 mg/L.



3.5 Cape Fear River Subbasin 03-06-18

Location: South River headwaters above Dunn down to Black River
Counties: Bladen, Cumberland, Harnett, Johnston, Sampson
Waterbodies: South River, Mingo Swamp
Municipalities: Dunn, Roseboro
NPDES Dischargers: 2 @ 0.08 million gallons per day
Concentrated Swine Operations: 105

LCFRP monitoring stations (DWQ #): SR (B8470000) **DWQ monitoring stations:** none

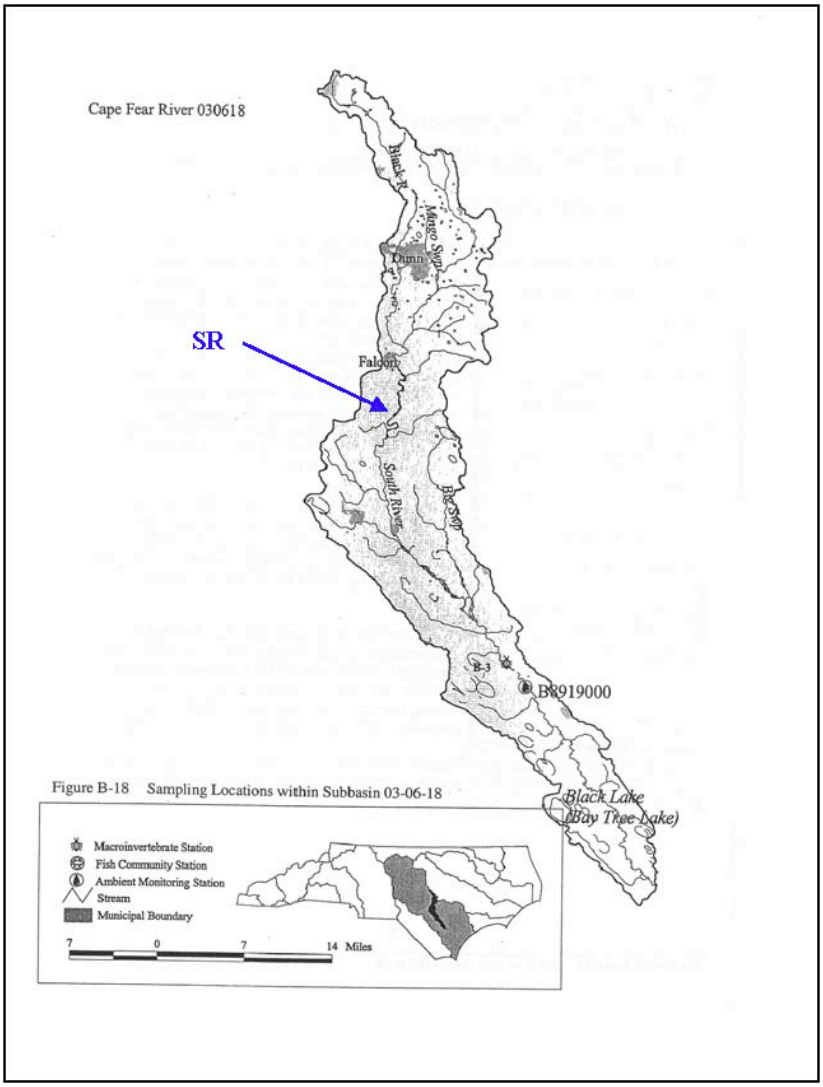


Figure B-18 Sampling Locations within Subbasin 03-06-18

This subbasin is located on the inner coastal plain and includes the South River which converges with the Great Coharie Creek to form the Black River, a major tributary of the Cape Fear River. Land use is primarily agriculture including row crops and concentrated animal operations.

The CFR Basinwide Water Quality Plan lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Not Rated	52.1 freshwater miles	Supporting	52.1 freshwater miles
Not Rated	1,454.2 freshwater acres	No Data	242.5 freshwater miles
No Data	242.5 freshwater miles	No Data	1,454.2 freshwater acres

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: Since February 1996
Sampling relevance: Below City of Dunn, hog operations in watershed

SR – a slow black water tributary

SR had a poor rating for dissolved oxygen concentrations in 2009 (Table 3.5.1). The North Carolina State Standard for swampwater of 4.0 mg/L was not met 58% of the time. The lowest levels were found in summer and late fall (Figure 3.5.1). This station has had low dissolved oxygen problems for many years.

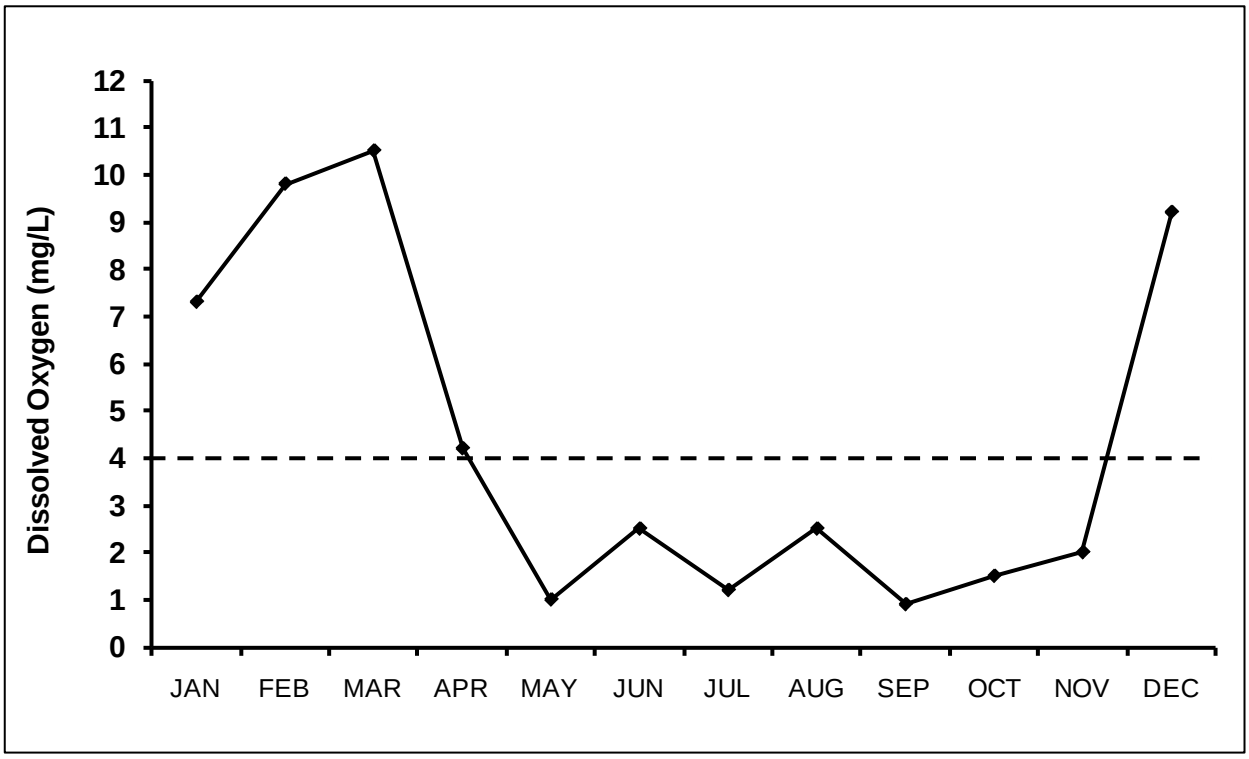
SR had a good rating for chlorophyll *a* exceeding the NC State standard of 40 µg/L on only one occasion (Table 3.5.1).

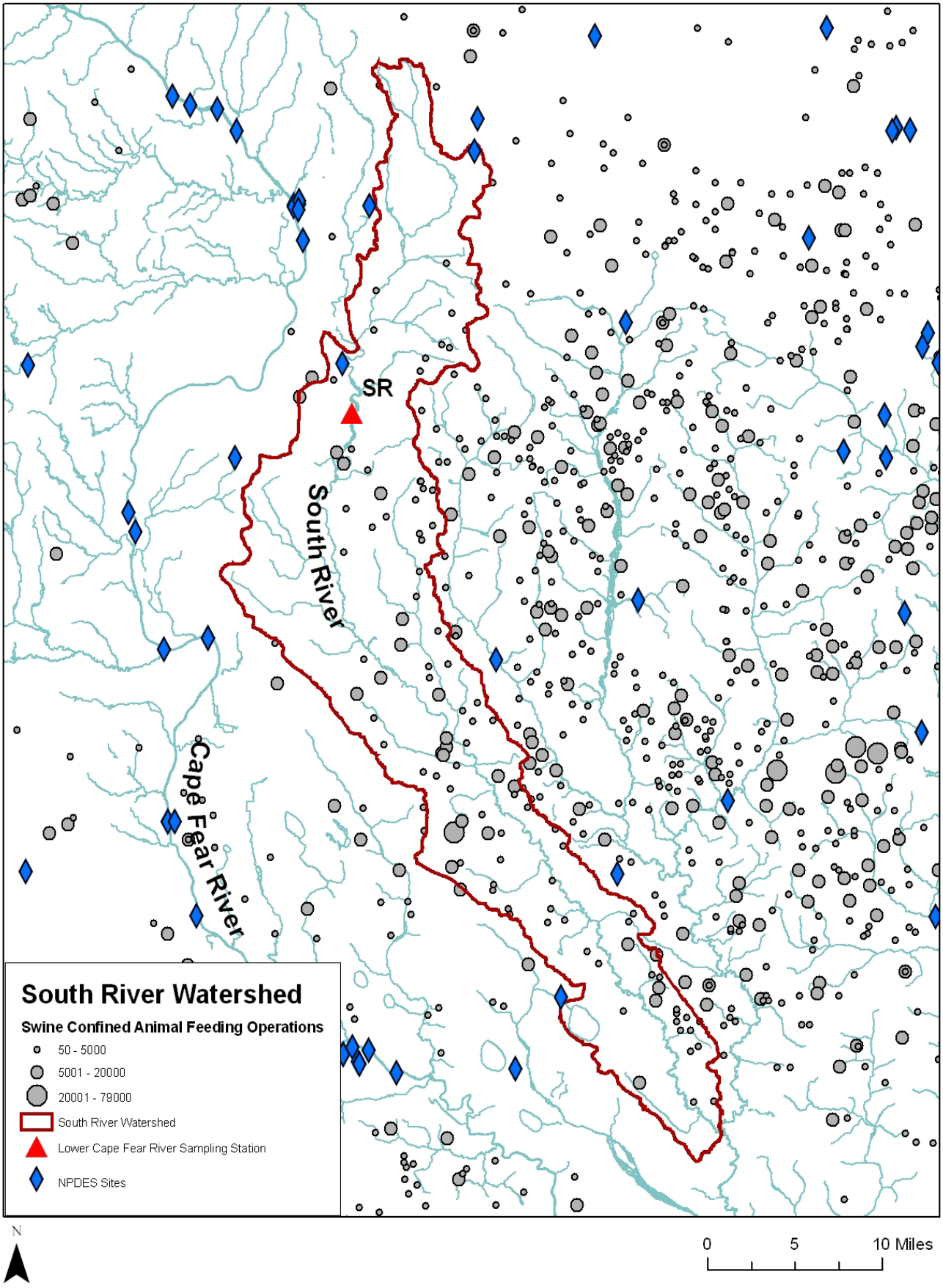
SR had a fair water quality rating for fecal coliform bacteria concentrations exceeding the NC state standard of 200 CFU/100mL in 25% of samples (Table 3.5.1). The highest concentration was in August (11,200 cfu/100mL).

SR had a good rating for field turbidity and total phosphorus (Table 3.5.1). The nitrate rating was fair with samples exceeding the standard 17% of the time.

Table 3.5.1 UNCW AEL 2009 evaluation for subbasin 03-06-18						
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
SR	P	G	F	G	F	G

Figure 3.5.1 Dissolved oxygen (mg/L) at SR during 2009. The dashed line shows the NC state standard for swampwater DO of 4.0 mg/L.




SR
South River
Cape Fear River
South River Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
South River Watershed
Lower Cape Fear River Sampling Station
NPDES Sites
N
0
5
10 Miles

3.6 Cape Fear River Subbasin 03-06-19

Location: Three main tributaries of Black River near Clinton
Counties: Sampson
Waterbodies: Black River, Six Runs Ck., Great Coharie Ck., Little Coharie Ck.
Municipalities: Clinton, Newton Grove, Warsaw
NPDES Dischargers: 8 @ 6.8 million gallons per day
Concentrated Swine Operations: 374

LCFRP monitoring stations (DWQ #):
LCO (B8610001), GCO (B8604000), 6RC (B8740000)

DWQ monitoring stations: none

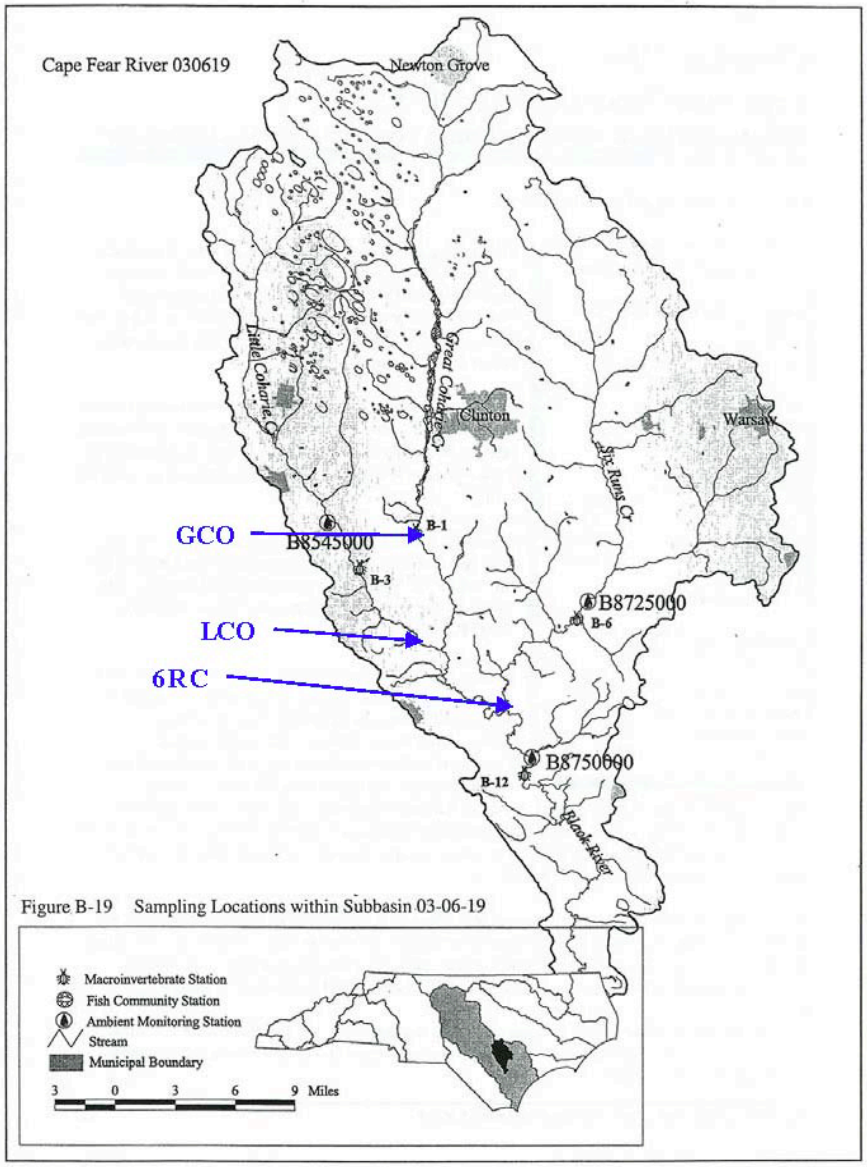


Figure B-19 Sampling Locations within Subbasin 03-06-19

This subbasin is located in the coastal plain within Sampson County. Land adjacent to the Black River is primarily undisturbed forest. There are numerous concentrated swine operations within this subbasin.
The CFR Basinwide Water Quality Plan lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Supporting	71.3 freshwater miles	Supporting	153.0 freshwater miles
Not Rated	99.7 freshwater miles	Not Rated	8.8 freshwater miles
No Data	338.4 freshwater miles	No Data	347.6 freshwater miles

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: February 1996 to present
Sampling relevance: Many concentrated animal operations (CAOs) within the watershed, reference areas for point and nonpoint source pollution


GCO - blackwater stream, drains riparian wetlands

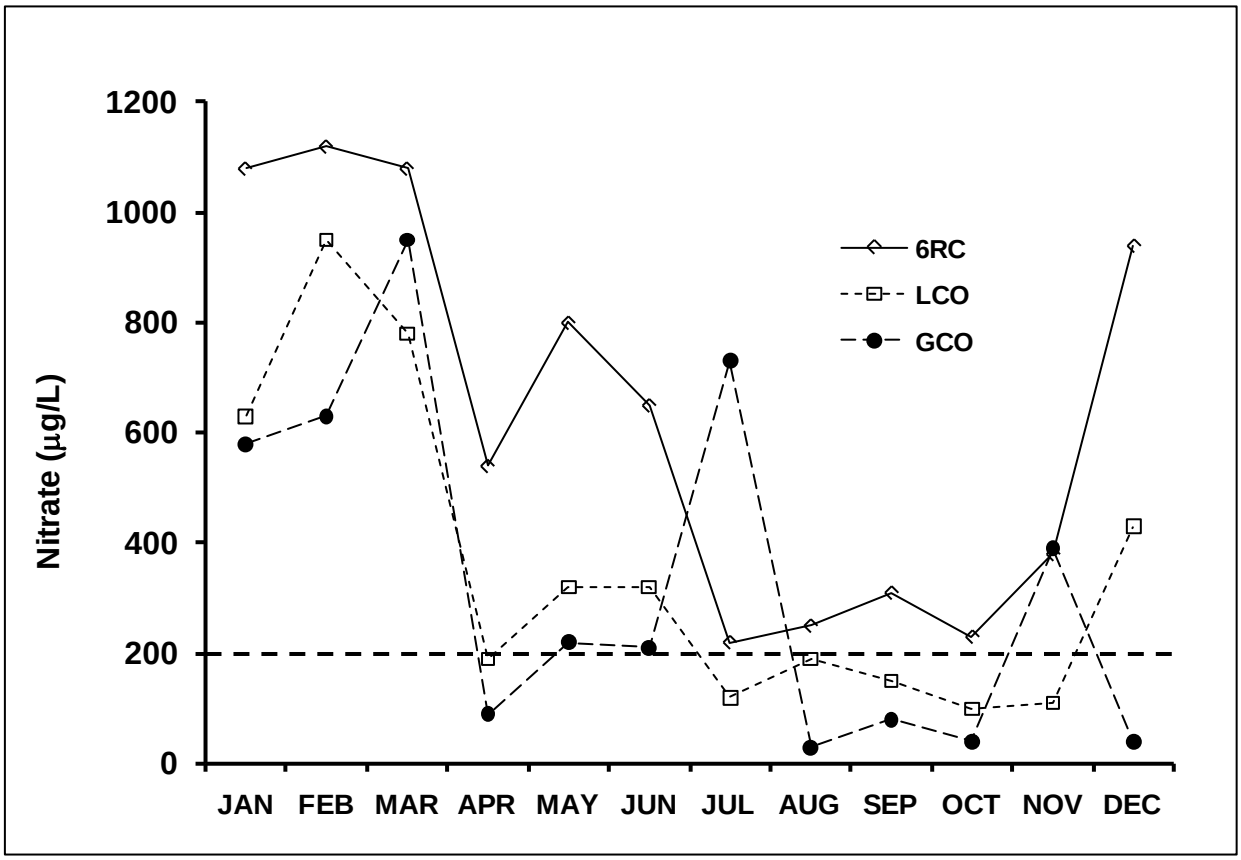
6RC, LCO and GCO all had a good rating for dissolved oxygen, chlorophyll *a* and field turbidity concentrations during 2009 (Table 3.6.1).

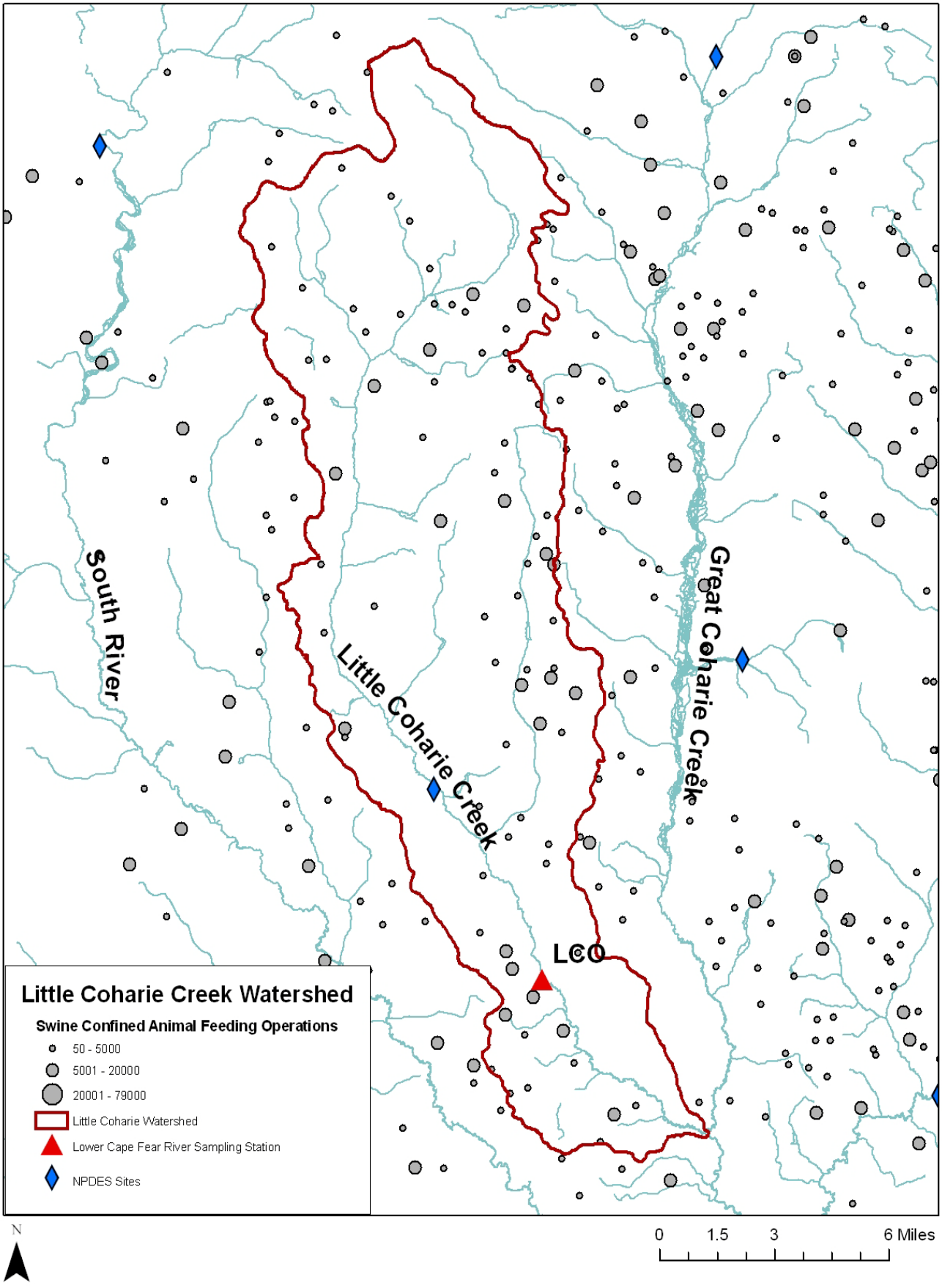
LCO and GCO had a good rating for fecal coliform during 2009. 6RC had a fair rating for fecal coliform bacteria with 25% of samples exceeding the NC State human contact standard of 200 CFU/100mL (Table 3.6.1).

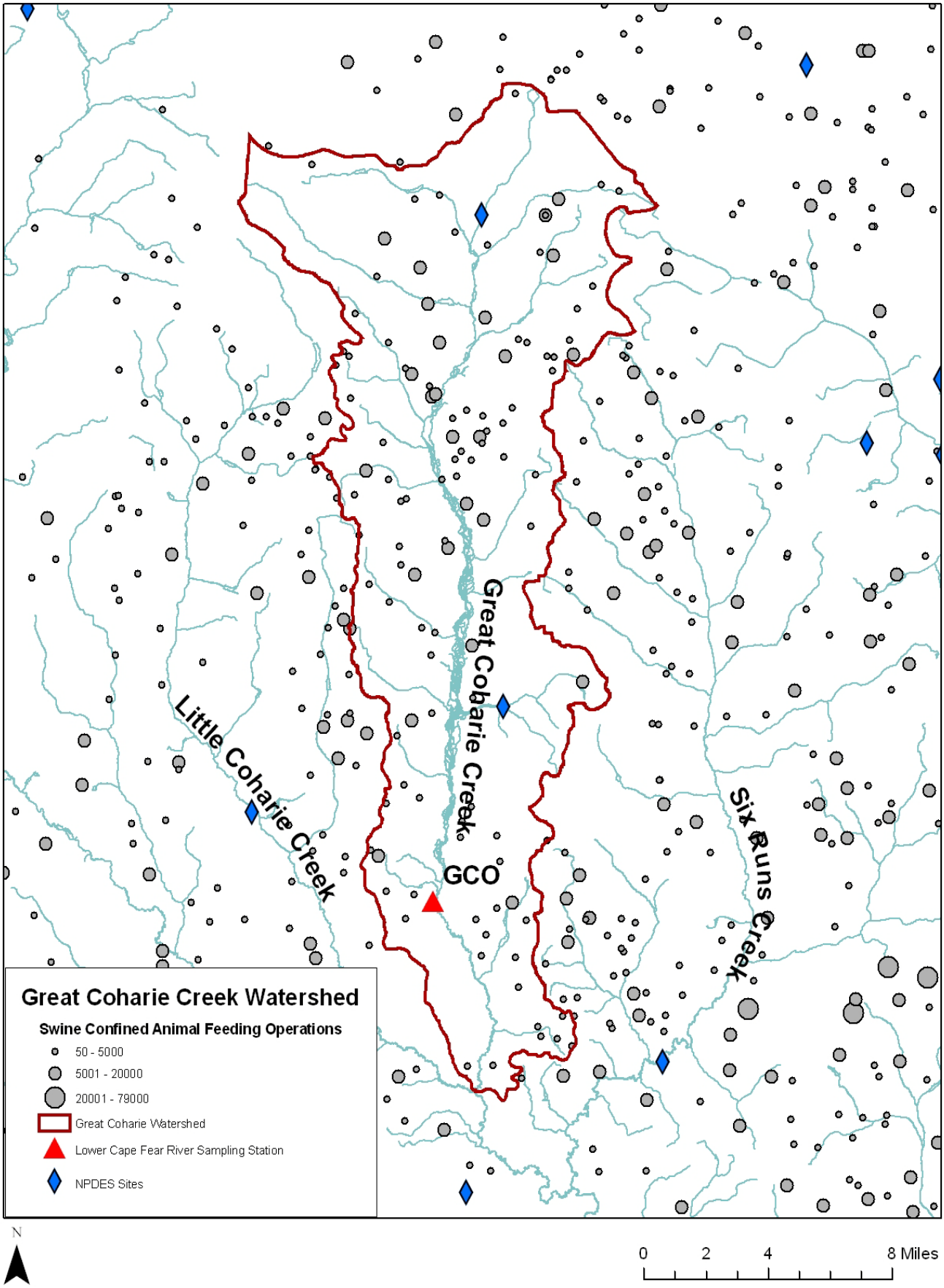
Nitrate levels were rated poor at 6RC, LCO and GCO exceeding 200 µg/L in 100%, 50%, and 58% of the samples, respectively (Table 3.6.1, Figure 3.6.1). All sites within this subbasin had a good rating for total phosphorus concentrations (Table 3.6.1).

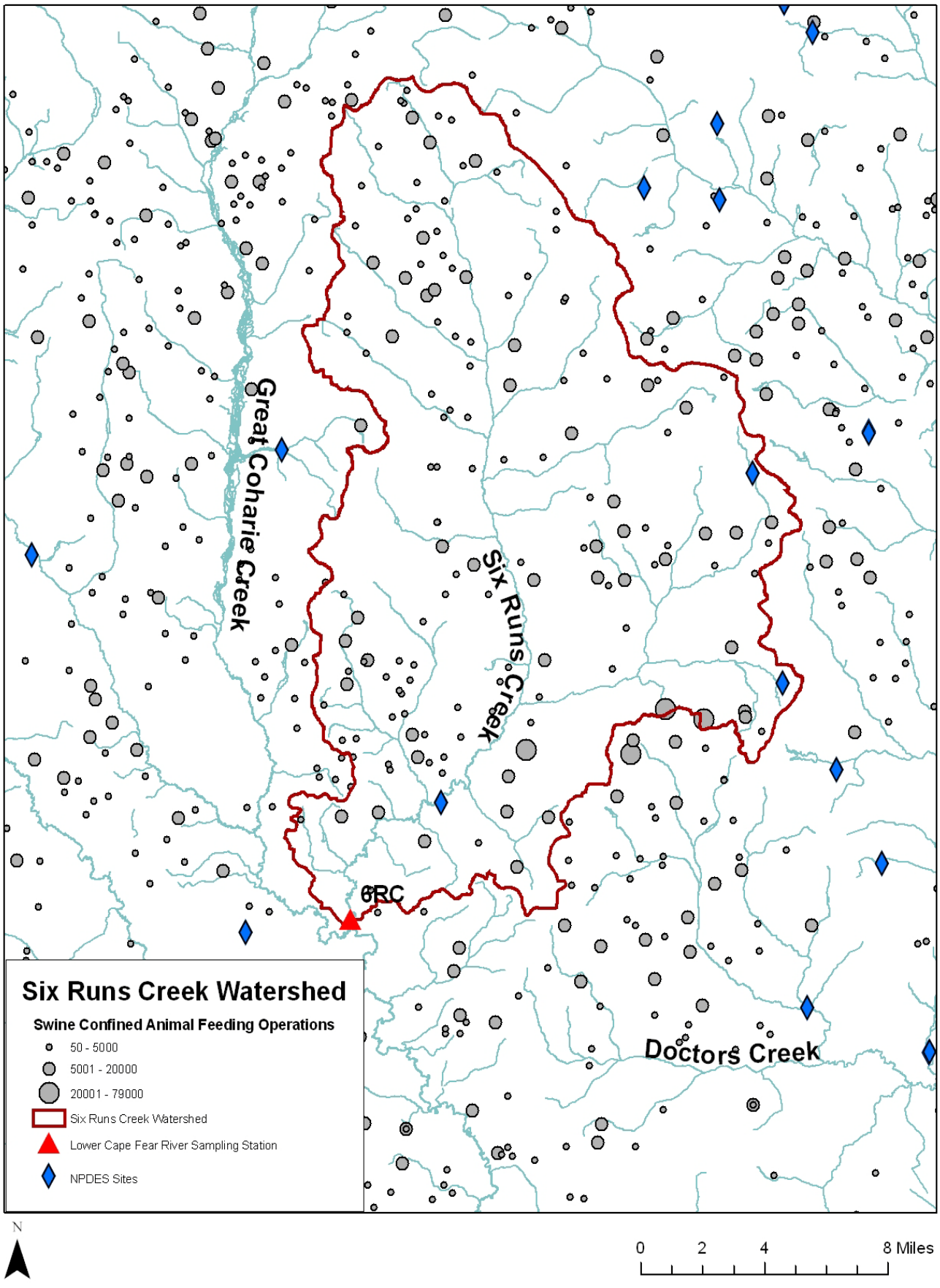
Table 3.6.1 UNCW AEL 2009 evaluation for subbasin 03-06-19						
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
6RC	G	G	F	G	P	G
LCO	G	G	G	G	P	G
GCO	G	G	G	G	P	G

Figure 3.6.1 Nitrate concentrations (µg/L) at 6RC, LCO, and GCO during 2009. The dashed line shows the UNCW-AEL standard of 200 µg/L.




South River
Little Coharie Creek
Great Coharie Creek
LCO
Little Coharie Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Little Coharie Watershed
Lower Cape Fear River Sampling Station
NPDES Sites
N
0
1.5
3
6 Miles


Great Coharie Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Great Coharie Watershed
Lower Cape Fear River Sampling Station
NPDES Sites
Little Coharie Creek
Great Coharie Creek
Six Runs Creek
GCO
N
0
2
4
8 Miles


Great Coharie Creek
Six Runs Creek
6RC
Doctors Creek
Six Runs Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Six Runs Creek Watershed
Lower Cape Fear River Sampling Station
NPDES Sites
N
0
2
4
8 Miles

3.7 Cape Fear River Subbasin 03-06-20

Location: Lower reach of Black River
Counties: Pender
Waterbodies: Black River, Colly Creek, Moores Creek
Municipalities: Town of White Lake, Currie, Atkinson
NPDES Dischargers: 2 at 0.82 million gallons per day
Concentrated Swine Operations: 18
LCFRP monitoring stations (DWQ #):
COL (B8981000), B210 (B9000000), BBT (none)

DWQ monitoring stations: none

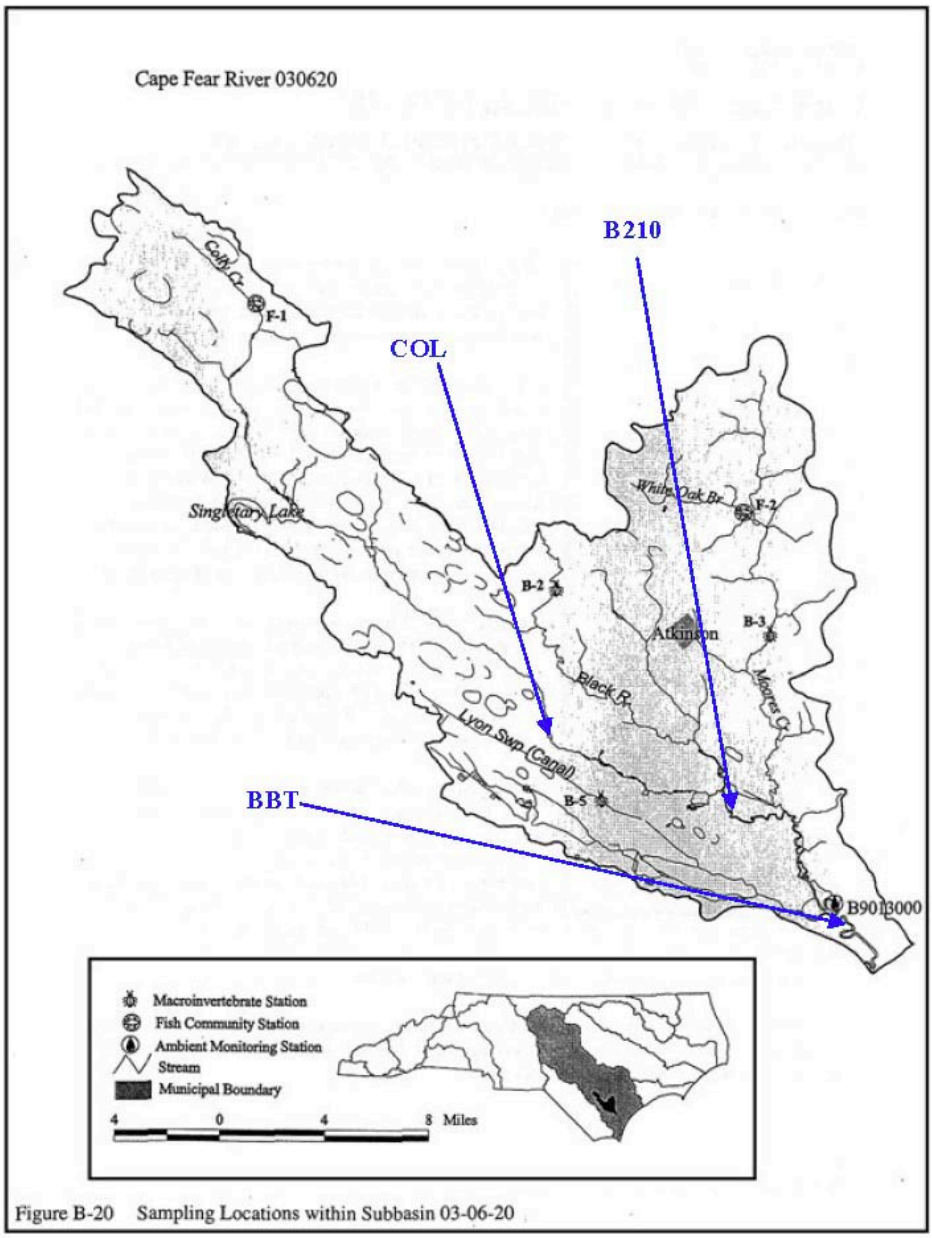


Figure B-20 Sampling Locations within Subbasin 03-06-20

This subbasin is located on the coastal plain in Pender County and the land is mostly forested with some agriculture. The streams in this watershed typically have acidic black waters. The Black River in this area has been classified as Outstanding Resource Waters (ORW) (NCDENR DWQ Cape Fear River Basinwide Water Quality Plan, October 2005).

The CFR Basinwide Water Quality Plan lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Supporting	13.0 freshwater miles	Supporting	34.9 freshwater miles
Not Rated	77.9 freshwater miles	No Data	199.8 freshwater miles
Not Rated	576.0 freshwater acres	No Data	576.0 freshwater miles
No Data	143.8 freshwater acres		

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: February 1996 to present
Sampling relevance: Colly Creek is a pristine swamp reference site, B210 and BBT are middle and lower Black River sites

COL – blackwater stream, drains swamp area, very low pH

B210- Black River at Hwy 210 bridge

All three sites had a good rating for dissolved oxygen when using the NC State swampwater standard of 4.0 mg/L (Table 3.7.1).

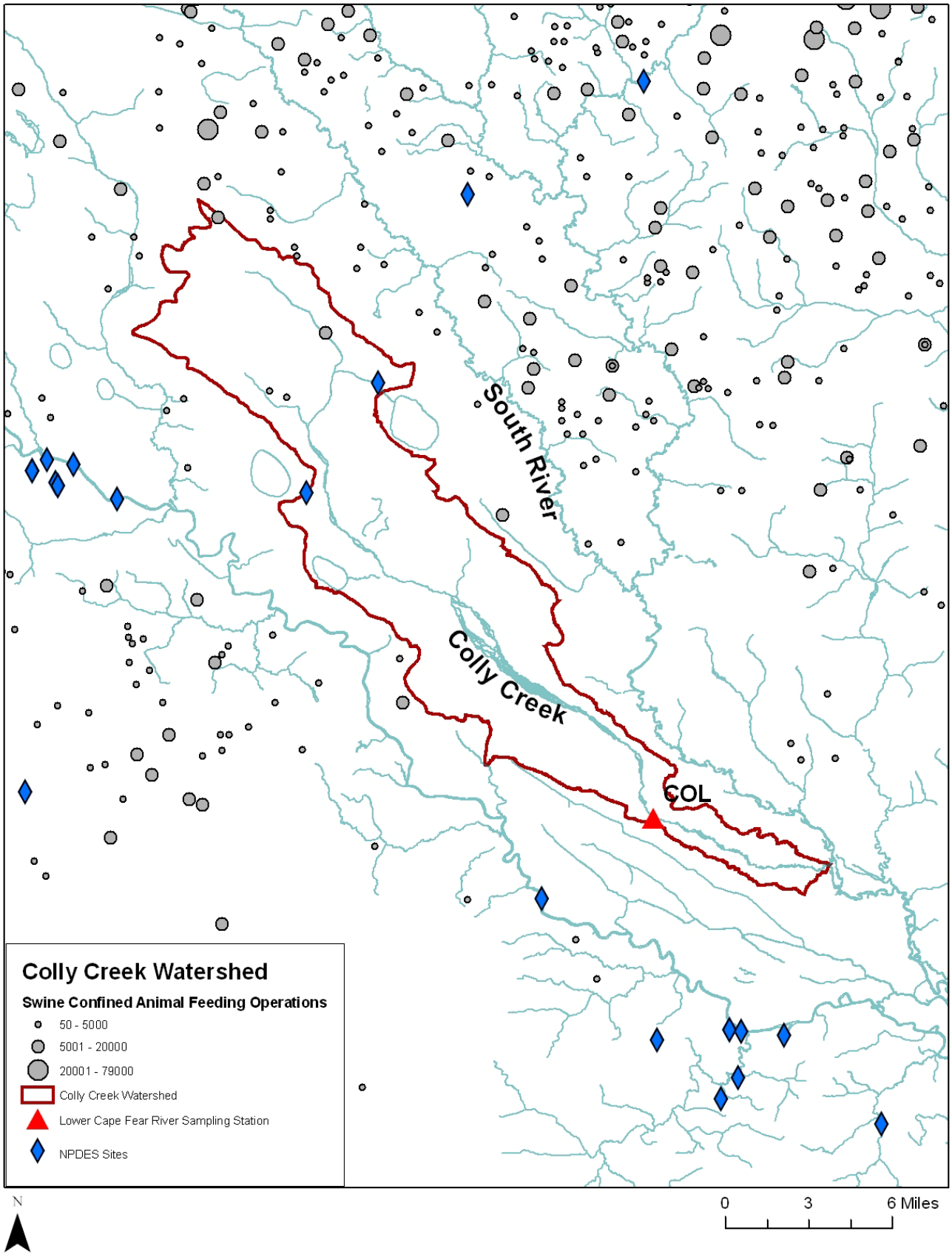
Chlorophyll *a* and field turbidity concentrations were low for each site within this subbasin and all sites had a good rating for these parameters (Table 3.7.1).

Fecal coliform bacteria concentrations were low with B210 and COL rated as good (Table 3.7.1). BBT samples were not analyzed for fecal coliform bacteria.

B210 and COL rated good for both nutrient species. BBT samples were not analyzed for nutrients.

Table 3.7.1 UNCW AEL 2009 evaluation for subbasin 03-06-20

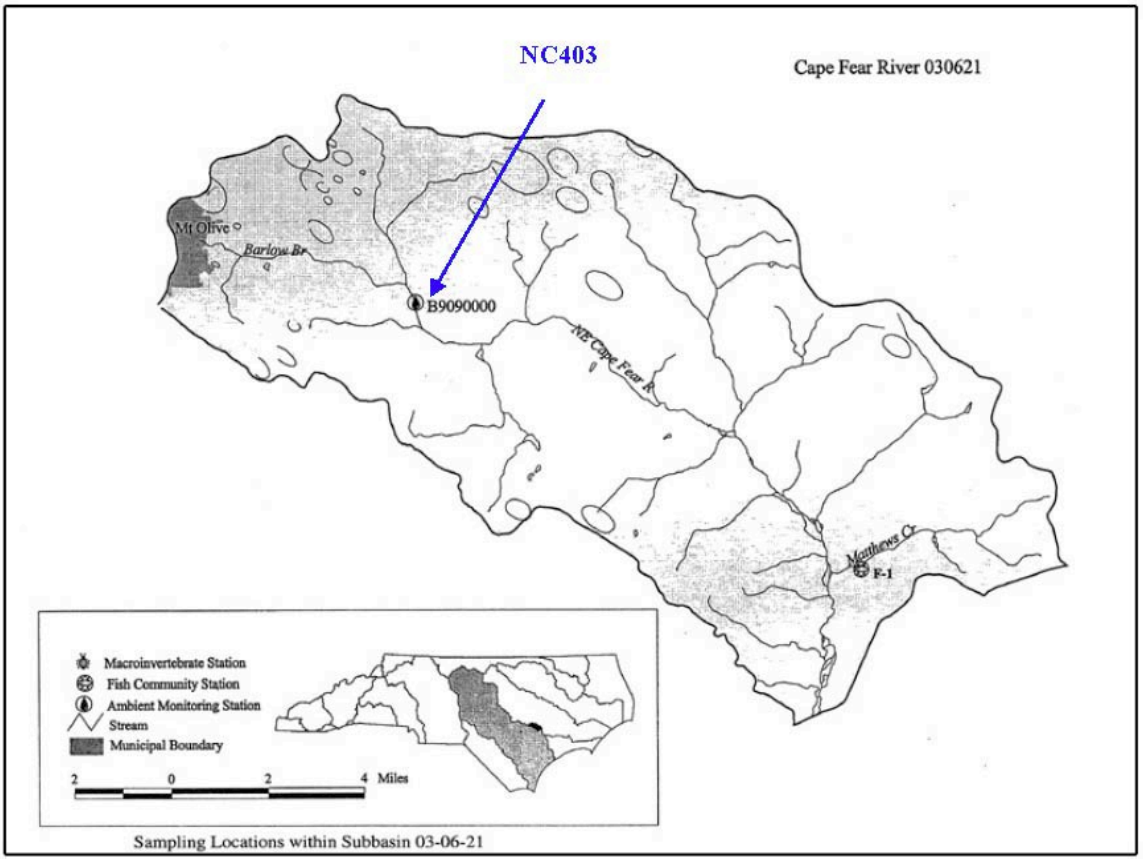
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
B210	G	G	G	G	G	G
COL	G	G	G	G	G	G
BBT	G	G		G		


South River
Colly Creek
COL
Colly Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Colly Creek Watershed
Lower Cape Fear River Sampling Station
NPDES Sites
N
0
3
6 Miles

3.8 Cape Fear River Subbasin 03-06-21

Location: Headwaters of NE Cape Fear River below Mount Olive
Counties: Duplin, Wayne
Waterbodies: Northeast Cape Fear River
Municipalities: Mount Olive
NPDES Dischargers: 6 @ 1.4 million gallons per day
Concentrated Swine Operations: 75

LCFRP monitoring stations (DWQ#): NC403 (B9090000) **DWQ monitoring stations**: NC403



Sampling Locations within Subbasin 03-06-21

This subbasin includes the headwaters of the Northeast Cape Fear River and small tributaries. This section of the NE Cape Fear River is very slow moving and somewhat congested with macrophytic growth. Most of the watershed is forested and there is significant agriculture in the basin.

The CFR Basinwide Water Quality Plan lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Supporting	21.7 freshwater miles	Supporting	57.3 freshwater miles
Not Rated	38.9 freshwater miles	No Data	88.1 freshwater miles
No Data	84.7 freshwater miles		

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: June 1997 – present
Sampling relevance: Below Mount Olive Pickle Plant

NC403 - slow moving headwaters of NE Cape Fear River

NC403 had a poor rating for dissolved oxygen concentrations, not meeting the NC State Standard for swampwater of 4.0 mg/L in 50% of the samples (Table 3.8.1, Figure 3.8.1)

NC403 had a good rating for chlorophyll *a* yet had very high aquatic macrophyte biomass present, often times completely covering and blocking the waterway (Table 3.8.1). As we have noticed at several of our stations over the years, chlorophyll *a*, a measurement of phytoplankton biomass, often used as an indicator of eutrophic conditions, is not always adequate to determine problematic conditions with regard to aquatic flora.

NC403 had a fair rating for fecal coliform bacteria with samples exceeding the NC State standard for human contact (200 cfu/100 mL) 17% of the time.

Field turbidity was rated as good at NC 403 (Table 3.8.1).

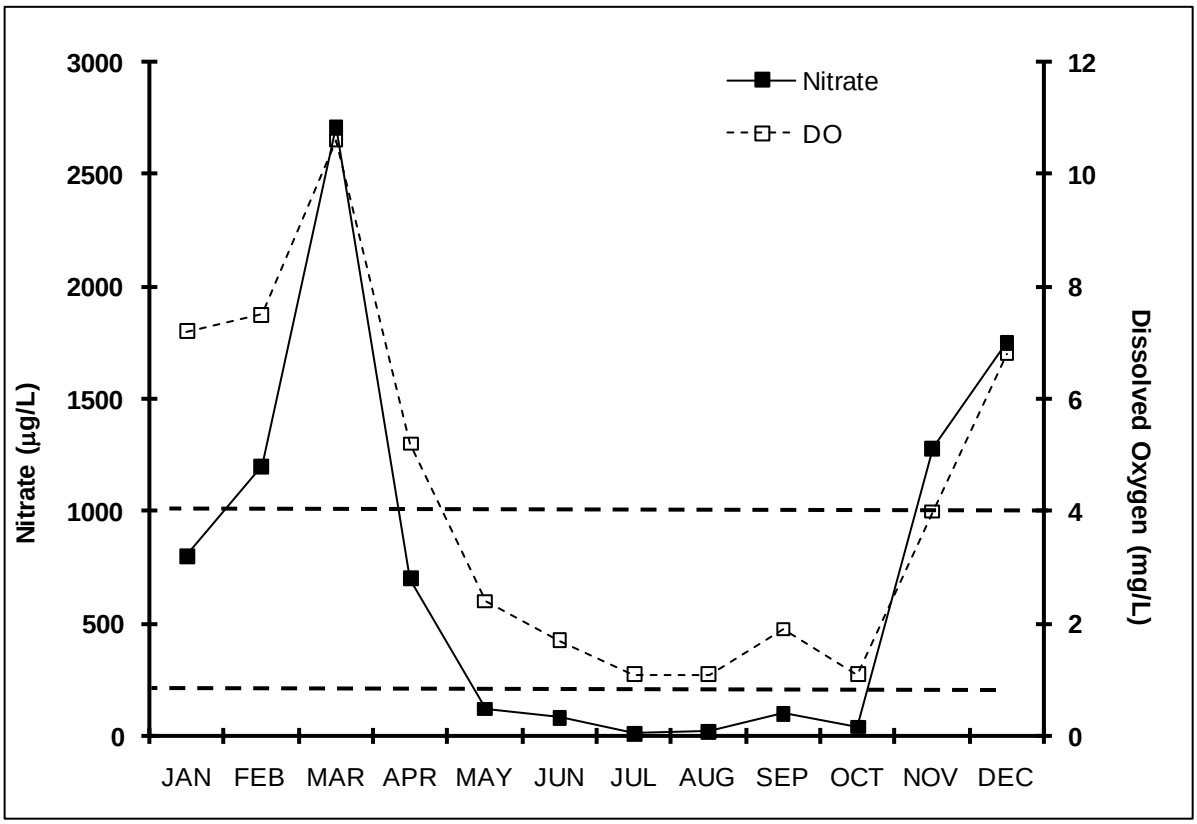
High nitrate levels at NC403 led to a poor rating, with nitrate concentrations >200 µg/L for 50% of the samples (Table 3.8.1, Figure 3.8.1). UNCW AEL researchers are concerned about the elevated nitrate levels that are periodically found at this site since these levels

increase the likelihood of algal blooms and excessive aquatic macrophyte growth. Total phosphorus had a fair rating for 2009, exceeding the AEL standard 17% of the time.

Table 3.8.1 UNCW AEL 2009 evaluation for subbasin 03-06-21

Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
NC403	P	G	F	G	P	F

Figure 3.8.1 Dissolved oxygen (mg/L) and nitrate (µg/L) concentrations at NC403 during 2009. The dashed lines show the NC State DO standard of 4.0 mg/L for swampwater and the UNCW AEL standard for Nitrate of 200 µg/L.



3.9 Cape Fear River Subbasin 03-06-22

Location: NE Cape Fear River and tributaries in the vicinity of Kenansville
Counties: Duplin
Waterbodies: Northeast Cape Fear River, Rockfish Creek
Municipalities: Beulaville, Kenansville, Rose Hill and Wallace
NPDES Dischargers: 13 @ 9.9 million gallons per day
Concentrated Swine Operations: 449

LCFRP monitoring stations (DWQ #):

PB (B9130000), GS (B9191000), SAR (B9191500), LRC (9460000) ROC (B9430000)

DWQ monitoring stations: none

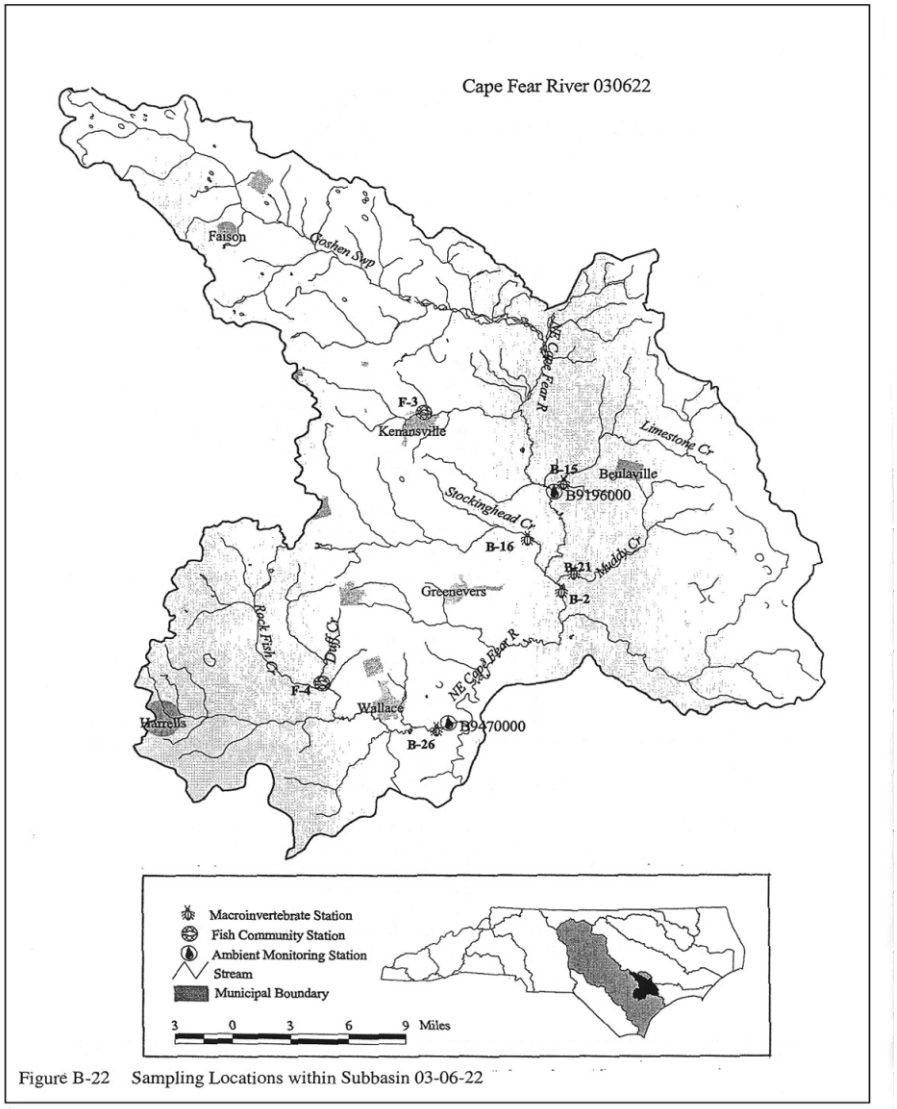


Figure B-22 Sampling Locations within Subbasin 03-06-22

Land coverage in this watershed is mostly forested with significant agriculture including row crops and a dense concentration of animal operations (poultry and swine).

The CFR Basinwide Water Quality Plans lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Supporting	51.1 freshwater miles	Supporting	73.2 freshwater miles
Not Rated	72.1 freshwater miles	Not Rated	3.0 freshwater miles
Impaired	50.1 freshwater miles	No Data	505.9 freshwater miles
No Data	408.8 freshwater miles		

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: February 1996 to present
Sampling relevance: Below point and non-point source discharges

PB – slow moving swamp-like stream

ROC - Rockfish Creek below Wallace

All sites in this subbasin were rated using the dissolved oxygen NC State swampwater standard of 4.0 mg/L. SAR, PB, LRC and ROC all had a good rating (Table 3.9.1). GS had a poor rating with DO values dropping below the standard 50% of the time.

For chlorophyll *a* concentrations all sites had a good rating (Table 3.9.1).

For fecal coliform bacteria concentrations GS had a good rating (Table 3.9.1). SAR, PB LRC and ROC each had a poor rating with 42%, 75% 50% and 50% of samples above the standard, respectively. Fecal coliform bacteria concentrations are shown graphically in Figure 3.9.1 and 3.9.2.

All sites had a good rating for field turbidity concentrations (Table 3.9.1). Mean levels were $\leq$ 15 NTU for all sites within this subbasin for 2009.

For nitrate GS had a fair rating with levels exceeding the UNCW AEL standard (200 µg/L) 17% of the time (Table 3.9.1). SAR, PB, LRC and ROC all had a poor rating with levels exceeding the UNCW AEL standard 50%, 67%, 42% and 100% of the time, respectively. Nitrate levels for SAR, PB, LRC and ROC are shown graphically in Figure 3.9.3 and 3.9.4.

For total phosphorus all stations had a good rating except PB. PB was rated fair, exceeding the UNCW AEL standard of 500 mg/L in 25% of the samples (Table 3.9.1).

Table 3.9.1 UNCW AEL 2009 evaluation for subbasin 03-06-22

Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
SAR	G	G	P	G	P	G
GS	P	G	G	G	F	G
PB	G	G	P	G	P	F
LRC	G	G	P	G	P	G
ROC	G	G	P	G	P	G

Figure 3.9.1 Fecal coliform bacteria (cfu/100mL) at SAR and PB, both rated poor during 2009. The dashed line is the NC State Standard for human contact of 200 cfu/100mL).

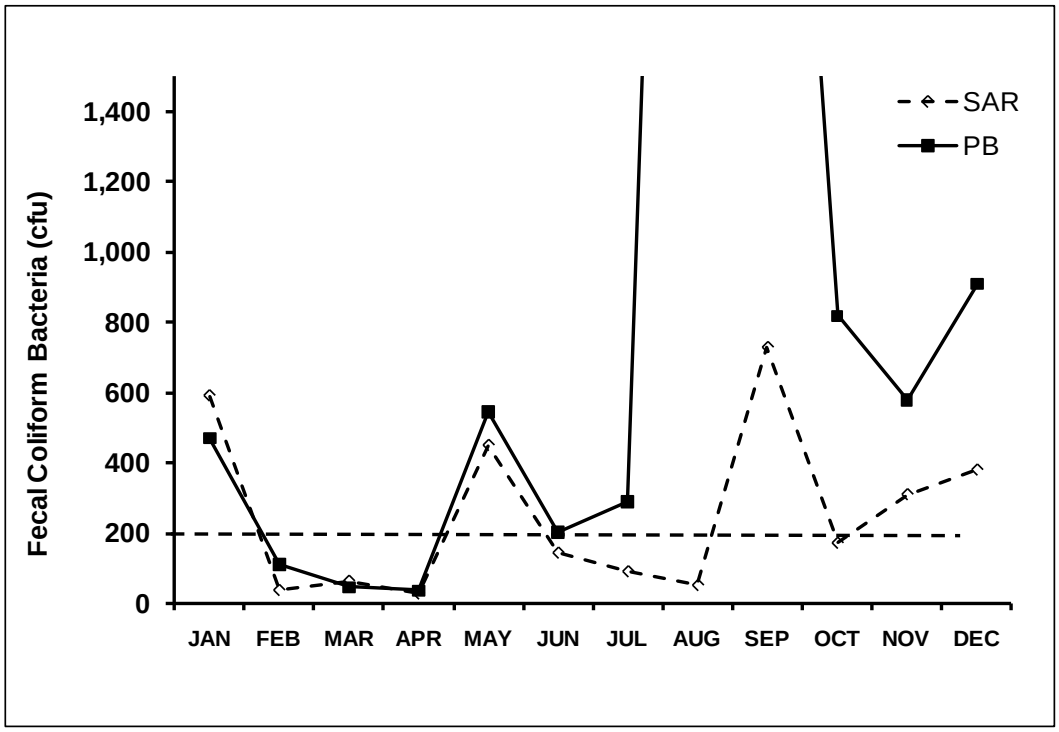


Figure 3.9.2 Fecal coliform bacteria (cfu/100mL) at LRC and ROC, both rated poor during 2009. The dashed line is the NC State Standard for human contact of 200 cfu/100mL).

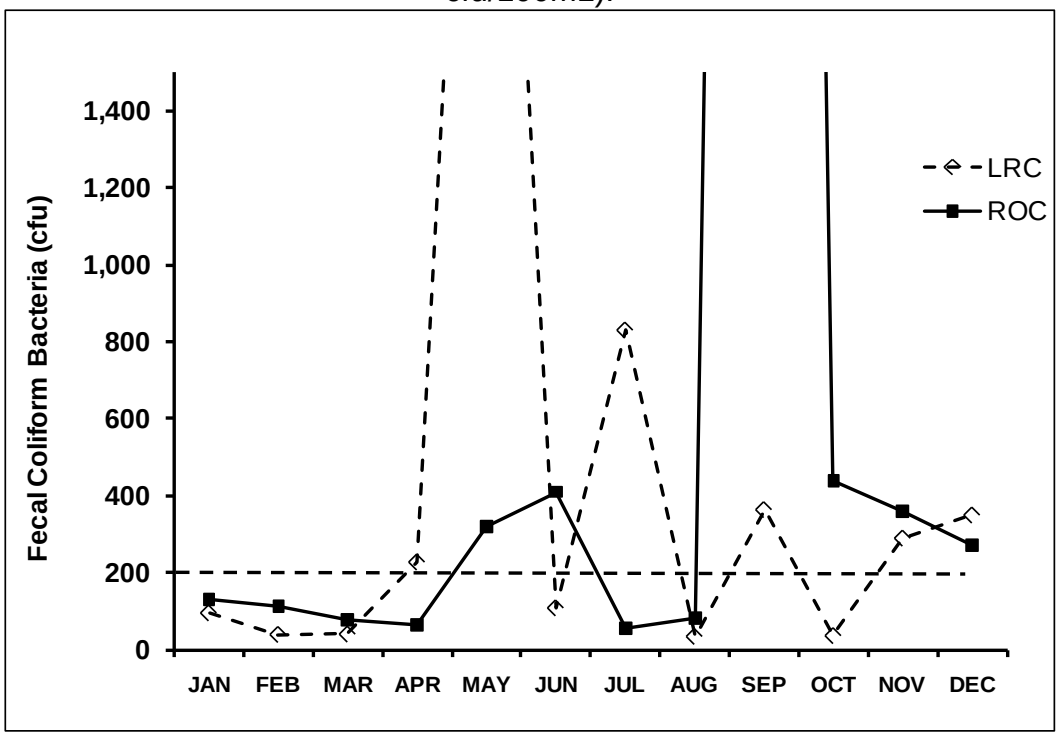


Figure 3.9.3 Nitrate-N concentrations (μg/L) at SAR and PB, both rated poor during 2009. The dashed line represents the UNCW AEL standard of 200 μg/L.

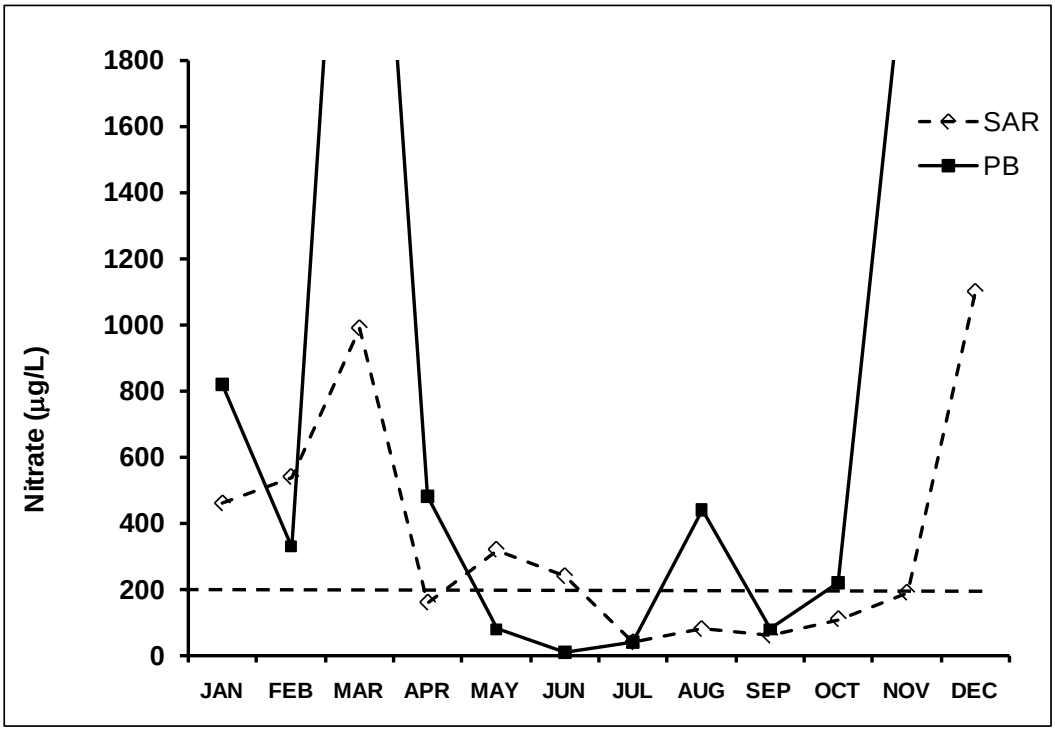
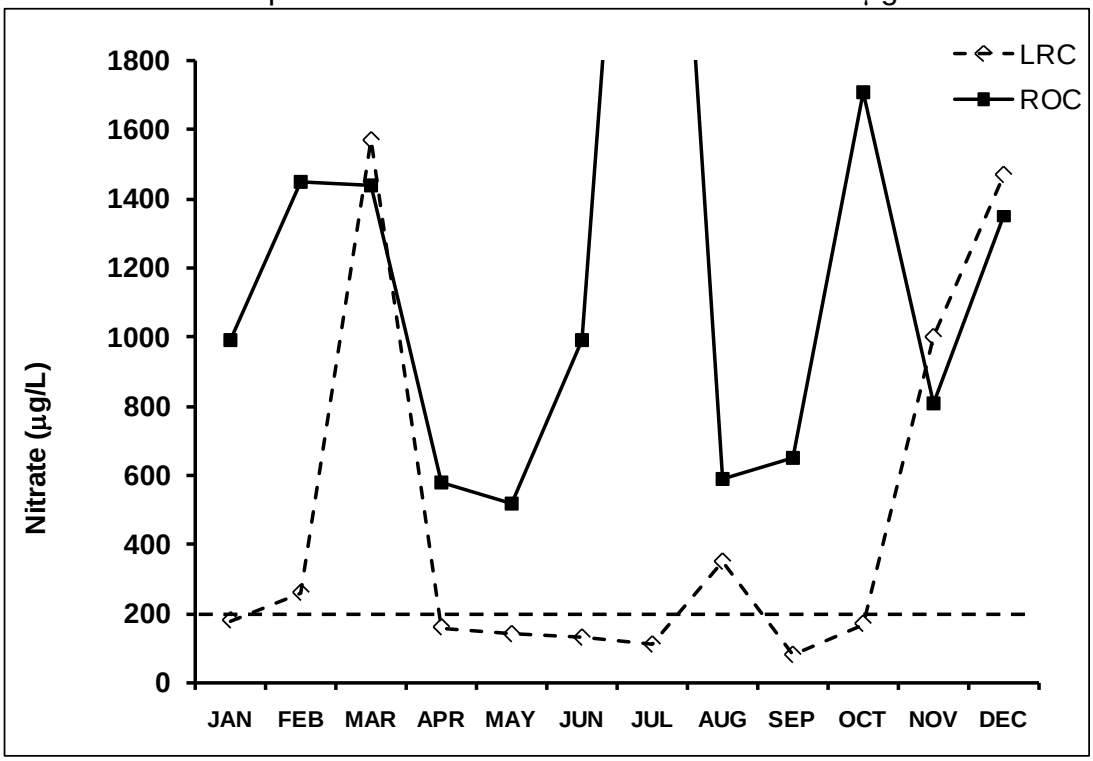
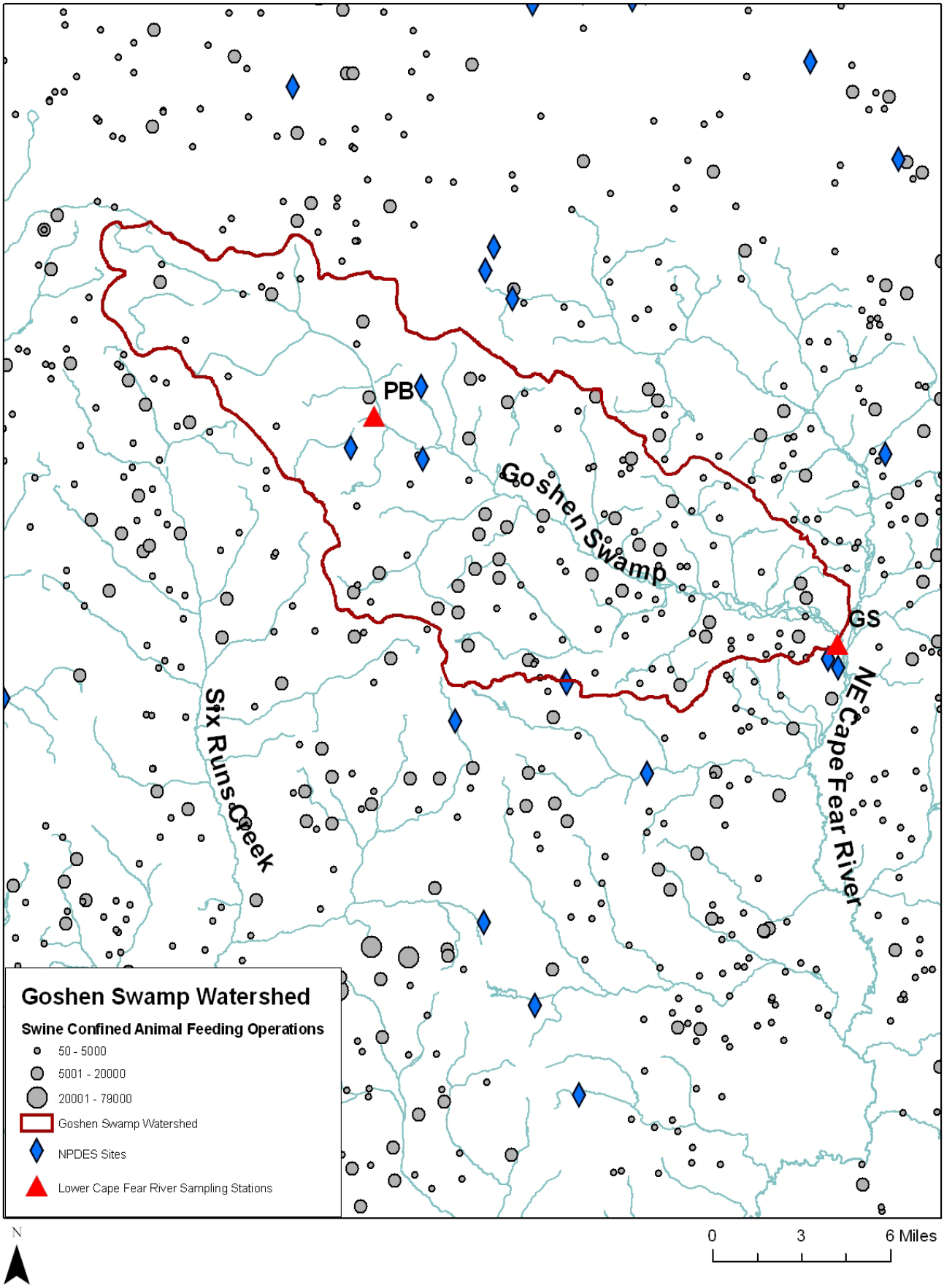
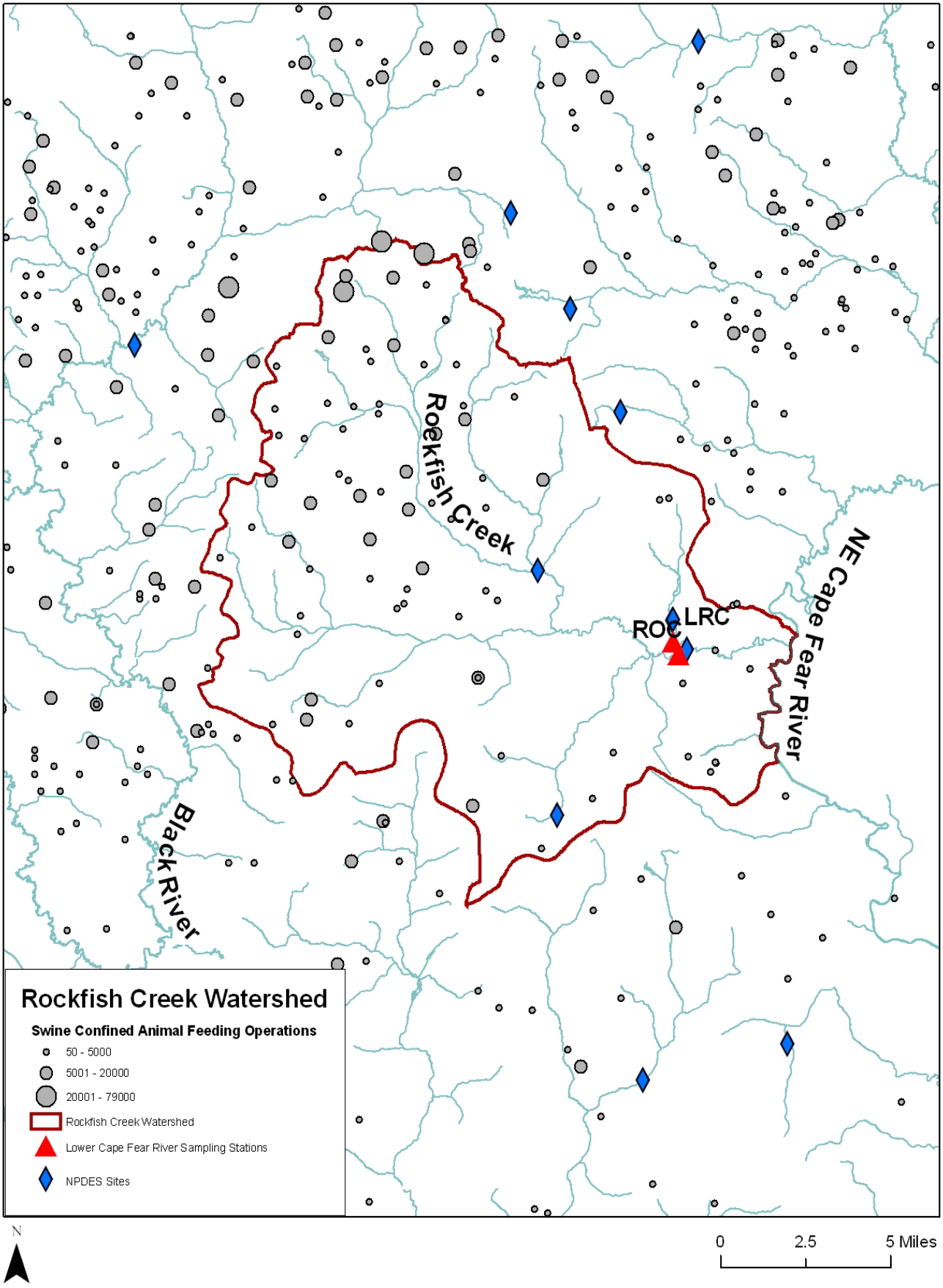


Figure 3.9.4 Nitrate-N concentrations (µg/L) at LRC and ROC, both rated poor during 2009. The dashed line represents the UNCW AEL standard of 200 µg/L.




PB
Goshen Swamp
GS
Six Runs Creek
NE Cape Fear River
Goshen Swamp Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Goshen Swamp Watershed
NPDES Sites
Lower Cape Fear River Sampling Stations
N
0
3
6 Miles


Rockfish Creek
NE Cape Fear River
Black River
ROC
LRC
Rockfish Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Rockfish Creek Watershed
Lower Cape Fear River Sampling Stations
NPDES Sites
N
0
2.5
5 Miles

3.10 Cape Fear River Subbasin 03-06-23

Location: Area near Burgaw and Angola swamp
Counties: Pender
Waterbodies: Northeast Cape Fear River,Burgaw Creek
Municipalities: Burgaw
NPDES Dischargers: 7 @ 3.8 million gallons per day
Concentrated Swine Operations: 52

LCFRP monitoring stations (DWQ #):
ANC (69), BCRR (82), BC117 (83), NCF117 (84), NCF6 (85)

DWQ monitoring stations: NCF117

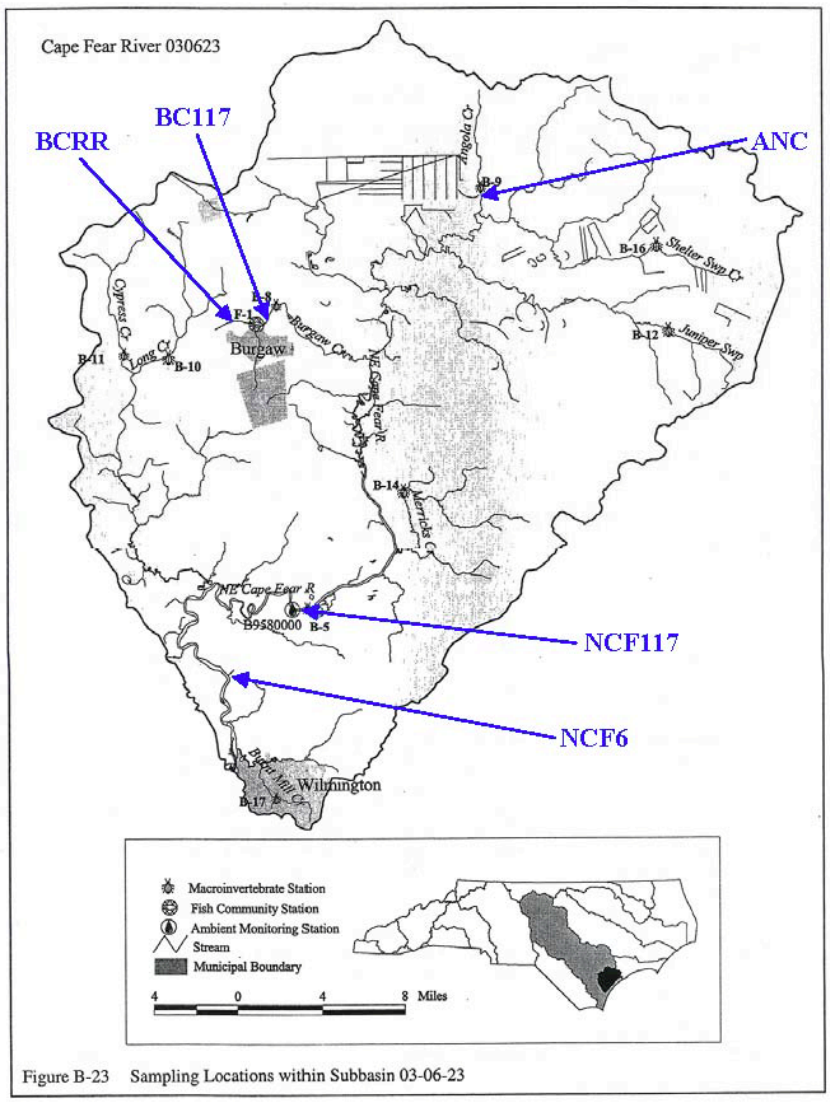


Figure B-23 Sampling Locations within Subbasin 03-06-23

This subbasin is located in the outer coastal plain where many streams are slow flowing blackwater streams that often dry up during the summer months. Most of the watershed

is forested with some agriculture and increasing human development.

The CFR Basinwide Water Quality Plan lists the following ratings for this subbasin:

Aquatic Life		Recreation	
Supporting	73.8 freshwater miles	Supporting	39.5 freshwater miles
Not Rated	45.1 freshwater miles	Supporting	1.0 saltwater acre
Impaired	23.4 freshwater miles	Not Rated	11.6 freshwater miles
No Data	233.2 freshwater miles	Not Data	324.5 freshwater miles
Not Rated	1.0 saltwater acre		

UNCW Aquatic Ecology Laboratory Evaluation

Data collection: NCF117 & NCF6 since June 1995, others from February 1996
Sampling relevance: point and non-point source dischargers

ANC - Angola Creek

BC117 - Burgaw Canal at US 117

NCF117 - Northeast Cape Fear River at US117

For dissolved oxygen BC117, NCF117, NCF6 and SC-CH had a good rating when using the 4.0 mg/L standard (Table 3.10.1). ANC and BCRR had a fair rating with sub-standard samples 17% and 25% of the time, respectively.

For chlorophyll *a* all sites rated good during 2009 (Table 3.10.1). Chlorophyll *a* was not analyzed at SC-CH.

For fecal coliform bacteria ANC, NCF117, NCF6 and SC-CH had a good rating (Table 3.10.1). BC117 and BCRR each had a poor rating exceeding the human contact standard 58% and 83% of the time, respectively. Fecal coliform bacteria concentrations for BC117 and BCRR are shown in Figure 3.10.1.

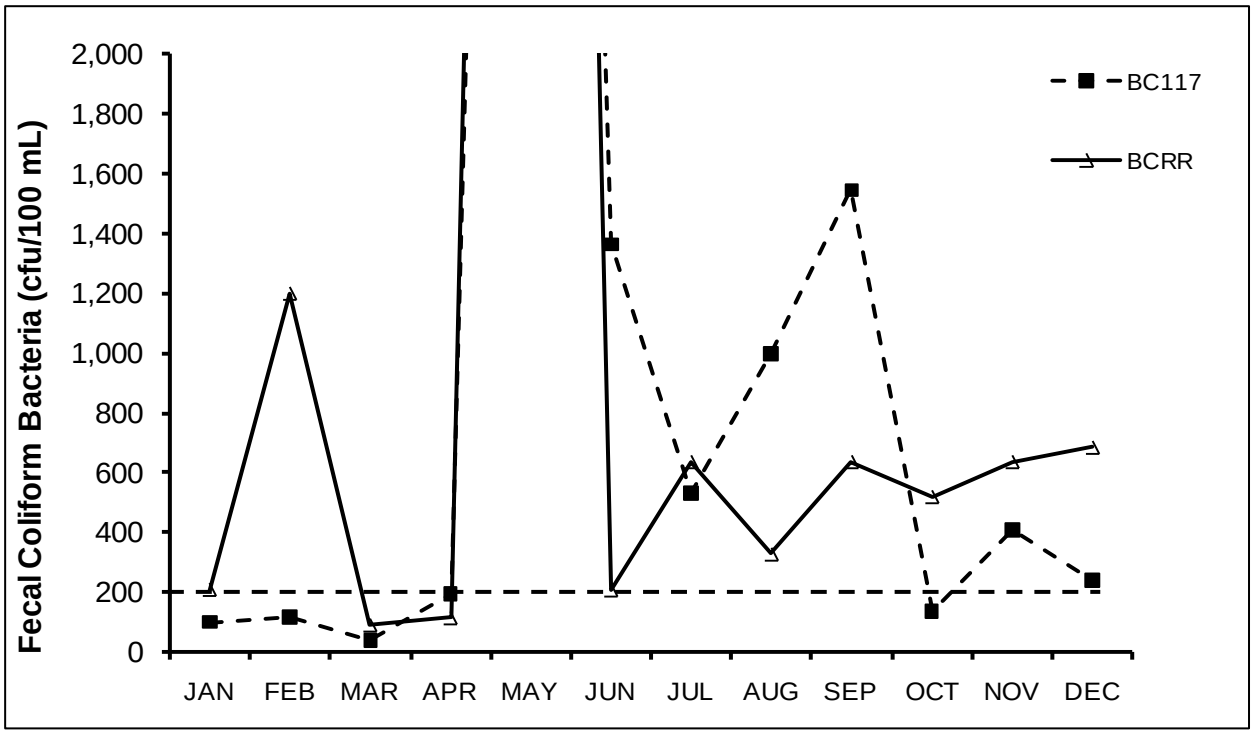
Four of the five stations were rated good for field turbidity. NCF6 was rated fair with values exceeding the NC State Standard for tidal waters of 25 NTU 25% of the time (Table 3.10.1).

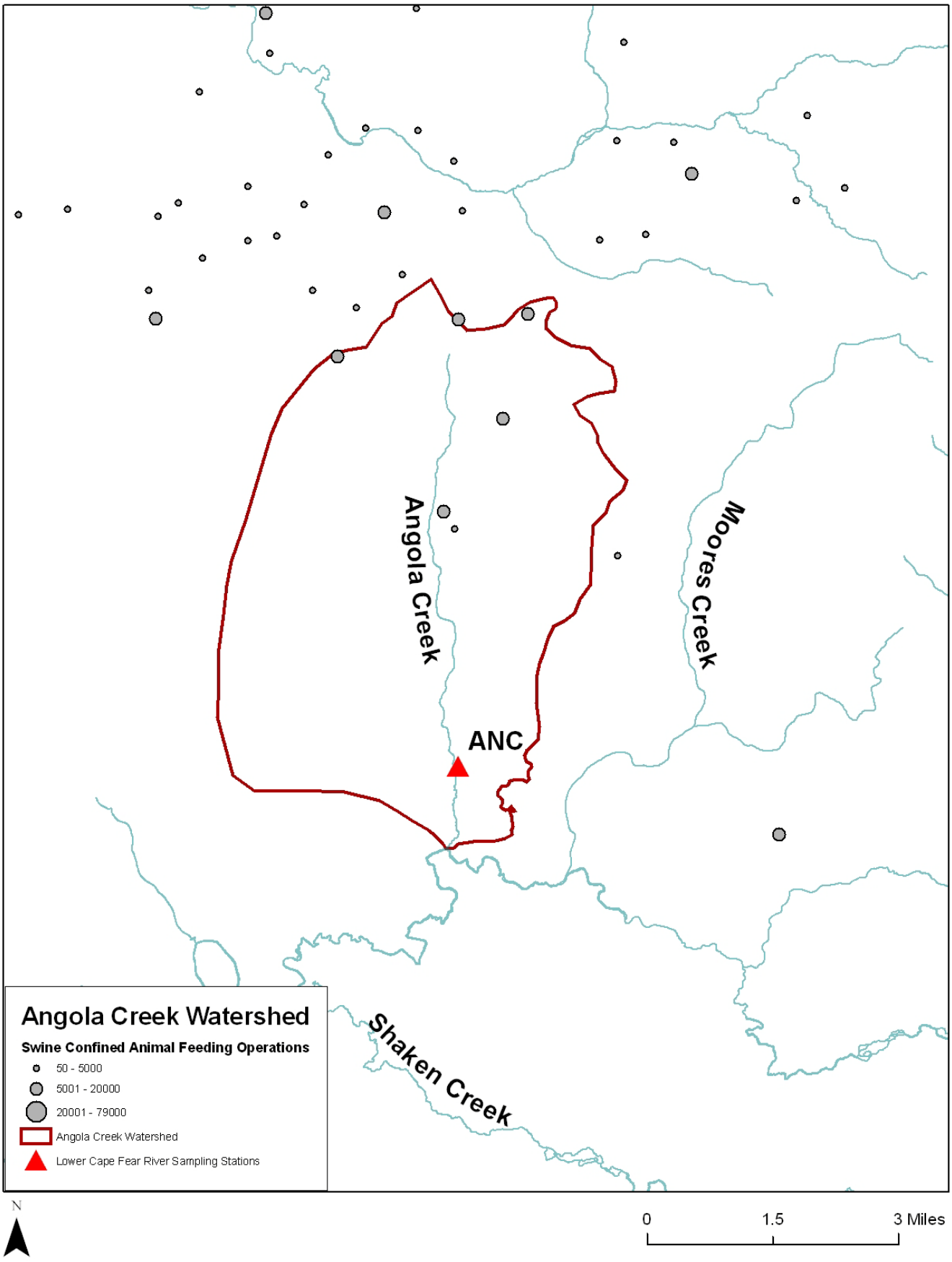
Nutrient loading of nitrate and total phosphorus was problematic at BC117 which had a poor rating for both (Table 3.10.1). Nitrate levels exceeded the UNCW AEL standard 100% of the time and total phosphorus levels exceeded the UNCW AEL standard 75% of the time. BC117 had the highest nitrate and TP levels seen in the LCFRP system. These levels were far above the concentrations known to lead to algal bloom formation, bacterial increases and increased biochemical oxygen demand (BOD) in blackwater streams (Mallin et al. 2001, Mallin et al. 2002). NCF6 was rated fair for nitrate exceeding the UNCW AEL standard 25% of the time. ANC and BCRR were both rated poor for nitrate as well, exceeding the UNCW AEL standard 33% of the time. Nutrients were not analyzed at SC-CH.

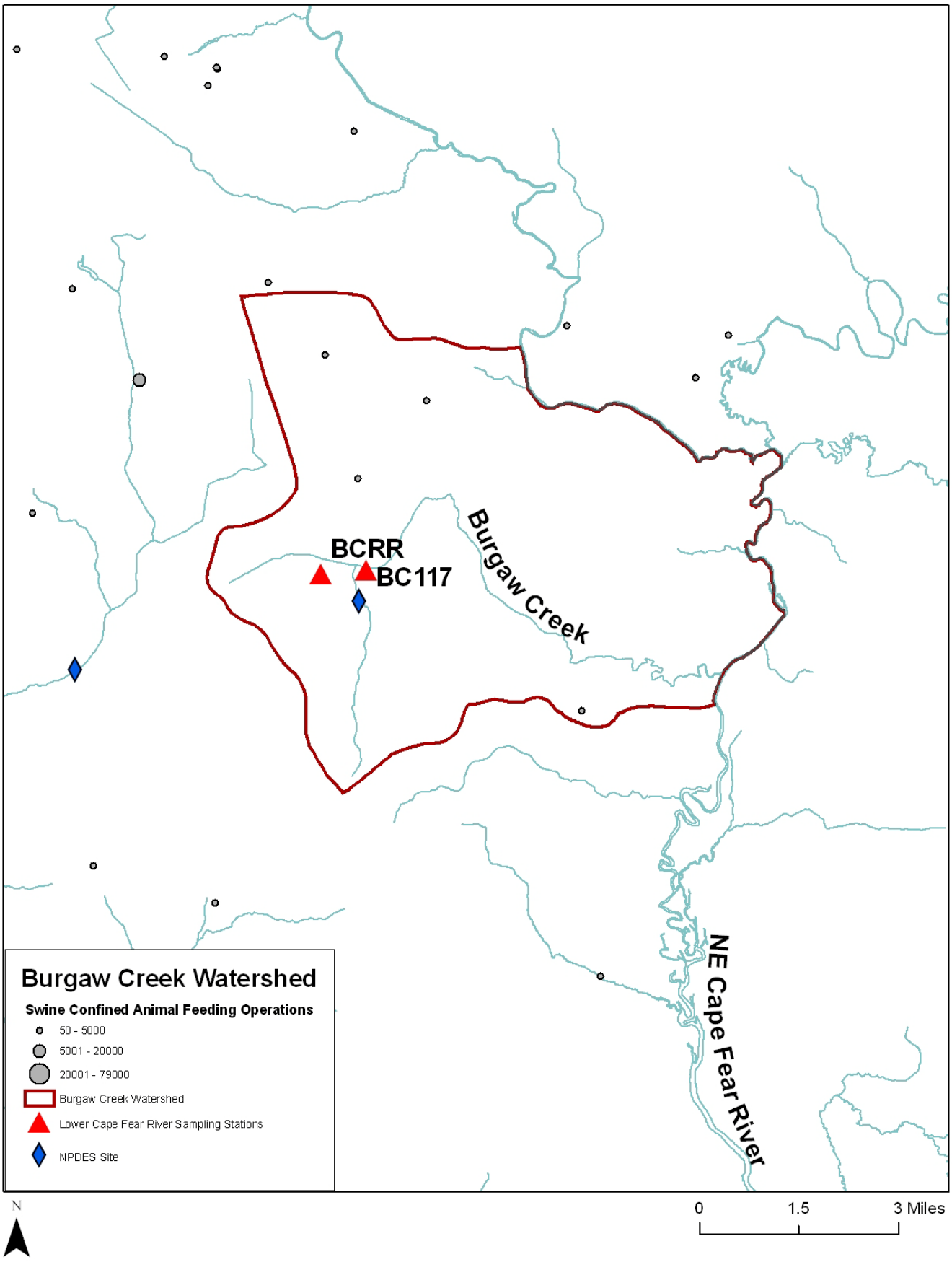
Table 3.10.1 UNCW AEL 2009 evaluation for subbasin 03-06-23

Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
ANC	F	G	G	G	P	G
BC117	G	G	P	G	P	P
BCRR	F	G	P	G	P	G
NCF117	G	G	G	G	G	G
NCF6	G	G	G	F	F	G
SC-CH	P		G	G		

Figure 3.10.1 Fecal coliform bacteria concentrations (cfu/100mL) at BC117 and BCRR during 2009. The dashed line shows the NC State Standard for human contact, 200 cfu/100 mL.




Angola Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Angola Creek Watershed
Lower Cape Fear River Sampling Stations
Angola Creek
Moores Creek
Shaken Creek
ANC
N
0
1.5
3 Miles


Burgaw Creek Watershed
Swine Confined Animal Feeding Operations
50 - 5000
5001 - 20000
20001 - 79000
Burgaw Creek Watershed
Lower Cape Fear River Sampling Stations
NPDES Site
BCRR
BC117
Burgaw Creek
NE Cape Fear River
N
0
1.5
3 Miles

3.11 References Cited

Mallin, M.A., L.B. Cahoon, D.C. Parsons and S.H. Ensign. 2001. Effect of nitrogen and phosphorus loading on plankton in Coastal Plain blackwater streams. *Journal of Freshwater Ecology* 16:455-466.

Mallin, M.A., L.B. Cahoon, M.R. McIver and S.H. Ensign. 2002. Seeking science-based nutrient standards for coastal blackwater stream systems. Report No. 341. Water Resources Research Institute of the University of North Carolina, Raleigh, N.C.

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.

NCDENR-DWQ (North Carolina Department of Environment and Natural Resources-Division of Water Quality), Cape Fear River Basinwide Water Quality Plan. July 2000, Raleigh, N.C.

NCDENR-DWQ (North Carolina Department of Environment and Natural Resources-Division of Water Quality), Cape Fear River Basinwide Water Quality Plan. October 2005, Raleigh, N.C.