Environmental Assessment of the Lower Cape Fear River System, 2010

By

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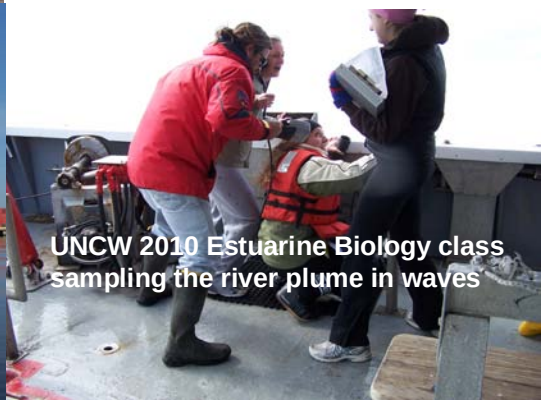
UNCW 2011 River Ecology class


Alligator on the Black River 2011


The Port of Wilmington


UNCW 2010 Estuarine Biology class sampling the river plume in waves

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 2010. 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 2008-2010) 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 2010 were higher than the average for 1995-2009. Dissolved oxygen levels were lowest during the summer and early fall, 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 2010 DO levels occurred at the lower river and upper estuary stations DP, IC, NAV, HB, BRR and M61 (7.2-7.6 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 2010 Stations NCF117 and B210,

representing those rivers, had average DO concentrations of 6.7 and 7.0 mg/L, respectively. Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2010. Station BCRR (upper Burgaw Creek) had DO levels below 4.0 mg/L 67% of the occasions sampled, with SR (South River) and GS (Goshen Swamp) 50%, LVC2 (Livingston Creek) 45%, ANC (Angola Creek) 42% and NC403 (Northeast Cape Fear River headwaters) 33%. Considering all sites sampled in 2010, we rated 22% as poor for dissolved oxygen, 22% as fair, and 56% as good, a worsening from 2009

Annual mean turbidity levels for 2010 were lower than the long-term average in most stations, with the exception of the mid-estuary sites M42-M35. Highest mean turbidities were at the river sites NC11 (21 NTU) and AC and DP (22 NTU) followed by the upper estuary sites NAV, HB, BRR, M54 and M42 (17 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), LRC (Little Rockfish Creek), 6RC (Six Runs Creek), NC403, and PB (Panther Branch). Average chlorophyll *a* concentrations were larger than usual, particularly from June through August 2010; during this same period river flow as measured by USGS at Lock and Dam #1 was lower for 2010 compared with the 1995-2009 long-term average (1,769 CFS compared with 3,702 CFS). Low discharge allows for settling of suspended solids and more light penetration into the water column, where the relatively high nutrient levels and slow moving waters support algal bloom formation. In the estuary a substantial bloom (76 µg/L) occurred at M42, and stream algal blooms exceeding the State standard of 40 µg/L in 2010 occurred at ANC, GS, PB and SR. The most troublesome occurrence was the recurrence of cyanobacteria (i.e. blue-green algal blooms) in the Cape Fear River during summer centered in the river near NC11. These consisted largely 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 were not reported related to the blooms.

Several stream stations, particularly BC117, BCRR, PB, BRN (Browns Creek), HAM (Hammond Creek), SAR (Northeast Cape Fear River near Sarecta), LCO, 6RC and LRC showed high fecal coliform bacteria counts on a number of occasions. On rare occasions biochemical oxygen demand (BOD) concentrations at a few Cape Fear River watershed stations (NC11, NCF117 and LVC2 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 2010 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 2010 period UNCW rated 94% of the stations as good and 6% fair in terms of chlorophyll *a*. For turbidity 86% of the sites were rated good and 14% fair (all located in the upper estuary). Fecal coliform bacteria counts showed slightly worse water quality in 2010 compared to 2009, with 43% of the sites rated as poor to fair compared with 40% in 2009. 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, 44% of the sites were rated poor or fair for dissolved oxygen, somewhat higher than in 2009. 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 2010.

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 15-year (1995-2010) data base that is available to the public, and is used as a teaching tool for programs like UNCW's River Run. 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 (UNCW Aquatic Ecology Laboratory, 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. These data are collected and analyzed depending upon the availability of funding. 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, 2010, 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

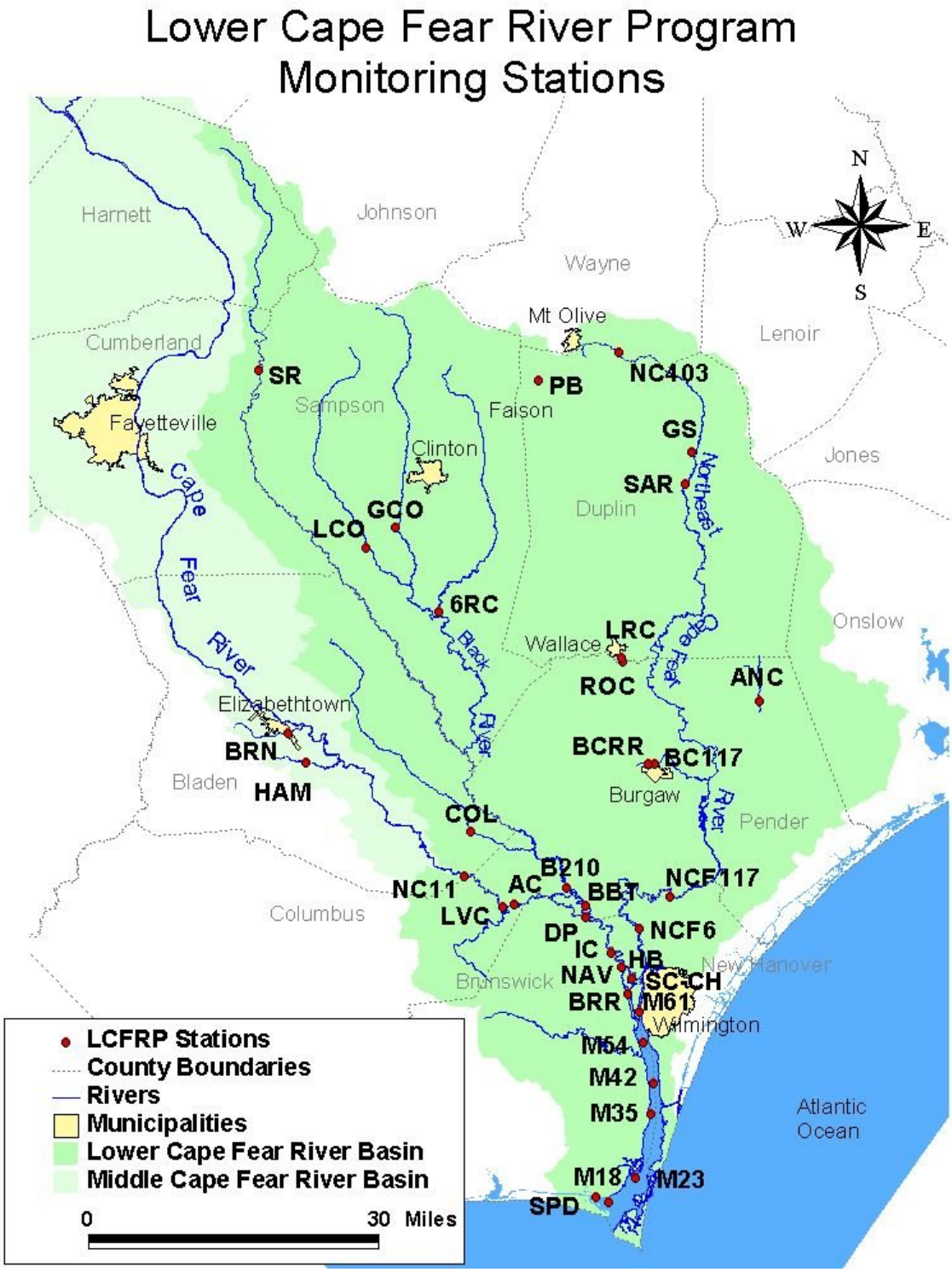
M54	B7950000	Channel Marker 54, 5 km downstream of Wilmington	
GPS		N 34.13933	W 77.94595
M42	B9845100	Channel Marker 42 near Keg Island	
GPS		N 34.09017	W 77.93355
M35	B9850100	Channel Marker 35 near Olde Brunswick Towne	
GPS		N 34.03408	W 77.93943
M23	B9910000	Channel Marker 23 near CP&L intake canal	
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 2010 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 for several years. 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. Data are presented within for the five original sites.

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 2010. 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 3.7 to 31.3^{o}C, and individual station annual averages ranged from 15.9 to 21.3^{o}C (Table 2.1). Highest temperatures occurred during July and August and lowest temperatures during January. 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 0.0 to 35.0 practical salinity units (psu) and station annual means ranged from 2.4 to 25.9 psu (Table 2.2). Lowest salinities occurred in February and October and highest salinities occurred in September. The annual mean salinity for 2010 was higher than that of the fourteen-year average for 1996-2009 for the upper through middle estuary stations, and equal to or less than the long-term mean for the lower stations (Figure 2.1). Two stream stations, NC403 and PB, had occasional oligohaline conditions due to discharges from pickle production facilities. SC-CH is a tidal creek that enters the Northeast Cape Fear River upstream of Wilmington and salinity there ranges widely, from freshwater to salinity exceeding 20 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.09 to 53.20 mS/cm and from 0.06 to 10.70 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 8.3 and station annual means ranged from 3.9 to 8.0 (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; 2009; 2010).

Surface concentrations for all sites in 2010 ranged from 0.3 to 17.5 mg/L and station annual means ranged from 3.8 to 10.4 mg/L (Table 2.5). Average annual DO levels at the river channel and estuarine stations for 2010 were higher than the average for 1996-2009 (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 M35 to M18. Lowest mainstem mean 2010 DO levels occurred at the river and upper estuary stations IC, NAV, HB, BRR and M61 (7.2-7.6 mg/L). NAV and BRR were both below 5.0 mg/L on 33% of occasions sampled and BRR, HB and IC was below on 25%, an improvement from 2009. Based on number of occasions the river stations were below 5 mg/L UNCW rated NAV, IC and BRR as poor for 2010, and DP, HB, M61 and M54 as fair for 2010; the mid to lower estuary stations were 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, helps to diminish oxygen in the lower river and 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 2010 mean = 6.7, NCF6 = 6.8, B210 2010 mean = 7.0). 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 have been 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 2010 Stations NCF117 DO concentrations were again somewhat lower

than at B210 (means 6.7 and 7.0 mg/L, respectively). Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2010. Station BCRR had DO levels below 4.0 mg/L 67% of the occasions sampled, with SR and GS 50%, LVC2 45%, ANC 42% and NC403 33% (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 continuing widespread problem, with 44% of the sites impacted in 2010.

Field Turbidity

Field turbidity levels ranged from 0 to 122 Nephelometric turbidity units (NTU) and station annual means ranged from 2 to 22 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Annual mean turbidity levels for 2010 were lower than the long-term average in most stations, with the exception of the mid-estuary sites M42-M35 (Fig. 2.3). Highest mean and median turbidities were at AC, DP and NC11 (21-22 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 BCRR and to a lesser extent BRN and BC117. 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 118 mg/L with station annual means from 2 to 20 mg/L (Table 2.7). The overall highest river values were at M42, M54, AC and DP. In the stream stations TSS was generally considerably lower than the river and estuary, except for Station BCRR. 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 0.87 to 7.39/m and station annual means ranged from 1.64 at M18 to 3.86 /m at NCF6 (Table 2.8). Elevated mean and median light attenuation persisted from NC11 downstream to IC; the estuary from M61-M42 also had high attenuation (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 120 to 30,000 μg/L and station annual means ranged from 415 to 14,383 μg/L (Table 2.9). Mean total nitrogen in 2010 was slightly less than the fourteen-year mean at most river and estuary stations (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. One stream station, BC117, had a very high median of 16,100 μg/L, likely from the upstream Town of Burgaw wastewater discharge. PB, ROC, LRC, NC403 and 6RC also had comparatively high TN values among the stream stations.

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 30,000 μg/L and station annual means ranged from 97 to 14,008 μg/L (Table 2.10). The highest average riverine nitrate levels were at NC11 and AC (743 and 715 μg/L, respectively) 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 = 402 μg/L) and the Black River (B210 = 328 μg/L). Lowest river nitrate occurred during summer, along with lowest flows and lowest dissolved oxygen concentrations.

Several stream stations showed high levels of nitrate on occasion including BC117, ROC, LRC, 6RC and NC403. NC403 is downstream of industrial wastewater discharges and ROC, LRC 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 930 μg/L and station annual means ranged from 12 to 268 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 highest levels of ammonium were BCRR, PB and LVC2, 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 100 to 2,800 μg/L and station annual means ranged from 273 to 1,217 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 2,800 μg/L of TN was seen at BCRR in May. Station ANC had the highest mean and median concentrations; other sites with elevated TKN included PB, COL, BCRR and ROC.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from below detection limit to 3,780 μg/L and station annual means ranged from 23 to 1,668 μg/L (Table 2.13). Mean TP for 2010 was approximately equal to the fourteen-year mean in the majority of the stations (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.

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 BCRR. Some of these stations (BC117, PB) are downstream of industrial or wastewater discharges, while GCO, BCRR and ROC are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from undetectable to 2,940 μg/L and station annual means ranged from 6 to 1,484 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 have high levels; there are also inputs of orthophosphate from the paper mill above AC (Table 2.14). 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 and GCO had comparatively high levels. BC117 is below a municipal wastewater discharge, and ROC, and GCO 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 periodic elevated concentrations from May – September at a few locations (Table 2.15). At many of the river and estuarine stations chlorophyll *a* for 2010 was considerably higher than the fourteen-year mean for those sites (Figure 2.6). Algal blooms occurred in July and August at Station NC11, with chlorophyll *a* levels of 39-47 μg/L. 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). What was of human health as well as ecological interest was that blooms of cyanobacteria (blue-green algae) called *Microcystis aeruginosa* that began occurring in 2009 continued to occur in summer 2010. These blooms are primarily a surface phenomenon. UNCW sampled chlorophyll *a* July 15th and got high values, with a surface *Microcystis* bloom at NC11 yielding 364 ppb, subsurface at NC11 yielding 41 ppb, and subsurface at Lock and Dam 1 yielding 28 ppb. The bloom persisted for a number of weeks before dissipating. The presence of the bloom affected Brunswick County water treatment in 2009 and they contracted with UNCW LCFRP to collect periodic 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 217 μg/L and station annual means ranged from 1–36 μg/L, lower than in 2009. 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, along the mainstem 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 2010 it was well below that at 1,769 CFS. Thus, chlorophyll *a* concentrations in the river and 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 late spring and summer in 2010 (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 2010 occurred at ANC, GS, PB 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 2010 (as was the case with 2007 through 2009) there as little discernable effect of BOD loading from the nearby pulp/paper mill inputs (Table 2.16). BOD5 values between 1.0 and 2.0 mg/L are typical for the rivers in the Cape Fear system (Mallin et al. 2006b) and in 2010 the highest value seen was 3.3 mg/L at NCF117, indicating there was no significant BOD problem in 2010. Stations LVC2 and AC had the highest mean and median BOD5 and BOD20 concentrations in 2010.

Fecal Coliform Bacteria

Fecal coliform (FC) bacterial counts ranged from 5 to 23,000 CFU/100 mL and station annual geometric means ranged from 7 to 483 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded at the mainstem sites only rarely in 2010, once in October at M42 and once in July at AC. Geometric mean fecal coliform counts in 2010 in the Cape Fear, Black, and Northeast Cape Fear Rivers as well as the estuary were mixed compared with the fourteen-year average (Figure 2.7).

During 2010 BRN exceeded the state standard 75% of the time; BC117 67%, PB 50%, BCRR and HAM 58%, LRC, LCO and SR 33%, SAR, NC403 and GCO 25%, and GS and SC-CH 17% of the time. BC117, NC403 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 43% of the stations impacted in 2010, slightly higher than the previous year 2009.

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Table 2.1 Water temperature (^{o}C) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	3.2	3.3	3.6	4.4	4.3	4.6	5.0	6.0	5.9	5.4
FEB	5.2	5.3	5.3	5.6	5.8	5.7	6.3	6.7	7.9	6.7
MAR	9.0	9.2	8.9	9.3	9.5	9.3	9.5	10.3	9.7	10.5
APR	20.1	20.4	20.4	21.4	20.3	20.5	20.1	19.3	18.4	18.6
MAY	24.5	27.3	24.7	24.3	24.3	24.5	23.9	22.8	22.4	23.1
JUN	27.7	28.0	27.9	27.9	27.6	27.2	27.4	27.6	27.6	28.9
JUL	30.6	31.1	31.2	30.4	29.9	29.2	29.1	28.3	28.2	29.2
AUG	30.6	30.7	31.3	30.9	30.6	30.1	29.8	29.3	28.8	29.6
SEP	28.8	29.2	28.7	29.3	28.9	28.9	28.9	28.2	28.2	28.1
OCT	19.1	19.3	20.1	20.0	20.3	20.4	20.3			
NOV	13.8	14.4	15.0	15.5	15.8	16.0	16.2	16.4	16.5	16.6
DEC	6.4	6.9	7.2	7.6	6.5	8.8	8.7	8.6	10.3	8.7
mean	**19.6**	**20.2**	**20.1**	**20.2**	**20.0**	**20.1**	**20.0**	**19.8**	**19.8**	**20.0**
std dev	9.7	9.9	9.7	9.4	9.4	8.9	8.8	8.8	8.4	9.1
median	19.6	19.9	20.3	20.7	20.3	20.5	20.2	19.3	18.4	18.6
max	30.6	31.1	31.3	30.9	30.6	30.1	29.8	29.3	28.8	29.6
min	5.2	5.3	5.3	5.6	5.8	5.7	6.3	6.7	7.9	6.7

month	NC11	AC	DP	BBT	IC	NCF6
JAN	4.4	4.5	4.4	2.7	3.5	3.1
FEB	5.2	5.3	5.5	5.2	5.2	5.8
MAR	14.1	14.0	14.1	14.6	14.2	14.9
APR	18.6	18.8	18.8	20.8	19.6	20.7
MAY	23.5	23.7	24.0	24.6	24.6	24.5
JUN	25.6	25.7	25.6	24.8	25.3	26.4
JUL	30.3	30.3	30.1	27.9	29.2	30.8
AUG	30.7	31.1	31.0	30.4	30.8	30.8
SEP	28.7	28.5	28.0	28.0	28.3	28.6
OCT	19.4	19.2	19.3	18.6	18.9	19.4
NOV	13.8	14.4	14.1	12.8	13.4	14.4
DEC	9.0	8.9	8.2	8.1	8.9	9.9
mean	**19.9**	**20.0**	**19.9**	**19.6**	**19.9**	**20.6**
std dev	8.7	8.7	8.7	8.5	8.6	8.5
median	19.0	19.0	19.1	19.7	19.3	20.1
max	30.7	31.1	31.0	30.4	30.8	30.8
min	5.2	5.3	5.5	5.2	5.2	5.8

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	4.7	1.8	2.8	3.1		3.5	2.4	3.7	3.3
FEB	8.9	5.1	6.7	5.7	6.2	5.8	5.6	7.2	6.8
MAR	12.7	13.5	14.6	13.7	13.5	13.5	12.4	11.0	9.9
APR	17.3	15.6	16.7	17.7	16.3	14.5	14.8	14.6	14.3
MAY	21.5	22.1	22.9	21.4	21.9	19.9	21.9	20.7	20.1
JUN	23.1	24.1	24.7	25.9	24.1	23.0	23.3	22.9	23.2
JUL	25.5	28.3	29.0	27.5	28.0	27.5	26.8	26.4	24.4
AUG	25.0	24.8	25.3	25.7	25.6		24.6	24.4	24.0
SEP	26.7	26.1	24.5	26.1	27.9	25.2	24.7	25.0	23.6
OCT	16.1	15.5	15.7	16.4	16.0	15.5	15.4	17.9	15.7
NOV	9.1	8.6	8.1	9.1	7.3	8.4	9.3	11.5	9.9
DEC	6.0	5.1	4.6	4.8	3.7	5.2	5.9	6.6	8.3
mean	**17.4**	**17.2**	**17.5**	**17.6**	**17.3**	**15.9**	**16.8**	**17.1**	**16.4**
std dev	7.4	8.5	8.4	8.4	8.9	7.9	7.9	7.3	6.9
median	16.7	15.6	16.2	17.1	16.3	14.5	15.1	16.3	15.0
max	26.7	28.3	29.0	27.5	28.0	27.5	26.8	26.4	24.4
min	6.0	5.1	4.6	4.8	3.7	5.2	5.6	6.6	6.8

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	1.6	1.0	0.1	0.3	2.1	2.4
FEB	5.7	5.4	5.4	5.4	6.5	6.4
MAR	7.5	7.3	6.7	7.0	7.5	7.2
APR	19.9	19.9	20.7	21.0	19.8	19.0
MAY	23.2	23.3	24.3	21.9	21.6	20.6
JUN	23.5	23.1	23.9	23.4	22.6	20.8
JUL	25.0	26.0	26.5	25.1	24.9	25.3
AUG	25.6	25.6	25.5	24.9	24.7	24.5
SEP		21.3	22.0	22.8	21.2	20.8
OCT	19.1	18.7	18.8	19.1	18.1	17.6
NOV	14.4	14.6	14.7	14.4	14.9	14.5
DEC	12.8	12.9	13.7	13.4	14.5	12.3
mean	**17.7**	**18.0**	**18.4**	**18.0**	**17.8**	**17.2**
std dev	7.2	7.1	7.4	7.0	6.4	6.4
median	19.1	19.3	19.8	20.1	19.0	18.3
max	25.6	26.0	26.5	25.1	24.9	25.3
min	5.7	5.4	5.4	5.4	6.5	6.4

month	NCF117	B210	COL	LVC2	SC-CH
JAN	7.8	8.1	7.4	10.4	6.9
FEB	6.2	5.5	4.1		7.1
MAR	7.5	6.8	6.0	7.0	7.9
APR	20.1	20.8	19.9	19.8	21.0
MAY	23.6	23.8	21.4	22.0	25.2
JUN	30.0	29.3	26.4	27.9	29.6
JUL	29.8	24.9	22.4	26.1	29.4
AUG	30.0	29.2	25.0	27.8	30.8
SEP	27.8	26.3	23.5	26.0	29.0
OCT	19.4	19.3	18.6	19.8	21.8
NOV	18.0	15.2	13.6	15.2	18.7
DEC	13.4	12.3	9.7	11.8	14.1
mean	**20.5**	**19.4**	**17.3**	**20.3**	**21.3**
std dev	8.7	8.4	7.8	7.1	8.6
median	19.8	20.1	19.3	19.8	21.4
max	30.0	29.3	26.4	27.9	30.8
min	6.2	5.5	4.1	7.0	7.1

Table 2.2 Salinity (psu) during 2010 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	0.5	0.7	4.9	5.3	7.2	10.8	17.7	19.6	22.6	0.1	0.1
FEB	0.0	0.0	0.0	0.1	0.1	0.1	1.2	6.3	20.6	7.0	0.0	0.1
MAR	0.1	0.1	0.1	1.1	1.8	2.9	3.8	13.6	14.7	18.4	0.1	0.1
APR	0.1	1.0	0.7	2.7	5.3	8.0	12.9	17.9	24.8	21.7	0.1	0.3
MAY	5.4	7.1	10.1	13.9	16.4	19.2	23.7	29.0	31.7	30.3	1.2	3.2
JUN	0.1	0.1	0.1	3.0	3.9	4.6	6.3	14.4	16.7	22.7	5.5	6.7
JUL	1.1	2.9	5.5	12.5	14.9	16.6	19.3	25.0	26.7	30.7	3.5	7.4
AUG	7.0	7.6	9.6	16.0	18.3	20.8	24.8	30.6	33.0	30.5	17.2	12.0
SEP	13.8	12.5	16.1	17.5	21.2	23.8	27.9	33.9	35.0	32.9	15.6	6.3
OCT	0.1	0.1	0.1	0.1	0.2	0.7	1.6				0.0	0.3
NOV	0.1	2.8	6.0	11.1	13.7	16.4	18.5	25.5	27.8	31.0	0.1	6.3
DEC	0.9	3.9	6.4	11.5	13.2	23.7	25.2	29.1	33.9	29.7	9.5	4.5
mean	**2.4**	**3.2**	**4.6**	**7.9**	**9.5**	**12.0**	**14.7**	**22.1**	**25.9**	**25.2**	**4.4**	**3.9**
std dev	4.3	4.0	5.3	6.5	7.5	9.0	9.8	8.6	7.2	7.7	6.3	3.9
median	0.1	1.9	3.1	8.0	9.3	12.2	15.7	25.0	26.7	29.7	0.7	3.9
max	13.8	12.5	16.1	17.5	21.2	23.8	27.9	33.9	35.0	32.9	17.2	12.0
min	0.0	0.0	0.0	0.1	0.1	0.1	1.2	6.3	14.7	7.0	0.0	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations, 1995-2009 versus 2010.

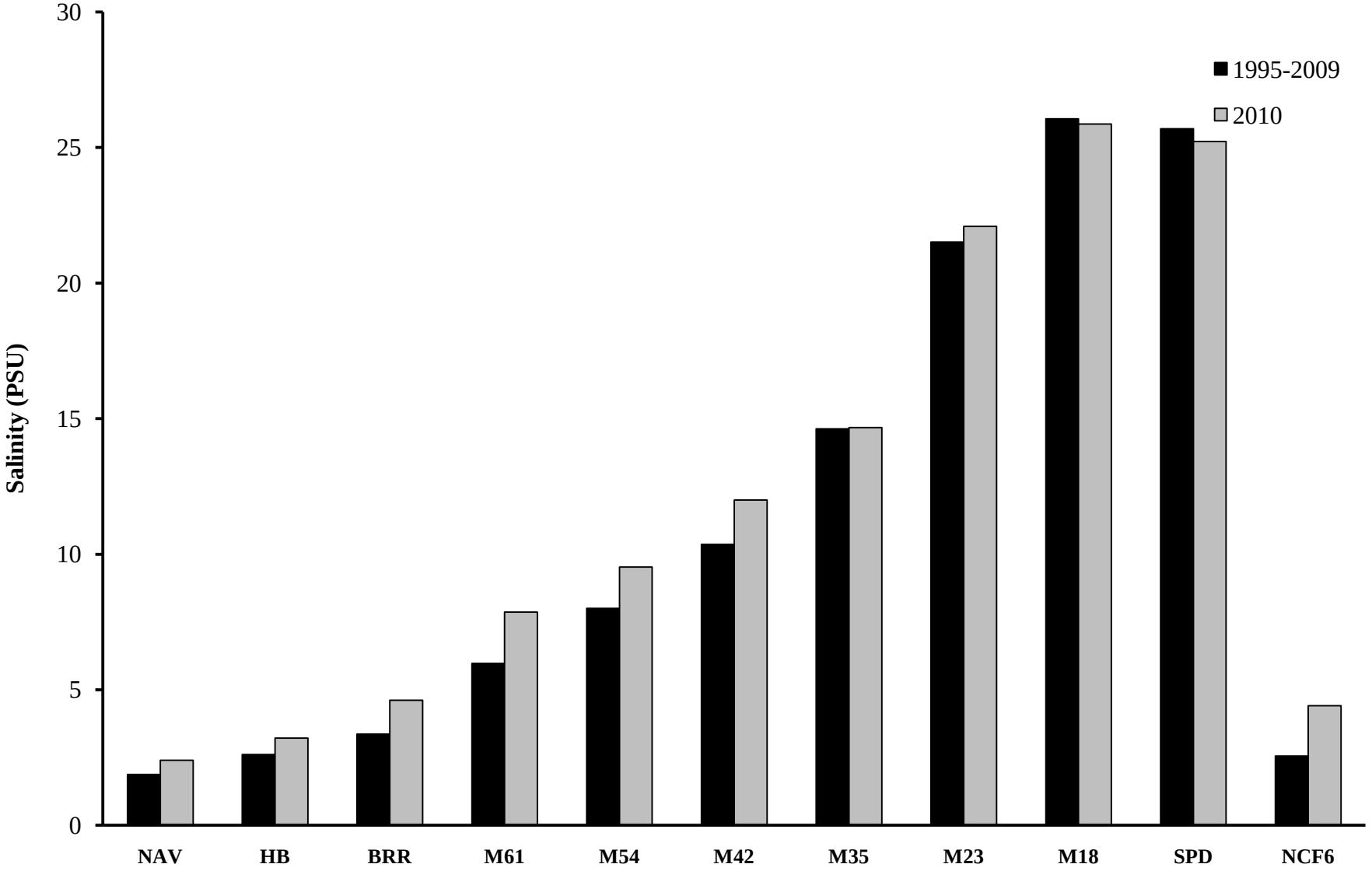


Table 2.3 Conductivity (mS/cm) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	0.14	1.02	1.47	8.90	9.60	12.61	18.38	29.01	31.93	36.35
FEB	0.09	0.09	0.09	0.10	0.10	0.22	2.28	11.12	33.11	12.28
MAR	0.11	0.11	0.12	2.16	3.41	5.35	6.88	22.52	24.06	29.80
APR	0.13	1.86	1.47	5.05	9.33	13.71	21.45	29.08	38.91	34.38
MAY	9.57	12.25	17.13	22.96	26.81	30.91	37.42	44.75	48.48	46.53
JUN	0.13	0.15	0.17	5.49	7.06	8.39	11.09	23.82	27.36	36.05
JUL	2.22	5.40	9.78	20.97	24.67	27.12	31.13	39.32	41.73	47.30
AUG	12.13	13.41	16.45	26.38	29.68	33.41	39.11	47.21	50.44	47.06
SEP	22.87	20.85	36.39	28.53	33.98	37.72	43.51	51.65	53.20	50.34
OCT	0.11	0.11	0.12	0.14	0.42	1.39	2.97			
NOV	0.30	5.16	10.51	18.56	22.69	26.73	29.80	39.88	43.10	47.59
DEC	1.80	7.12	11.34	19.37	22.03	37.52	39.75	45.27	51.83	46.05
mean	**4.13**	**5.63**	**8.75**	**13.22**	**15.82**	**19.59**	**23.65**	**34.87**	**40.38**	**39.43**
std dev	7.17	6.71	10.90	10.62	12.07	14.13	15.17	12.61	10.17	11.30
median	0.2	3.5	5.6	13.7	15.8	20.2	25.6	39.3	41.7	46.0
max	22.87	20.85	36.39	28.53	33.98	37.72	43.51	51.65	53.20	50.34
min	0.09	0.09	0.09	0.10	0.10	0.22	2.28	11.12	24.06	12.28

month	NC11	AC	DP	BBT	IC	NCF6
JAN	0.12	0.14	0.13	0.09	0.11	0.13
FEB	0.10	0.11	0.11	0.08	0.09	0.09
MAR	0.10	0.13	0.12	0.08	0.11	0.12
APR	0.10	0.11	0.11	0.09	0.10	0.15
MAY	0.12	0.14	0.23	0.14	0.19	2.32
JUN	0.13	0.15	0.15	0.11	0.13	9.87
JUL	0.11	0.27	0.24	0.10	0.16	6.43
AUG	0.17	0.46	0.29	0.20	0.24	28.07
SEP	0.14	0.31	0.25	0.25	1.92	25.71
OCT	0.08	0.10	0.10	0.09	0.10	0.07
NOV	0.17	0.34	0.27	0.13	0.20	0.30
DEC	0.18	0.21	0.23	0.23	0.28	16.25
mean	**0.13**	**0.21**	**0.19**	**0.13**	**0.30**	**7.46**
std dev	0.03	0.12	0.07	0.06	0.51	10.40
median	0.1	0.1	0.2	0.1	0.1	1.3
max	0.18	0.46	0.29	0.25	1.92	28.07
min	0.08	0.10	0.10	0.08	0.09	0.07

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	0.10	0.17	0.16	0.32		0.13	0.13	0.33	0.13
FEB	0.09	0.13	0.13	0.17	0.33	0.12	0.11	0.15	0.12
MAR	0.08	0.13	0.13	0.34	0.52	0.12	0.12	0.28	0.12
APR	0.09	0.17	0.16	0.50	0.45	0.21	0.18	0.82	0.29
MAY	0.14	0.20	0.23	0.52	1.42	0.21	0.31	0.89	0.40
JUN	0.14	0.20	0.19	0.74	1.83	0.20	0.15	0.44	0.25
JUL	0.14	0.27	0.23	1.33	10.70	0.19	0.18	1.15	0.23
AUG	0.18	0.30	0.34	1.06	3.78		0.18	0.71	0.18
SEP	0.15	0.34	0.32	1.04	7.59	0.17	0.15	0.89	0.15
OCT	0.09	0.21	0.20	0.57	0.59	0.16	0.16	0.99	0.16
NOV	0.08	0.23	0.25	0.63	0.55	0.14	0.15	0.87	0.33
DEC	0.09	0.19	0.19	0.73	1.75	0.13	0.13	0.34	0.23
mean	**0.11**	**0.21**	**0.21**	**0.66**	**2.68**	**0.16**	**0.16**	**0.65**	**0.22**
std dev	0.03	0.06	0.07	0.34	3.42	0.04	0.05	0.33	0.09
median	0.09	0.20	0.19	0.60	1.42	0.16	0.15	0.77	0.20
max	0.18	0.34	0.34	1.33	10.70	0.21	0.31	1.15	0.40
min	0.08	0.13	0.13	0.17	0.33	0.12	0.11	0.15	0.12

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.15	0.10	0.12	0.09	0.12	0.07
FEB	0.12	0.08	0.11	0.07	0.10	0.10
MAR	0.13	0.09	0.12	0.08	0.10	0.12
APR	0.11	0.07	0.09	0.06	0.10	0.12
MAY	0.13	0.09	0.17	0.10	0.11	0.11
JUN	0.11	0.07	0.09	0.08	0.08	0.16
JUL	0.10	0.09	0.15	0.14	0.11	0.11
AUG	0.13	0.10	0.18	0.42	0.17	0.21
SEP		0.36	0.11	0.10	0.25	
OCT	0.10	0.07	0.11	0.07	0.15	0.17
NOV	0.17	0.11	0.19	0.09	0.15	0.19
DEC	0.14	0.10	0.18	0.10	0.13	0.22
mean	**0.13**	**0.11**	**0.13**	**0.12**	**0.13**	**0.14**
std dev	0.02	0.08	0.04	0.10	0.05	0.05
median	0.13	0.09	0.12	0.09	0.12	0.12
max	0.17	0.36	0.19	0.42	0.25	0.22
min	0.10	0.07	0.09	0.06	0.08	0.07

month	NCF117	B210	COL	LVC2	SC-CH
JAN	0.12	0.09	0.09	0.10	0.24
FEB	0.10	0.08	0.09		0.12
MAR	0.11	0.08	0.08	0.10	0.20
APR	0.14	0.08	0.07	0.12	0.63
MAY	0.24	0.10	0.07	0.16	5.95
JUN	0.27	0.09	0.08	0.18	11.86
JUL	0.28	0.07	0.08	0.16	12.88
AUG	0.32	0.13	0.07	0.17	20.27
SEP	0.19	0.11	0.07	0.17	11.18
OCT	0.12	0.08	0.10	0.10	0.53
NOV	0.14	0.10	0.08	0.14	10.96
DEC	0.21	0.11	0.07	0.15	8.01
mean	**0.19**	**0.09**	**0.08**	**0.14**	**6.90**
std dev	0.08	0.02	0.01	0.03	6.68
median	0.17	0.09	0.08	0.15	6.98
max	0.32	0.13	0.10	0.18	20.27
min	0.10	0.07	0.07	0.10	0.12

Table 2.4 pH during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	7.3	7.3	7.6	7.2	7.6	7.7	7.9	8.0	8.0	8.0
FEB	6.9	7.0	7.2	6.9	7.3	7.9	8.3	8.2	7.9	7.8
MAR	7.3	7.3	7.6	7.3	7.7	7.9	8.0	8.0	7.9	7.7
APR	6.8	6.9	6.9	7.0	7.7	7.4	8.0	7.9	8.0	7.9
MAY	7.1	7.3	7.3	7.5	7.8	8.3	8.1	8.0	8.0	7.9
JUN	6.8	6.9	6.9	7.0	7.1	7.2	7.4	7.8	7.9	7.6
JUL	7.0	7.1	7.1	7.3	7.6	7.7	8.0	8.1	8.1	7.7
AUG	7.0	7.2	7.2	7.3	7.5	7.6	7.8	7.9	7.9	7.9
SEP	7.1	7.1	7.2	7.4	7.6	7.7	7.9	8.0	8.1	7.9
OCT	6.0	6.1	6.2	6.0	6.3	6.5	7.0			
NOV	7.3	7.2	7.3	7.3	7.5	7.6	7.7	7.9	8.0	7.7
DEC	7.5	7.3	7.3	7.5	7.5	8.0	8.0	8.1	8.1	8.0
mean	**7.0**	**7.1**	**7.2**	**7.1**	**7.4**	**7.6**	**7.8**	**8.0**	**8.0**	**7.8**
std dev	0.4	0.3	0.4	0.4	0.4	0.5	0.3	0.1	0.1	0.1
median	7.1	7.2	7.2	7.3	7.6	7.7	8.0	8.0	8.0	7.9
max	7.5	7.3	7.6	7.5	7.8	8.3	8.3	8.2	8.1	8.0
min	6.0	6.1	6.2	6.0	6.3	6.5	7.0	7.8	7.9	7.6

month	NC11	AC	DP	BBT	IC	NCF6
JAN	6.2	6.6	6.7	6.3	6.5	6.7
FEB	6.7	6.6	6.7	6.5	6.5	6.3
MAR	6.6	6.8	6.8	6.4	6.7	6.5
APR	6.6	6.8	6.8	6.4	6.6	6.5
MAY	6.9	6.9	7.0	6.6	6.9	6.8
JUN	7.0	7.1	7.1	6.4	6.8	7.0
JUL	6.6	7.0	6.8	6.1	6.6	6.9
AUG	7.4	7.4	7.1	6.9	7.0	7.1
SEP	6.9	7.1	6.8	6.8	6.8	7.1
OCT	6.1	6.2	6.2	5.6	5.9	5.5
NOV	6.6	7.0	7.0	6.5	6.7	6.5
DEC	6.8	7.1	7.0	7.0	7.0	7.3
mean	**6.7**	**6.9**	**6.8**	**6.5**	**6.7**	**6.7**
std dev	0.3	0.3	0.2	0.4	0.3	0.5
median	6.7	7.0	6.8	6.5	6.7	6.8
max	7.4	7.4	7.1	7.0	7.0	7.3
min	6.1	6.2	6.2	5.6	5.9	5.5

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	5.0	6.7	6.8	6.7		6.9	6.9	6.7	5.6
FEB	4.7	6.6	6.6	6.4	6.4	6.6	6.5	6.3	6.0
MAR	5.4	6.7	6.9	6.7	6.7	6.9	6.8	6.6	5.9
APR	5.7	6.9	6.9	6.8	7.0	7.4	7.1	7.4	7.0
MAY	7.2	7.4	7.3	7.1	7.2	7.7	7.5	7.6	7.3
JUN	6.5	6.8	6.5	6.6	7.0	7.6	7.0	7.5	7.2
JUL	6.4	7.1	6.9	6.6	8.0	8.1	7.2	7.8	6.9
AUG	6.6	6.5	6.2	6.6	7.2		7.2	7.6	6.9
SEP	6.4	6.8	6.4	6.5	7.8	7.3	6.8	7.6	6.7
OCT	4.4	6.6	6.5	6.6	6.9	7.2	7.0	7.5	6.3
NOV	5.5	6.9	6.8	6.9	6.9	7.3	7.2	7.4	6.6
DEC	5.3	6.7	6.9	6.9	6.8	7.1	7.0	6.9	6.6
mean	**5.8**	**6.8**	**6.7**	**6.7**	**7.1**	**7.3**	**7.0**	**7.2**	**6.6**
std dev	0.9	0.2	0.3	0.2	0.5	0.4	0.3	0.5	0.5
median	5.6	6.8	6.8	6.7	7.0	7.3	7.0	7.5	6.7
max	7.2	7.4	7.3	7.1	8.0	8.1	7.5	7.8	7.3
min	4.4	6.5	6.2	6.4	6.4	6.6	6.5	6.3	5.6

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	6.2	6.2	6.3	6.4	6.6	6.5
FEB	5.8	5.8	6.1	6.2	6.1	6.2
MAR	6.2	6.2	6.3	6.4	6.5	6.5
APR	6.6	6.2	6.5	6.3	6.7	6.8
MAY	7.1	6.8	7.0	6.2	7.0	7.1
JUN	6.6	6.1	6.5	6.3	6.8	6.9
JUL	6.6	6.7	6.8	6.2	6.8	6.7
AUG	6.8	6.5	6.6	6.0	7.0	7.2
SEP		6.3	6.7	6.2	7.0	7.0
OCT	5.9	5.1	5.9	5.9	6.4	6.6
NOV	6.6	6.6	6.5	6.4	7.0	6.9
DEC	6.9	6.7	6.6	6.1	6.9	7.0
mean	**6.5**	**6.3**	**6.5**	**6.2**	**6.7**	**6.8**
std dev	0.4	0.5	0.3	0.2	0.3	0.3
median	6.6	6.3	6.5	6.2	6.8	6.9
max	7.1	6.8	7.0	6.4	7.0	7.2
min	5.8	5.1	5.9	5.9	6.1	6.2

month	NCF117	B210	COL	LVC2	SC-CH
JAN	5.9	5.7	3.8	6.4	6.1
FEB	6.0	5.6	3.8		5.9
MAR	5.8	6.6	3.9	6.3	5.8
APR	6.5	6.2	4.0	6.6	7.0
MAY	6.9	6.6	4.0	6.7	7.2
JUN	6.9	6.4	4.0	6.8	6.9
JUL	6.9	4.8	3.9	7.1	7.0
AUG	7.1	6.8	3.9	6.8	7.0
SEP	6.8	6.3	4.1	6.9	7.2
OCT	5.7	5.6	3.8	6.3	6.4
NOV	6.2	6.1	4.0	6.8	6.6
DEC	6.6	6.3	4.0	6.9	6.9
mean	**6.4**	**6.1**	**3.9**	**6.7**	**6.7**
std dev	0.5	0.6	0.1	0.3	0.5
median	6.6	6.3	4.0	6.8	6.9
max	7.1	6.8	4.1	7.1	7.2
min	5.7	4.8	3.8	6.3	5.8

Table 2.5 Dissolved Oxygen (mg/l) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	12.4	12.1	12.1	11.2	11.3	11.2	11.0	10.7	10.6	10.0
FEB	11.7	11.7	11.7	11.4	11.7	11.5	11.4	11.4	10.5	11.3
MAR	10.9	11.0	11.0	10.5	10.5	10.5	10.5	10.0	10.0	10.4
APR	7.2	7.1	7.0	7.0	6.9	7.3	7.9	7.9	8.2	7.7
MAY	5.6	7.3	6.0	6.4	7.5	10.9	9.6	7.6	7.4	7.0
JUN	6.2	6.4	6.4	6.0	6.4	6.4	6.8	6.8	7.1	5.8
JUL	4.6	4.8	4.7	5.2	6.3	6.1	8.0	7.4	7.0	5.9
AUG	3.2	3.4	4.2	4.2	4.7	5.2	5.5	5.9	5.8	5.9
SEP	3.8	4.1	4.1	4.8	5.0	6.0	5.8	6.1	6.0	5.4
OCT	4.8	5.0	4.8	3.9	4.0	4.2	5.0			
NOV	8.1	8.1	7.7	8.0	7.3	7.3	7.5	7.7	8.1	7.7
DEC	10.1	9.8	9.9	9.6	10.3	9.6	9.5	9.6	9.1	9.5
mean	**7.4**	**7.6**	**7.5**	**7.4**	**7.7**	**8.0**	**8.2**	**8.3**	**8.2**	**7.9**
std dev	3.2	3.0	3.0	2.7	2.7	2.6	2.2	1.9	1.7	2.1
median	6.7	7.2	6.7	6.7	7.1	7.3	8.0	7.7	8.1	7.7
max	12.4	12.1	12.1	11.4	11.7	11.5	11.4	11.4	10.6	11.3
min	3.2	3.4	4.1	3.9	4.0	4.2	5.0	5.9	5.8	5.4

month	NC11	AC	DP	BBT	IC	NCF6
JAN	12.4	12.1	11.9	11.5	11.4	11.3
FEB	12.7	12.6	12.4	11.7	11.8	11.0
MAR	10.4	10.2	9.9	8.7	9.3	8.0
APR	9.0	8.7	8.4	6.2	7.4	6.4
MAY	8.0	7.8	6.6	4.9	5.8	6.3
JUN	7.5	7.3	6.9	5.3	6.1	5.8
JUL	6.7	6.0	3.8	3.9	3.9	5.3
AUG	8.4	7.3	5.6	4.7	5.0	4.0
SEP	7.4	6.1	3.9	4.1	3.7	3.8
OCT	7.4	6.4	5.8	4.3	4.5	3.8
NOV	9.7	9.2	8.3	7.8	8.0	7.2
DEC	10.3	10.0	9.3	9.4	8.9	8.6
mean	**9.2**	**8.6**	**7.7**	**6.9**	**7.2**	**6.8**
std dev	2.0	2.2	2.8	2.9	2.8	2.6
median	8.7	8.3	7.6	5.8	6.8	6.4
max	12.7	12.6	12.4	11.7	11.8	11.3
min	6.7	6.0	3.8	3.9	3.7	3.8

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	10.9	13.0	13.7	11.2		13.0	12.9	12.0	11.9
FEB	11.1	12.1	12.1	11.9	10.8	12.7	11.8	10.6	10.2
MAR	11.3	8.9	10.5	9.3	9.7	11.4	9.7	10.4	8.9
APR	5.7	7.2	8.6	7.0	7.5	10.3	8.0	3.2	0.6
MAY	1.9	6.7	3.1	3.1	6.7	7.5	5.5	3.0	0.2
JUN	0.7	5.4	1.8	1.4	6.5	8.0	5.7	5.1	3.5
JUL	0.3	6.1	3.1	0.8	9.1	10.4	4.8	4.1	0.5
AUG	0.5	5.8	1.3	4.9	8.5		7.0	6.5	1.7
SEP	2.1	4.9	0.5	1.0	10.1	7.5	5.5	4.7	0.7
OCT	5.2	7.4	3.6	6.6	8.4	9.5	7.7	6.2	0.4
NOV	7.2	9.4	5.1	7.3	7.1	11.2	9.7	6.3	1.0
DEC	8.9	9.7	9.6	9.2	10.6	12.4	11.0	8.8	6.2
mean	**5.5**	**8.1**	**6.1**	**6.1**	**8.6**	**10.4**	**8.3**	**6.7**	**3.8**
std dev	4.4	2.6	4.6	3.9	1.6	2.0	2.7	3.0	4.3
median	5.5	7.3	4.4	6.8	8.5	10.4	7.9	6.3	1.4
max	11.3	13.0	13.7	11.9	10.8	13.0	12.9	12.0	11.9
min	0.3	4.9	0.5	0.8	6.5	7.5	4.8	3.0	0.2

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	13.5	14.1	16.8	14.9	17.0	17.5
FEB	11.9	12.0	11.3	11.3	11.6	12.0
MAR	11.4	11.8	10.6	10.2	11.8	12.1
APR	9.1	6.6	5.5	4.3	9.0	8.0
MAY	7.0	6.9	5.9	1.5	7.4	4.4
JUN	6.5	6.3	5.0	2.6	7.5	5.4
JUL	6.4	6.5	5.4	4.8	7.1	6.3
AUG	7.2	7.4	6.3	0.5	7.7	4.7
SEP		7.2	5.3	0.3	8.0	2.9
OCT	5.4	5.9	5.6	3.5	8.3	7.2
NOV	9.0	9.0	5.2	3.0	9.6	5.5
DEC	10.6	10.2	8.3	4.6	10.7	8.7
mean	**8.9**	**8.7**	**7.6**	**5.1**	**9.6**	**7.9**
std dev	2.6	2.7	3.6	4.6	2.8	4.2
median	9.0	7.3	5.8	3.9	8.7	6.8
max	13.5	14.1	16.8	14.9	17.0	17.5
min	5.4	5.9	5.0	0.3	7.1	2.9

month	NCF117	B210	COL	LVC2	SC-CH
JAN	10.6	10.4	9.0	8.7	11.3
FEB	10.7	10.9	11.1		9.6
MAR	11.0	11.3	10.5	10.8	11.1
APR	7.2	6.6	5.6	4.6	8.4
MAY	5.6	5.3	5.5	2.3	6.4
JUN	5.0	4.6	5.3	2.1	4.4
JUL	5.3	4.7	3.8	3.7	5.0
AUG	5.4	5.2	5.2	2.9	4.6
SEP	3.7	4.8	5.0	2.6	5.4
OCT	2.9	5.7	4.7	5.5	4.6
NOV	5.8	6.8	6.7	6.1	5.7
DEC	7.1	7.6	8.0	5.4	7.4
mean	**6.7**	**7.0**	**6.7**	**5.0**	**7.0**
std dev	2.7	2.5	2.4	2.8	2.5
median	5.7	6.2	5.6	4.6	6.1
max	11.0	11.3	11.1	10.8	11.3
min	2.9	4.6	3.8	2.1	4.4

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations, 1995-2009 versus 2010.

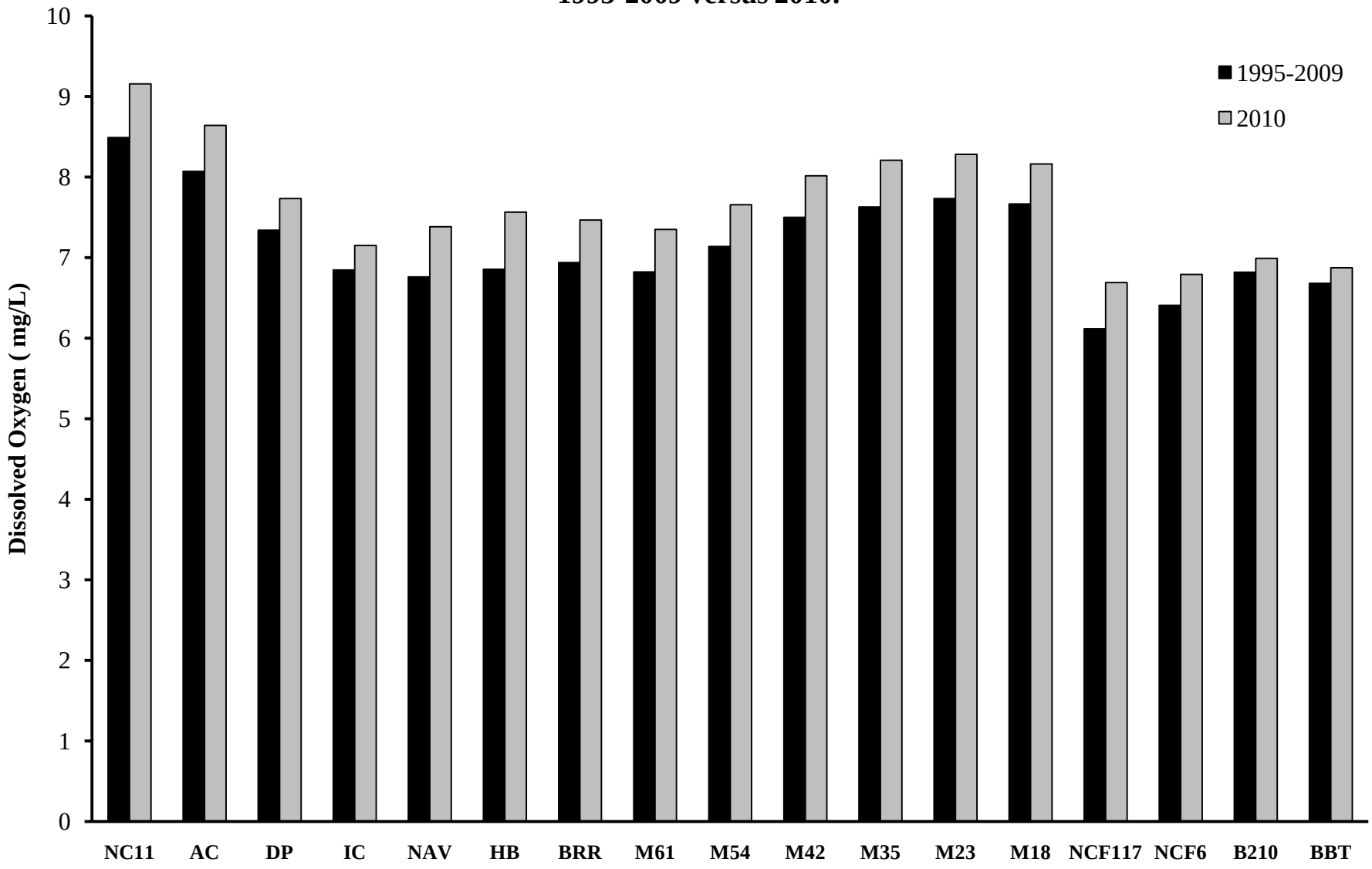


Table 2.6 Field Turbidity (NTU) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	12	12	12	20	14	13	9	8	10	6
FEB	30	31	32	26	36	64	42	30	16	25
MAR	13	15	15	15	19	20	16	11	14	6
APR	16	14	18	13	14	9	8	7	6	11
MAY	18	21	11	11	15	13	15	6	8	15
JUN	11	11	12	11	11	11	9	9	7	17
JUL	13	11	9	7	7	8	9	6	6	14
AUG	14	11	10	9	9	10	14	5	11	4
SEP	19	24	12	7	16	7	4	4	5	13
OCT	30	38	50	25	45	34	20			
NOV	17	11	9	10	9	7	6	6	7	10
DEC	9	9	6	7	7	12	12	11	6	9
mean	**17**	**17**	**16**	**13**	**17**	**17**	**14**	**9**	**9**	**12**
std dev	7	9	13	7	12	16	10	7	4	6
median	15	13	12	11	14	12	11	7	7	11
max	30	38	50	26	45	64	42	30	16	25
min	9	9	6	7	7	7	4	4	5	4

month	NC11	AC	DP	BBT	IC	NCF6
JAN	29	39	34	10	19	7
FEB	37	43	41	16	25	6
MAR	34	42	43	4	16	5
APR	23	28	26	8	15	4
MAY	11	13	14	7	7	18
JUN	22	20	17	8	11	14
JUL	17	12	19	9	13	11
AUG	8	9	13	5	10	20
SEP	8	10	15	11	22	19
OCT	41	31	24	7	16	7
NOV	8	8	12	5	9	20
DEC	9	7	5	5	11	12
mean	**21**	**22**	**22**	**8**	**15**	**12**
std dev	12	14	12	3	5	6
median	20	17	18	8	14	12
max	41	43	43	16	25	20
min	8	7	5	4	7	4

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	9	2	0	1		5	7	13	9
FEB	10	3	2	7	36	9	10	32	20
MAR	8	6	4	2	9	5	6	10	12
APR	14	7	3	5	9	10	6	7	18
MAY	2	3	8	3	7	22	3	7	27
JUN	5	5	6	4	9	12	86	25	49
JUL	3	2	14	7	12	2	7	20	30
AUG	4	9	9	6	8		5	22	12
SEP	6	2	23	13	3	3	4	9	8
OCT	5	3	2	3	5	6	6	13	15
NOV	5	3	4	2	16	5	5	8	8
DEC	8	5	2	3	12	8	12	17	21
mean	**7**	**4**	**6**	**5**	**11**	**8**	**13**	**15**	**19**
std dev	3	2	7	3	9	6	23	8	12
median	6	3	4	4	9	6	6	13	17
max	14	9	23	13	36	22	86	32	49
min	2	2	0	1	3	2	3	7	8

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	4	2	1	0	6	8
FEB	6	4	1	2	10	13
MAR	7	2	1	1	6	10
APR	4	2	2	1	6	7
MAY	4	4	3	4	8	5
JUN	6	5	4	3	122	38
JUL	14	3	5	30	30	45
AUG	14	9	13	56	3	4
SEP		4	7	17	3	6
OCT	3	2	2	2	10	5
NOV	6	4	14	4	3	3
DEC	3	3	3	2	4	5
mean	**6**	**4**	**5**	**10**	**18**	**12**
std dev	4	2	4	17	34	14
median	6	4	3	3	6	7
max	14	9	14	56	122	45
min	3	2	1	0	3	3

month	NCF117	B210	COL	LVC2	SC-CH
JAN	6	3	3	5	25
FEB	33	5	2		15
MAR	5	3	2	12	19
APR	3	2	3	3	6
MAY	6	7	3	7	9
JUN	6	4	2	5	25
JUL	5	3	1	5	10
AUG	2	2	1	5	13
SEP	2	2	1	3	6
OCT	3	2	1	8	4
NOV	4	2	2	3	20
DEC	3	9	2	3	22
mean	**7**	**4**	**2**	**5**	**15**
std dev	8	2	1	3	8
median	5	3	2	5	14
max	33	9	3	12	25
min	2	2	1	3	4

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2009 versus 2010.

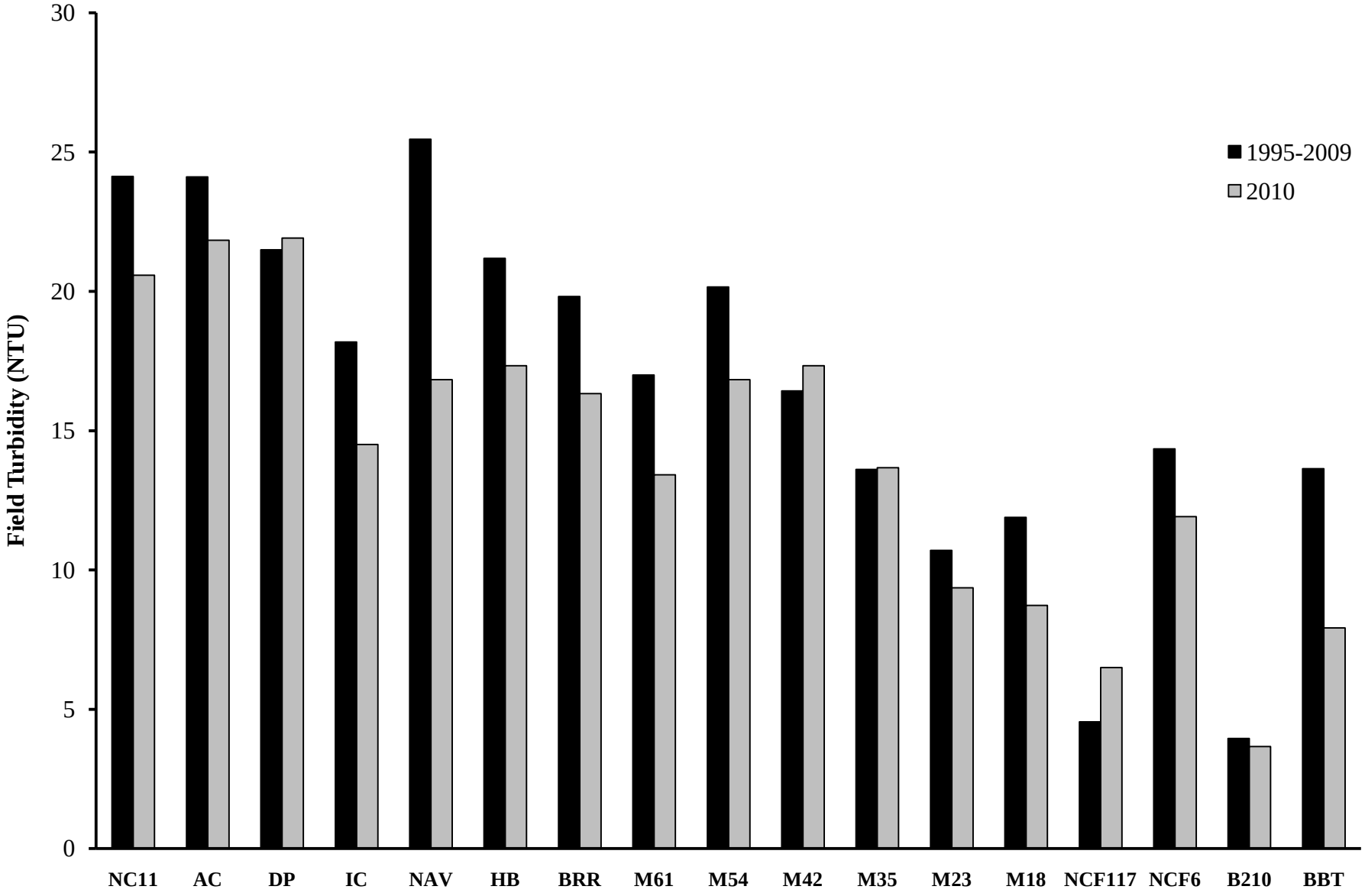


Table 2.7 Total Suspended Solids (mg/L) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	6	6	6	11	10	11	8	7	8	10
FEB	12	16	12	10	14	57	24	17	18	18
MAR	7	8	7	9	13	17	12	9	8	8
APR	15	10	10	9	14	8	8	12	8	16
MAY	14	20	10	9	16	15	9	14	9	27
JUN	6	7	6	9	9	8	7	8	12	17
JUL	8	6	8	8	12	12	12	10	10	18
AUG	12	11	11	12	14	10	18	8	9	14
SEP	31	37	20	13	25	19	13	16	12	34
OCT	22	25	30	16	54	24	16			
NOV	13	9	8	11	11	13	7	12	8	12
DEC	9	7	8	8	11	22	17	18	16	16
mean	**13**	**14**	**11**	**10**	**17**	**18**	**13**	**12**	**11**	**17**
std dev	7	10	7	2	12	13	5	4	4	8
median	12	10	9	10	13	14	12	12	9	16
max	31	37	30	16	54	57	24	18	18	34
min	6	6	6	8	9	8	7	7	8	8

month	NC11	AC	DP	IC	NCF6
JAN	15	21	21	7	5
FEB	18	19	21	12	2
MAR	33	55	52	13	9
APR	23	25	28	16	8
MAY	9	9	12	3	6
JUN	18	19	10	7	14
JUL	9	9	2	10	9
AUG	9	12	14	10	38
SEP	4	8	7	15	28
OCT	17	20	13	12	6
NOV	3	5	6	6	21
DEC	6	6	4	9	13
mean	**14**	**17**	**16**	**10**	**13**
std dev	9	14	14	4	11
median	12	15	13	10	9
max	33	55	52	16	38
min	3	5	2	3	2

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1	1	1	1		1	3	6	4
FEB	2	1	1	2	9	36	7	18	7
MAR	7	4	1	1	4	3	4	5	5
APR	5	5	1	2	5	4	1	3	10
MAY	5	3	10	4	8	30	2	6	25
JUN	6	6	9	4	7	14	37	14	24
JUL	5	5	10	6	29	2	2	12	4
AUG	5	10	8	4	7		3	12	8
SEP	7	2	13	8	6	2	4	8	11
OCT	2	2	2	2	4	3	2	9	118
NOV	2	2	2	2	34	10	2	3	15
DEC	2	2	3	3	6	4	8	8	9
mean	**4**	**4**	**5**	**3**	**11**	**10**	**6**	**9**	**20**
std dev	2	3	5	2	11	12	10	5	32
median	5	2	2	3	7	4	3	8	9
max	7	10	13	8	34	36	37	18	118
min	1	1	1	1	4	1	1	3	4

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	1	1	1	1	3	1
FEB	2	1	1	1	9	4
MAR	2	1	1	1	4	3
APR	5	1	1	3	9	4
MAY	2	2	2	10	6	3
JUN	6	4	4	3	105	23
JUL	10	2	5	13	26	30
AUG	15	7	13	22	4	4
SEP		2	4	11	2	5
OCT	2	2	2	3	10	8
NOV	4	3	9	6	2	3
DEC	2	2	2	2	2	3
mean	**5**	**2**	**4**	**6**	**15**	**8**
std dev	4	2	4	7	29	9
median	2	2	2	3	5	4
max	15	7	13	22	105	30
min	1	1	1	1	2	1

month	NCF117	B210	COL	LVC2
JAN	3	1	1	2
FEB	3	1	1	
MAR	2	1	1	4
APR	5	2	1	5
MAY	5	2	2	4
JUN	8	1	2	3
JUL	4	2	2	4
AUG	5	2	2	5
SEP	4	2	2	4
OCT	2	2	2	3
NOV	3	2	2	2
DEC	5	2	2	2
mean	**4**	**2**	**2**	**4**
std dev	2	0	0	1
median	4	2	2	4
max	8	2	2	5
min	2	1	1	2

Table 2.8 Light Attenuation (k) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	2.62	3.11	2.44	3.43	2.94	2.97	2.56	2.08	2.78	2.11
FEB	3.51	3.51	3.47	4.06	4.00	6.20	4.48	3.75	2.38	3.38
MAR	2.51	2.62	2.63	3.05	3.02	3.14	2.92	2.14	2.20	1.63
APR	3.35	3.11	3.19	3.07	3.07	2.54	2.24	1.84	1.46	2.24
MAY										2.30
JUN	2.14	2.45	2.43	2.41	2.46	2.39	1.50	1.68	1.98	2.20
JUL	2.81	2.65	2.39	1.48	1.78	1.94	1.91	1.38	1.17	1.69
AUG	2.30	2.08	2.13	1.77	1.82	1.74	1.75	1.06	0.87	1.03
SEP	3.34	3.58	2.34	1.69	3.06	1.56	1.13	0.98	1.01	2.03
OCT			5.75	5.87	7.39	6.12	5.24			
NOV										
DEC	3.31	2.87	2.90	3.10	2.06	2.30	1.62	1.62	0.87	1.65
mean	**2.88**	**2.89**	**2.97**	**2.99**	**3.16**	**3.09**	**2.54**	**1.84**	**1.64**	**2.03**
std dev	0.51	0.49	1.06	1.31	1.64	1.69	1.34	0.82	0.72	0.61
median	2.81	2.87	2.54	3.06	2.98	2.47	2.08	1.68	1.46	2.07
max	3.51	3.58	5.75	5.87	7.39	6.20	5.24	3.75	2.78	3.38
min	2.14	2.08	2.13	1.48	1.78	1.56	1.13	0.98	0.87	1.03

month	NC11	AC	DP	BBT	IC	NCF6
JAN	3.41	3.50	3.25	2.94	3.08	4.41
FEB	3.21	3.62	3.37	2.80	3.22	3.62
MAR	3.9	4.29	4.08	2.98	3.26	4.07
APR	3.2	3.50	3.68	3.25	3.37	4.16
MAY	2.4	2.46	2.58	2.93	2.47	5.12
JUN						
JUL	3.7	3.75	4.80	4.44	4.26	2.99
AUG	2.38	3.62	3.37	3.09		3.38
SEP	1.97	2.38	3.39	3.02	3.70	2.47
OCT	4.48	4.00	3.74	4.14	4.24	4.59
NOV						
DEC	1.96	2.03	2.78	2.73	3.32	3.80
mean	**3.06**	**3.32**	**3.50**	**3.23**	**3.44**	**3.86**
std dev	0.85	0.75	0.63	0.58	0.56	0.78
median	3.20	3.56	3.38	3.00	3.32	3.94
max	4.48	4.29	4.80	4.44	4.26	5.12
min	1.96	2.03	2.58	2.73	2.47	2.47

Table 2.9 Total Nitrogen (µg/l) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	1,060	1,090	1,060	1,100	1,090	990	690	660	560	480
FEB	1,240	1,140	1,150	1,430	1,430	1,500	1,220	940	380	890
MAR	1,200	1,270	1,280	1,290	1,290	1,040	1,030	630	590	450
APR	1,170	990	1,060	960	1,240	810	560	420	270	540
MAY	1,170	1,030	850	750	680	730	450	200	600	400
JUN	1,040	1,140	1,150	1,660	1,120	1,120	1,080	700	510	540
JUL	1,200	1,070	830	1,040	1,050	490	430	200	200	300
AUG	1,250	1,350	1,310	1,030	950	960	770	650	620	550
SEP	830	890	690	360	580	510	340	130	120	250
OCT	990	900	930	930	830	810	870			
NOV	1,240	970	870	760	760	590	660	150	420	140
DEC	1,480	1,300	1,270	770	850	670	580	410	300	480
mean	**1,156**	**1,095**	**1,038**	**1,007**	**989**	**852**	**723**	**463**	**415**	**456**
std dev	155	145	194	330	248	278	266	259	167	186
median	1,185	1,080	1,060	995	1,000	810	675	420	420	480
max	1,480	1,350	1,310	1,660	1,430	1,500	1,220	940	620	890
min	830	890	690	360	580	490	340	130	120	140

month	NC11	AC	DP	IC	NCF6
JAN	600	960	610	850	1,430
FEB	1,010	1,020	1,030	1,020	1,540
MAR	1,410	1,400	1,420	1,180	1,480
APR	1,160	1,260	1,110	2,340	1,230
MAY	1,440	1,470	1,750	1,390	980
JUN	1,140	1,090	1,090	1,250	940
JUL	1,390	1,260	1,210	1,200	790
AUG	360	880	690	630	730
SEP	620	850	870	960	420
OCT	1,070	920	930	810	910
NOV	1,340	1,360	1,170	980	1,060
DEC	2,180	2,110	1,520	1,530	990
mean	**1,143**	**1,215**	**1,117**	**1,178**	**1,042**
std dev	460	339	318	426	317
median	1,150	1,175	1,100	1,100	985
max	2,180	2,110	1,750	2,340	1,540
min	360	850	610	630	420

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1,430	2,950	2,160	3,820		1,840	2,230	4,420	850
FEB	1,810	2,990	2,820	3,570	4,350	2,330	2,660	2,070	1,370
MAR	960	2,220	1,910	3,570	2,550	1,500	1,920	4,140	640
APR	1,500	1,640	830	1,700	1,430	1,180	3,470	19,500	940
MAY	1,000	1,820	1,200	1,020	1,190	1,910	3,780	21,100	2,800
JUN	1,100	1,340	530	820	1,070	1,080	3,420	6,760	2,510
JUL	1,100	730	1,200	1,100	2,060	11,300	2,710	30,000	980
AUG	2,500	1,310	1,100	840	1,460		2,290	13,200	820
SEP	1,090	1,810	1,060	750	3,490	910	2,410	19,000	1,220
OCT	1,490	880	630	970	1,100	740	2,650	26,800	1,110
NOV	900	1,000	500	880	860	350	800	21,800	580
DEC	1,200	1,330	500	1,670	840	630	940	3,800	1,020
mean	**1,340**	**1,668**	**1,203**	**1,726**	**1,855**	**2,161**	**2,440**	**14,383**	**1,237**
std dev	435	709	705	1,152	1,104	2,946	878	9,456	671
median	1,150	1,490	1,080	1,060	1,430	1,180	2,530	16,100	1,000
max	2,500	2,990	2,820	3,820	4,350	11,300	3,780	30,000	2,800
min	900	730	500	750	840	350	800	2,070	580

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	2,400	2,080	1,340	190	1,300	1,860
FEB	3,090	2,250	2,460	780	1,560	2,080
MAR	2,550	2,090	2,010	740	1,250	1,270
APR	1,490	840	740	890	840	830
MAY	1,530	1,320	1,160	1,150	950	760
JUN	1,350	1,150	900	880	1,360	840
JUL	1,350	860	940	800	670	910
AUG	1,480	670	830	1,440	250	160
SEP		870	2,650	1,250	450	120
OCT	880	800	570	720	910	890
NOV	1,250	710	1,040	570	460	300
DEC	1,520	670	680	330	170	200
mean	**1,717**	**1,193**	**1,277**	**812**	**848**	**852**
std dev	634	577	677	342	438	609
median	1,490	865	990	790	875	835
max	3,090	2,250	2,650	1,440	1,560	2,080
min	880	670	570	190	170	120

month	NCF117	B210	COL	LVC2
JAN	1,720	1,380	640	580
FEB	1,540	700	1,420	
MAR	1,590	1,420	600	810
APR	1,350	920	900	910
MAY	1,230	1,250	1,100	1,730
JUN	1,110	1,120	1,310	1,830
JUL	890	1,100	1,200	830
AUG	450	1,250	1,040	1,540
SEP	890	920	940	1,220
OCT	810	730	850	670
NOV	1,060	830	1,000	670
DEC	680	610	500	1,120
mean	**1,110**	**1,019**	**958**	**1,083**
std dev	373	262	271	423
median	1,085	1,010	970	910
max	1,720	1,420	1,420	1,830
min	450	610	500	580

Figure 2.4 Total Nitrogen at the Lower Cape Fear River Program mainstem stations, 1995-2009 versus 2010.

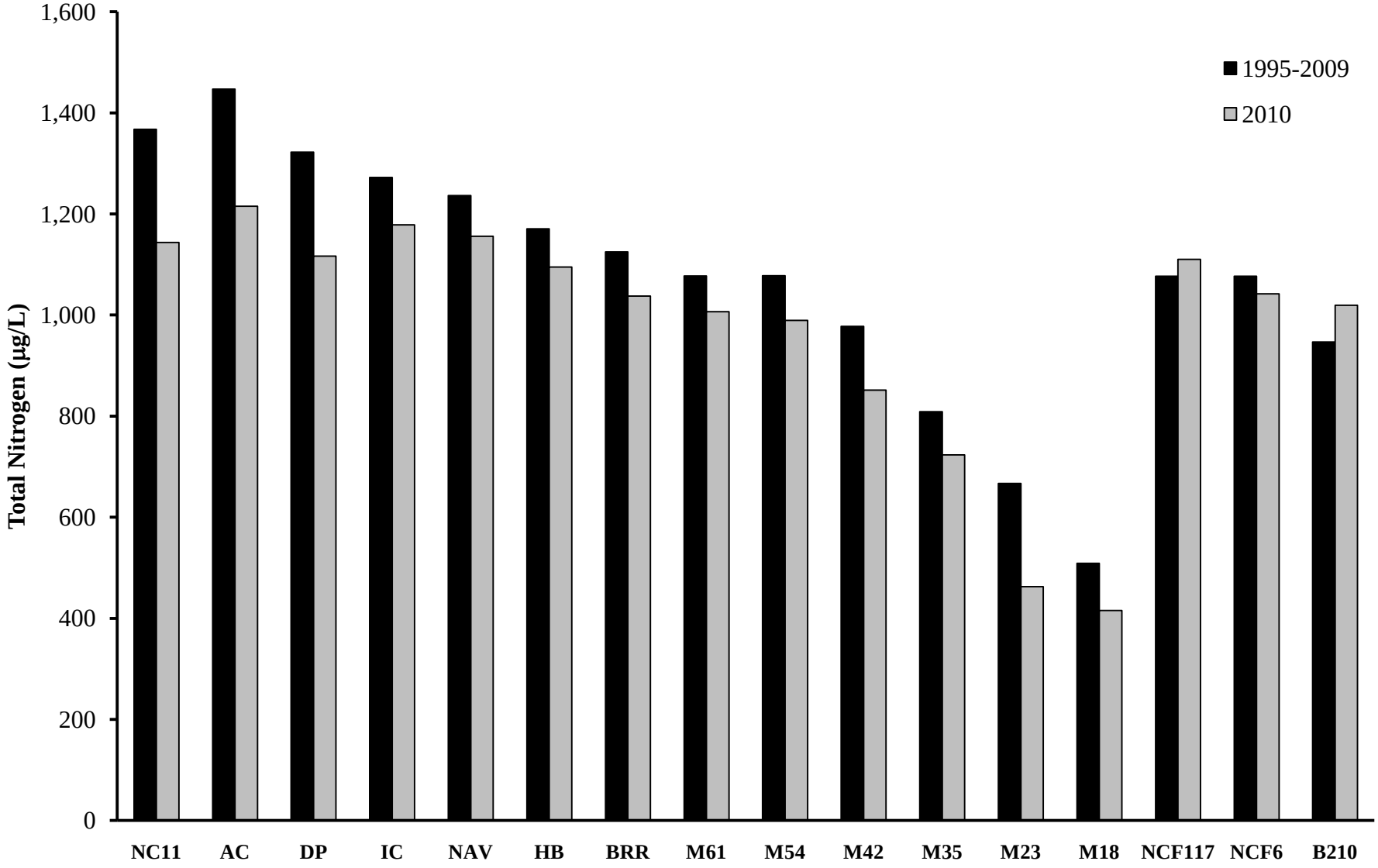


Table 2.10 Nitrate/Nitrite (µg/l) during 2010 at the Lower Cape Fear River stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	760	790	760	700	690	590	490	360	260	180
FEB	640	640	650	830	730	700	620	540	180	490
MAR	700	670	680	690	690	640	630	430	390	250
APR	370	390	360	360	340	310	260	220	70	140
MAY	670	530	450	350	280	130	50	10	10	10
JUN	540	540	550	960	520	520	480	300	210	40
JUL	500	470	430	340	250	190	30	10	10	10
AUG	550	550	510	430	350	260	170	50	20	50
SEP	430	390	390	360	280	210	140	30	10	50
OCT	390	400	530	330	330	310	270			
NOV	740	570	470	360	360	290	260	150	120	40
DEC	980	900	770	470	450	270	180	110	10	80
mean	**606**	**570**	**546**	**515**	**439**	**368**	**298**	**201**	**117**	**122**
std dev	170	152	133	211	168	183	199	175	122	137
median	595	545	520	395	355	300	260	150	70	50
max	980	900	770	960	730	700	630	540	390	490
min	370	390	360	330	250	130	30	10	10	10

month	NC11	AC	DP	IC	NCF6
JAN	600	560	610	650	930
FEB	510	520	530	620	940
MAR	810	800	720	580	580
APR	560	560	510	440	330
MAY	840	970	850	690	380
JUN	640	590	690	650	440
JUL	590	460	510	400	290
AUG	360	580	690	630	330
SEP	620	550	470	560	420
OCT	470	420	430	310	210
NOV	1,040	860	670	480	160
DEC	1,880	1,710	1,120	1,030	390
mean	**743**	**715**	**650**	**587**	**450**
std dev	384	339	184	174	240
median	610	570	640	600	385
max	1,880	1,710	1,120	1,030	940
min	360	420	430	310	160

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	330	2,550	1,960	3,520		1,540	1,930	4,420	650
FEB	610	2,290	2,020	3,070	3,350	1,630	1,860	1,170	570
MAR	60	1,620	1,410	3,070	1,850	1,000	1,320	3,840	140
APR	100	340	30	900	330	180	2,170	19,500	40
MAY	10	520	10	220	90	510	2,880	21,100	10
JUN	10	140	30	120	170	280	1,820	5,460	810
JUL	10	30	10	10	60	10,700	1,710	30,000	80
AUG	10	110	10	40	360		1,390	12,000	120
SEP	90	610	60	50	1,390	210	1,410	19,000	20
OCT	90	280	30	470	600	240	1,850	26,800	110
NOV	10	300	10	680	160	50	300	21,800	80
DEC	200	630	10	1,270	140	130	340	3,000	420
mean	**128**	**785**	**466**	**1,118**	**773**	**1,497**	**1,582**	**14,008**	**254**
std dev	172	833	781	1,272	986	2,960	689	9,763	269
median	75	430	30	575	330	280	1,765	15,500	115
max	610	2,550	2,020	3,520	3,350	10,700	2,880	30,000	810
min	10	30	10	10	60	50	300	1,170	10

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	2,000	168	134	190	1,100	1,360
FEB	2,390	1,750	1,860	480	960	1,080
MAR	2,150	1,690	1,510	340	750	770
APR	790	240	40	90	240	230
MAY	930	520	60	450	250	160
JUN	550	250	100	80	260	140
JUL	850	460	440	10	170	310
AUG	880	370	130	40	250	60
SEP		470	1,950	50	450	10
OCT	380	200	70	20	210	290
NOV	650	210	40	70	260	10
DEC	1,120	370	380	30	170	10
mean	**1,154**	**558**	**560**	**154**	**423**	**369**
std dev	661	531	718	164	313	434
median	880	370	132	75	255	195
max	2,390	1,750	1,950	480	1,100	1,360
min	380	168	40	10	170	10

month	NCF117	B210	COL	LVC2
JAN	1,020	980	40	280
FEB	840	10	820	
MAR	890	920	10	310
APR	450	220	10	110
MAY	230	350	10	630
JUN	310	320	110	830
JUL	190	100	10	230
AUG	150	150	40	740
SEP	290	220	40	520
OCT	110	130	50	170
NOV	160	230	10	70
DEC	180	310	10	220
mean	**402**	**328**	**97**	**374**
std dev	312	293	220	250
median	260	225	25	280
max	1,020	980	820	830
min	110	10	10	70

Table 2.11 Ammonium (µg/l) during 2010 at the Lower Cape Fear River stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	5	80	80	100	90	90	70	50	10	20
FEB	5	5	10	20	30	20	40	20	5	20
MAR	30	10	20	70	150	80	50	30	30	10
APR	40	50	60	80	240	70	60	30	5	5
MAY	90	70	80	60	160	5	5	5	5	5
JUN	60	60	60	80	60	70	90	30	20	40
JUL	70	70	60	30	5	10	10	5	5	5
AUG	30	40	10	10	10	5	10	5	5	5
SEP	20	20	5	10	5	5	5	5	5	5
OCT	40	30	70	20	60	50	50			
NOV	50	50	50	80	80	70	80	20	20	5
DEC	90	80	90	100	120	60	50	30	20	10
mean	**44**	**47**	**50**	**55**	**84**	**45**	**43**	**21**	**12**	**12**
std dev	29	26	30	35	73	33	30	15	9	11
median	40	50	60	65	70	55	50	20	5	5
max	90	80	90	100	240	90	90	50	30	40
min	5	5	5	10	5	5	5	5	5	5

month	NC11	AC	DP	IC	NCF6
JAN	50	60	60	60	40
FEB	10	10	5	10	10
MAR	40	80	70	40	40
APR	20	60	60	50	40
MAY	20	20	120	120	20
JUN	40	80	70	70	60
JUL	40	180	160	90	10
AUG	30	220	50	50	300
SEP	20	210	70	20	60
OCT	30	40	50	20	10
NOV	40	60	90	60	5
DEC	30	40	40	30	70
mean	**31**	**88**	**70**	**52**	**55**
std dev	12	73	39	32	80
median	30	60	65	50	40
max	50	220	160	120	300
min	10	10	5	10	5

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	130	110	30	50		90	110	130	50
FEB	150	70	40	20	40	30	50	210	40
MAR	40	30	30	20	100	5	30	40	30
APR	180	110	20	130	150	110	40	100	190
MAY	40	620	80	100	230	480	60	150	930
JUN	80	80	30	140	80	100	380	420	710
JUL	10	30	100	340	60	10	40	60	150
AUG	70	90	50	160	140		90	110	120
SEP	160	350	90	260	680	180	150	120	200
OCT	250	100	20	30	60	60	50	30	60
NOV	10	150	20	50	230	40	40	60	10
DEC	70	70	50	60	140	70	70	50	170
mean	**99**	**151**	**47**	**113**	**174**	**107**	**93**	**123**	**222**
std dev	75	170	28	101	180	134	97	107	291
median	75	95	35	80	140	70	55	105	135
max	250	620	100	340	680	480	380	420	930
min	10	30	20	20	40	5	30	30	10

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	120	20	10	20	50	260
FEB	60	20	40	10	20	190
MAR	60	30	30	40	60	70
APR	40	30	20	40	20	40
MAY	40	40	70	40	50	60
JUN	120	70	50	60	70	160
JUL	50	40	50	280	40	40
AUG	70	50	100	500	40	50
SEP		30	50	90	20	30
OCT	10	5	5	10	30	30
NOV	30	5	40	5	10	5
DEC	5	10	50	20	20	5
mean	**55**	**29**	**43**	**93**	**36**	**78**
std dev	38	19	26	148	19	81
median	50	30	45	40	35	45
max	120	70	100	500	70	260
min	5	5	5	5	10	5

month	NCF117	B210	COL	LVC2
JAN	100	5	10	40
FEB	20	5	10	
MAR	30	10	30	220
APR	70	20	5	160
MAY	60	70	50	410
JUN	10	30	80	500
JUL	20	30	40	140
AUG	10	50	160	290
SEP	40	30	100	280
OCT	30	5	10	90
NOV	10	10	5	100
DEC	40	30	10	720
mean	**37**	**25**	**43**	**268**
std dev	28	20	48	205
median	30	25	20	220
max	100	70	160	720
min	10	5	5	40

Table 2.12 Total Kjeldahl Nitrogen (µg/l) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	300	300	300	400	400	400	200	300	300	300
FEB	600	500	500	600	700	800	600	400	200	400
MAR	500	600	600	600	600	400	400	200	200	200
APR	800	600	700	600	900	500	300	200	200	400
MAY	500	500	400	400	400	600	400	200	600	400
JUN	500	600	600	700	600	600	600	400	300	500
JUL	700	600	400	700	800	300	400	200	200	300
AUG	700	800	800	600	600	700	600	600	600	500
SEP	400	500	300	100	300	300	200	100	100	200
OCT	600	500	400	600	500	500	600			
NOV	500	400	400	400	400	300	400	100	300	100
DEC	500	400	500	300	400	400	400	300	300	400
mean	**550**	**525**	**492**	**500**	**550**	**483**	**425**	**273**	**300**	**336**
std dev	132	123	150	173	176	157	142	142	154	123
median	500	500	450	600	550	450	400	200	300	400
max	800	800	800	700	900	800	600	600	600	500
min	300	300	300	100	300	300	200	100	100	100

month	NC11	AC	DP	IC	NCF6
JAN	100	400	100	200	500
FEB	500	500	500	400	600
MAR	600	600	700	600	900
APR	600	700	600	1,900	900
MAY	600	500	900	700	600
JUN	500	500	400	600	500
JUL	800	800	700	800	500
AUG	100	300	100	100	400
SEP	100	300	400	400	100
OCT	600	500	500	500	700
NOV	300	500	500	500	900
DEC	300	400	400	500	600
mean	**425**	**500**	**483**	**600**	**600**
std dev	228	141	223	434	224
median	500	500	500	500	600
max	800	800	900	1,900	900
min	100	300	100	100	100

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1,100	400	200	300		300	300	100	200
FEB	1,200	700	800	500	1,000	700	800	900	800
MAR	900	600	500	500	700	500	600	300	500
APR	1,400	1,300	800	800	1,100	1,000	1,300	100	900
MAY	1,000	1,300	1,200	800	1,100	1,400	900	100	2,800
JUN	1,100	1,200	500	700	900	800	1,600	1,300	1,700
JUL	1,100	700	1,200	1,100	2,000	600	1,000	100	900
AUG	2,500	1,200	1,100	800	1,100		900	1,200	700
SEP	1,000	1,200	1,000	700	2,100	700	1,000	100	1,200
OCT	1,400	600	600	500	500	500	800	100	1,000
NOV	900	700	500	200	700	300	500	100	500
DEC	1,000	700	500	400	700	500	600	800	600
mean	**1,217**	**883**	**742**	**608**	**1,082**	**664**	**858**	**433**	**983**
std dev	418	313	312	243	495	305	338	455	659
median	1,100	700	700	600	1,000	600	850	100	850
max	2,500	1,300	1,200	1,100	2,100	1,400	1,600	1,300	2,800
min	900	400	200	200	500	300	300	100	200

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	400	400	100	100	200	500
FEB	700	500	600	300	600	1,000
MAR	400	400	500	400	500	500
APR	700	600	700	800	600	600
MAY	600	800	1,100	700	700	600
JUN	800	900	800	800	1,100	700
JUL	500	400	500	800	500	600
AUG	600	300	700	1,400	100	100
SEP		400	700	1,200	100	100
OCT	500	600	500	700	700	600
NOV	600	500	1,000	500	200	300
DEC	400	300	300	300	100	200
mean	**564**	**508**	**625**	**667**	**450**	**483**
std dev	130	180	265	361	301	254
median	600	450	650	700	500	550
max	800	900	1,100	1,400	1,100	1,000
min	400	300	100	100	100	100

month	NCF117	B210	COL	LVC2
JAN	700	400	600	300
FEB	700	700	600	300
MAR	700	500	600	500
APR	900	700	900	800
MAY	1,000	900	1,100	1,100
JUN	800	800	1,200	1,000
JUL	700	1,000	1,200	600
AUG	300	1,100	1,000	800
SEP	600	700	900	700
OCT	700	600	800	500
NOV	900	600	1,000	600
DEC	500	300	500	900
mean	**708**	**692**	**867**	**675**
std dev	180	225	236	245
median	700	700	900	650
max	1,000	1,100	1,200	1,100
min	300	300	500	300

Table 2.13 Total Phosphorus (µg/l) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	90	80	150	70	130	60	60	50	60	50
FEB	80	60	70	70	70	140	80	60	40	50
MAR	80	80	70	70	110	80	80	40	50	30
APR	150	100	90	80	100	70	50	40	30	40
MAY	110	110	90	80	110	110	40	30	20	50
JUN	210	110	190	70	130	70	90	40	30	20
JUL	140	130	110	100	80	80	70	40	30	40
AUG	150	130	130	120	100	90	70	40	40	40
SEP	150	160	140	110	110	90	90	60	100	60
OCT	120	140	180	150	180	130	100			
NOV	180	120	100	100	80	70	70	60	40	50
DEC	200	170	140	130	100	80	70	60	40	50
mean	**138**	**116**	**122**	**96**	**108**	**89**	**73**	**47**	**44**	**44**
std dev	42	31	38	26	28	24	16	11	21	11
median	145	115	120	90	105	80	70	40	40	50
max	210	170	190	150	180	140	100	60	100	60
min	80	60	70	70	70	60	40	30	20	20

month	NC11	AC	DP	IC	NCF6
JAN	120	200	90	130	60
FEB	80	90	80	60	40
MAR	150	150	170	90	100
APR	120	140	140	100	70
MAY	140	140	160	140	90
JUN	140	160	130	130	90
JUL	150	180	170	140	90
AUG	120	200	200	170	160
SEP	140	190	160	210	130
OCT	130	120	110	100	150
NOV	160	160	160	150	150
DEC	240	230	170	200	100
mean	**141**	**163**	**145**	**135**	**135**
std dev	36	37	35	42	42
median	140	160	160	135	95
max	240	230	200	210	210
min	80	90	80	60	60

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	230	160	140	60		40	200	400	120
FEB	160	30	40	60	130	50	90	210	100
MAR	80	50	40	70	160	40	100	280	40
APR	160	140	100	170	260	110	400	1,890	300
MAY	90	190	180	290	260	210	790	3,040	860
JUN	90	140	180	290	230	80	710	960	540
JUL	100	510	430	350	1,280	50	440	3,780	210
AUG	120	120	180	320	340		650	1,850	170
SEP	240	180	290	590	690	100	650	2,130	270
OCT	220	90	110	140	160	70	450	2,240	290
NOV	140	120	110	100	330	80	250	2,660	300
DEC	140	90	80	70	270	70	180	580	390
mean	**148**	**152**	**157**	**209**	**374**	**82**	**409**	**1,668**	**299**
std dev	54	118	106	156	321	46	237	1,129	213
median	140	130	125	155	260	70	420	1,870	280
max	240	510	430	590	1,280	210	790	3,780	860
min	80	30	40	60	130	40	90	210	40

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	120	140	120	100	160	150
FEB	50	20	50	10	60	50
MAR	40	10	30	10	40	50
APR	70	30	120	60	80	110
MAY	110	80	100	100	350	170
JUN	120	70	220	90	360	370
JUL	140	70	410	140	140	160
AUG	200	80	590	180	90	210
SEP		110	470	240	70	230
OCT	110	40	120	50	110	140
NOV	170	70	590	90	90	200
DEC	100	50	270	70	60	190
mean	**112**	**64**	**258**	**95**	**134**	**169**
std dev	46	36	197	64	104	82
median	110	70	170	90	90	165
max	200	140	590	240	360	370
min	40	10	30	10	40	50

month	NCF117	B210	COL	LVC2
JAN	40	20	30	30
FEB	60	10	30	
MAR	50	20	10	10
APR	80	50	10	40
MAY	110	110	30	60
JUN	120	110	10	30
JUL	120	70	10	30
AUG	110	110	40	50
SEP	150	140	40	50
OCT	130	40	10	20
NOV	80	70	20	40
DEC	110	90	30	40
mean	**97**	**70**	**23**	**36**
std dev	33	41	12	14
median	110	70	25	40
max	150	140	40	60
min	40	10	10	10

Figure 2.5 Total Phosphorus at the Lower Cape Fear River mainstem stations, 1995-2009 versus 2010.

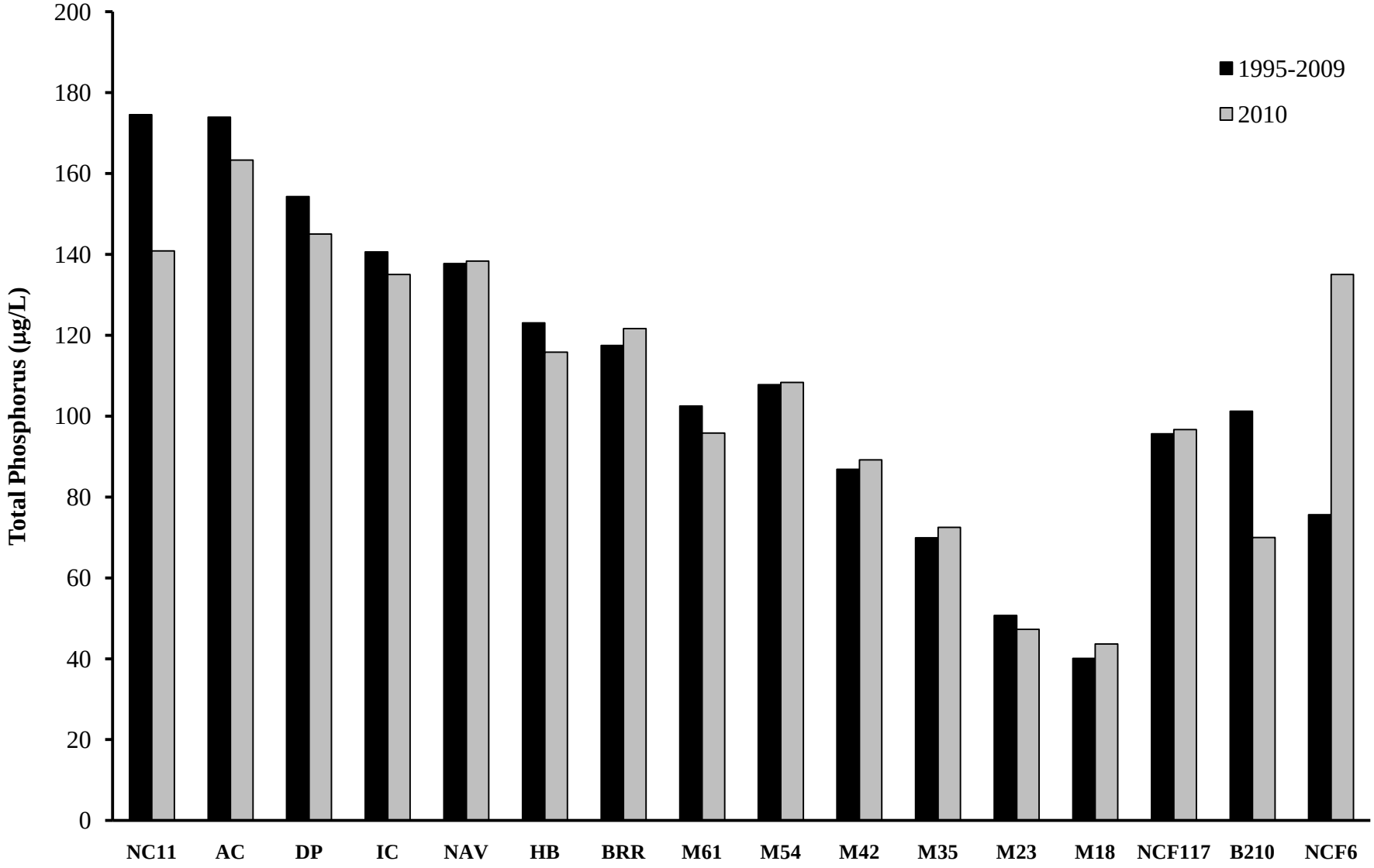


Table 2.14 Orthophosphate (µg/l) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	30	30	30	20	20	20	20	20	10	10
FEB	20	20	20	20	40	20	20	10	10	5
MAR	40	30	40	40	50	30	20	10	5	10
APR										
MAY	40	40	30	20	40	10	10	10	5	20
JUN	60	60	60	40	30	50	30	20	20	10
JUL	80	80	70	50	40	30	10	10	0	10
AUG	70	60	50	50	40	40	30	20	10	20
SEP										
OCT	40	40	40	60	50	50	40			
NOV	70	60	70	30	30	40	40	30	10	10
DEC	90	70	60	40	40	40	10	10	5	10
mean	**54**	**49**	**47**	**37**	**38**	**33**	**23**	**16**	**8**	**12**
std dev	23	20	18	14	9	13	12	7	6	5
median	50	50	45	40	40	35	20	10	10	10
max	90	80	70	60	50	50	40	30	20	20
min	20	20	20	20	20	10	10	10	0	5

month	NC11	AC	DP	BBT	IC	NCF6
JAN	20	20	50	10	20	20
FEB	30	30	30	10	30	20
MAR	40	40	40		30	30
APR						
MAY	60	70	80	50	70	40
JUN	70	70	80	40	60	30
JUL	50	90	80	40	60	40
AUG	40	110	110	70	100	50
SEP						
OCT	50	40	40	30	30	110
NOV	90	90	80	30	60	50
DEC	80	110	40	100	110	40
mean	**53**	**67**	**63**	**42**	**57**	**43**
std dev	22	33	26	29	31	26
median	50	70	65	40	60	40
max	90	110	110	100	110	110
min	20	20	30	10	20	20

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	70	20	10	20		10	60	220	5
FEB	70	20	10	40	80	10	60	210	10
MAR	100	50	40	110	80	20	280	1,880	10
APR									
MAY	20	60	40	120	120	30	670	2,940	200
JUN	20	50	40	130	60	20	480	790	310
JUL	10	60	60	60	50	10	30	2,350	60
AUG	40	40	40	150	70	5	70	1,650	50
SEP									
OCT	170	30	30	70	70	20	240	2,140	40
NOV	80	30	40	40	110	30	20	2,340	40
DEC	70	40	30	20	80	20	70	320	230
mean	**65**	**40**	**34**	**76**	**80**	**18**	**198**	**1,484**	**96**
std dev	47	15	15	48	22	9	221	1,015	109
median	70	40	40	65	80	20	70	1,765	45
max	170	60	60	150	120	30	670	2,940	310
min	10	20	10	20	50	5	20	210	5

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	20	5	20	5	20	20
FEB	10	5	20	5	10	10
MAR	20	10	80	10	20	40
APR						
MAY	40	30	100	20	20	60
JUN	40	30	130	20	30	70
JUL	50	30	230	10	30	30
AUG	60	30	270	10	20	110
SEP						
OCT	60	10	70	10	40	70
NOV	40	20	240	20	90	30
DEC	40	20	130	30	40	110
mean	**38**	**19**	**129**	**14**	**32**	**55**
std dev	17	11	90	8	23	35
median	40	20	115	10	25	50
max	60	30	270	30	90	110
min	10	5	20	5	10	10

month	NCF117	B210	COL	LVC2
JAN	20	10	10	5
FEB	20	10	5	
MAR	30	20	5	
APR				
MAY	40	30	10	5
JUN	50	50	10	10
JUL	40	30	5	5
AUG	40	40	20	5
SEP				
OCT	80	20	5	5
NOV	40	50	20	10
DEC	50	30	5	5
mean	**41**	**29**	**10**	**6**
std dev	17	14	6	2
median	40	30	8	5
max	80	50	20	10
min	20	10	5	5

Table 2.15 Chlorophyll *a* (µg/l) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	3	3	3	2	2	2	2	5	4	6
FEB	4	3	3	2	3	4	3	3	4	3
MAR	5	5	6	4	3	3	3	3	4	5
APR	9	8	9	7	4	10	9	5	5	4
MAY	5	8	12	24		76	23	7	4	7
JUN	5	6	6	9	10	9	14	13	13	22
JUL	7	16	5	21	20	22	33	12	9	8
AUG	5	6	14	13	10	14	13	6	6	5
SEP	6	7	7	8	10	15	8	7	7	7
OCT	1	2	2	1	3	2	2			
NOV	2	2	2	3	3	3	4	3	3	5
DEC	2	2	2	3	3	4	4	4	5	4
mean	**5**	**6**	**6**	**8**	**6**	**14**	**10**	**6**	**6**	**7**
std dev	2	4	4	7	5	20	9	3	3	5
median	5	6	6	6	3	7	6	5	5	5
max	9	16	14	24	20	76	33	13	13	22
min	1	2	2	1	2	2	2	3	3	3

month	NC11	AC	DP	BBT	IC	NCF6
JAN	6	6	3	1	6	1
FEB	10	9	9	3	5	1
MAR	6	3	4	1	3	1
APR	8	7	7	2	4	2
MAY	11	11	9	2	4	3
JUN	7	9	7	2	4	7
JUL	39	10	6	2	4	12
AUG	47	31	23	12	17	7
SEP	24	8	3	2	6	4
OCT	2	1	1	1	1	0
NOV	2	1	1	0	1	1
DEC	0	0	0	0	0	1
mean	**14**	**8**	**6**	**2**	**5**	**3**
std dev	15	8	6	3	4	3
median	8	8	5	2	4	2
max	47	31	23	12	17	12
min	0	0	0	0	0	0

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1	1	1	3		1	1	1	0
FEB	2	2	2	4	2	2	2	2	3
MAR	2	2	1	2	3	4	1	2	1
APR	3	2	6	2	8	4	1	2	2
MAY	19	2	43	8	8	7	2	1	10
JUN	28	2	5	7	42	2	4	4	3
JUL	26	8	29	34	217	3	2	29	3
AUG	47	3	7	8	39		2	4	10
SEP	49	1	16	11	34	3	1	2	23
OCT	2	1	3	5	25	12	0	1	1
NOV	1	1	2	2	13	5	1	1	2
DEC	4	2	1	4	3	9	1	5	1
mean	**15**	**2**	**10**	**8**	**36**	**5**	**2**	**5**	**5**
std dev	17	2	13	8	59	3	1	8	6
median	4	2	4	5	13	4	1	2	3
max	49	8	43	34	217	12	4	29	23
min	1	1	1	2	2	1	0	1	0

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	1	1	1	1	1	1
FEB	2	2	1	1	1	2
MAR	2	3	1	1	1	4
APR	1	3	2	3	2	2
MAY	1	1	1	3	1	1
JUN	1	1	2	5	5	3
JUL	2	1	2	5	5	14
AUG	3	2	5	62	1	4
SEP		0	14	14	1	4
OCT	1	0	1	2	2	1
NOV	1	0	3	2	5	1
DEC	0	1	1	1	1	1
mean	**1**	**1**	**3**	**8**	**2**	**3**
std dev	1	1	4	17	2	3
median	1	1	2	3	1	2
max	3	3	14	62	5	14
min	0	0	1	1	1	1

month	NCF117	B210	COL	LVC2
JAN	0	3	0	1
FEB	1	2	1	
MAR	1	2	7	1
APR	1	2	3	8
MAY	1	1	1	10
JUN	4	1	1	11
JUL	11	1	0	18
AUG	11	2	1	19
SEP	3	1	2	14
OCT	0	0	0	1
NOV	0	0	0	1
DEC	0	0	0	1
mean	**3**	**1**	**1**	**8**
std dev	4	1	2	7
median	1	1	1	8
max	11	3	7	19
min	0	0	0	1

Figure 2.6 Chlorophyll *a* at the Lower Cape Fear River mainstem stations, 1995-2009 versus 2010.

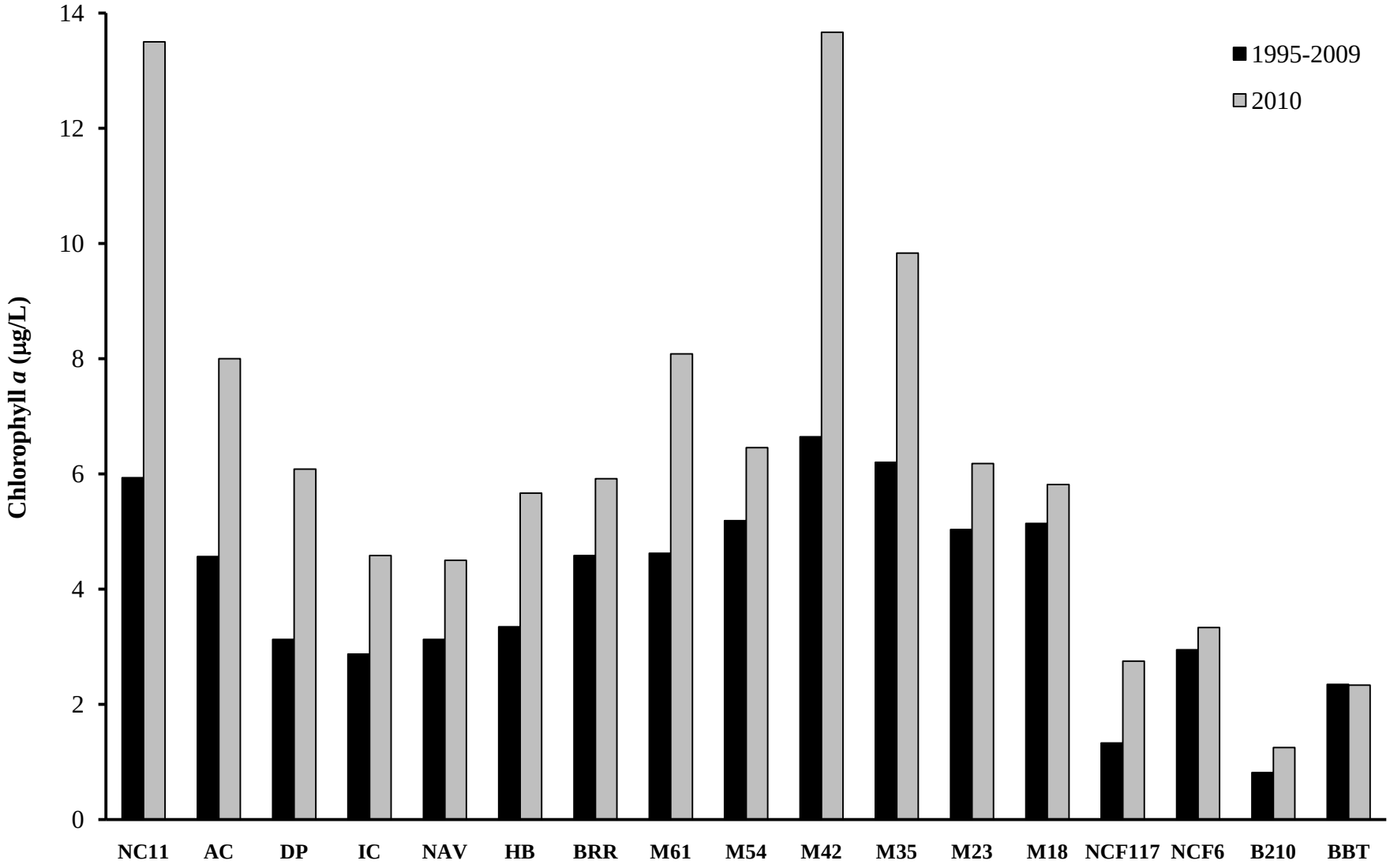


Table 2.16 Biochemical Oxygen Demand (mg/l) during 2010 at the Lower Cape Fear River Program stations.

5-Day Biochemical Oxygen Demand

month	NC11	AC	NCF117	B210	LVC2	BBT
JAN	1.2	1.7	0.8	0.7	0.8	1.0
FEB			0.9	0.9		
MAR	1.2	1.4	0.9	1.0	1.8	1.0
APR	1.3	1.8	1.6	1.5	1.6	1.2
MAY	1.7	1.0	1.1	0.9	2.7	0.8
JUN	1.5	1.5	0.7	1.3	2.1	1.1
JUL	3.1	1.9	0.9	1.3	1.6	1.6
AUG	1.8	2.3	2.0	1.0	1.9	1.5
SEP	2.8	1.7	0.8	1.1	1.8	1.2
OCT	1.4	1.7	3.3		3.1	1.4
NOV	2.4	1.4				0.7
DEC	0.6	1.1	0.6	0.6	1.2	1.0
mean	1.7	1.6	1.2	1.0	1.9	1.1
stdev	0.8	0.4	0.8	0.3	0.7	0.3
median	1.5	1.7	0.9	1.0	1.8	1.1
max	3.1	2.3	3.3	1.5	3.1	1.6
min	0.6	1.0	0.6	0.6	0.8	0.7

20-Day Biochemical Oxygen Demand

month	NC11	AC	NCF117	B210	LVC2	BBT
JAN	2.9	3.5	2.3	1.5	2.2	2.1
FEB			2.0	1.8		
MAR	3.2	3.8	2.8	2.0	4.6	2.7
APR	4.0	4.7	4.3	3.5	4.6	3.4
MAY						
JUN	2.8	3.2	2.1	3.2	5.5	2.8
JUL	6.6	5.2	2.2	3.0	4.1	3.8
AUG	4.6	7.2	3.3	2.4	5.5	3.7
SEP	5.9	5.5	2.4	2.9	5.1	3.4
OCT	4.7	5.3	4.9		3.6	4.2
NOV	3.5	4.6	3.5	2.4	3.9	2.4
DEC	3.5	3.4	2.6	1.9	5.8	3.6
mean	4.2	4.6	2.9	2.5	4.5	3.2
stdev	1.3	1.2	1.0	0.7	1.1	0.7
median	3.8	4.7	2.6	2.4	4.6	3.4
max	6.6	7.2	4.9	3.5	5.8	4.2
min	2.8	3.2	2.0	1.5	2.2	2.1

Table 2.17 Fecal Coliform (cfu/100 ml) during 2010 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	19	10	19	5	5	5	5	5	5	5
FEB	73	91	64	37	91	136	73	82	28	10
MAR	19	19	37	46	109	64	73	5	10	5
APR	5	28	28	37	5	5	10	5	5	5
MAY	109	28	55	10	10	10	10	10	10	10
JUN	19	10	46	28	10	28	10	10	10	10
JUL	28	10	10	19	5	5	5	5	5	5
AUG	19	19	19	28	5	5	5	5	5	5
SEP	28	109	10	10	10	10	5	5	5	5
OCT	82	154	136	136	145	210	91			
NOV	37	46	19	28	5	10	5	5	5	10
DEC	19	5	19	10	19	5	5	5	5	28
mean	**38**	**44**	**39**	**33**	**35**	**41**	**25**	**13**	**8**	**9**
std dev	31	46	34	33	48	63	32	22	7	6
max	109	154	136	136	145	210	91	82	28	28
min	5	5	10	5	5	5	5	5	5	5
Geomea	28	26	29	23	14	15	12	7	7	8

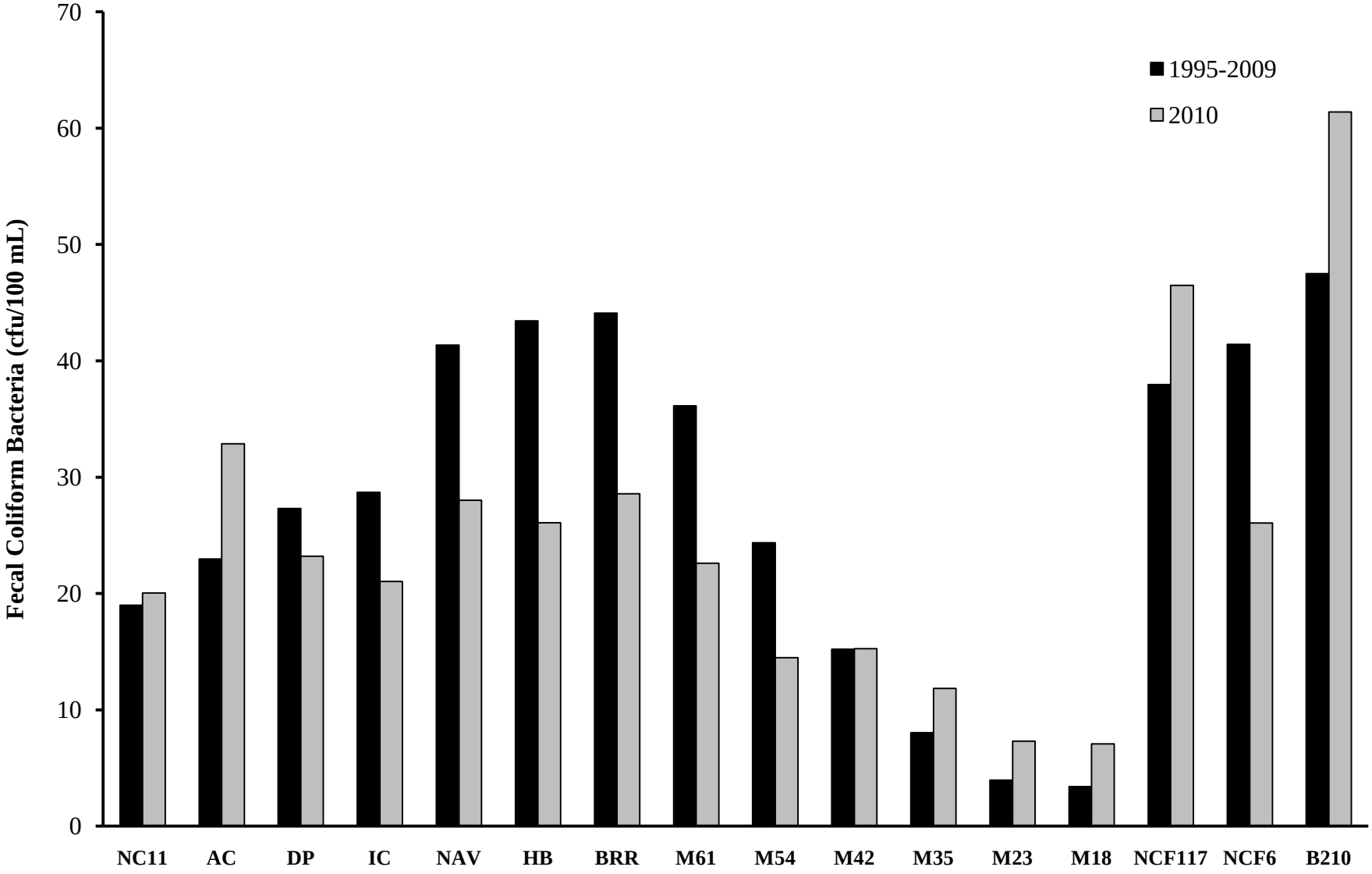
month	NC11	AC	DP	IC	NCF6
JAN	46	64	136	64	10
FEB	37	55	37	46	46
MAR	10	10	5	10	10
APR	10	19	28	28	19
MAY	10	10	10	10	10
JUN	19	37	19	10	100
JUL	28	310	10	10	55
AUG	5	64	28	19	64
SEP	64	37	55	46	19
OCT	145	46	64	55	73
NOV	10	19	37	10	46
DEC	10	10	5	19	5
mean	**33**	**57**	**36**	**27**	**38**
std dev	38	79	35	19	29
max	145	310	136	64	100
min	5	10	5	10	5
Geomea	20	33	23	21	26

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	28	100	10	64		37	91	819	19
FEB	163	290	37	64	390	118	172	350	352
MAR	37	46	5	10	46	10	10	199	10
APR	28	118	109	270	181	136	19	172	100
MAY	73	172	109	136	637	13,000	73	82	21,000
JUN	480	127	127	310	1,091	4,300	6,000	5,300	12,000
JUL	37	73	637	109	637	172	100	1,091	46
AUG	145	330	546	73	3,400		163	2,182	350
SEP	190	37	100	637	190	455	210	273	380
OCT	55	109	181	82	199	220	172	910	340
NOV	91	55	163	5	163	46	10	100	100
DEC	91	637	100	127	430	109	1,091	637	5,900
mean	**118**	**175**	**177**	**157**	**669**	**1,691**	**676**	**1,010**	**3,383**
std dev	121	165	193	170	910	3,770	1,629	1,414	6,344
max	480	637	637	637	3,400	13,000	6,000	5,300	21,000
min	28	37	5	5	46	10	10	82	10
Geomea	81	123	90	84	359	206	119	483	336

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	55	136	91	37	270	390
FEB	181	64	109	46	55	154
MAR	10	10	28	64	28	55
APR	100	5	28	10	210	910
MAY	55	55	127	127	210	181
JUN	570	300	4,600	390	23,000	6,000
JUL	280	46	136	1,728	8,000	1,091
AUG	1,000	637	1,728	15,000	273	819
SEP		46	109	240	290	5
OCT	380	364	100	118	230	154
NOV	55	91	250	37	190	260
DEC	73	300	28	37	250	455
mean	**251**	**171**	**611**	**1,486**	**2,751**	**873**
std dev	288	184	1,285	4,100	6,472	1,583
max	1,000	637	4,600	15,000	23,000	6,000
min	10	5	28	10	28	5
Geomea	127	82	144	139	346	283

month	NCF117	B210	COL	LVC2	SC-CH
JAN	55	64	28	163	46
FEB	163	46	64		64
MAR	46	64	28	91	37
APR	28	82	10	10	28
MAY	10	37	73	64	55
JUN	73	5	19	28	82
JUL	10	163	10	118	364
AUG	64	230	73	28	28
SEP	127	145	37	64	73
OCT	55	55	55	127	100
NOV	37	73	55	46	64
DEC	73	46	37	37	3,400
mean	**62**	**84**	**41**	**71**	**362**
std dev	43	61	22	46	920
max	163	230	73	163	3,400
min	10	5	10	10	28
Geomea	46	61	34	54	88

Figure 2.7 Fecal Coliform Bacteria at the Lower Cape Fear River mainstem stations, 1995-2009 versus 2010.



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 $\leq$ 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 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 (≤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 pres

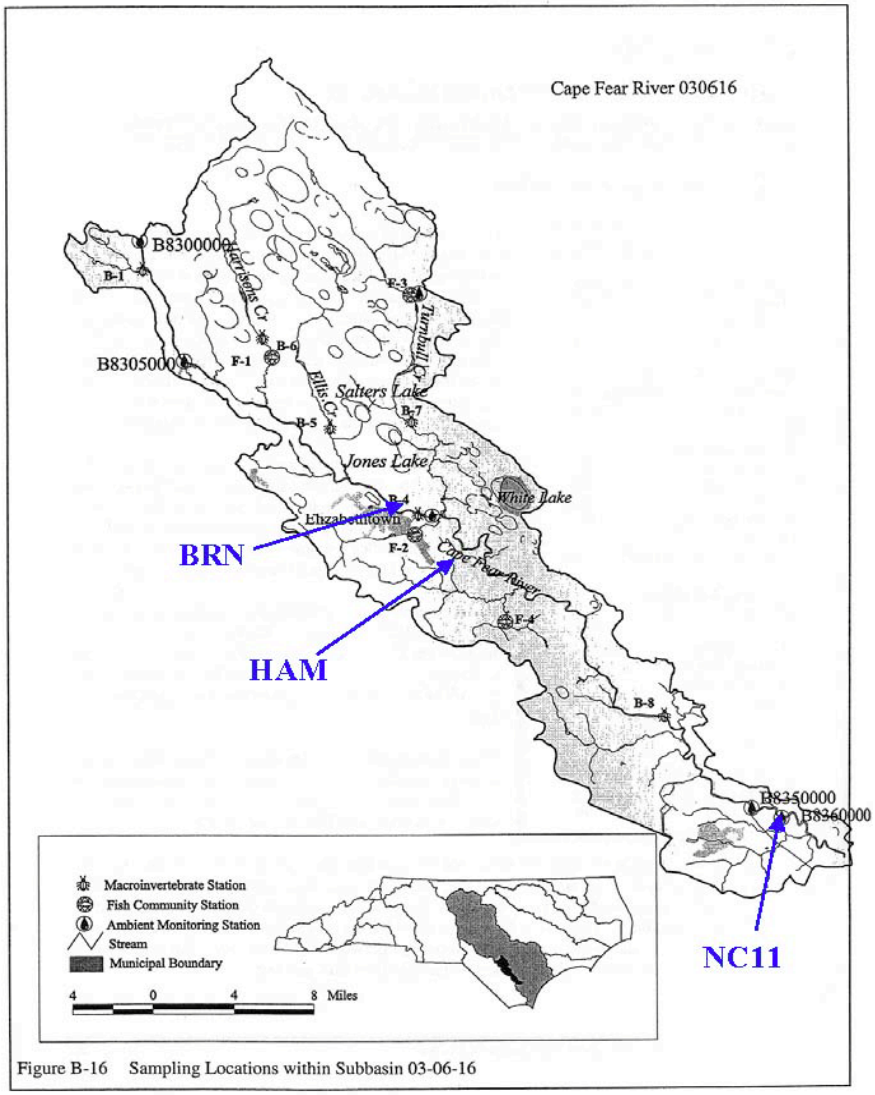


Figure B-16 Sampling Locations within Subbasin 03-06-16

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 deep channel, 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 25% 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 August 2010.

For fecal coliform bacteria concentrations NC11 had a good rating (Table 3.3.1). BRN and HAM received poor ratings exceeding the standard 75% and 58% of the time, respectively (Figure 3.3.1).

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

For nitrate BRN and HAM received a poor rating exceeding the standard 84% and 50% of the time, respectively (Table, 3.3.1, Figure 3.3.2). A fair rating was given to NC11 for nitrate as samples exceeded the standard on two occasions in 2010. All stations rated good for total phosphorus.

Table 3.3.1 UNCW AEL 2010 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	F	G

Figure 3.3.1 Fecal coliform bacteria concentrations at the LCFRP stations BRN and HAM for 2010. The dashed line represents the NC State Standard, 200 cfu/100 mL.

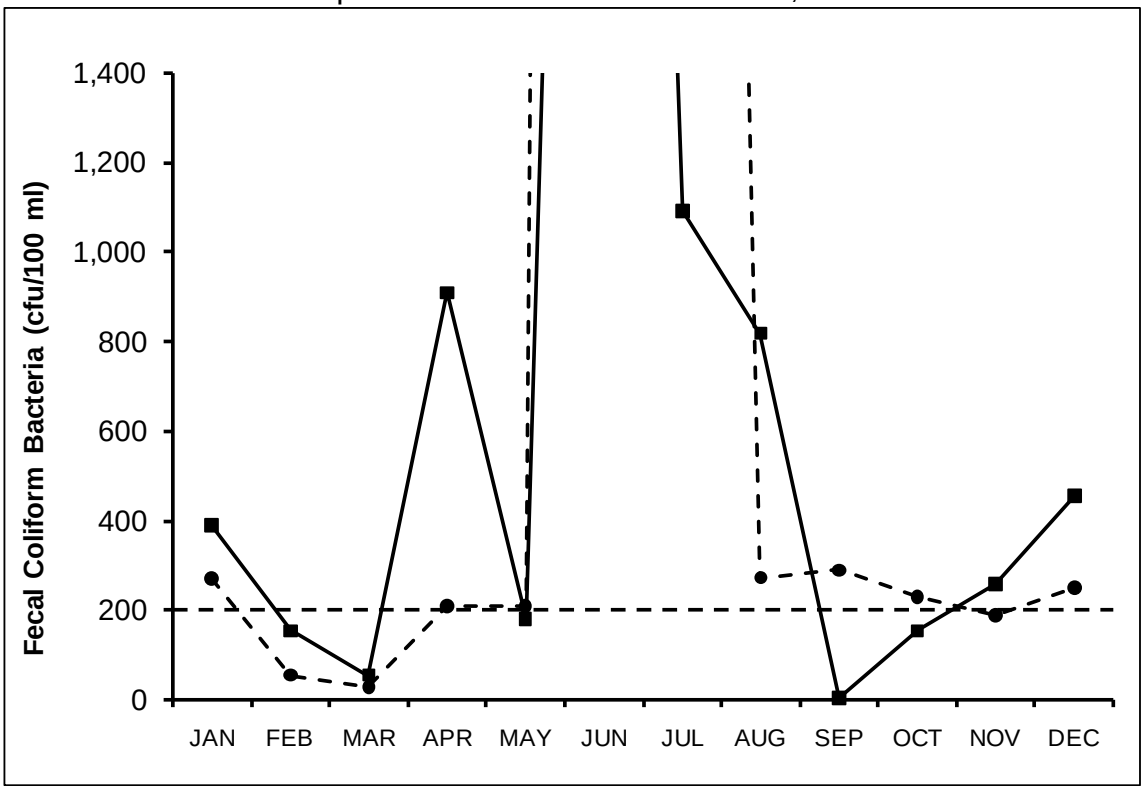
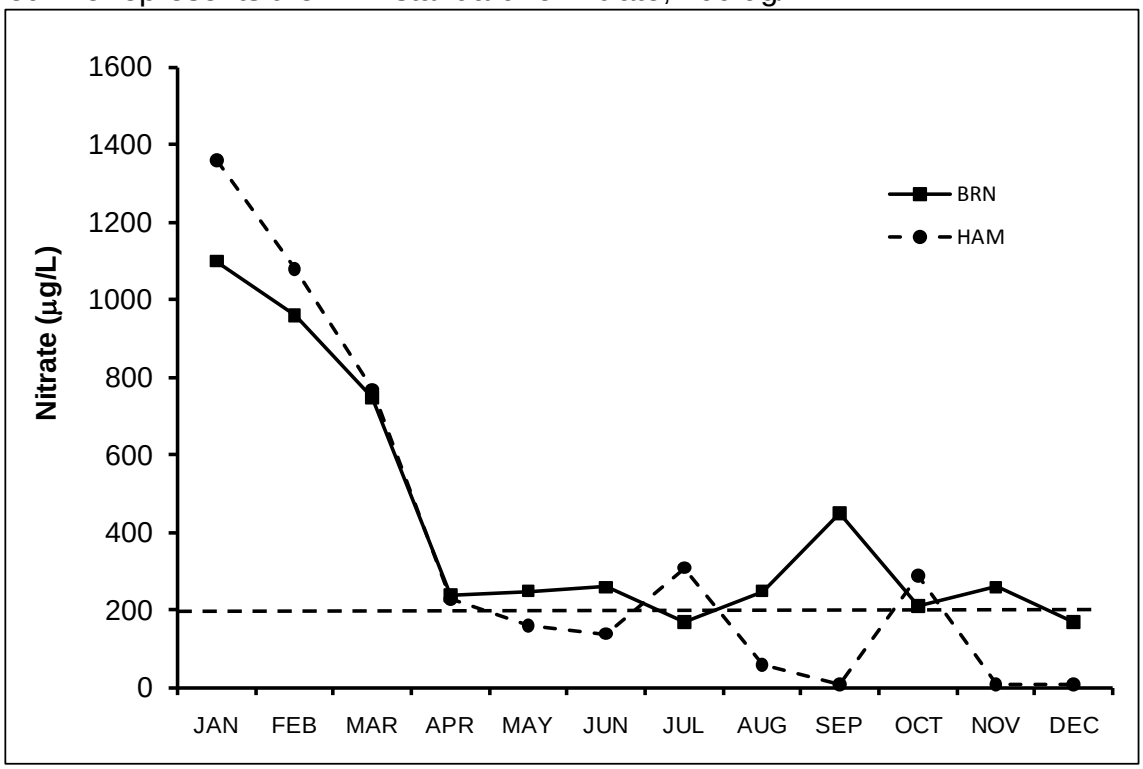
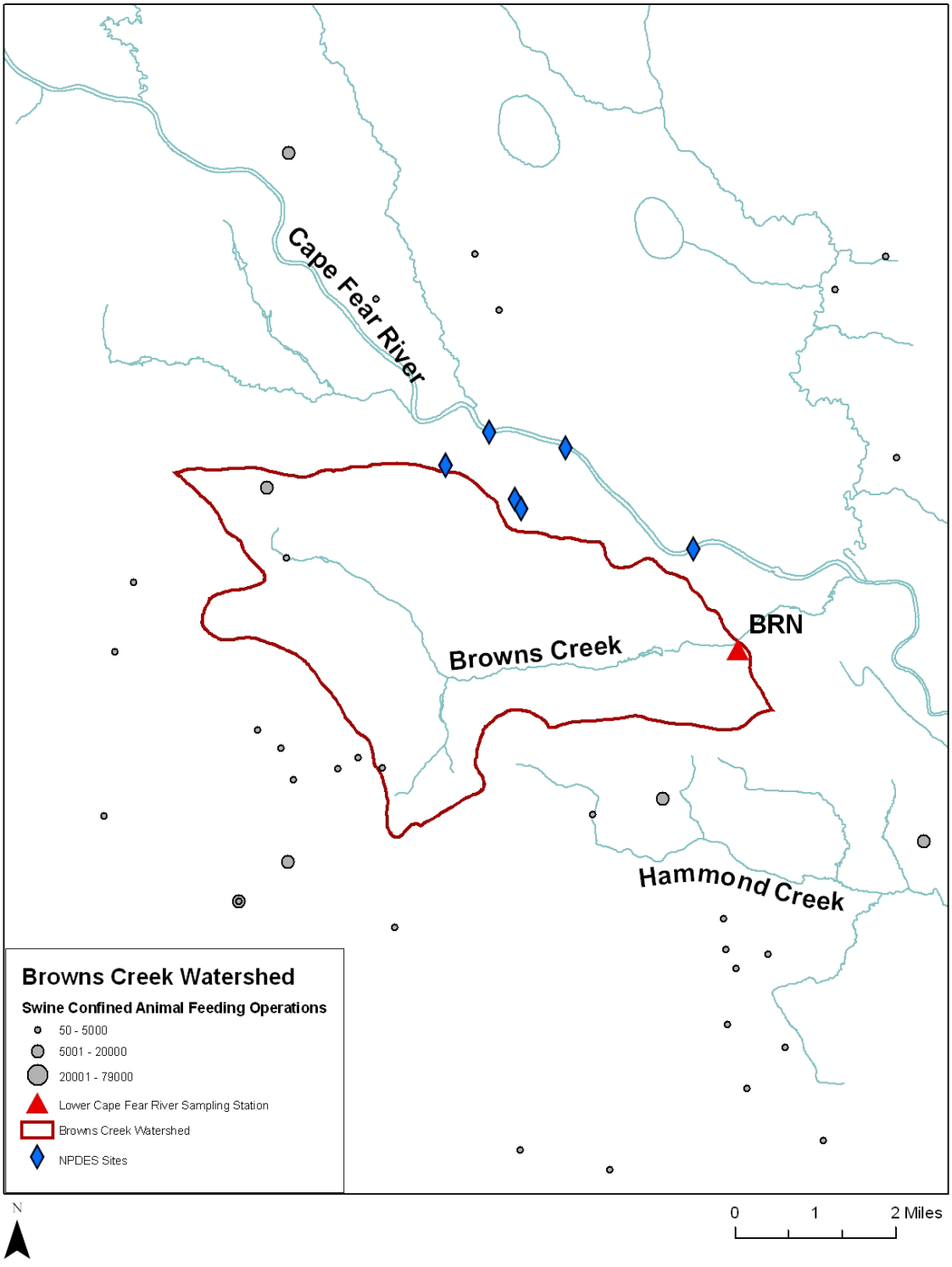
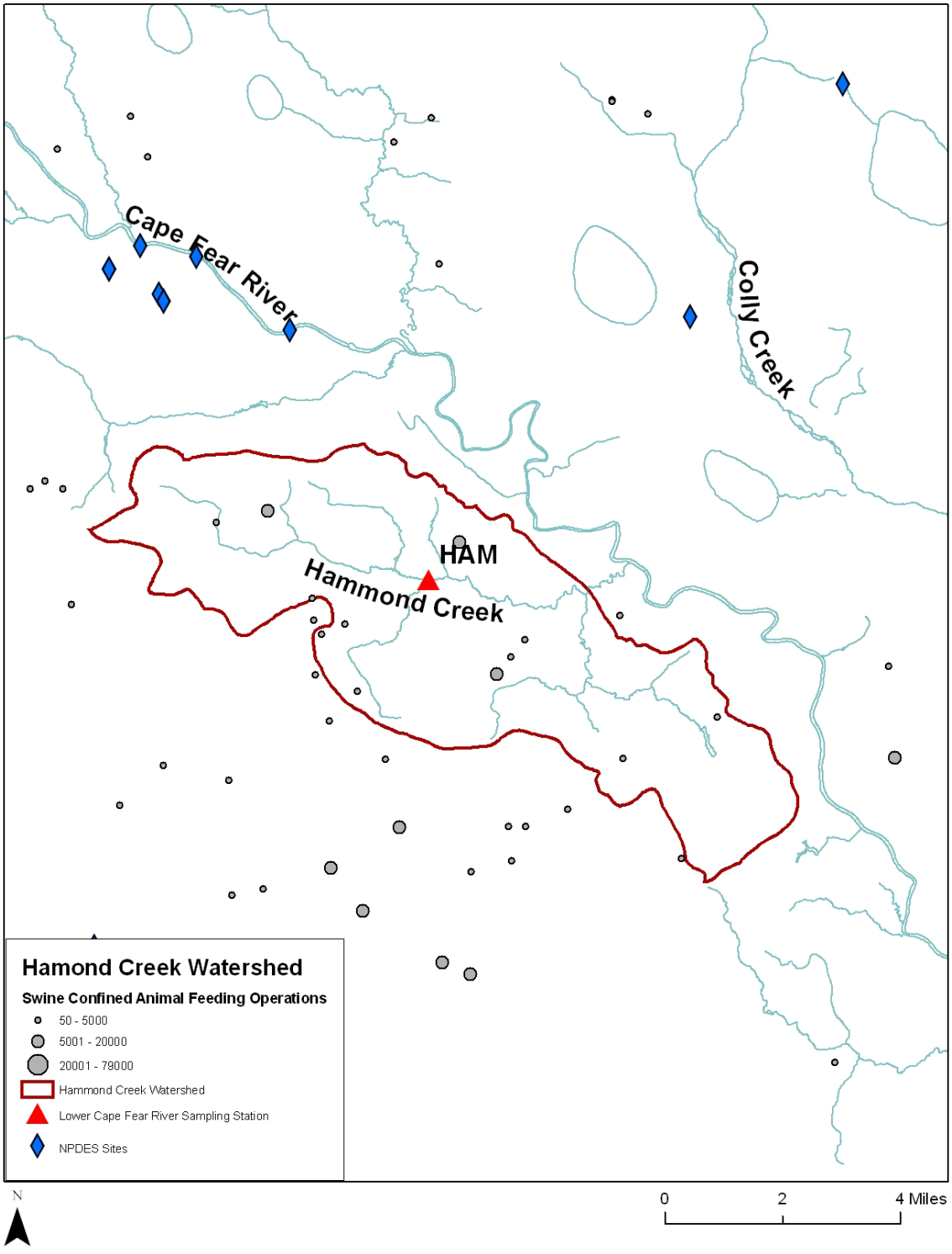


Figure 3.3.2 Nitrate concentrations at the LCFRP stations BRN and HAM for 2010. The dashed line represents the AEL standard for nitrate, 200 ug/L.




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)

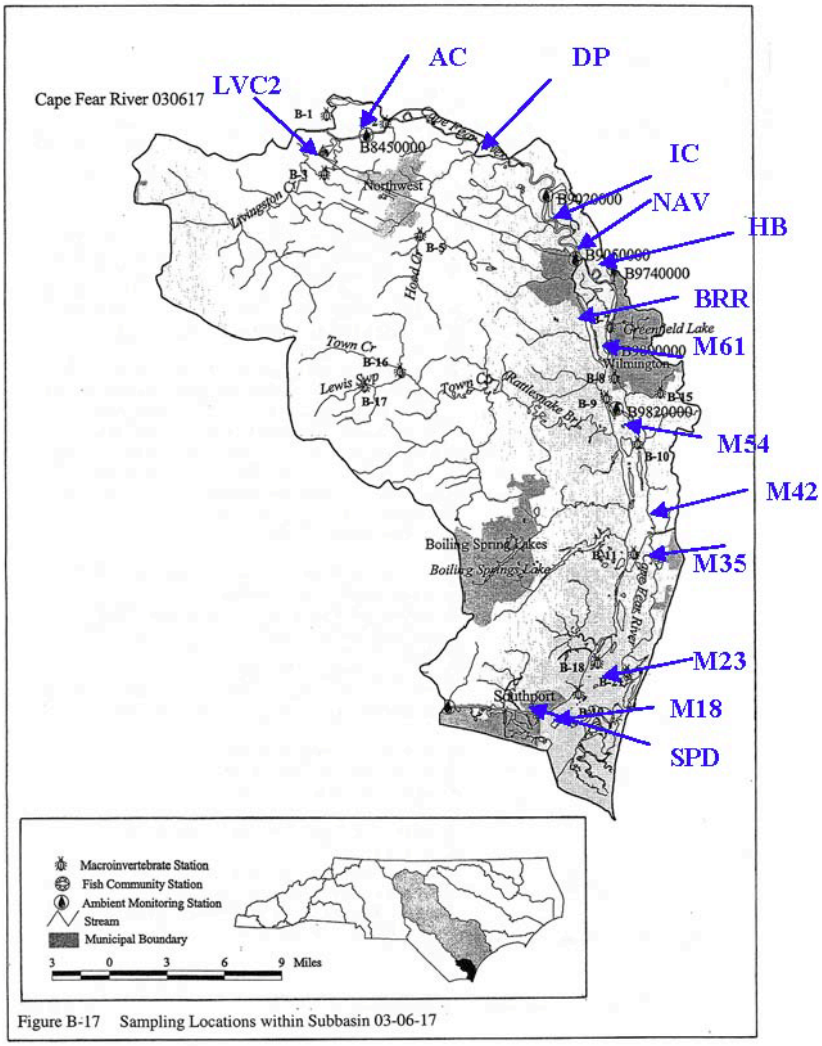


Figure B-17 Sampling Locations within Subbasin 03-06-17

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, 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 DP (17%), IC(17%), NAV (17%), HB (25%), M61 (25%) and M54 (17%). LVC2 and BRR were rated poor with samples below the standard 45% and 33% of the time, respectively (Figure 3.4.1).

All sites within this subbasin had a good rating in terms of chlorophyll *a* concentrations (Table 3.4.1). One sample exceeded the 40 μg/L NC State Standard during 2010: the May sample from M42 measured 76 μg/L.

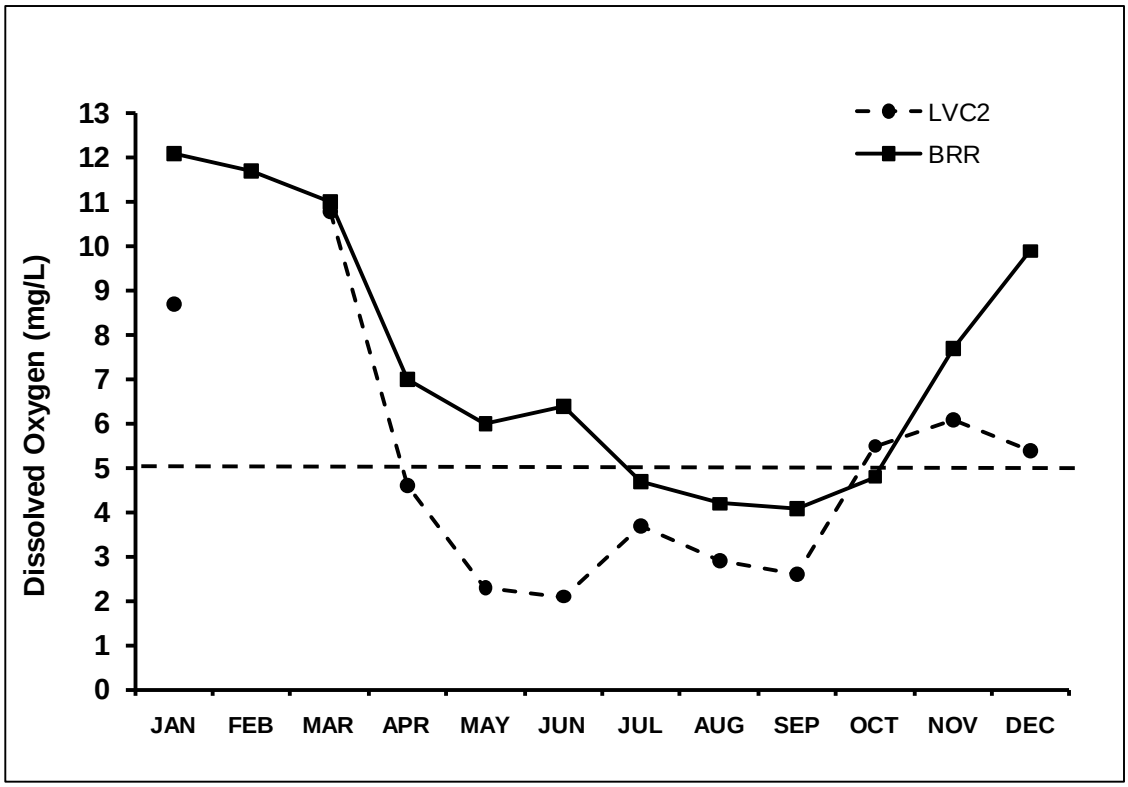
All sites within this subbasin rated good for fecal coliform bacteria during 2010 (Table 3.4.1). Only two samples exceeded the NC State Standard.

Ten of the fourteen sites within this subbasin had a good rating for field turbidity (Table 3.4.1). Four stations were rated fair including HB, BRR, M54 and M42 with all sites exceeding the NC state standard for brackish waters of 25 NTU 17% of the time.

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) 73% of the time (Table 3.4.1). All stations rated good for total phosphorus.

Table 3.4.1 UNCW AEL 20010 evaluation for subbasin 03-06-17						
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
LVC2	P	G	G	G	P	G
AC	G	G	G	G	G	G
DP	F	G	G	G	G	G
IC	F	G	G	G	G	G
NAV	F	G	G	G	G	G
HB	F	G	G	F	G	G
BRR	P	G	G	F	G	G
M61	F	G	G	G	G	G
M54	F	G	G	F	G	G
M42	G	G	G	F	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 LVC2 and BRR, rated poor for 2010. 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

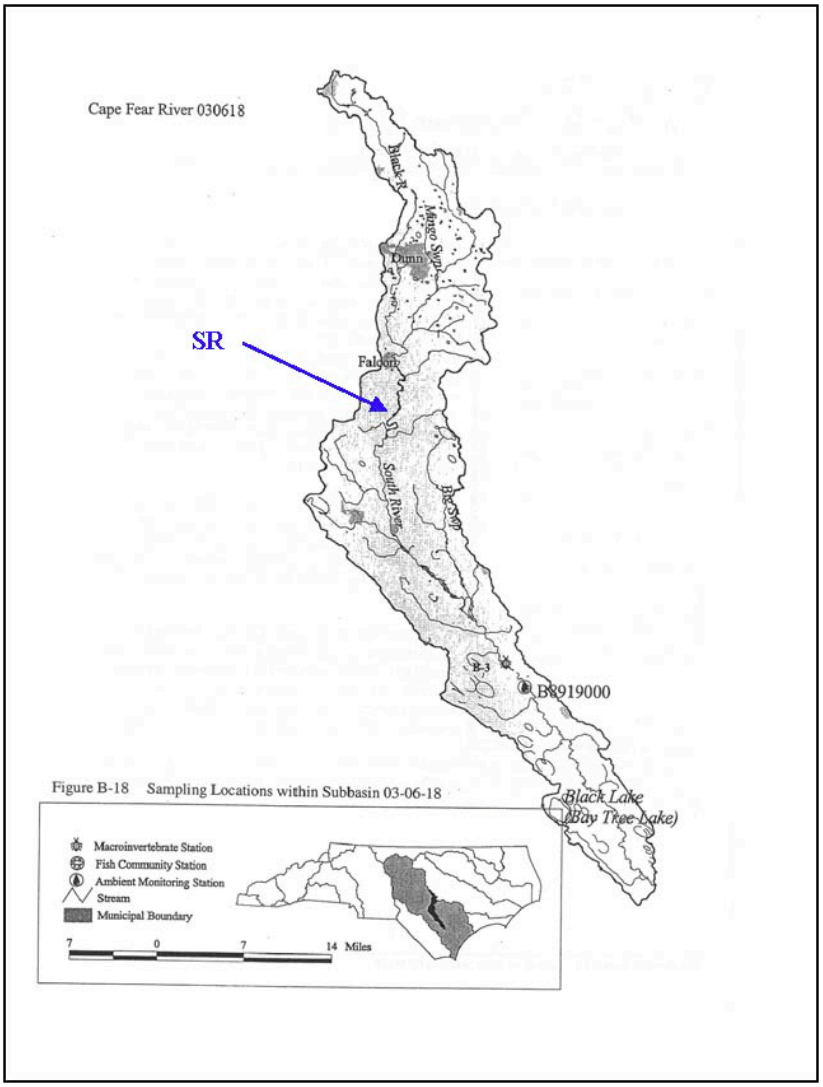


Figure B-18 Sampling Locations within Subbasin 03-06-18

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 2010 (Table 3.5.1). The NC State Standard for swampwater of 4.0 mg/L was not met 50% of the time. The lowest levels were found in summer and late fall (Figure 3.5.1).

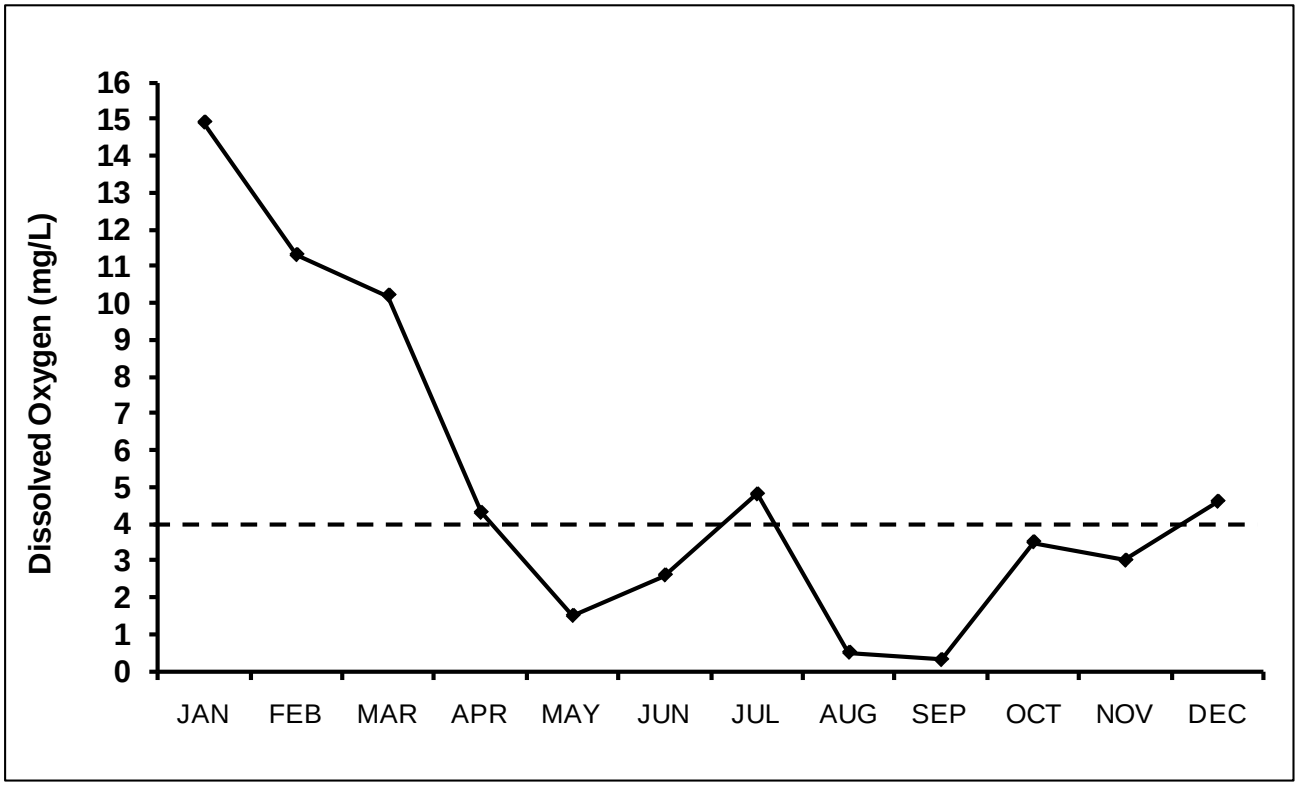
SR had a good rating for chlorophyll *a* exceeding the NC State standard of 40 µg/L on one occasion (Table 3.5.1).

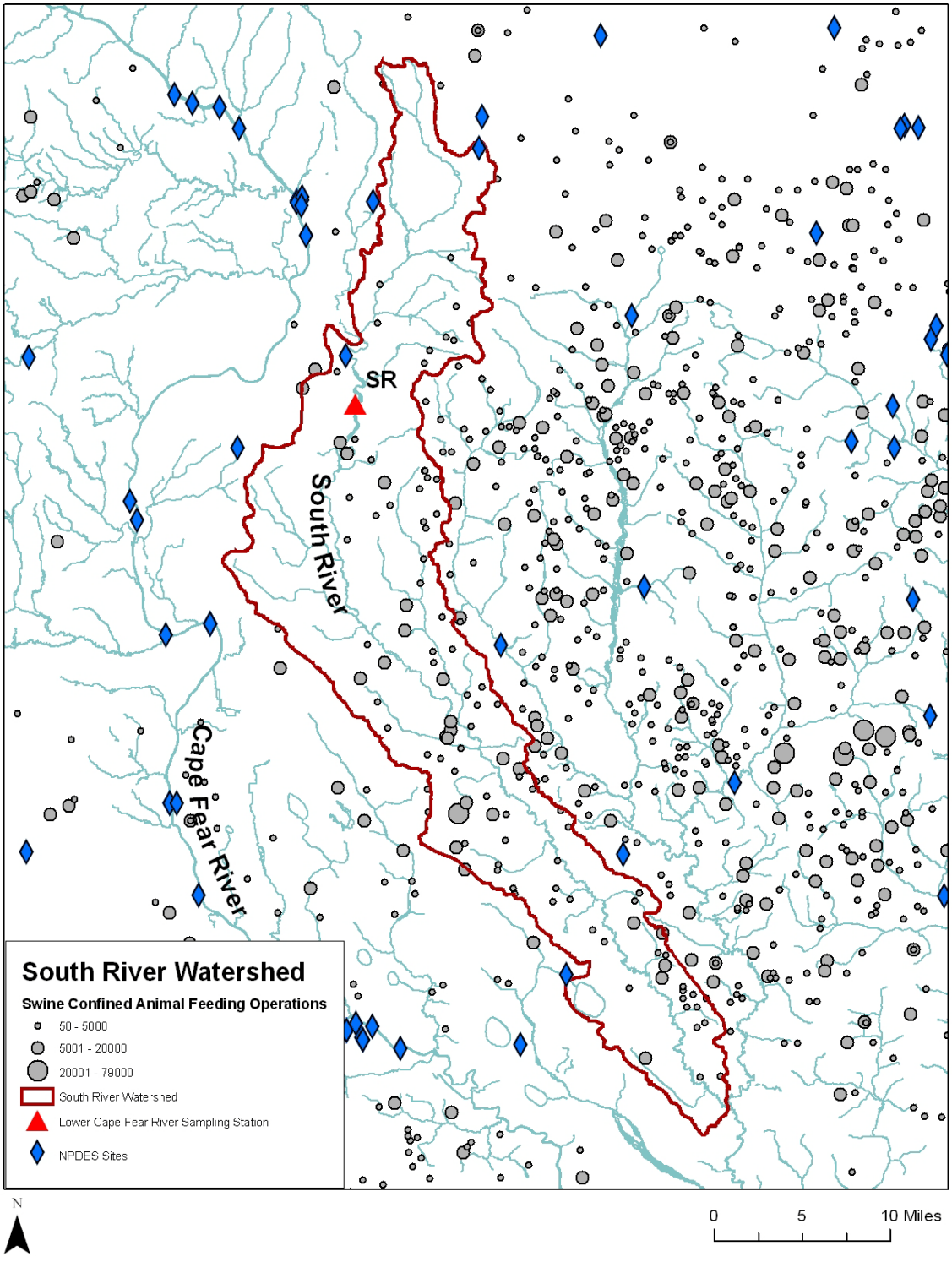
SR had a poor water quality rating for fecal coliform bacteria concentrations exceeding the NC state standard of 200 CFU/100mL in 33% of samples (Table 3.5.1). The highest concentration was in August (15,000 cfu/100mL).

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 25% of the time.

Table 3.5.1 UNCW AEL 2010 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 2010. 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

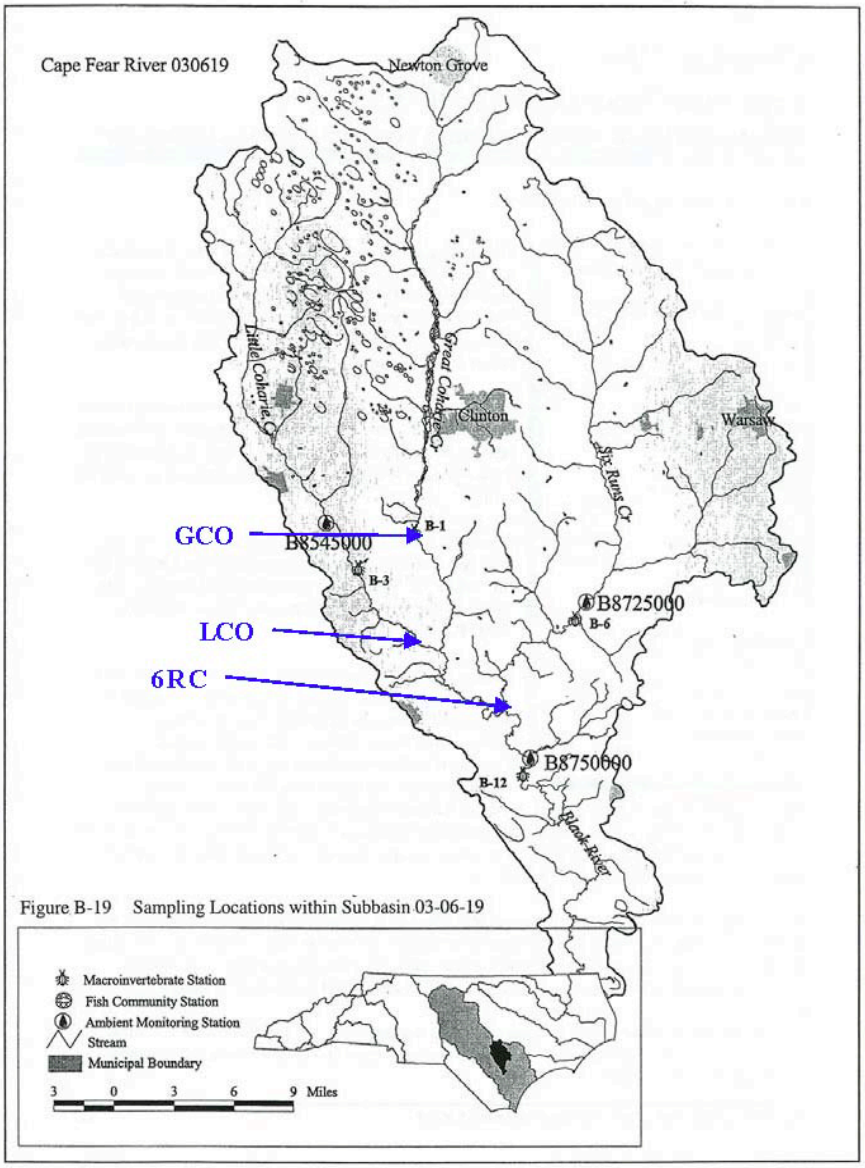


Figure B-19 Sampling Locations within Subbasin 03-06-19

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 2010 (Table 3.6.1).

GCO had a fair rating for fecal coliform bacteria during 2010. 6RC and LCO had a poor rating for fecal coliform bacteria with 36% and 33% of samples exceeding the NC State human contact standard of 200 CFU/100mL, respectively (Table 3.6.1, Figure 3.6.1).

Nitrate levels were rated poor at 6RC, LCO and GCO exceeding 200 µg/L in 100%, 84%, and 42% of the samples, respectively (Table 3.6.1, Figure 3.6.1). 6RC and LCO had a good rating for total phosphorus concentrations, while GCO rated fair with 17% of samples exceeding the UNCW-AEL recommended standard of 500 µg/L (Table 3.6.1).

Table 3.6.1 UNCW AEL 2010 evaluation for subbasin 03-06-19						
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
6RC	G	G	P	G	P	G
LCO	G	G	P	G	P	G
GCO	G	G	F	G	P	F

Figure 3.6.1 Fecal coliform bacteria concentrations at 6RC and LCO during 2010. The dashed line shows the NC State standard of 200 cfu/100 mL.

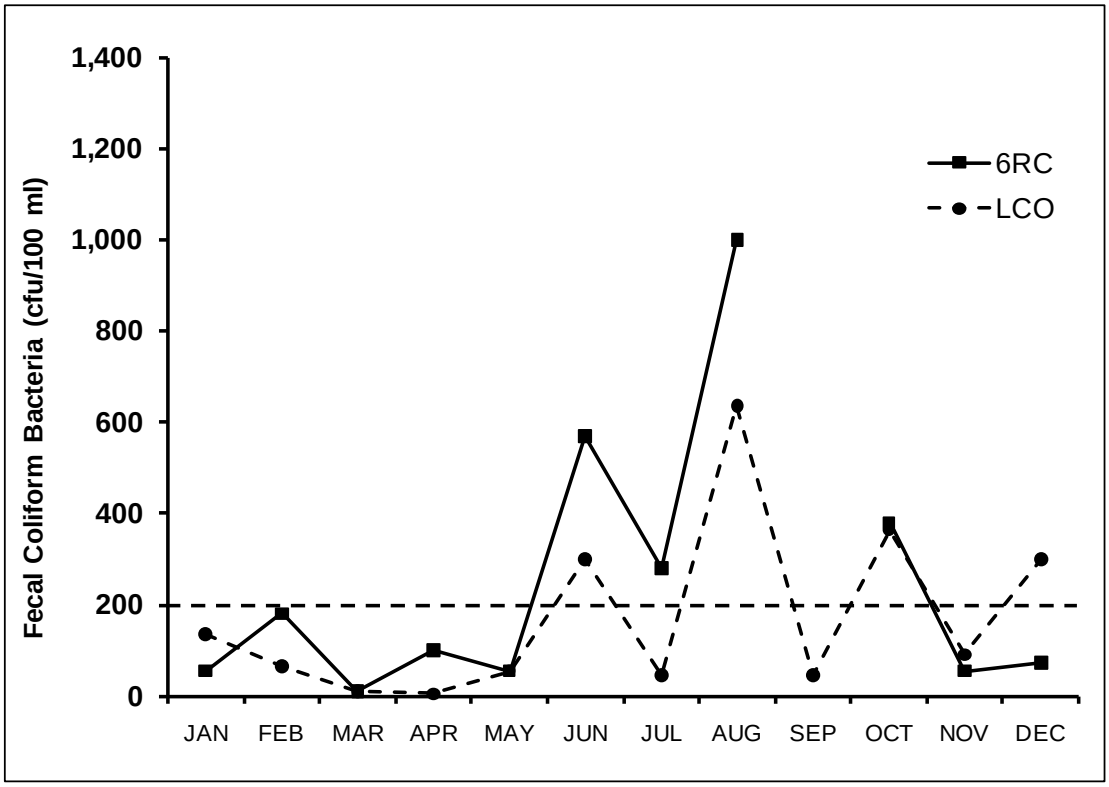
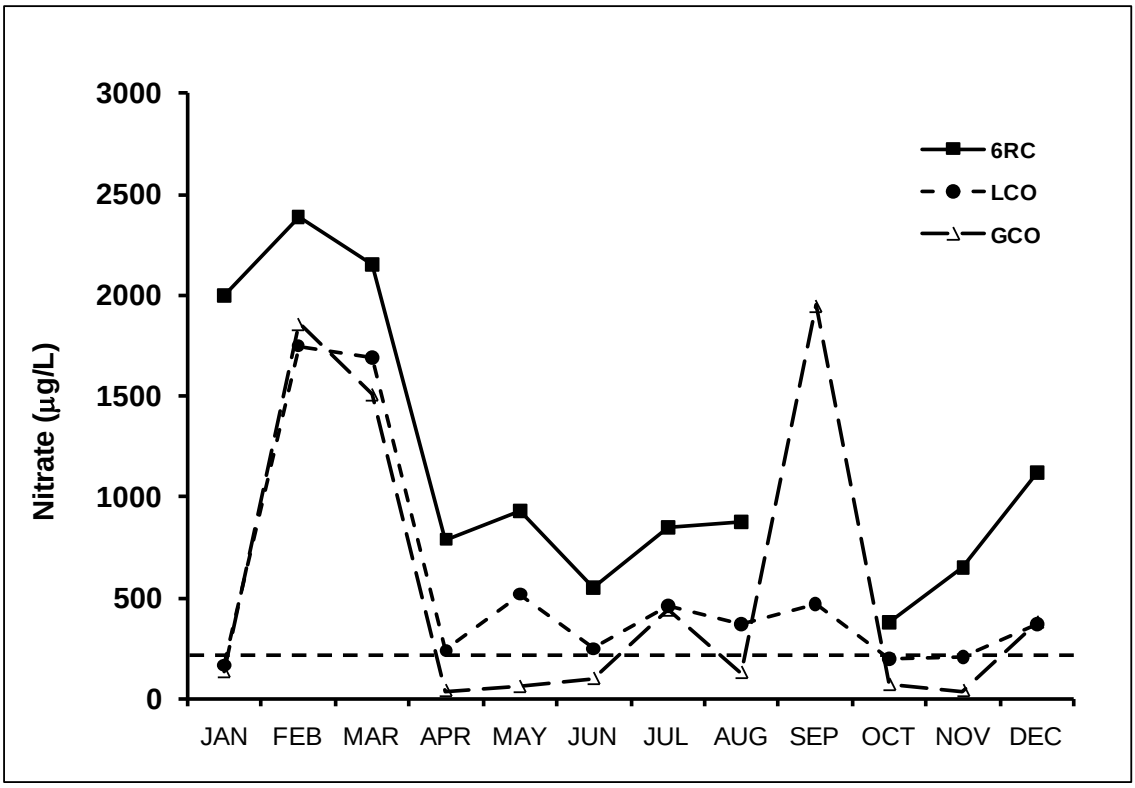
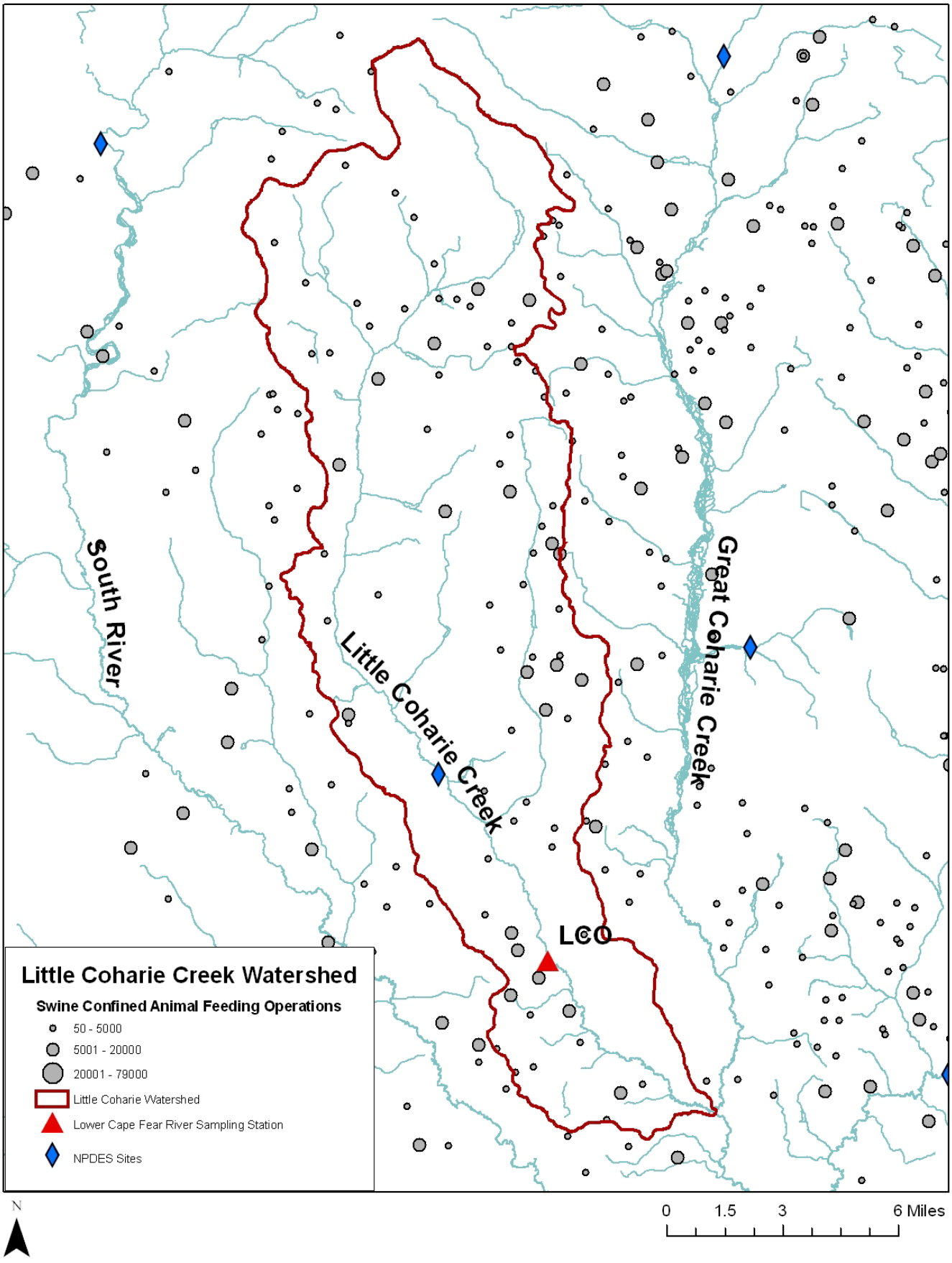
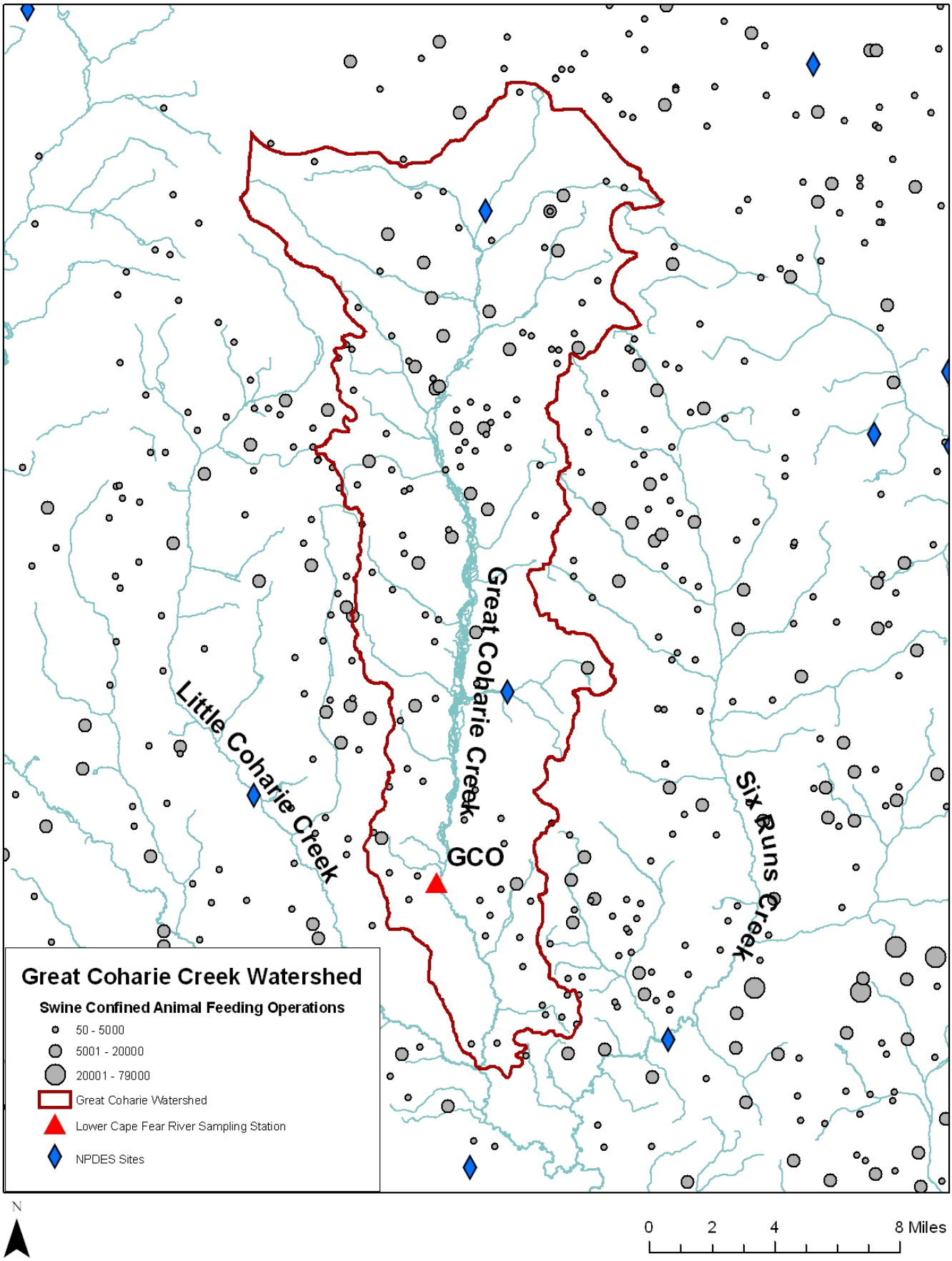
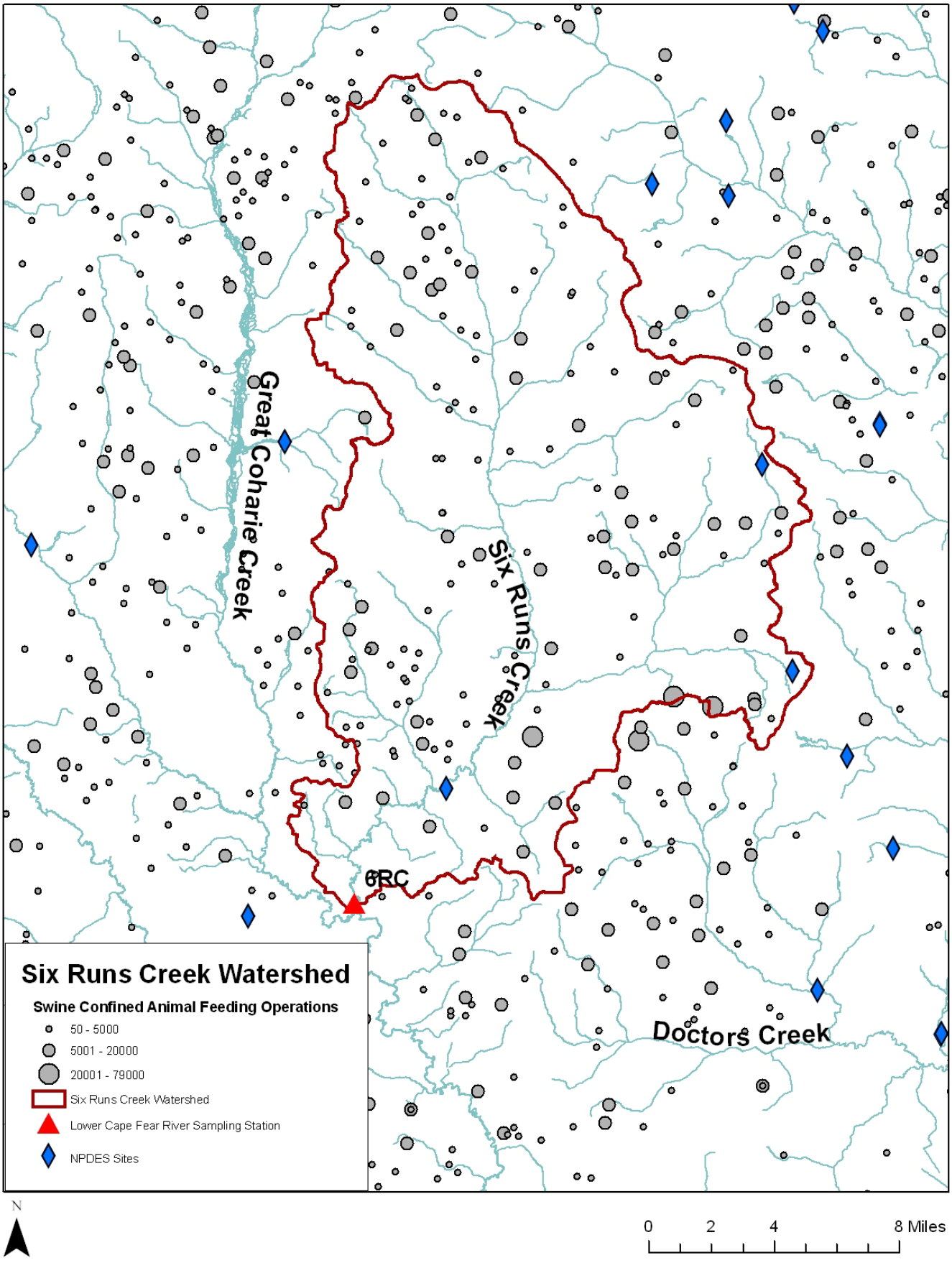


Figure 3.6.1 Nitrate concentrations (µg/L) at 6RC, LCO, and GCO during 2010. The dashed line shows the UNCW-AEL standard of 200 µg/L.




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 Cohaire 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

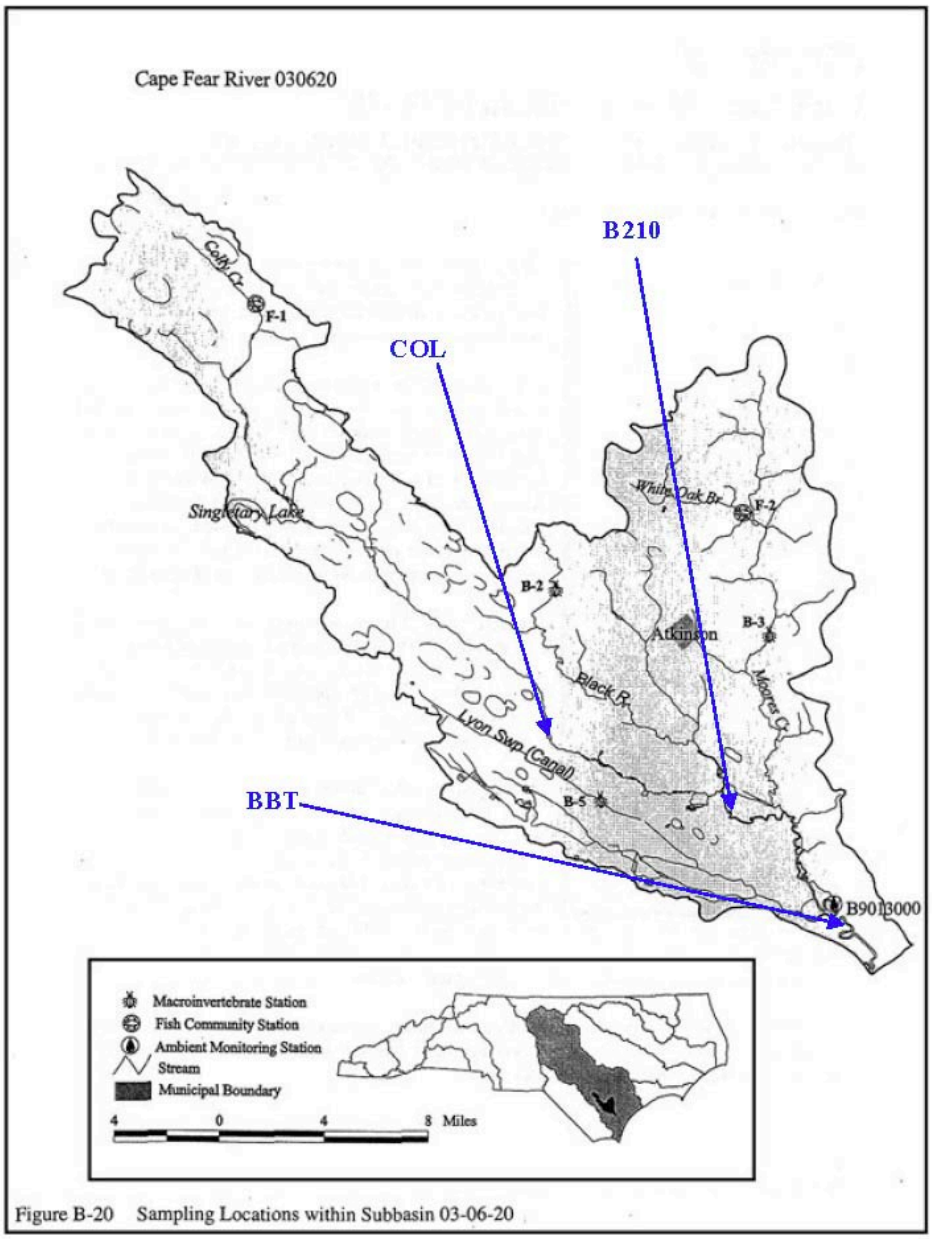


Figure B-20 Sampling Locations within Subbasin 03-06-20

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).

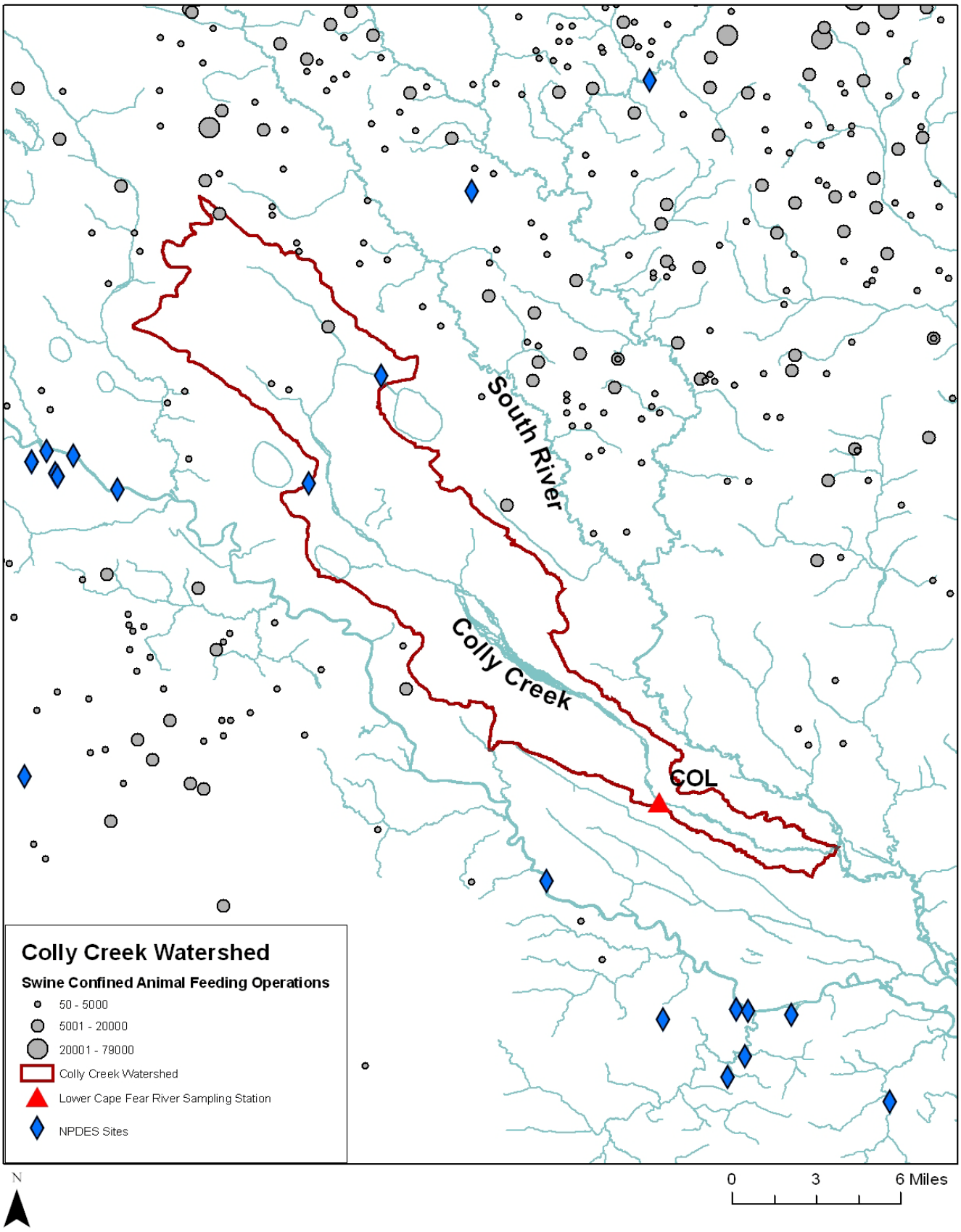
Chlorophyll *a* and field turbidity concentrations were low for each site within this subbasin and all sites had a good rating for these parameters (Table 3.7.1).

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.

For nitrate COL rated good and B210 rated fair with 17% of the samples exceeding the UNCW-AEL recommended standard of 500 μg/L. BBT samples were not analyzed for nutrients.

Table 3.7.1 UNCW AEL 2010 evaluation for subbasin 03-06-20

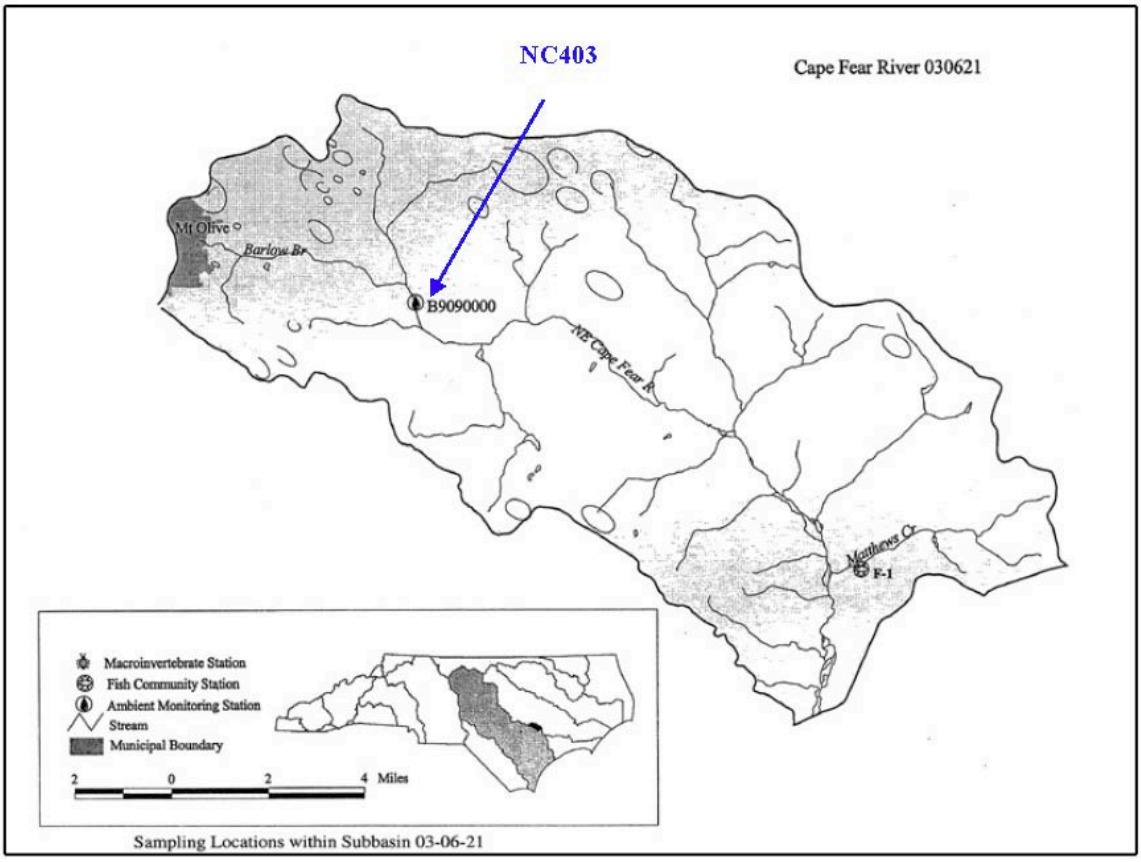
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
B210	G	G	G	G	F	G
COL	G	G	G	G	G	G
BBT	G	G		G		


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 33% 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.

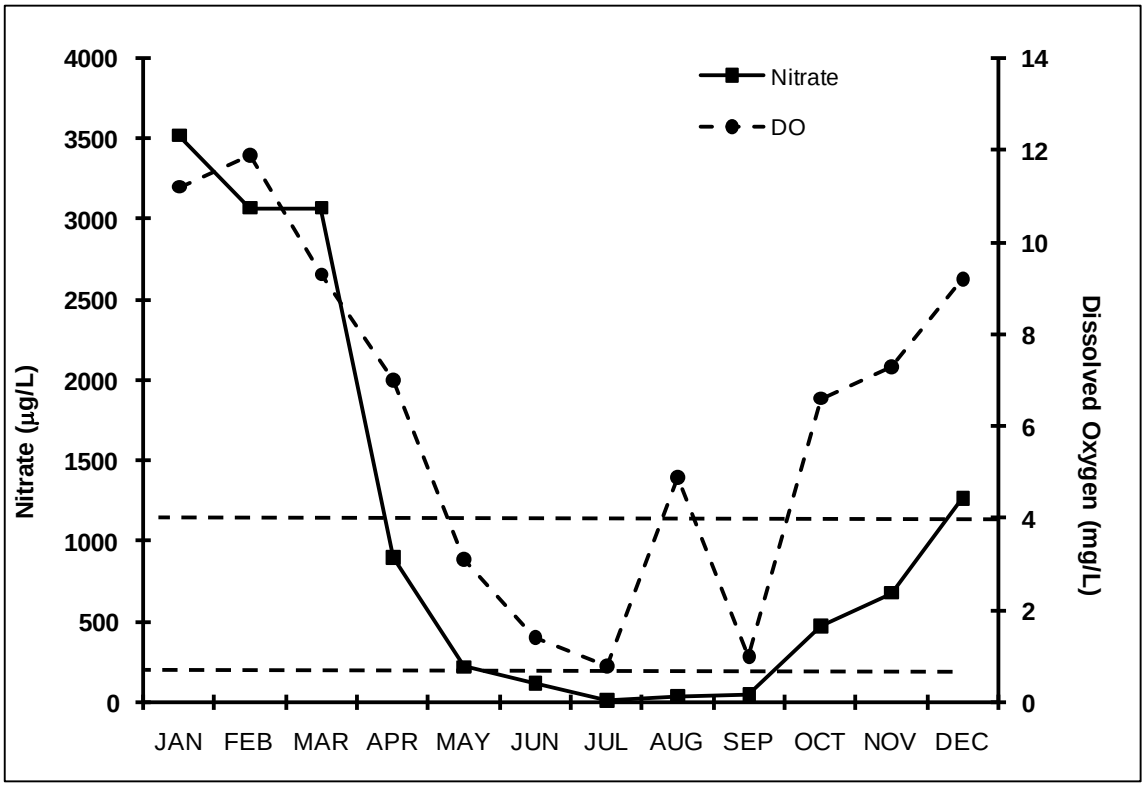
NC403 had a fair rating for fecal coliform bacteria with samples exceeding the NC State standard for human contact (200 cfu/100 mL) 25% of the time.

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

For nitrate NC403 had a poor rating with concentrations >200 µg/L for 67% of the samples (Table 3.8.1, Figure 3.8.1). UNCW AEL researchers are concerned about the elevated nitrate levels at this site since these levels increase the likelihood of algal blooms and excessive aquatic macrophyte growth. Total phosphorus had a good rating for 2010.

Table 3.8.1 UNCW AEL 2010 evaluation for subbasin 03-06-21						
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
NC403	P	G	F	G	P	G

Figure 3.8.1 Dissolved oxygen (mg/L) and nitrate (µg/L) concentrations at NC403 during 2010. 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

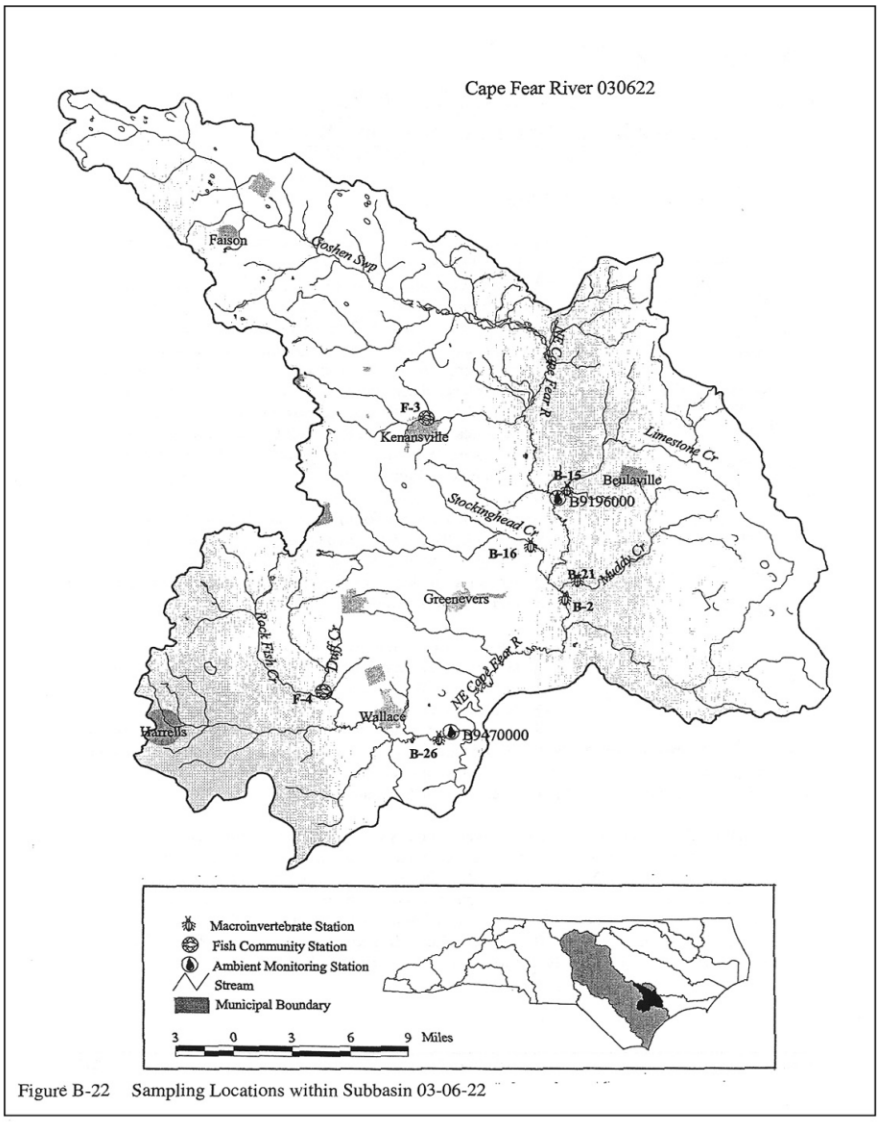


Figure B-22 Sampling Locations within Subbasin 03-06-22

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* SAR, GS, LRC and ROC had a good rating (Table 3.9.1). PB was rated poor having concentrations exceeding the NC State standard of 40 μg/L 18% of the time.

For fecal coliform bacteria concentrations SAR, GS and ROC each had a fair rating with 25%, 17% and 25% of samples above the standard, respectively (Table 3.9.1, Figure 3.9.1). Sites PB and LRC were rated poor with 55% and 36% of samples above the standard (Figure 3.9.2).

All sites had a good rating for field turbidity concentrations (Table 3.9.1).

For nitrate GS had a fair rating with levels exceeding the UNCW AEL standard (200 µg/L) 25% of the time (Table 3.9.1). SAR, PB, LRC and ROC all had a poor rating with levels exceeding the UNCW AEL standard 75%, 55%, 73% 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 PB was rated fair, exceeding the UNCW AEL standard of 500 mg/L in 18% of the samples (Table 3.9.1). ROC was rated poor, exceeding the standard 33% of the time.

Table 3.9.1 UNCW AEL 2010 evaluation for subbasin 03-06-22

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

Figure 3.9.1 Fecal coliform bacteria (cfu/100mL) at SAR, GS and ROC which rated poor during 2010. The dashed line is the NC State Standard for human contact of 200 cfu/100mL).

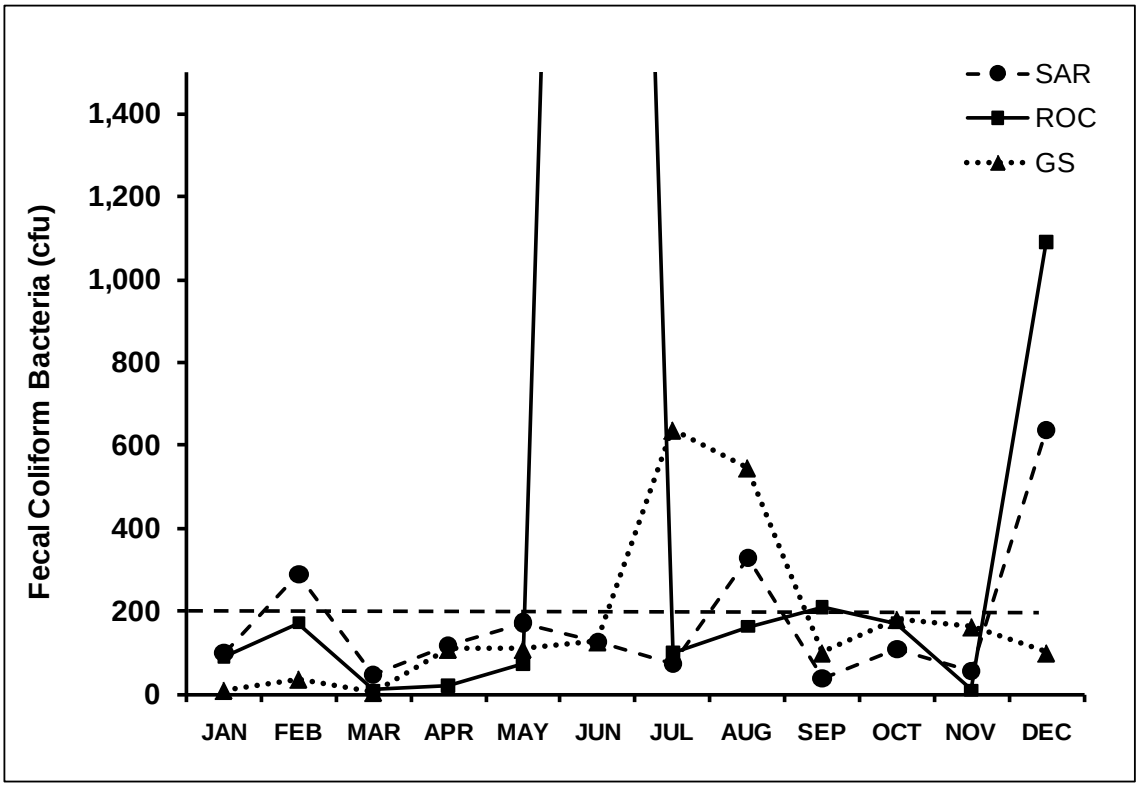


Figure 3.9.2 Fecal coliform bacteria (cfu/100mL) at LRC and PB which rated poor during 2010. The dashed line is the NC State Standard for human contact of 200 cfu/100mL.

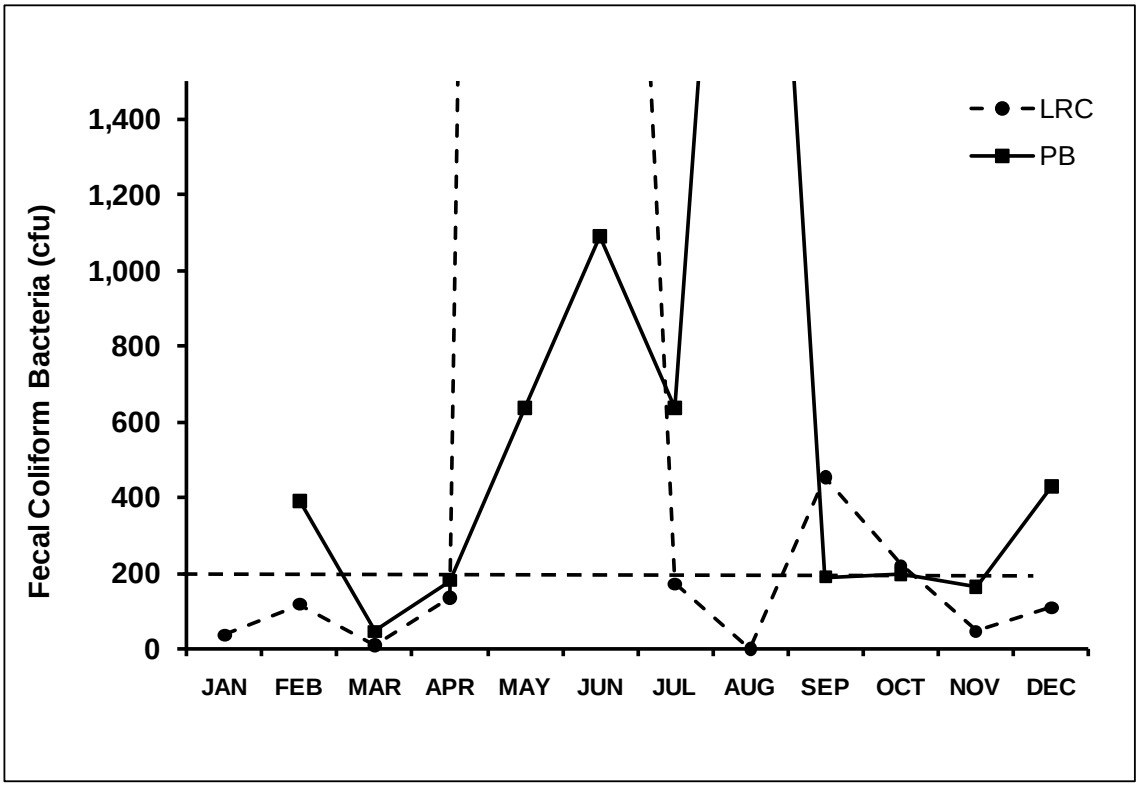


Figure 3.9.3 Nitrate-N concentrations (µg/L) at SAR and PB which rated poor during 2010. The dashed line represents the UNCW AEL standard of 200 µg/L.

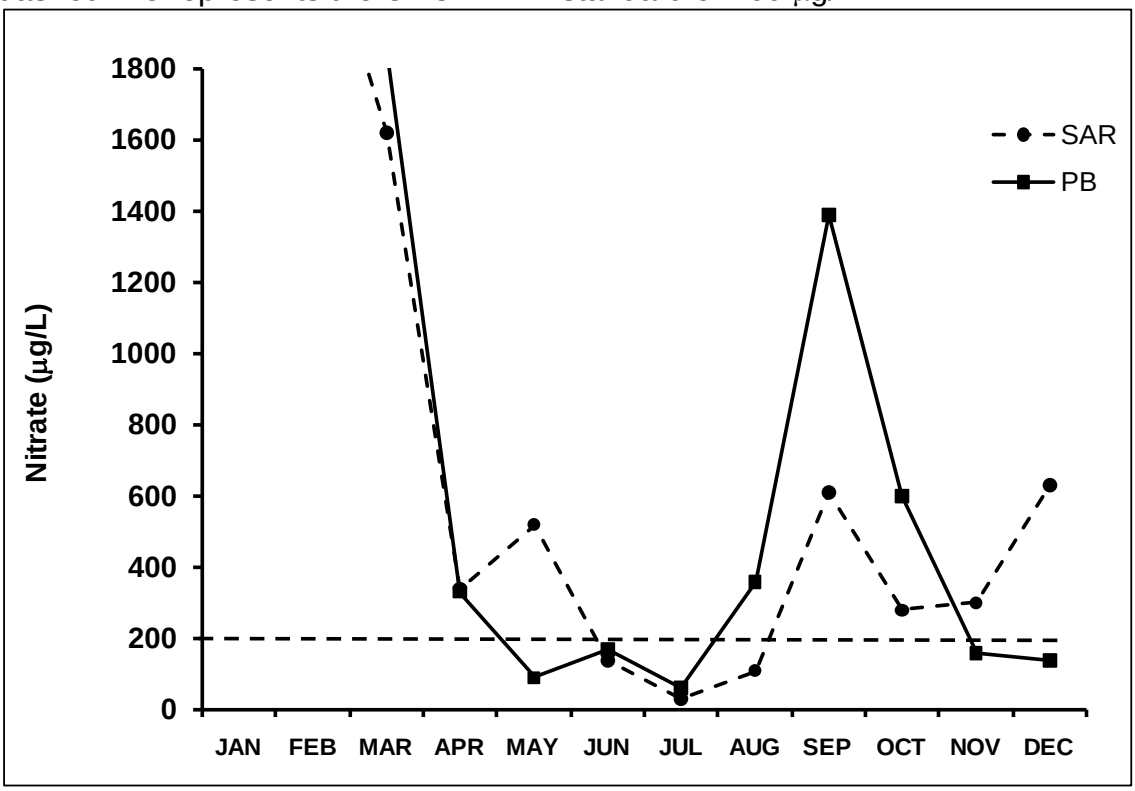
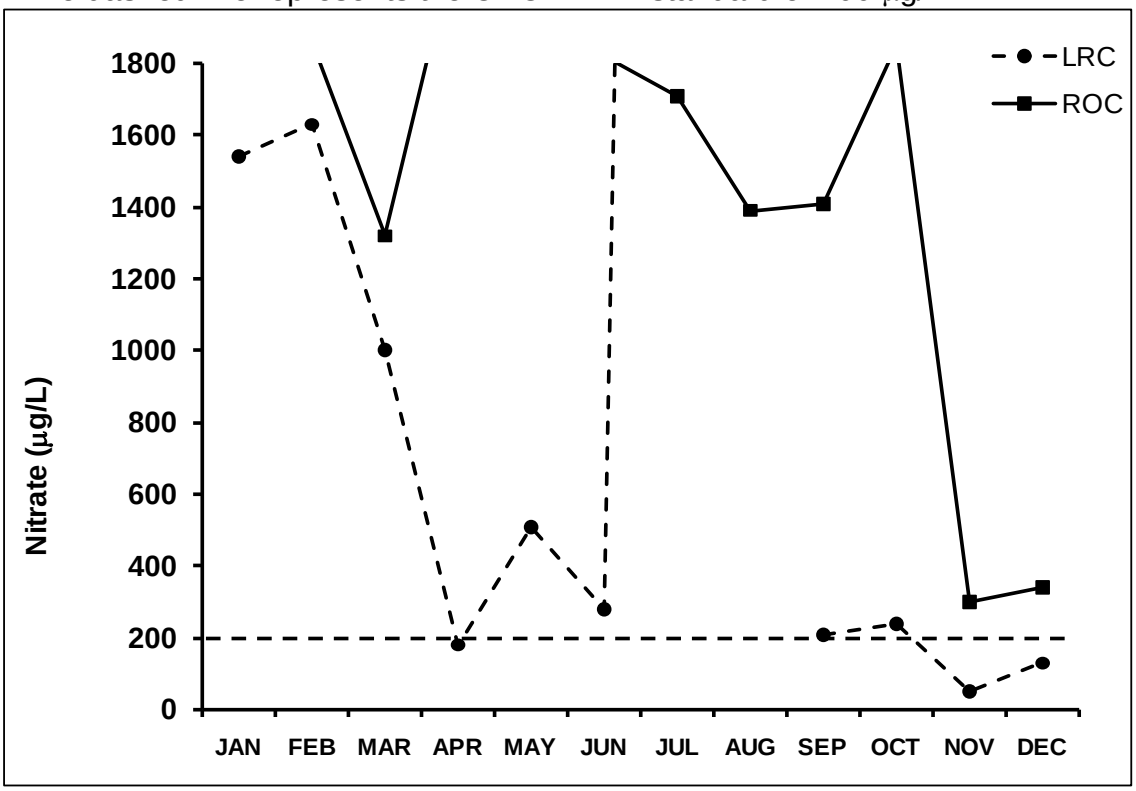
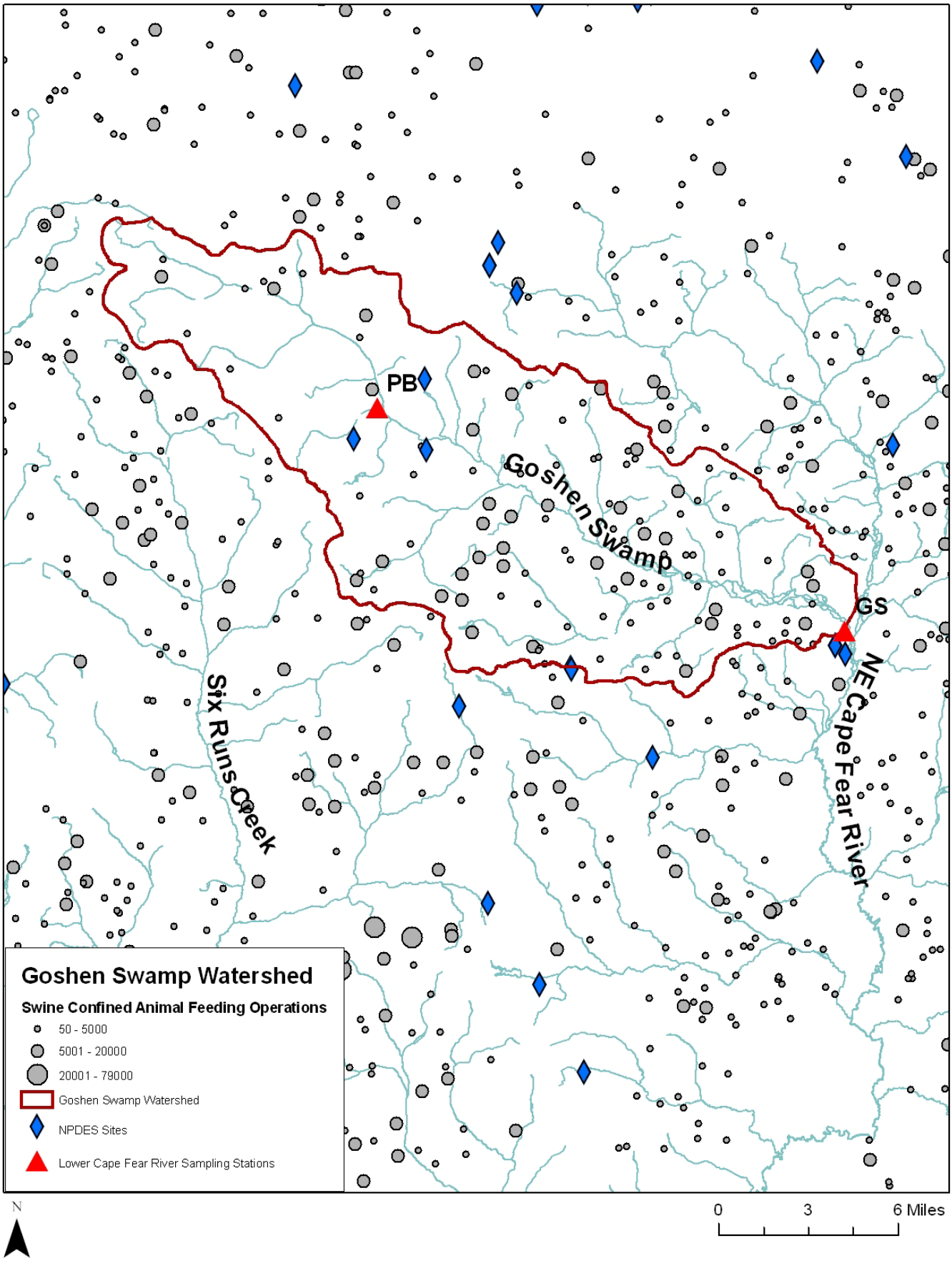
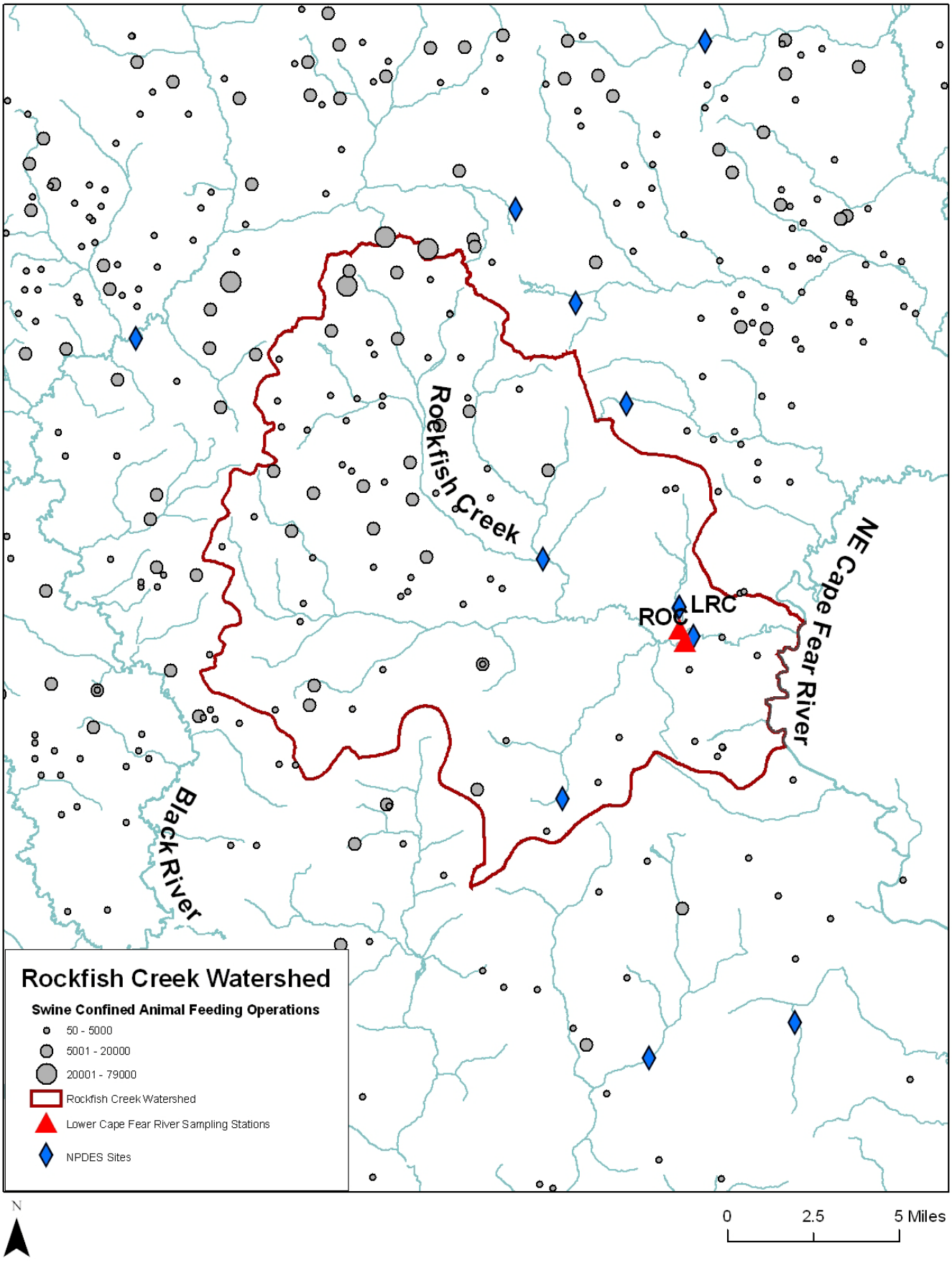


Figure 3.9.4 Nitrate-N concentrations (μg/L) at LRC and ROC which rated poor during 2010. The dashed line represents the UNCW AEL standard of 200 μg/L.




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

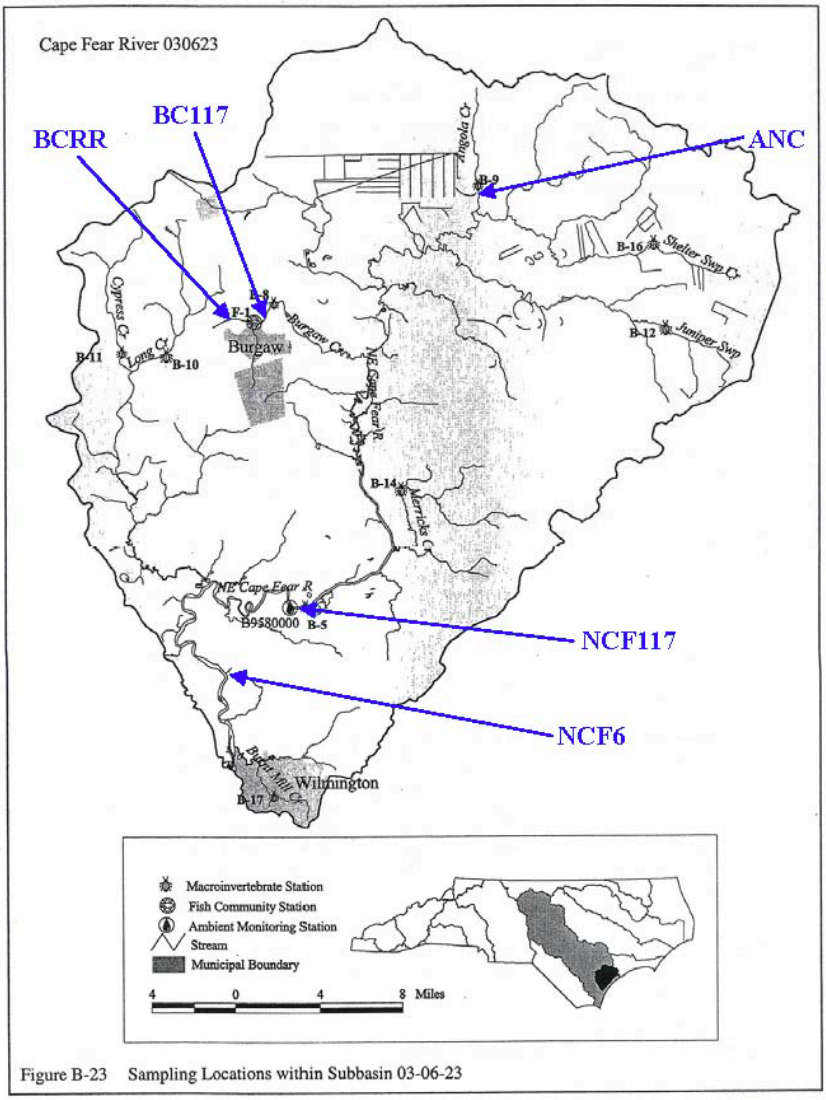


Figure B-23 Sampling Locations within Subbasin 03-06-23

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 SC-CH had a good rating when using the 4.0 mg/L standard (Table 3.10.1). BC117, NCF117 and NCF6 had a fair rating with 17% of samples sub-standard for all three sites. ANC and BCRR had a poor rating with sub-standard samples 42% and 67% of the time, respectively (Figure 3.10.1).

For chlorophyll *a* BC1117, BCRR, NCF117 and NCF6 were all rated good (Table 3.10.1). ANC was rated poor, exceeding the NC State standard of 40 μg/L 17% of the time. Chlorophyll *a* was not analyzed at SC-CH.

For fecal coliform bacteria ANC, NCF117 and NCF6 had a good rating (Table 3.10.1). SC-CH was rated fair, exceeding the NC State human contact standard 17% of the time. BC117 and BCRR each had a poor rating exceeding the human contact standard 67% and 58% of the time, respectively (Figure 3.10.1).

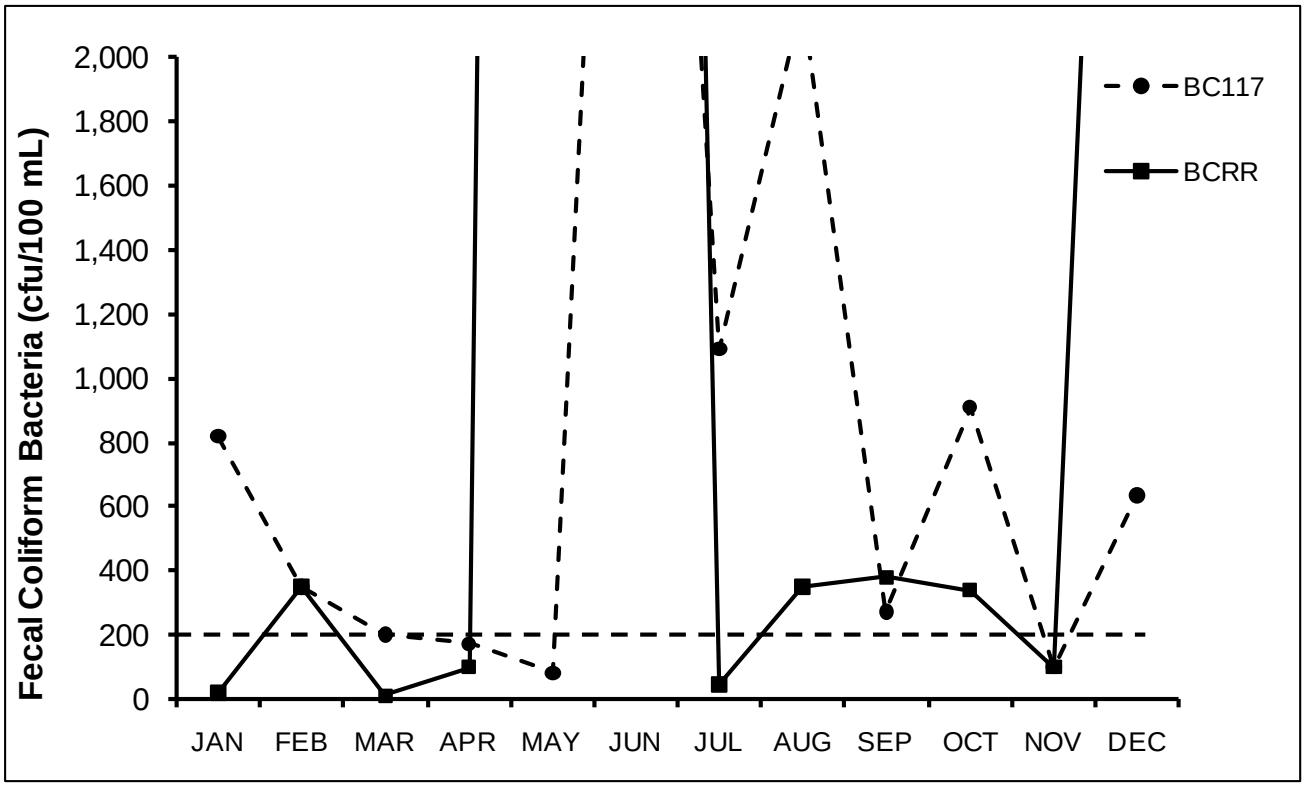
All five stations were rated good for field turbidity during 2010 (Table 3.10.1).

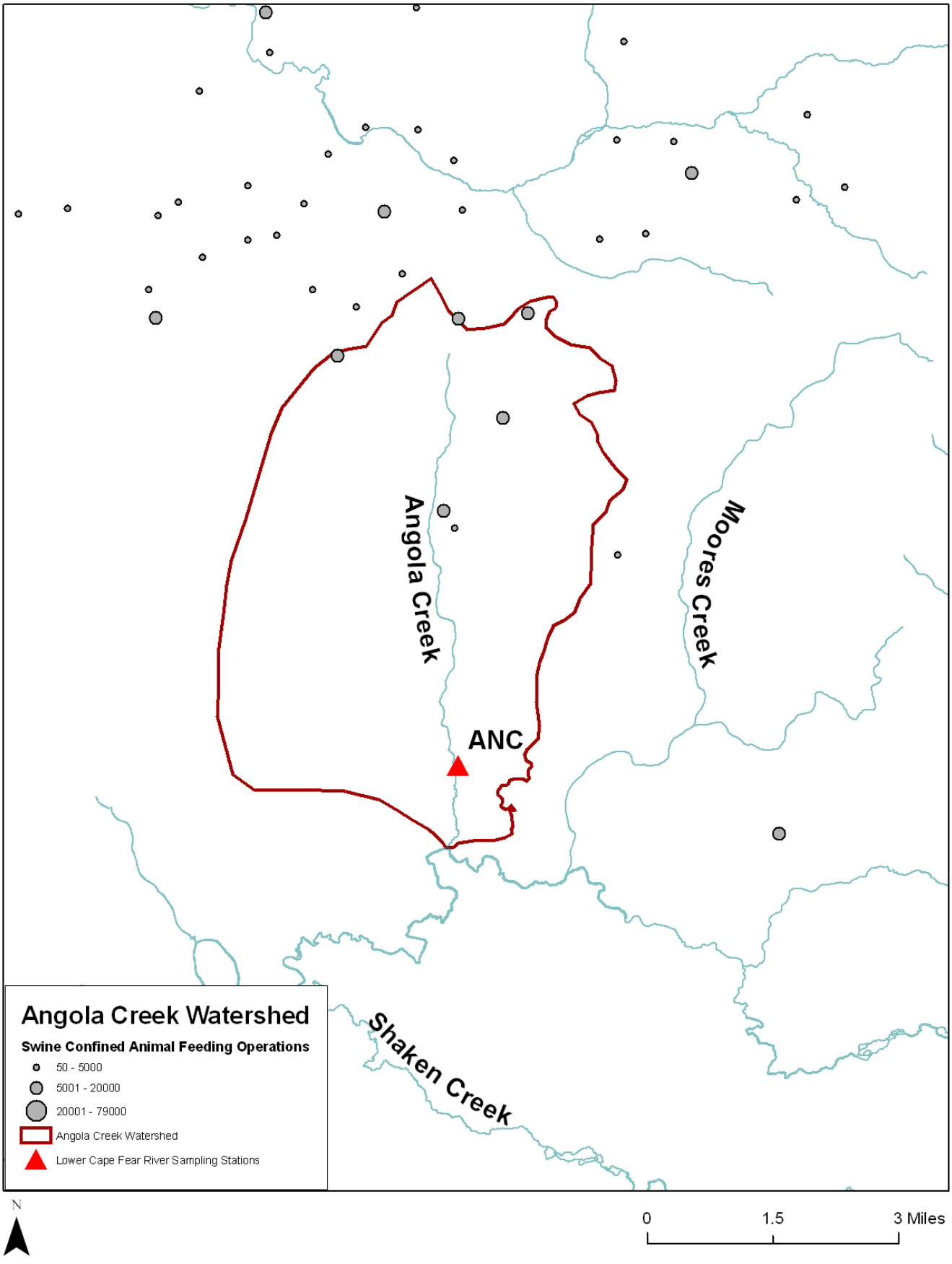
Nutrient loading of nitrate and total phosphorus was problematic at BC117 which had a poor rating for both (Table 3.10.1). Nitrate levels exceeded the UNCW AEL standard 100% of the time and total phosphorus levels exceeded the UNCW AEL standard 75% of the time. BC117 had the highest nitrate and TP levels 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). All other sites were rated fair for nitrate exceeding the UNCW AEL standard 25% of the time. ANC, NCF117 and NCF6 were rated good for total phosphorus. BCRR was rated fair for total phosphorus, exceeding the UNCW AEL recommended standard 17% of the time. Nutrients were not analyzed at SC-CH.

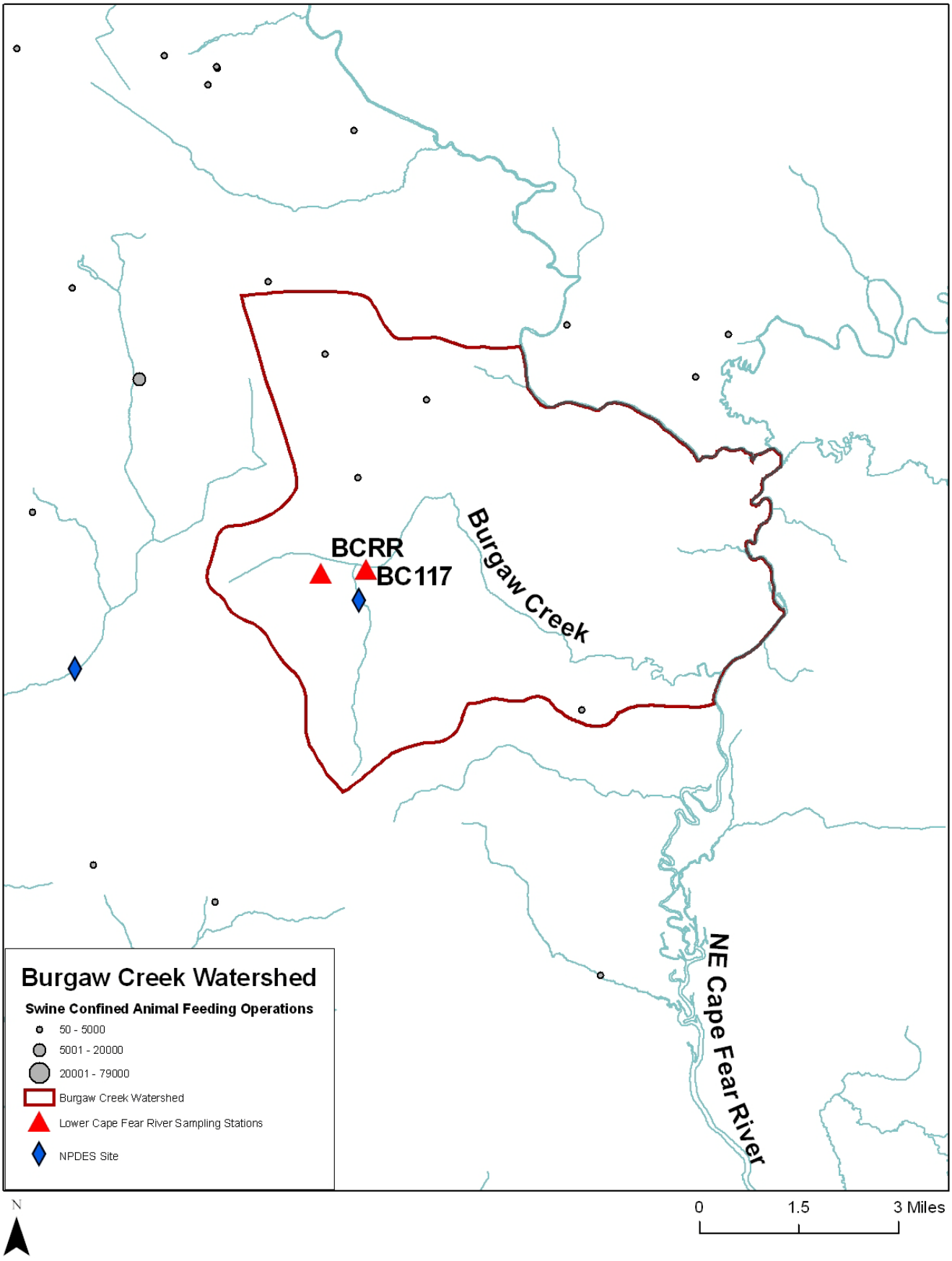
Table 3.10.1 UNCW AEL 2010 evaluation for subbasin 03-06-23

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

Figure 3.10.1 Fecal coliform bacteria concentrations (cfu/100mL) at BC117 and BCRR which rated poor during 2010. 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.