Environmental Assessment of the Lower Cape Fear River System, 2008

By

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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 (UNCW) 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 the period January - December 2008. 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 are rare because light is attenuated by water color or turbidity, and flushing is high (Ensign et al. 2004). During periods of low flow (as in 2008) algal biomass as chlorophyll *a* increases in the river because lower flow causes settling of more solids and improves light conditions for algal growth. Periodically major algal blooms are seen in the tributary stream stations, some of which are impacted by point source discharges. Below some point sources, nutrient loading can be high and fecal coliform contamination occurs. Other stream stations drain blackwater swamps or agricultural areas, some of which periodically show elevated pollutant loads or effects (Mallin et al. 2001).

Average annual dissolved oxygen (DO) levels at the river channel stations for 2008 were similar to the average for 1996-2007. Dissolved oxygen levels were lowest during the summer, often falling below the state standard of 5.0 mg/L at several river and upper estuary stations. There is a dissolved oxygen sag in the main river channel that begins at Station DP below a paper mill discharge and near the Black River input, and persists into the mesohaline portion of the estuary. Mean oxygen levels were highest at the upper river stations NC11 and AC and in the middle to lower estuary at stations M42 to M18. Lowest mainstem average 2008 DO levels occurred at the lower river and upper estuary stations DP, BBT, IC, NAV, HB, BRR and M61 (6.2-6.9 mg/L). As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems. For this low water year we rated one several stations as fair (DO less than 5.0 mg/L on 11-25% of occasions sampled); HB, BRR, M61, DP and IC.

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 2008 Stations NCF117 and B210,

representing those rivers, had average DO concentrations of 6.4 and 6.8 mg/L, respectively. Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2008. Stations BCRR (upper Burgaw Creek) and SR (South River) had DO levels below 4.0 mg/L 58% of the occasions sampled, with LVC2 (Livingston Creek) 42%, NC403 (Northeast Cape Fear River headwaters) 33% and ANC (Angola Creek), GS (Goshen Swamp) and HAM (Hammond Creek) 25%. Smith Creek (SC-CH) had DO levels below 5.0 mg/L 33% of the time. Considering all sites sampled in 2008, we rated 19% as poor for dissolved oxygen, 28% as fair, and 53% as good.

Annual mean turbidity levels for 2008 were considerably lower than the long-term average, probably a result of low rainfall and lower river discharge. Highest mean turbidities were at the upper estuary site NAV (25 NTU), and the upper river sites N11 (26 NTU), AC (25 NTU) and DP (19 NTU) with turbidities gradually decreasing downstream through the estuary. Turbidity was much lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river, and were low in general in the lower order streams.

Regarding stream stations, chronic or periodic high nitrate levels were found at a number of sites, including BC117 (Burgaw Creek below Burgaw), ROC (Rockfish Creek), 6RC (Six Runs Creek), NC403, LVC2 and PB (Panther Branch). Algal blooms occurred more frequently than usual, particularly from June through September 2008. In the estuary blooms occurred from M61 through M35, and stream stations strongly impacted by algal blooms included ANC, GS, NC403, PB, LRC (Little rockfish Creek) and BCRR. This was a considerable increase over both 2006 and 2007, possibly a result of lower flow (better bloom formation conditions for phytoplankton) yet sufficient nitrogen and phosphorus availability. Several stream stations, particularly BC117, BCRR, ROC, PB, BRN (Browns Creek), HAM, SAR (Northeast Cape Fear River near Sarecta), NC403, GS and LRC showed high fecal coliform bacteria counts on a number of occasions. Periodically biochemical oxygen demand (BOD) concentrations in several Northeast Cape Fear River watershed stream stations (especially N403, GS, ANC) and Station LVC2 in the Cape Fear Watershed were elevated (BOD5 3.0 mg/L or greater). Collection of water column metals was suspended in early 2007 as they are no longer required by NC DWQ.

This report also includes an in-depth look at each subbasin, providing information regarding the results of the North Carolina Division of Water Quality's 2005 Basinwide Management Plan, and providing the UNCW-Aquatic Ecology Laboratory's (AEL) assessments of the 2008 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 2008 period UNCW rated 83% of the stations as good in terms of chlorophyll *a*, with one (PB) rated as poor and four (ANC, GS, NC403 and BCRR) rated as fair. For turbidity all of the sites were rated good except for SC-CH, which was rated poor with the brackish water standard of 25 NTU exceeded 33% of occasions sampled. Fecal coliform bacteria counts showed poorer water quality in 2008 compared to 2007, with 52% of the sites rated as poor or fair compared with 41% in 2007. 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, 47% of the sites were rated poor or fair for dissolved oxygen, slightly less than in 2007. 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 2008.

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 13-year (1995-2008) data base freely available to the public. Using this monitoring data as a framework the program goals also include focused scientific projects and investigation of pollution episodes. The scientific aspects of the program are carried out by investigators from the University of North Carolina Wilmington Center for Marine Science. The monitoring program was developed by the Lower Cape Fear River Program Technical Committee, which consists of representatives from UNCW, the North Carolina Division of Water Quality, The NC Division of Marine Fisheries, the US Army Corps of Engineers, technical representatives from streamside industries, the City of Wilmington Wastewater Treatment Plants, Cape Fear Community College, Cape Fear River Watch, the North Carolina Cooperative Extension Service, the US Geological Survey, forestry and agriculture organizations, and others. This integrated and cooperative program was the first of its kind in North Carolina.

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

program involved cooperative sampling with the North Carolina Division of Marine Fisheries and the North Carolina Wildlife Resources Commission. The fisheries program ended in December 1999, but was renewed with additional funds from the Z. Smith Reynolds Foundation from spring – winter 2000, and has been operational periodically for special projects since that period. 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. 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). 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 sampled 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, 2008, 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

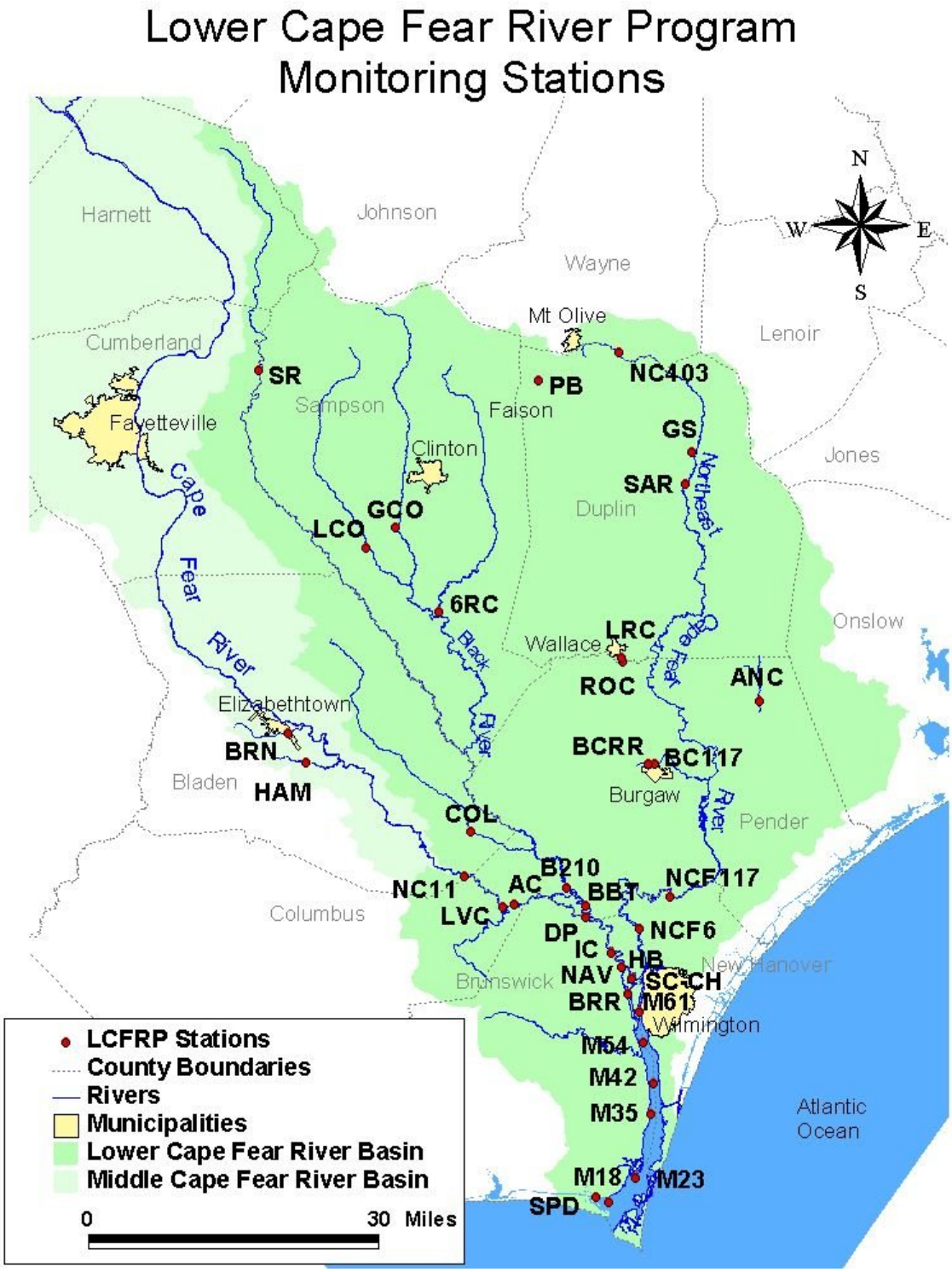
M54	B7950000	Channel Marker 54, 5 km downstream of Wilmington	
GPS		N 34.13933	W 77.94595
M42	B9845100	Channel Marker 42 near Keg Island	
GPS		N 34.09017	W 77.93355
M35	B9850100	Channel Marker 35 near Olde Brunswick Towne	
GPS		N 34.03408	W 77.93943
M23	B9910000	Channel Marker 23 near CP&L intake canal	
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 2008 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 directly from 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 is immersed in 10 mL of

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

Biochemical Oxygen Demand (BOD)

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

2.3 - Results and Discussion

This section includes results from monitoring of the physical, biological, and chemical parameters at all stations for the time period January-December 2008. Discussion of the data focuses both on the river channel stations and stream stations, which sometimes reflect poorer water quality than mainstem staions. 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 6.0 to 32.3^{o}C and individual station annual averages ranged from 16.5 to 20.9^{o}C (Table 2.1). Highest temperatures occurred during July and August and lowest temperatures during February. Stream stations were generally cooler than river stations, most likely because of shading and lower nighttime air temperatures affecting the shallower waters.

Salinity

Salinity at the estuarine stations ranged from 0.1 to 35.2 practical salinity units (psu) and station annual means ranged from 1.3 to 30.8 psu (Table 2.2), somewhat lower than in 2007. Lowest salinities occurred in December and highest salinities occurred in July. We note that average river discharge as computed by the U.S. Geological Survey (USGS) for 2008 was 3,201 CFS, compared with 5,119 CFS in 2007 and 3,301 CFS in 2006; see http://nc.water.usgs.gov/realtime/real_time_cape_fear.html. In the mid-to-lower estuary annual mean salinity for 2008 was higher than that of the twelve-year average for 1996-2007 for all stations (Figure 2.1), due to low runoff and discharge conditions. Two stream stations, NC403 and PB, had occasional oligohaline conditions due to discharges from pickle production facilities.

Conductivity

Conductivity at the estuarine stations ranged from 0.11 to 53.5 mS/cm and from 0.0 to 13.91 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 3.7 to 8.1 and station annual medians 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). Surface concentrations for all sites in 2008 ranged from 0.2 to 12.0 mg/L and station annual means ranged from 4.1 to 9.6 mg/L (Table 2.5). Average annual DO levels at the river channel and estuarine stations for 2008 were very similar to the average for 1996-2007 (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 middle estuary at stations M42 and M35. Lowest mainstem mean 2008 DO levels occurred at the lower river and upper estuary stations IC, NAV, HB, BRR and M61 (6.6-6.9 mg/L). NAV had DO concentrations less than 4.0 mg/L 17% of occasions sampled, and IC, NCF6, HB, BRR and M61 were below 5.0 mg/L 25% of the time. Discharge of high BOD waste from the paper/pulp mill just above the AC station (Mallin et al. 2003), as well as inflow of blackwater from the Northeast Cape Fear and Black Rivers, has in other years helped to diminish oxygen in the upper estuary. Additionally, algal blooms periodically form behind Lock and Dam #1, and the chlorophyll *a* they produce is strongly correlated with BOD at Station NC11 (Mallin et al. 2006b); thus the blooms do contribute to lower DO in the river. As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River (NCF117 2008 mean = 6.4, NCF6 = 6.7, B210 2008 mean = 6.8). These rivers are classified as blackwater systems because of their tea colored water. As the water passes through swamps en route to the river channel, tannins from decaying vegetation leach into the water, resulting in the observed color. Decaying vegetation on the swamp floor has an elevated biochemical oxygen demand and usurps oxygen from the water, leading to naturally low dissolved oxygen levels. Runoff from concentrated animal feeding operations (CAFOs) may also contribute to chronic low dissolved oxygen levels in these blackwater rivers (Mallin et al. 1998; 1999; 2006; Mallin 2000). We note that phosphorus and nitrogen (components of animal manure) levels are positively correlated with BOD in the blackwater rivers and their major tributaries (Mallin et al. 2006b).

In the past the Northeast Cape Fear River has often been more oxygen stressed than the Black River, and in 2008 Stations NCF117 DO concentrations were again somewhat lower than at B210 (means 6.4 and 6.8 mg/L, respectively). Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2008. Stations SR and

BCRR had DO levels below 4.0 mg/L 58% of the occasions sampled, with LVC2 42%, NC403 33%, and ANC, GS and HAM 25% (Table 2.5). Smith Creek had DO levels below 5.0 mg/L 33% of the time. Some of this can be attributed to low summer water conditions and some potentially to CAFO runoff; however point-source discharges also likely contribute to low dissolved oxygen levels at NC403 and possibly SR, especially via nutrient loading (Mallin et al. 2001a; 2002a; 2004). Hypoxia is thus a widespread problem, with 47% of the sites impacted in 2008.

Field Turbidity

Field turbidity levels ranged from 0 to 145 nephelometric turbidity units (NTU) and station annual means ranged from 1 to 26 NTU (Table 2.6). Annual mean turbidity levels for 2008 were considerably lower than the long-term average at the main river and estuarine stations (Fig. 2.3) probably a result of low river discharge and a lack of major stormwater runoff activity. Highest mean turbidities were at NC11 (26 NTU), NAV (25 NTU) and AC (25 NTU) with turbidities generally low in the middle to lower estuary (Figure 2.3). Turbidity was lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river.

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 96 mg/L with station annual means from 2 to 19 mg/L (Table 2.7). The overall highest values were at NCF6, followed by the upper river stations NC11, and AC, and the upper estuary site NAV. In the stream stations TSS was generally considerably lower than the river and estuary, except for BCRR and PB. Although total suspended solids (TSS) and turbidity both quantify suspended material in the water column, they do not always go hand in hand. High TSS does not mean high turbidity and vice versa. This anomaly may be explained by the fact that fine clay particles are effective at dispersing light and causing high turbidity readings, while not resulting in high TSS. On the other hand, large organic or inorganic particles may be less effective at dispersing light, yet their greater mass results in high TSS levels. While there is no NC ambient standard for TSS, many years of data from the lower Cape Fear watershed indicates that 25 mg/L can be considered elevated.

Light Attenuation

The attenuation of solar irradiance through the water column is measured by a logarithmic function (k) per meter. The higher this light attenuation coefficient is the more strongly light is attenuated (through absorbance or reflection) in the water column. River and estuary light attenuation coefficients ranged from 0.74 to 7.77/m and station annual means ranged from 1.25 at M18 to 4.22 /m at NAV (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 50 to 27,300 μg/L and station annual means ranged from 371 to 12,557 μg/L (Table 2.9). Mean total nitrogen in 2008 was slightly higher than the twelve-year mean at most river stations, but lower than the mean in the lower estuary (Figure 2.4). Previous research (Mallin et al. 1999) has shown a positive correlation between river flow and TN in the Cape Fear system. In the main river total nitrogen concentrations were highest at NC11, entering the system, then remained fairly constant down the river and declined from mid-estuary into the lower estuary, most likely reflecting uptake of nitrogen into the food chain through algal productivity and subsequent grazing by planktivores as well as through dilution and marsh denitrification. The blackwater rivers maintained TN concentrations considerably lower than those found in the mainstem Cape Fear River. One stream station, BC117, had a very high mean of 12,557 μg/L, likely from the upstream Town of Burgaw wastewater discharge. ROC and LVC2 also had comparatively high TN values among the stream stations. Temporal patterns for TN were not evident.

Nitrate+Nitrite

Nitrate+nitrite (henceforth referred to as nitrate) is the main species of inorganic nitrogen in the Lower Cape Fear River. Concentrations system wide ranged from 10 (detection limit) to 27,300 μg/L and station annual means ranged from 45 to 11,832 μg/L (Table 2.10). The highest average riverine nitrate levels were at AC (764 μg/L) and NC11 (739 μg/L) indicating that much of this nutrient is imported from upstream. Moving downstream, nitrate levels decrease most likely as a result of uptake by primary producers, microbial

denitrification in riparian marshes and tidal dilution. Despite this, the rapid flushing of the estuary (Ensign et al. 2004) permits sufficient nitrate to enter the coastal ocean in the plume and contribute to offshore productivity (Mallin et al. 2005b). Nitrate can limit phytoplankton production in the lower estuary in summer (Mallin et al. 1999). The blackwater rivers carried lower loads of nitrate compared to the mainstem Cape Fear stations; i.e. the Northeast Cape Fear River (NCF117 mean = 283 μg/L) and the Black River (B210 = 220 μg/L). No clear temporal pattern was observable for nitrate.

Several stream stations showed high levels of nitrate on occasion including BC117, ROC, 6RC, LVC2, NC403 and LCO. NC403 and LVC2 are downstream of industrial wastewater discharges and LCO, ROC and 6RC primarily receive non-point agricultural or animal waste drainage. BC117 always showed very high nitrate levels. The Town of Burgaw wastewater plant, upstream of BC117, has no nitrate discharge limits. Over the past several years a considerable number of experiments have been carried out by UNCW researchers to assess the effects of nutrient additions to water collected from blackwater streams and rivers (i.e. the Black and Northeast Cape Fear Rivers, and Colly and Great Coharie Creeks). These experiments have collectively found that additions of nitrogen (as either nitrate, ammonium, or urea) significantly stimulate phytoplankton production and BOD increases. Critical levels of these nutrients were in the range of 0.2 to 0.5 mg/L as N (Mallin et al. 1998; Mallin et al. 2001a; Mallin et al. 2002a, Mallin et al. 2004). Thus, we conservatively consider nitrate concentrations exceeding 0.5 mg/L as N in Cape Fear watershed streams to be potentially problematic to the stream's environmental health.

Ammonium

Ammonium concentrations ranged from 5 (detection limit) to 1,810 μg/L and station annual means ranged from 5 to 676 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, andM54, located downstream of the Wilmington South Side Wastewater Treatment Plant discharge. Ocean dilution and biological uptake accounts for decreasing levels in the lower estuary. At the stream stations, areas with periodic high levels of ammonium include BCRR, PB, GS and especially LVC2 (below point sources), which had the highest mean and median ammonium concentrations in the system (Table 2.11).

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of the total concentration of organic nitrogen plus ammonium. TKN ranged from 50 to 9,200 μg/L and station annual means ranged from 188 to 1,905 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 anomalous peak of 6,200 µg/L of TN was seen at M42 in July; this was a real number according to the laboratory, but clearly an isolate, and rare excursion in that area of the estuary. Likewise an unusual peak of 9,200 µg/L occurred at AC in March.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from below detection limit to 3,860 μg/L and station annual means ranged from 31 to 1,576 μg/L (Table 2.13). Mean TP for 2008 was approximately equal to the twelve-year mean in all areas except the Northeast Cape Fear River, where it was much higher than the mean (Figure 2.5). In the river TP is highest at the upper riverine channel stations and declines downstream into the estuary. Some of this decline is attributable to the settling of phosphorus-bearing suspended sediments, yet incorporation of phosphorus into bacteria and algae is also responsible. A temporal pattern of higher summer TP is a result of increasing orthophosphate during the summer.

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

Orthophosphate

Orthophosphate ranged from undetectable to 2,820 μg/L and station annual means ranged from 7 to 1,108 μg/L (Table 2.14). Much of the orthophosphate load is imported into the Lower Cape Fear system from upstream areas, as NC11 or AC typically has the highest levels. The Northeast Cape Fear River had higher orthophosphate levels than the Black River. Orthophosphate can bind to suspended materials and is transported downstream via particle attachment; thus high levels of turbidity at the uppermost river stations may be an important factor in the high orthophosphate levels. Turbidity declines toward the 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 chlorophyll *a* was moderate in the river but relatively high at the estuarine stations (Table 2.15). At many of the estuarine stations chlorophyll *a* for 2008 was approximately double that of the twelve-year mean for those sites (Figure 2.6). Two moderate algal blooms occurred at Station NC11, with chlorophyll *a* levels of 24 μg/L in July and 34 μg/L in August. At this site it has been demonstrated that chlorophyll *a* biomass is significantly correlated with biochemical oxygen demand (BOD5 – Mallin et al. 2006b). High chlorophyll at NC11 may represent remnants of algal blooms forming in the more lentic (lake-like) conditions found above Lock and Dam #1. System wide, chlorophyll *a* ranged from undetectable to 376.0 μg/L and station annual means ranged from 1.4 – 41.9 μg/L; these numbers represent a considerable increase in phytoplankton production throughout the system compared with 2007. 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. However, in 2008 phytoplankton biomass as chlorophyll *a* was unusually elevated from M61 to M35 during the months of June – September (Table 2.15).

Spatially, highest values are normally found in the mid-to-lower estuary stations because light becomes more available downstream of the estuarine turbidity maximum (Table 2.6). On average, flushing time of the Cape Fear estuary is rapid, ranging from 1-22 days with a median of 6.7 days (Ensign et al. 2004). This does not allow for much settling of suspended materials, leading to light limitation of phytoplankton production. However, the low flow conditions prevailing in 2008 allowed for clearer water through less suspended material and less blackwater swamp inputs. Thus, chlorophyll *a* concentrations in the estuary were larger than the average for the preceding eleven years (Figure 2.6). Highest chlorophyll *a* concentrations were found from June through September in both the main channels and at the stream stations.

Substantial phytoplankton blooms occasionally occur at the stream stations, with more than usual occurring in 2008 (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 in 2008 were particularly high at GS, PB, NC403, BCRR and ANC (Table 2.15).

Biochemical Oxygen Demand

For the mainstem river, mean annual five-day biochemical oxygen demand (BOD5) concentrations were approximately equivalent between NC11 and AC, suggesting that in 2008 (as was the case with 2007) there were no discernable effects of BOD loading from the nearby pulp/paper mill inputs (Table 2.16). BOD was somewhat lower during the winter than summer.

Results of 2008 BOD analyses from several stream stations in the Northeast Cape Fear River watershed can be seen in Table 2.16. ANC, GS, and N403 all showed large (> 4.3 mg/L) individual BOD5 measurements during 2008, particularly during summer. Station N403 is below point sources, but the other two sites are non-point runoff areas.

Fecal Coliform Bacteria

Fecal coliform (FC) bacterial counts ranged from 1 to >30,000 CFU/100 mL and station annual geometric means ranged from 5 to 788 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded at the mainstem sites only rarely in 2008. Geometric mean fecal coliform counts in 2008 in the Cape Fear, Black, and Northeast Cape Fear Rivers were high compared with the twelve-year average, whereas the estuarine counts were approximately equal to the long-term geometric means (Figure 2.7).

All stream stations surpassed the state standard for human contact of 200 CFU/100 mL on at least one occasion and many were particularly problematic. During 2008 BC117 exceeded the state standard 100% of the time; BRN 58%, 6RC, SAR and HAM 50%, PB, ROC, and BCRR 42%, N403 and SR 33%, and ANC, GS, LRC 25% 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 52% of the stations impacted in 2008, a worsening from the previous year 2007.

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Table 2.1 Water temperature (°C) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	10.1	11.0	10.8	11.1	11.5	11.7	11.6	11.8	11.9	11.3
FEB	13.1	13.3	13.2	13.8	13.7	13.4	13.6	13.6	13.1	13.0
MAR	13.4	14.1	14.2	14.1	14.7	14.9	15.0	14.9	14.4	14.8
APR	19.9	19.7	20.0	20.7	20.3	20.8	20.5	19.8	19.4	20.2
MAY	22.3	22.8	23.3	22.5	22.4	22.7	22.6	22.3	21.7	21.9
JUN	25.6	26.0	25.9	26.2	26.8	26.4	29.3	29.1	28.2	28.7
JUL	29.5	30.0	30.0	29.9	28.9	28.6	28.2	28.0	27.8	28.2
AUG	31.3	31.4	32.3	31.7	30.8	30.8	31.2	30.3	30.2	30.5
SEP	27.5	28.5	28.5	28.5	28.2	28.1	28.7	28.0	28.3	28.1
OCT	23.4	24.4	23.4	23.7	23.5	24.3	24.7	25.4	24.9	24.6
NOV	15.4	15.7	15.8	16.3	16.2	16.2	16.3	16.5	16.4	15.4
DEC	8.6	8.7	9.3	10.3	10.2	10.5	10.6	11.3	11.4	10.8
mean	**20.0**	**20.5**	**20.6**	**20.7**	**20.6**	**20.7**	**21.0**	**20.9**	**20.6**	**20.6**
std dev	7.8	7.8	7.8	7.5	7.2	7.1	7.4	7.2	7.1	7.4
median	21.1	21.3	21.7	21.6	21.4	21.8	21.6	21.1	20.6	21.1
max	31.3	31.4	32.3	31.7	30.8	30.8	31.2	30.3	30.2	30.5
min	8.6	8.7	9.3	10.3	10.2	10.5	10.6	11.3	11.4	10.8

month	NC11	AC	DP	BBT	IC	NCF6
JAN	9.6	9.9	9.6	9.5	9.4	11.5
FEB	11.8	11.9	12.3	12.3	12.7	12.9
MAR	12.5	13.2	13.2	13.7	13.2	13.4
APR	17.5	17.6	17.7	16.6	17.2	17.9
MAY	21.5	22.1	21.3	21.4	21.9	23.0
JUN	27.7	28	27.8	27.6	28.4	27.9
JUL	28.9	29.4	29.1	29.2	29.1	28.5
AUG	27.9	28.0	27.1	26.8	27.7	28.5
SEP	26.3	26.1	26.3	26.2	29.1	27.9
OCT	21.8	22.2	22.1	21.9	22.3	23.1
NOV	13.3	13.2	13.0	12.3	13.2	14.3
DEC	10.9	11.1	11.3	11.5	11.8	12.0
mean	**19.1**	**19.4**	**19.2**	**19.1**	**19.7**	**20.1**
std dev	7.4	7.4	7.2	7.2	7.6	7.1
median	19.5	19.9	19.5	19.0	19.6	20.5
max	28.9	29.4	29.1	29.2	29.1	28.5
min	9.6	9.9	9.6	9.5	9.4	11.5

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	10.9	13.2	13.2	12.3	13.4	13.5	12.4	15.3	11.2
FEB	17.5	16.5	17.1	15.6	15.3	13.8	15.9	16.4	13.4
MAR	15.7	14.9	15.3	15.2	12.8	13.8	15.9	12.7	14.2
APR	18.0	16.2	16.6	17.2	16.2	16.7	16.4	16.0	15.9
MAY	22.2	17.8	21.8	23.3	24.8	22.1	20.7	18.9	19.8
JUN	30.2	30.1	29.6	30.2	30.9	29.4	27.1	26.2	25.0
JUL	28.0	26.5	26.7	26.8	27.2	26.5	26.5	25.6	24.5
AUG	25.3	23.5	24.4	23.3	22.9	23.0	22.3	21.9	21.7
SEP	25.3	24.7	25.2	24.5	25.7	23.5	23.2	22.6	22.7
OCT	20.8	19.9	20.5	20.5	20.2	19.5	21.0	19.3	20.1
NOV	7.8	7.0	8.0	7.8	7.0	7.9	6.6	8.2	6.3
DEC	7.4	6.2	8.2	7.1	6.0	7.2	6.1	7.3	6.1
mean	**19.1**	**18.0**	**18.9**	**18.7**	**18.5**	**18.1**	**17.8**	**17.5**	**16.7**
std dev	7.6	7.4	7.0	7.4	8.0	7.1	6.9	6.1	6.6
median	19.4	17.2	18.8	18.9	18.2	18.1	18.6	17.7	17.9
max	30.2	30.1	29.6	30.2	30.9	29.4	27.1	26.2	25.0
min	7.4	6.2	8.0	7.1	6.0	7.2	6.1	7.3	6.1

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	6.9	6.9	7.3	7.4	9.8	6.6
FEB	9.7	9.1	10.3	9.3	11.6	10.3
MAR	12.8	12.5	13.7	13.2	13.7	13.2
APR	16.0	15.5	15.5	15.6	15.5	15.2
MAY	20.9	21.0	21.3	20.8	20.6	19.3
JUN	25.3	24.7	26.1	23.0	20.7	20.8
JUL	22.7	22.8	25.0	24.7	22.9	22.3
AUG	26.9	26.5	26.7	26.6	27.0	25.4
SEP	24.5	24.3	24.8	24.3	24.3	23.3
OCT	18.1	18.2	18.4	18.7	18.6	17.7
NOV	13.5	13.3	13.8	13.2	14.4	13.3
DEC	10.0	9.6	9.7	9.0	10.6	10.3
mean	**17.3**	**17.0**	**17.7**	**17.1**	**17.5**	**16.5**
std dev	6.8	6.8	7.0	6.8	5.7	5.9
median	17.1	16.9	17.0	17.2	17.1	16.5
max	26.9	26.5	26.7	26.6	27.0	25.4
min	6.9	6.9	7.3	7.4	9.8	6.6

month	NCF117	B210	COL	LVC2	SC-CH
JAN	10.3	10.2	11.8	9.3	11.8
FEB	11.5	14.1	14.1	11.6	11.6
MAR	12.9	14.1	15.1	13.6	15.4
APR	17.4	16.4	15.5	17.5	18.0
MAY	21.8	20.4	18.1	19.8	22.2
JUN	29.3	30.6	27.7	28.0	30.6
JUL	28.5	28.6		27.0	28.8
AUG	30.5	29.5	26.7	28.5	30.9
SEP	27.6	25.3	23.8	25.4	28.1
OCT	21.2	18.8	17.2	18.6	22.8
NOV	11.5	8.5	7.0	8.3	11.5
DEC	10.2	10.6	12.5	12.3	12.0
mean	**19.4**	**18.9**	**17.2**	**18.3**	**20.3**
std dev	8.1	7.9	6.5	7.5	7.9
median	19.3	17.6	15.5	18.1	20.1
max	30.5	30.6	27.7	28.5	30.9
min	10.2	8.5	7.0	8.3	11.5

Table 2.2 Salinity (psu) during 2008 at the Lower Cape Fear River Program estuarine stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD	NCF6
JAN	3.3	5.4	4.6	8.4	10.8	13.8	20.4	25.1	31.2	27.4	7.6
FEB	0.1	0.5	1.1	5.9	8.0	9.6	14.3	23.9	27.6	28.3	0.3
MAR	0.1	0.1	0.1	0.4	1.5	4.6	10.2	20.2	30.4	21.4	0.1
APR	0.1	0.1	0.1	4.0	6.5	7.2	13.6	21.8	29.0	22	0.1
MAY	1.3	2.3	1.2	3.1	8.2	10.8	16.9	25.5	31.8	27.1	1.6
JUN	2.1	5.8	7.3	11.8	13.8	17.3	21.5	27.6	31.6	32.9	4.6
JUL	1.2	3.1	5.5	12.3	18.4	21.0	24.3	31.9	34.2	35.2	12.0
AUG	5.9	6.6	8.3	13.0	16.8	19.9	22.8	32.5	34.6	32.1	13.3
SEP	0.5	1.2	0.8	4.3	7.9	12.1	19.8	29.1	32.0	29.2	5.8
OCT	1.1	1.6	0.8	3.0	7.1	12.3	16.1	25.3	33.3	29.7	0.7
NOV	0.3	4.5	8.9	13.6	15.8	17.8	21.4	27.7	30.2	30.9	0.4
DEC	0.1	0.1	2.0	7.7	8.2	10.6	12.9	19.6	24.0	24.9	0.2
mean	**1.3**	**2.6**	**3.4**	**7.3**	**10.3**	**13.1**	**17.9**	**25.9**	**30.8**	**28.4**	**3.9**
std dev	1.7	2.4	3.3	4.5	5.0	5.1	4.5	4.2	2.9	4.2	4.8
median	0.8	2.0	1.6	6.8	8.2	12.2	18.4	25.4	31.4	28.8	1.2
max	5.9	6.6	8.9	13.6	18.4	21.0	24.3	32.5	34.6	35.2	13.3
min	0.1	0.1	0.1	0.4	1.5	4.6	10.2	19.6	24.0	21.4	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations, 1995-2007 versus 2008.

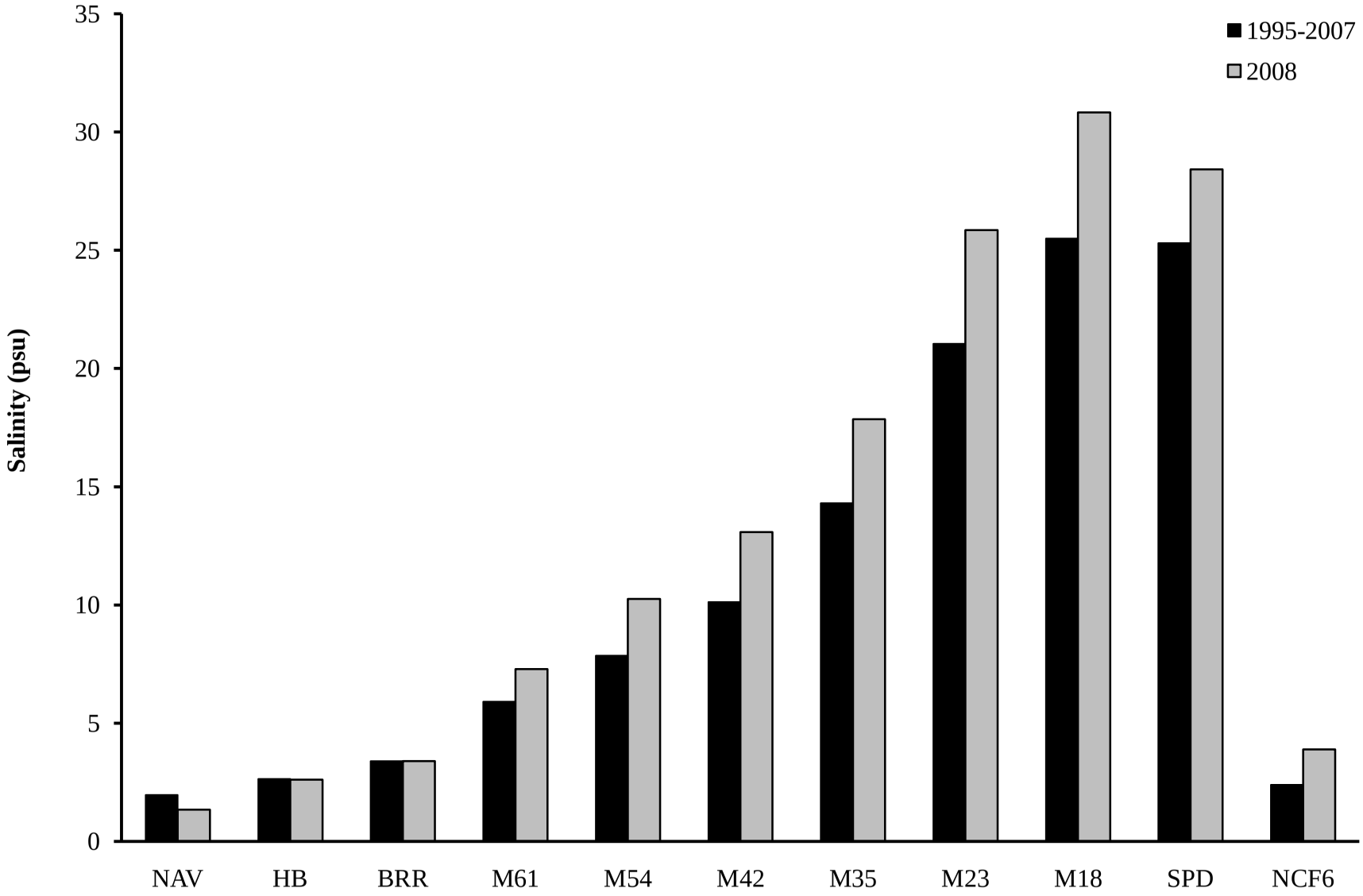


Table 2.3 Specific Conductivity (mS/cm) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	6.06	9.59	8.24	14.42	18.27	22.83	32.67	39.44	47.94	42.68
FEB	0.20	1.06	2.14	10.39	13.70	16.26	23.55	35.64	43.00	43.85
MAR	0.11	0.11	0.16	0.72	2.91	8.22	17.32	32.25	46.71	34.05
APR	0.15	0.15	0.31	7.16	11.40	12.54	22.48	34.72	44.79	34.89
MAY	2.56	4.32	2.26	5.69	14.14	18.25	27.55	39.75	48.61	42.09
JUN	3.94	10.28	12.69	19.87	22.89	28.18	34.40	43.03	48.52	50.45
JUL	2.29	5.77	9.90	20.76	29.82	33.64	38.33	49.00	52.12	53.50
AUG	10.55	11.85	14.43	21.75	27.61	32.06	36.30	49.91	52.85	49.36
SEP	1.11	1.77	1.60	7.79	13.72	20.26	31.90	44.93	49.18	45.20
OCT	2.05	3.06	1.57	5.59	12.31	20.57	26.35	39.65	50.76	45.56
NOV	0.68	8.01	15.22	22.37	25.82	28.84	34.03	42.95	46.37	47.36
DEC	0.14	0.17	3.83	13.31	14.06	17.86	21.50	31.51	37.89	39.16
mean	**2.49**	**4.68**	**6.03**	**12.48**	**17.22**	**21.63**	**28.86**	**40.23**	**47.39**	**44.01**
std dev	3.12	4.32	5.72	7.37	7.87	7.80	6.68	6.03	4.13	5.93
median	1.58	3.69	3.05	11.85	14.10	20.42	29.72	39.70	48.23	44.52
max	10.55	11.85	15.22	22.37	29.82	33.64	38.33	49.91	52.85	53.50
min	0.11	0.11	0.16	0.72	2.91	8.22	17.32	31.51	37.89	34.05

month	NC11	AC	DP	BBT	IC	NCF6
JAN	0.12	0.16	0.20	0.19	0.26	13.16
FEB	0.14	0.14	0.21	0.15	0.18	0.60
MAR	0.10	0.27	0.18	0.10	0.13	0.22
APR	0.09	0.11	0.12	0.08	0.09	0.15
MAY	0.09	0.13	0.14	0.12	0.14	3.02
JUN	0.15	0.29	0.23	0.23	0.28	8.31
JUL	0.15	0.35	0.32	0.32	0.57	20.28
AUG	0.15	0.20	0.17	0.16	0.21	22.20
SEP	0.10	0.11	0.14	0.11	0.14	10.35
OCT	0.10	0.10	0.12	0.11	0.13	1.42
NOV	0.12	0.12	0.14	0.12	0.14	0.85
DEC	0.08	0.10	0.10	0.10	0.10	0.38
mean	**0.11**	**0.17**	**0.17**	**0.15**	**0.20**	**6.74**
std dev	0.02	0.08	0.06	0.07	0.13	8.09
median	0.11	0.13	0.16	0.12	0.14	2.22
max	0.15	0.35	0.32	0.32	0.57	22.20
min	0.08	0.10	0.10	0.08	0.09	0.15

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	0.22	0.23	0.22	0.31	1.62	0.15	0.16	1.20	0.29
FEB	0.19	0.22	0.21	0.53	2.77	0.14	0.15	0.87	0.28
MAR	0.16	0.15	0.15	0.18	0.45	0.13	0.12	0.29	0.21
APR	0.11	0.13	0.12	0.27	0.43	0.11	0.09	0.24	0.17
MAY	0.09	0.10	0.16	0.32	4.90	0.10	0.11	0.38	0.21
JUN	0.15	0.30	0.22	0.61	8.81	0.17	0.14	1.09	0.32
JUL	0.18	0.38	0.22	0.63	13.91	0.29	0.33	1.13	0.60
AUG	0.16	0.40	0.22	0.65	4.99	0.16	0.14	0.35	0.20
SEP	0.22	0.53	0.62	0.80	8.03	0.29	0.11	0.59	0.24
OCT	0.14	0.19	0.19	0.34	1.95	0.13	0.12	0.57	0.27
NOV	0.18	0.21	0.22	0.27	1.39	0.15	0.16	0.45	0.28
DEC	0.19	0.19	0.18	0.33	1.27	0.14	0.15	0.40	0.25
mean	**0.16**	**0.25**	**0.23**	**0.44**	**4.21**	**0.16**	**0.15**	**0.63**	**0.28**
std dev	0.04	0.13	0.13	0.20	4.15	0.06	0.06	0.35	0.11
median	0.17	0.22	0.21	0.33	2.36	0.15	0.14	0.51	0.26
max	0.22	0.53	0.62	0.80	13.91	0.29	0.33	1.20	0.60
min	0.09	0.10	0.12	0.18	0.43	0.10	0.09	0.24	0.17

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.15	0.13	0.21	0.15	0.15	0.22
FEB	0.14	0.11	0.19	0.13	0.16	0.22
MAR	0.13	0.10	0.13	0.11	0.16	0.17
APR	0.03	0.09	0.09	0.08	0.09	0.08
MAY	0.11	0.08	0.11	0.08	0.11	0.16
JUN	0.14	0.09	0.17	0.14	0.11	0.22
JUL	0.15	0.10	0.33	0.06	0.10	0.23
AUG	0.13	0.09	0.18	0.07	0.10	0.16
SEP	0.09	0.06	0.08	0.07	0.08	0.09
OCT	0.12	0.08	0.10	0.07	0.10	0.15
NOV	0.13	0.09	0.15	0.08	0.12	0.18
DEC	0.13	0.09	0.12	0.09	0.11	0.17
mean	**0.12**	**0.09**	**0.15**	**0.09**	**0.11**	**0.17**
std dev	0.03	0.02	0.07	0.03	0.03	0.05
median	0.13	0.09	0.14	0.08	0.11	0.17
max	0.15	0.13	0.33	0.15	0.16	0.23
min	0.03	0.06	0.08	0.06	0.08	0.08

month	NCF117	B210	COL	LVC2	SC-CH
JAN	0.25	0.16	0.21	0.25	6.40
FEB	0.21	0.13	0.16	0.26	14.45
MAR	0.15	0.10	0.13	0.17	1.53
APR	0.10	0.07	0.09	0.13	0.53
MAY	0.13	0.08	0.08	0.14	4.16
JUN	0.16	0.09	0.06	0.14	11.24
JUL	0.39	0.14	0.00	0.18	24.48
AUG	0.30	0.11	0.11	0.19	13.43
SEP	0.18	0.08	0.10	0.16	3.44
OCT	0.17	0.08	0.08	0.12	4.23
NOV	0.20	0.10	0.08	0.13	3.61
DEC	0.19	0.09	0.08	0.13	1.78
mean	**0.20**	**0.10**	**0.10**	**0.17**	**7.44**
std dev	0.08	0.03	0.05	0.05	7.12
median	0.19	0.09	0.09	0.15	4.20
max	0.39	0.16	0.21	0.26	24.48
min	0.10	0.07	0.00	0.12	0.53

Table 2.4 pH during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	7.3	7.3	7.5	7.6	7.7	7.8	8.0	8.1	8.1	8.0
FEB	7.2	7.3	7.3	7.4	7.6	7.7	8.0	8.1	8.1	8.0
MAR	6.7	6.6	6.9	6.9	7.3	7.5	7.8	8.1	8.1	8.1
APR	6.8	7.2	7.0	7.0	7.2	7.4	7.7	8.0	8.1	7.9
MAY	6.8	6.9	7.1	7.1	7.4	7.6	7.7	7.9	7.9	7.8
JUN	7.0	7.1	7.1	7.4	7.7	7.9	8.0	8.0	8.0	7.7
JUL	7.1	7.3	7.2	7.4	7.6	7.7	7.8	7.9	8.0	7.8
AUG	7.0	7.0	7.2	7.3	7.5	7.9	8.0	8.0	8.0	8.0
SEP	7.2	7.4	7.1	7.1	7.3	7.7	8.1	8.0	8.0	8.0
OCT	6.7	6.9	6.9	6.9	7.1	7.4	7.6	7.9	8.1	7.9
NOV	7.5	7.4	7.4	7.4	7.5	7.6	7.7	7.9	7.9	7.6
DEC	7.0	6.9	7.4	7.4	7.4	7.6	7.7	7.9	7.9	7.7
median	**7.0**	**7.2**	**7.2**	**7.4**	**7.2**	**7.7**	**7.8**	**8.0**	**8.0**	**7.9**
std dev	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2
median	7.0	7.2	7.2	7.4	7.5	7.7	7.8	8.0	8.0	7.9
max	7.5	7.4	7.5	7.6	7.7	7.9	8.1	8.1	8.1	8.1
min	6.7	6.6	6.9	6.9	7.1	7.4	7.6	7.9	7.9	7.6

month	NC11	AC	DP	BBT	IC	NCF6
JAN	7.0	6.9	6.8	6.8	6.9	7.0
FEB	6.9	6.7	7.0	6.4	6.6	6.8
MAR	6.6	7.2	6.9	6.1	6.5	6.6
APR	6.7	6.7	6.8	5.9	6.3	6.3
MAY	6.6	6.7	6.6	6.5	6.6	6.7
JUN	7.0	7.0	6.9	6.8	6.9	7.0
JUL	6.8	7.0	6.9	6.9	7.0	7.2
AUG	6.8	6.9	6.6	6.6	6.7	7.0
SEP	6.7	6.6	6.7	6.2	6.6	6.7
OCT	6.6	6.6	6.4	6.2	6.4	6.6
NOV	6.5	6.7	6.8	6.6	6.7	6.7
DEC	6.6	6.5	6.6	6.5	6.4	6.7
median	**6.7**	**6.7**	**6.8**	**6.5**	**6.6**	**6.7**
std dev	0.2	0.2	0.2	0.3	0.2	0.2
median	6.7	6.7	6.7	6.8	6.5	6.6
max	7.0	7.2	7.0	6.9	7.0	7.2
min	6.5	6.5	6.4	5.9	6.3	6.3

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	7.0	6.5	6.9	6.6	6.7	7.4	7.1	7.6	7.2
FEB	6.7	6.7	6.7	6.5	6.8	7.4	6.8	7.6	6.9
MAR	5.9	6.5	6.8	6.4	6.7	7.0	6.8	7.2	7.6
APR	5.6	6.4	6.5	6.3	6.5	6.6	6.3	7.0	6.5
MAY	5.4	5.8	6.8	6.5	7.1	7.0	6.9	7.3	7.0
JUN	6.7	7.1	6.7	6.5	7.4	8.1	7.1	7.9	7.0
JUL	7.1	7.0	7.0	7.0	8.0	8.1	7.3	7.9	7.5
AUG	6.7	7.3	7.1	6.4	6.9	7.7	7.1	7.3	6.9
SEP	6.9	6.2	5.2	6.3	7.1	7.4	6.8	7.6	6.9
OCT	5.9	6.2	6.2	6.3	6.7	7.3	6.9	7.3	6.5
NOV	6.4	6.3	6.4	6.6	6.6	7.3	6.9	7.2	6.6
DEC	6.5	6.5	6.6	6.6	6.6	7.2	7.0	7.0	6.4
median	**6.6**	**6.5**	**6.7**	**6.5**	**6.8**	**7.4**	**6.9**	**7.3**	**6.9**
std dev	0.6	0.4	0.5	0.2	0.4	0.4	0.2	0.3	0.4
median	6.6	6.5	6.7	6.5	6.8	7.4	6.9	7.3	6.9
max	7.1	7.3	7.1	7.0	8.0	8.1	7.3	7.9	7.6
min	5.4	5.8	5.2	6.3	6.5	6.6	6.3	7.0	6.4

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	7.2	6.4	6.5	5.7	6.5	6.4
FEB	6.5	5.9	6.5	5.5	6.8	7.0
MAR	6.5	5.8	6.3	5.6	6.8	6.9
APR	5.8	6.0	6.3	5.9	6.1	6.0
MAY	6.9	6.4	6.5	6.0	6.9	6.9
JUN	7.2	6.9	7.2	6.0	7.1	6.7
JUL	7.1	6.7	7.1	6.0	6.9	7.0
AUG	7.0	6.4	6.4	6.1	6.8	6.7
SEP	5.9	5.2	6.0	5.9	5.9	6.1
OCT	6.4	6.1	6.1	5.9	6.5	6.7
NOV	7.4	6.6	6.5	5.9	6.6	7.0
DEC	6.5	6.0	6.2	5.9	6.4	6.7
median	**6.7**	**6.3**	**6.5**	**5.9**	**6.7**	**6.7**
std dev	0.5	0.5	0.4	0.2	0.4	0.3
median	6.7	6.3	6.5	5.9	6.7	6.7
max	7.4	6.9	7.2	6.1	7.1	7.0
min	5.8	5.2	6.0	5.5	5.9	6.0

month	NCF117	B210	COL	LVC2	SC-CH
JAN	6.8	6.2	3.7	7.6	6.5
FEB	6.6	6.2	6.2	6.6	6.5
MAR	6.5	5.9	3.7	6.9	7.1
APR	6.2	5.7	4.1	6.7	6.6
MAY	6.5	6.1	4.0	6.8	6.7
JUN	6.6	6.5	4.1	6.7	7.0
JUL	7.0	6.9		6.6	7.1
AUG	6.7	6.0	3.8	6.8	6.9
SEP	6.6	5.6	3.8	6.5	6.7
OCT	6.2	5.8	3.8	6.3	6.7
NOV	6.3	5.8	4.0	7.1	6.8
DEC	6.7	6.2	3.9	6.4	6.5
median	**6.6**	**6.1**	**3.9**	**6.7**	**6.7**
std dev	0.2	0.4	0.7	0.3	0.2
median	6.6	6.1	3.9	6.7	6.7
max	7.0	6.9	6.2	7.6	7.1
min	6.2	5.6	3.7	6.3	6.5

Table 2.5 Dissolved Oxygen (mg/l) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	9.3	9.4	9.4	9.2	9.4	9.5	9.5	9.5	9.3	9.4
FEB	9.3	9.2	9.2	8.9	9.2	9.3	9.4	9.4	9.4	8.8
MAR	8.6	8.5	8.4	8.4	8.8	8.9	9.0	9.0	8.8	9.0
APR	7.5	7.1	7.4	7.0	7.0	7.4	7.5	7.4	7.5	7.6
MAY	6.2	6.1	6.4	6.3	6.5	6.9	6.9	6.9	7.0	6.7
JUN	4.9	5.4	5.5	6.2	7.4	7.8	7.1	6.8	6.1	5.1
JUL	3.9	4.3	4.8	5.8	6.1	6.2	6.1	5.9	6.1	5.7
AUG	3.5	3.8	4.9	4.8	5.4	7.0	7.9	5.6	5.8	6.0
SEP	4.8	5.0	6.0	4.9	5.1	7.2	8.9	6.6	6.5	6.8
OCT	4.7	4.9	4.8	4.9	5.1	5.8	5.7	6.3	6.4	6.2
NOV	7.2	7.0	7.0	6.9	7.3	7.6	7.6	7.8	7.9	7.1
DEC	9.8	9.8	9.6	8.9	9.0	9.1	9.0	8.9	8.6	8.6
mean	**6.6**	**6.7**	**7.0**	**6.9**	**7.2**	**7.7**	**7.9**	**7.5**	**7.5**	**7.3**
std dev	2.3	2.1	1.8	1.7	1.6	1.2	1.3	1.4	1.3	1.4
median	6.7	6.6	6.7	6.6	7.2	7.5	7.8	7.2	7.3	7.0
max	9.8	9.8	9.6	9.2	9.4	9.5	9.5	9.5	9.4	9.4
min	3.5	3.8	4.8	4.8	5.1	5.8	5.7	5.6	5.8	5.1

month	NC11	AC	DP	BBT	IC	NCF6
JAN	10.7	10.1	9.9	10.0	9.9	9.1
FEB	10.4	9.8	9.7	9.2	9.2	9.3
MAR	10.8	10.3	10.2	9.4	9.8	9.3
APR	8.8	8.5	8.2	6.4	7.0	5.6
MAY	7.2	6.7	5.7	5.5	5.9	6.0
JUN	8.8	6.8	5.1	5.1	5.4	6.8
JUL	6.8	5.1	3.5	3.5	3.8	5.6
AUG	6.4	6.0	4.6	4.6	4.5	3.6
SEP	6.7	6.4	6.1	4.3	5.7	4.1
OCT	7.8	7.4	5.0	4.6	4.8	4.3
NOV	9.5	9.1	9.1	7.7	8.4	7.3
DEC	10.3	9.9	9.6	9.2	8.9	8.9
mean	**8.7**	**8.0**	**7.2**	**6.6**	**6.9**	**6.7**
std dev	1.7	1.8	2.5	2.3	2.2	2.1
median	8.8	8.8	8.0	7.2	6.0	6.5
max	10.8	10.3	10.2	10.0	9.9	9.3
min	6.4	5.1	3.5	3.5	3.8	3.6

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	6.1	7.1	8.7	6.8	8.4	10.7	9.2	7.3	3.7
FEB	11.7	6.6	8.3	5.2	8.3	10.8	8.3	6.8	3.6
MAR	9.9	7.1	9.5	8.1	8.6	10.5	8.8	9.5	6.0
APR	6.4	6.4	6.6	5.9	6.7	8.6	6.5	8.0	7.5
MAY	5.6	9.5	5.6	2.6	9.5	7.7	6.8	6.7	2.5
JUN	3.4	5.3	3.7	4.3	6.5	9.3	7.4	5.8	0.9
JUL	4.0	5.2	1.2	5.1	7.7	9.5	5.0	3.3	1.4
AUG	3.0	5.1	6.0	1.5	5.3	9.0	6.1	6.4	4.6
SEP	3.6	6.4	5.8	2.1	7.3	7.6	7.2	6.5	0.5
OCT	4.4	3.6	2.9	1.8	6.5	8.4	6.8	7.3	2.0
NOV	7.5	8.8	8.2	6.7	9.2	11.3	10.1	9.6	8.6
DEC	8.9	9.6	10.1	8.4	10.2	12.0	11.0	10.3	8.2
mean	**6.2**	**6.7**	**6.4**	**4.9**	**7.9**	**9.6**	**7.8**	**7.3**	**4.1**
std dev	2.8	1.8	2.8	2.4	1.4	1.4	1.7	1.9	2.9
median	5.9	6.5	6.3	5.2	8.0	9.4	7.3	7.1	3.7
max	11.7	9.6	10.1	8.4	10.2	12.0	11.0	10.3	8.6
min	3.0	3.6	1.2	1.5	5.3	7.6	5.0	3.3	0.5

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	11.6	11.5	9.7	8.9	11.1	10.3
FEB	11.2	10.8	8.4	9.0	11.7	9.5
MAR	9.4	9.3	6.8	6.8	9.8	9.2
APR	6.1	6.3	5.7	4.8	7.2	8.5
MAY	7.2	7.2	4.9	2.4	8.0	5.8
JUN	7.4	6.9	5.6	0.2	8.1	3.9
JUL	6.3	6.0	5.2	1.9	8.5	2.9
AUG	5.8	5.7	1.8	1.1	6.3	3.4
SEP	3.5	3.9	3.0	0.6	5.6	6.3
OCT	7.7	7.0	4.3	1.5	8.7	7.6
NOV	9.7	9.7	7.7	3.1	9.9	7.4
DEC	10.1	9.5	7.9	7.2	9.5	9.0
mean	**8.0**	**7.8**	**5.9**	**4.0**	**8.7**	**7.0**
std dev	2.4	2.3	2.3	3.2	1.8	2.5
median	7.6	7.1	5.7	2.8	8.6	7.5
max	11.6	11.5	9.7	9.0	11.7	10.3
min	3.5	3.9	1.8	0.2	5.6	2.9

month	NCF117	B210	COL	LVC2	SC-CH
JAN	8.9	10.1	8.4	7.5	9.4
FEB	10.2	9.4	8.5	8.0	9.5
MAR	9.1	8.5	7.2	9.9	8.7
APR	5.8	6.7	6.4	4.3	7.5
MAY	5.1	5.6	6.8	3.1	6.1
JUN	4.2	4.4	4.7	1.8	4.6
JUL	5.3	5.0		1.5	5.7
AUG	4.7	4.3	5.2	1.9	3.9
SEP	3.7	3.5	4.1	2.6	3.8
OCT	4.0	5.7	5.8	5.2	4.9
NOV	6.9	8.9	9.3	8.3	7.9
DEC	9.1	9.6	7.2	8.5	9.0
mean	**6.4**	**6.8**	**6.7**	**5.2**	**6.8**
std dev	2.3	2.4	1.7	3.1	2.2
median	5.6	6.2	6.8	4.8	6.8
max	10.2	10.1	9.3	9.9	9.5
min	3.7	3.5	4.1	1.5	3.8

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations, 1995-2007 versus 2008.

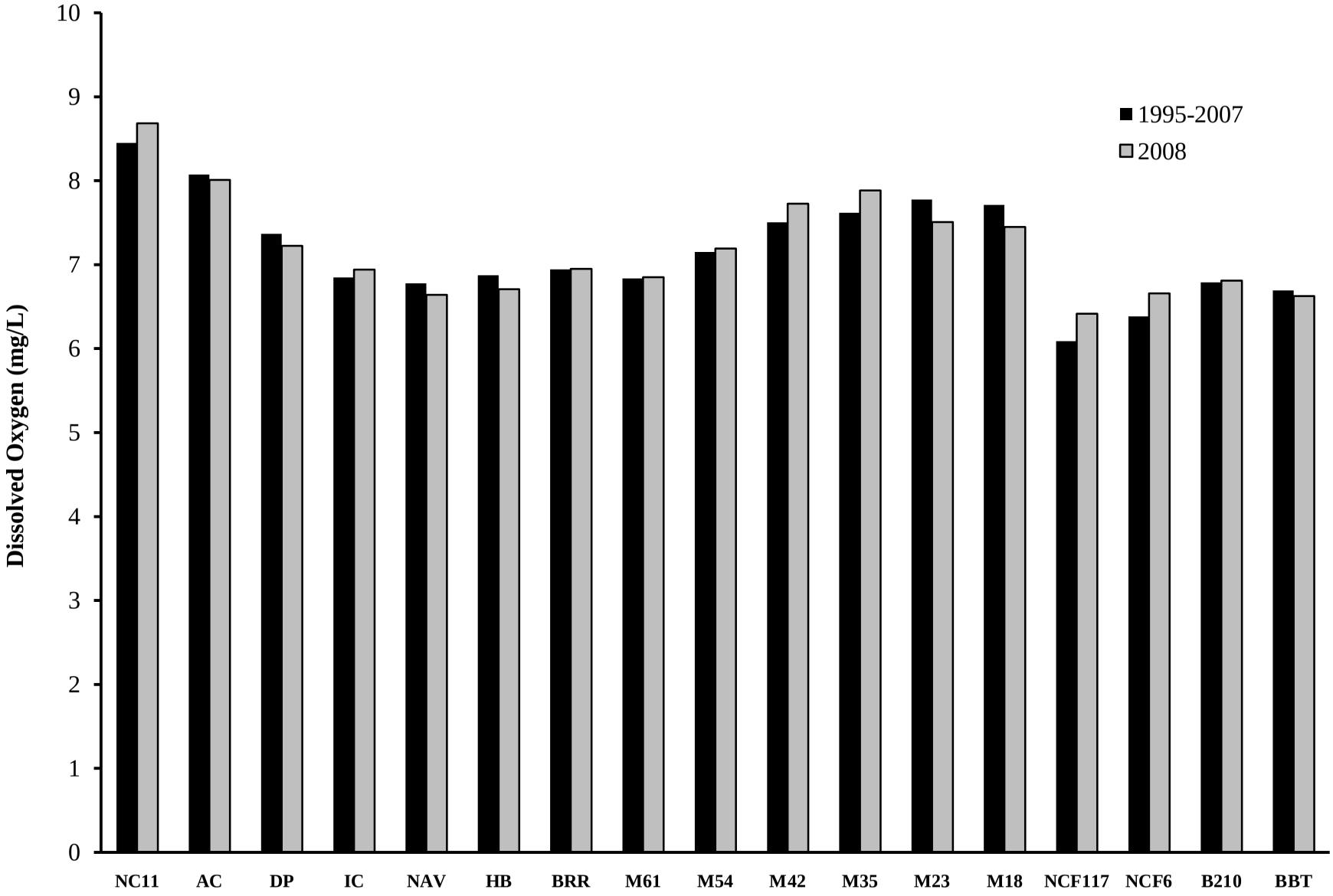


Table 2.6 Field Turbidity (NTU) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	33	15	16	7	22	4	3	4	5	7
FEB										
MAR	76	62	75	62	43	21	9	9	12	10
APR	8	6	7	7	6	6	3	5	5	5
MAY	10	13	11	6	5	5	4	5	6	8
JUN	37	10	9	6	9	7	5	3	3	7
JUL	16	12	11	8	8	6	5	3	1	5
AUG	13	8	9	7	6	7	5	3	3	4
SEP	13	16	14	8	7	6	4	3	3	3
OCT	7	6	7	5	6	3	3	3	3	5
NOV	48	7	6	8	8	7	8	8	10	6
DEC	16	14	11	9	8	6	7	9	11	8
mean	**25**	**15**	**16**	**12**	**12**	**7**	**5**	**5**	**6**	**6**
std dev	22	16	20	17	11	5	2	2	4	2
median	16	12	11	7	8	6	5	4	5	6
max	76	62	75	62	43	21	9	9	12	10
min	7	6	6	5	5	3	3	3	1	3

month	NC11	AC	DP	BBT	IC	NCF6
JAN	31	29	16	16	16	10
FEB	12	12	13	4	7	35
MAR	10	12	12	3	7	10
APR	20	17	18	4	12	11
MAY	14	13	11	8	7	5
JUN	7	17	10	9	9	8
JUL	11	15	14	13	18	7
AUG	11	9	8	8	7	15
SEP	33	42	19	9	13	12
OCT	12	9	7	7	7	14
NOV	12	17	9	6	10	30
DEC	143	110	87	62	39	18
mean	**26**	**25**	**19**	**12**	**13**	**15**
std dev	38	28	22	16	9	9
median	12	12	16	13	8	10
max	143	110	87	62	39	35
min	7	9	7	3	7	5

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	0	0	0	1	6	3	6	10	36
FEB	5	2	2	1	6	2	3	11	13
MAR	2	5	2	11	50	6	12	16	16
APR	5	3	2	2	6	17	4	9	13
MAY	4	4	5	1	11	5	15	10	12
JUN	4	1	20	14	12	5	6	7	5
JUL	1	1	12	11	13	1	3	2	7
AUG	1	2	20	4	12	7	10	12	14
SEP	0	1	0	2	12	0	3	6	13
OCT	2	1	0	2	5	2	5	5	6
NOV	3	3	2	2	8	9	5	7	9
DEC	3	3	2	1	6	4	5	11	10
mean	**3**	**2**	**6**	**4**	**12**	**5**	**6**	**9**	**13**
std dev	2	1	7	5	12	5	4	4	8
median	3	2	2	2	10	5	5	10	13
max	5	5	20	14	50	17	15	16	36
min	0	0	0	1	5	0	3	2	5

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	7	5	5	4	5	4
FEB	5	4	1	1	3	5
MAR	4	2	1	0	3	3
APR	18	4	3	2	18	13
MAY	5	4	3	2	6	4
JUN	2	1	3	22	7	6
JUL	3	2	5	31	4	6
AUG	3	13	40	4	16	8
SEP	1	0	1	3	9	18
OCT	5	2	1	2	3	3
NOV	4	2	1	0	8	4
DEC	11	3	1	0	9	11
mean	**6**	**4**	**5**	**6**	**8**	**7**
std dev	5	3	11	10	5	5
median	5	3	2	2	6	6
max	18	13	40	31	18	18
min	1	0	1	0	3	3

month	NCF117	B210	COL	LVC2	SC-CH
JAN	5	2	1	3	33
FEB	5	1	0	2	11
MAR	1	0	0	0	9
APR	8	5	0	1	21
MAY	3	2	0	4	25
JUN	5	3	2	9	16
JUL	6	9		5	32
AUG	3	3	2	5	19
SEP	14	3	3	3	32
OCT	1	1	0	1	4
NOV	2	1	0	1	8
DEC	3	2	2	11	79
mean	**5**	**3**	**1**	**4**	**24**
std dev	4	2	1	3	20
median	4	2	0	3	20
max	14	9	3	11	79
min	1	0	0	0	4

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2007 versus 2008.

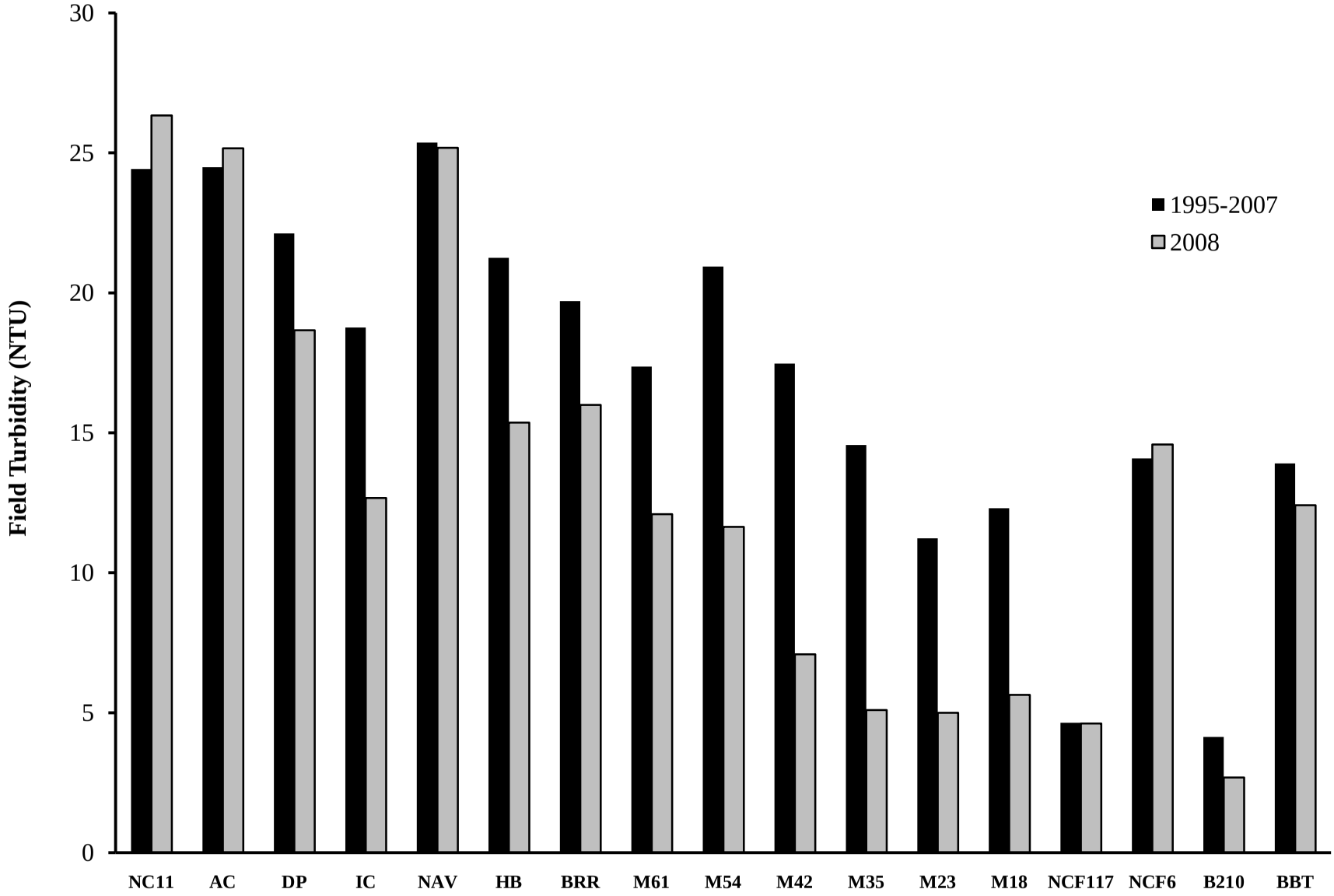


Table 2.7 Total Suspended Solids (mg/L) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	23	18	15	8	10	6	4	6	8	20
FEB	18	14	19	13	15	15	13	16	29	24
MAR	31	34	29	35	30	20	13	18	22	17
APR	6	7	5	7	9	7	5	9	10	8
MAY	12	9	11	9	10	9	9	7	16	24
JUN	42	15	14	17	17	21	7	10	7	9
JUL	12	11	10	10	16	9	9	7	5	10
AUG	18	8	4	9	9	9	9	8	17	16
SEP	10	8	12	9	9	11	18	9	10	10
OCT	9	8	6	6	8	6	7	20	8	8
NOV	8	11	16	16	15	17	18	24	26	20
DEC	10	9	8	9	8	10	11	12	15	14
mean	**17**	**13**	**12**	**12**	**13**	**12**	**10**	**12**	**14**	**15**
std dev	11	8	7	8	6	5	5	6	8	6
median	12	10	12	9	10	10	9	10	13	15
max	42	34	29	35	30	21	18	24	29	24
min	6	7	4	6	8	6	4	6	5	8

month	NC11	AC	DP	IC	NCF6
JAN	10	9	9	11	11
FEB	10	9	10	4	41
MAR	9	9	10	7	16
APR	17	15	16	13	13
MAY	7	4	1	5	6
JUN	5	7	6	5	6
JUL	8	11	11	20	18
AUG	6	6	7	5	22
SEP	29	24	10	7	26
OCT	9	5	5	4	8
NOV	12	15	8	10	40
DEC	96	77	47	14	24
mean	**18**	**16**	**12**	**9**	**19**
std dev	25	20	12	5	12
median	10	10	9	10	7
max	96	77	47	20	41
min	5	4	1	4	6

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	3	3	3	2	5	3	8	6	27
FEB	5	3	5	1	6	2	2	8	10
MAR	2	6	3	5	16	6	18	14	11
APR	4	4	4	2	5	25	5	7	7
MAY	4	6	8	5	5	10	18	16	12
JUN	27	1	21	14	16	14	8	10	15
JUL	1	11	9	8	5	1	4	5	10
AUG	1	1	24	4	8	4	10	9	5
SEP	2	4	3	5	46	3	5	10	15
OCT	3	3	1	5	4	1	8	5	7
NOV	2	1	1	1	8	5	3	3	3
DEC	2	1	1	1	1	4	1	4	4
mean	**5**	**4**	**7**	**4**	**10**	**7**	**8**	**8**	**11**
std dev	7	3	8	4	12	7	6	4	7
median	3	3	4	5	6	4	7	8	10
max	27	11	24	14	46	25	18	16	27
min	1	1	1	1	1	1	1	3	3

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	3	3	1	2	2	3
FEB	4	3	2	1	1	5
MAR	5	3	1	5	2	2
APR	7	3	1	3	25	11
MAY	4	3	5	4	5	3
JUN	1	1	40	18	3	4
JUL	1	1	3	16	2	6
AUG	3	13	12	6	20	4
SEP	2	1	3	7	14	18
OCT	4	3	3	3	5	1
NOV	2	1	3	2	7	1
DEC	8	3	1	1	11	5
mean	**4**	**3**	**6**	**6**	**8**	**5**
std dev	2	3	11	6	8	5
median	4	3	3	4	5	4
max	8	13	40	18	25	18
min	1	1	1	1	1	1

month	NCF117	B210	COL	LVC2
JAN	5	2	1	1
FEB	6	1	1	1
MAR	3	1	1	1
APR	7	8	1	5
MAY	4	3	1	5
JUN	6	3	15	14
JUL	5	1		3
AUG	3	3	1	3
SEP	6	3	1	2
OCT	3	4	1	2
NOV	4	2	1	1
DEC	3	1	1	5
mean	**5**	**3**	**2**	**4**
std dev	1	2	4	4
median	5	3	1	3
max	7	8	15	14
min	3	1	1	1

Table 2.8 Light Attenuation during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	3.81	2.75	2.12	2.41	1.92	1.85	1.57	0.96	0.94	1.23
FEB	3.67	4.22	2.53	3.79	2.52			1.96	2.77	1.47
MAR	5.60	5.30	5.49	5.76	4.47	3.27	2.66	1.53	1.35	1.61
APR	2.79	3.32	2.83	3.16	2.47	2.24	2.02	1.71	1.26	1.71
MAY	2.79	2.60	2.79	2.29	2.00	2.00	1.48	1.17	0.93	1.51
JUN	5.65	3.47	2.25	2.66	2.32	1.97	1.89	1.09	0.89	1.41
JUL	3.39	2.95	2.31	3.34	2.05	1.86	1.50	0.95	0.74	1.29
AUG	2.62	2.35	2.18	3.08	2.18	2.05	1.78	0.92	0.82	1.05
SEP	3.47	4.02	2.44	3.03	2.07	2.48	1.91	1.01	1.07	1.12
OCT	3.93	3.79	3.33	3.68	3.10	2.56	2.27	1.34	0.82	1.49
NOV	9.58	3.54	2.79	2.91	2.44	2.28	2.14	1.71	1.68	1.46
DEC	3.39	2.93	2.35	2.87	2.13			1.79	1.70	1.40
mean	**4.22**	**3.44**	**2.78**	**3.25**	**2.47**	**2.26**	**1.92**	**1.35**	**1.25**	**1.40**
std dev	1.95	0.82	0.92	0.91	0.71	0.43	0.37	0.38	0.58	0.19
median	3.57	3.40	2.49	3.06	2.25	2.15	1.90	1.26	1.01	1.44
max	9.58	5.30	5.49	5.76	4.47	3.27	2.66	1.96	2.77	1.71
min	2.62	2.35	2.12	2.29	1.92	1.85	1.48	0.92	0.74	1.05

month	NC11	AC	DP	BBT	IC	NCF6
JAN	3.88	3.66	3.39	3.16	3.12	2.35
FEB	2.17	2.21	3.24	2.11	1.96	5.78
MAR	2.38	3.53	3.17	2.42	2.86	4.12
APR	2.54	2.86	2.95	3.54	3.88	4.70
MAY	3.16	3.24	3.53	2.99	3.07	3.10
JUN	1.65	2.85	2.65	2.66	2.98	2.81
JUL	2.24	3.69	3.11	2.85	4.47	2.36
AUG	2.01	1.78	2.97	2.31	3.10	2.47
SEP	4.08	4.16	3.16	4.12	2.88	3.44
OCT	2.69	2.53	3.62	3.80	3.64	5.02
NOV	3.16	3.32	2.80	3.38	3.15	6.67
DEC	7.77	6.49	7.91	4.97	3.63	4.02
mean	**3.14**	**3.36**	**3.54**	**3.19**	**3.23**	**3.90**
std dev	1.63	1.19	1.40	0.83	0.62	1.41
median	2.62	2.62	3.28	3.17	3.08	3.11
max	7.77	6.49	7.91	4.97	4.47	6.67
min	1.65	1.78	2.65	2.11	1.96	2.35

Table 2.9 Total Nitrogen (µg/l) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	1,210	860	1,210	1,130	670	740	650	450	120	260
FEB	1,370	1,130	1,370	1,070	1,260	1,220	550	720	200	470
MAR	2,180	1,850	1,820	1,550	1,430	1,340	1,130	200	270	620
APR	1,280	1,550	1,610	750	900	660	730	360	200	350
MAY	1,190	1,320	1,140	1,190	970	830	720	110	50	70
JUN	1,200	1,200	900	1,000	870	530	390	160	150	600
JUL	1,580	1,550	1,270	1,200	910	6,720	480	200	200	200
AUG	1,240	1,290	1,090	1,170	1,130	780	700	500	300	700
SEP	1,040	930	980	950	1,050	900	1,210	260	200	260
OCT	890	1,060	1,090	1,100	910	670	570	360	1,920	350
NOV	1,670	790	910	1,140	880	750	360	740	580	430
DEC	850	890	960	880	980	680	640	540	260	290
mean	**1,308**	**1,202**	**1,196**	**1,094**	**997**	**1,318**	**678**	**383**	**371**	**383**
std dev	350	312	273	190	191	1,644	249	202	483	179
median	1,225	1,165	1,115	1,115	940	765	645	360	200	350
max	2,180	1,850	1,820	1,550	1,430	6,720	1,210	740	1,920	700
min	850	790	900	750	670	530	360	110	50	70

month	NC11	AC	DP	IC	NCF6
JAN	1,380	2,060	1,360	1,240	830
FEB	1,760	1,620	1,680	1,310	1,300
MAR	2,470	2,390	1,640	1,210	1,480
APR	1,200	1,040	1,170	1,400	1,440
MAY	1,090	1,450	900	700	700
JUN	1,330	1,800	1,350	1,230	810
JUL	2,050	2,110	2,560	2,350	830
AUG	1,320	1,580	1,390	1,550	950
SEP	1,410	1,090	1,390	970	960
OCT	1,340	980	1,350	2,130	550
NOV	1,400	1,490	1,530	1,610	1,090
DEC	1,700	1,550	1,910	1,180	1,040
mean	**1,538**	**1,597**	**1,519**	**1,407**	**998**
std dev	378	421	398	440	276
median	1,470	1,565	1,390	1,275	955
max	2,470	2,390	2,560	2,350	1,480
min	1,090	980	900	700	550

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	400	570	100	1,430	1,930	550	1,140	25,300	1,180
FEB	2,260	960	850	1,160	1,420	450	930	17,800	990
MAR	9,730	1,250	130	2,170	2,940	950	1,430	5,010	1,020
APR	2,260	1,280	1,240	1,700	2,220	2,050	1,870	3,300	1,240
MAY	1,560	1,340	1,190	1,190	1,000	900	1,920	6,740	1,830
JUN	1,290	2,960	1,730	1,500	1,190	660	1,730	27,300	2,010
JUL	830	890	1,930	1,070	1,300	400	2,350	24,000	1,510
AUG	970	3,450	2,330	940	1,140	720	2,420	4,920	590
SEP	800	1,590	1,600	1,100	3,580	600	1,740	12,300	1,200
OCT	1,440	1,050	1,020	1,080	690	1,010	970	9,470	680
NOV	1,770	630	500	2,230	3,360	1,200	1,660	8,100	900
DEC	1,640	760	500	1,640	2,380	830	1,360	6,440	790
mean	**2,079**	**1,394**	**1,093**	**1,434**	**1,929**	**860**	**1,627**	**12,557**	**1,162**
std dev	2,371	865	683	412	927	425	464	8,366	419
median	1,500	1,150	1,105	1,310	1,675	775	1,695	8,785	1,100
max	9,730	3,450	2,330	2,230	3,580	2,050	2,420	27,300	2,010
min	400	570	100	940	690	400	930	3,300	590

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,070	1,150	980	540	470	550
FEB	950	1,010	1,240	1,030	540	740
MAR	1,330	1,730	1,030	960	850	750
APR	2,820	910	1,660	1,900	1,250	1,720
MAY	1,700	1,230	940	970	710	580
JUN	940	910	1,640	1,840	770	440
JUL	380	870	1,180	1,130	720	230
AUG	1,050	1,930	2,640	1,130	1,180	850
SEP	1,190	1,170	1,030	1,260	850	1,270
OCT	1,590	1,060	530	660	550	510
NOV	1,560	940	930	460	680	300
DEC	1,890	1,230	720	800	910	1,330
mean	**1,373**	**1,178**	**1,210**	**1,057**	**790**	**773**
std dev	587	318	533	432	229	433
median	1,260	1,105	1,030	1,000	745	660
max	2,820	1,930	2,640	1,900	1,250	1,720
min	380	870	530	460	470	230

month	NCF117	B210	COL	LVC2
JAN	850	710	520	1,150
FEB	1,250	760	630	1,890
MAR	710	1,020	900	1,390
APR	1,050	950	1,200	900
MAY	1,150	1,150	960	1,200
JUN	1,030	890	1,040	1,870
JUL	960	670		4,180
AUG	660	960	830	2,500
SEP	750	1,020	1,240	1,220
OCT	1,200	1,210	1,040	1,220
NOV	1,100	670	600	760
DEC	770	620	600	1,330
mean	**957**	**886**	**869**	**1,634**
std dev	195	190	241	893
median	995	920	900	1,275
max	1,250	1,210	1,240	4,180
min	660	620	520	760

Figure 2.4 Total Nitrogen at the Lower Cape Fear River Program mainstem stations, 1995-2007 versus 2008.

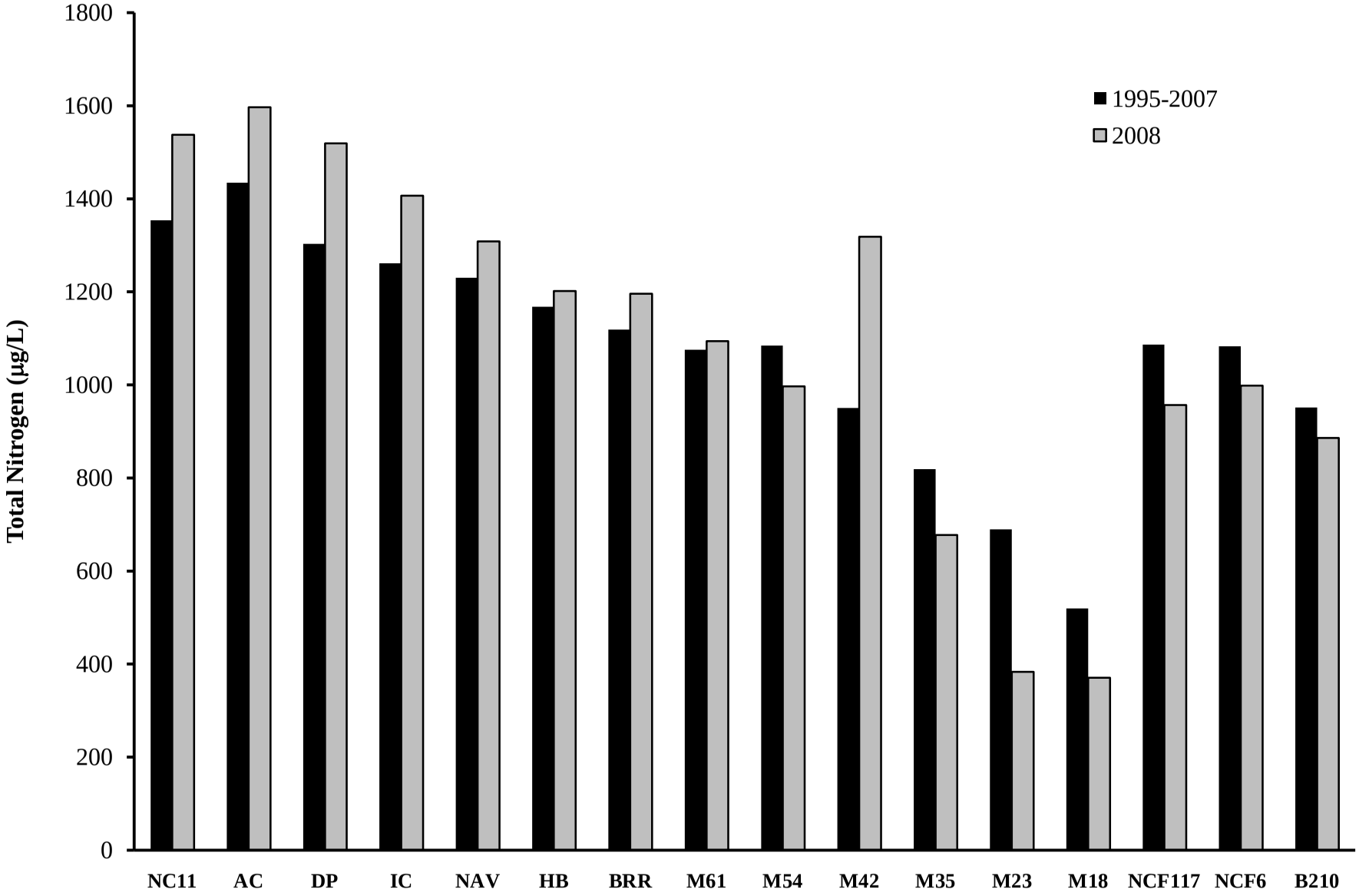


Table 2.10 Nitrate/Nitrite (µg/l) during 2008 at the Lower Cape Fear River stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	610	460	510	530	470	440	350	250	120	160
FEB	670	630	570	470	460	420	350	220	100	70
MAR	480	450	520	450	430	340	230	10	70	120
APR	380	350	410	250	200	160	130	60	10	50
MAY	550	550	550	470	420	340	270	110	10	70
JUN	460	390	360	330	280	180	60	10	10	10
JUL	880	850	770	500	310	520	80	10	10	10
AUG	640	590	590	470	330	180	100	10	10	10
SEP	440	530	480	550	550	400	210	60	10	60
OCT	390	360	390	300	210	170	170	60	1720	50
NOV	770	790	710	640	580	550	360	140	80	30
DEC	450	490	460	380	380	380	340	240	160	90
mean	**560**	**537**	**527**	**445**	**385**	**340**	**221**	**98**	**193**	**61**
std dev	150	152	118	107	118	132	108	89	463	44
median	515	510	515	470	400	360	220	60	40	55
max	880	850	770	640	580	550	360	250	1,720	160
min	380	350	360	250	200	160	60	10	10	10

month	NC11	AC	DP	IC	NCF6
JAN	880	1,060	760	640	430
FEB	1,060	1,020	980	710	400
MAR	770	790	740	510	480
APR	500	440	470	300	240
MAY	390	650	100	100	10
JUN	750	810	560	520	340
JUL	850	810	960	1,150	430
AUG	820	880	490	650	350
SEP	610	590	690	470	460
OCT	640	680	450	1,730	150
NOV	900	790	930	810	90
DEC	700	650	610	480	240
mean	**739**	**764**	**645**	**673**	**302**
std dev	177	168	244	404	148
median	715	650	580	345	345
max	1,060	1,060	980	1,730	480
min	390	440	100	100	10

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	10	70	10	730	1,530	50	340	24,900	380
FEB	160	160	50	460	420	50	530	16,900	190
MAR	530	250	30	1,070	1,740	150	430	4,010	220
APR	460	180	140	700	1,220	450	370	2,100	140
MAY	60	240	190	290	10	10	820	5,340	730
JUN	30	1,520	10	10	10	10	730	27,300	90
JUL	30	90	30	70	10	10	1,350	24,000	110
AUG	70	1,550	30	40	40	120	1,020	3,420	190
SEP	10	390	10	10	980	10	440	11,200	10
OCT	40	50	20	80	90	110	170	9,270	80
NOV	270	30	10	1,530	2,460	200	860	7,700	500
DEC	440	260	10	1,240	1,780	130	660	5,840	390
mean	**176**	**399**	**45**	**519**	**858**	**108**	**643**	**11,832**	**253**
std dev	188	518	56	510	837	120	319	8,720	200
median	65	210	25	375	700	80	595	8,485	190
max	530	1,550	190	1,530	2,460	450	1,350	27,300	730
min	10	30	10	10	10	10	170	2,100	10

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	870	450	180	40	170	50
FEB	550	410	340	30	40	40
MAR	1,030	930	130	60	250	150
APR	720	210	60	10	150	220
MAY	910	400	100	50	290	110
JUN	340	210	340	40	370	40
JUL	80	70	180	30	420	30
AUG	350	130	40	30	80	150
SEP	190	70	30	60	50	370
OCT	590	160	30	60	150	110
NOV	960	440	330	160	180	10
DEC	1,190	730	320	300	310	330
mean	**648**	**351**	**173**	**73**	**205**	**134**
std dev	340	256	123	77	118	113
median	655	305	155	45	175	110
max	1,190	930	340	300	420	370
min	80	70	30	10	40	10

month	NCF117	B210	COL	LVC2
JAN	350	310	20	450
FEB	350	260	30	290
MAR	510	320	10	290
APR	350	250	10	10
MAY	350	450	360	10
JUN	240	200	30	890
JUL	260	70		980
AUG	160	160	30	1,100
SEP	150	120	40	220
OCT	200	110	40	220
NOV	200	170	10	60
DEC	270	220	10	230
mean	**283**	**220**	**54**	**396**
std dev	99	102	98	366
median	265	210	30	260
max	510	450	360	1,100
min	150	70	10	10

Table 2.11 Ammonium (µg/l) during 2008 at the Lower Cape Fear River stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	100	120	180	130	140	120	50	30	5	10
FEB	60	60	70	120	100	110	80	10	5	5
MAR	100	90	110	110	130	60	40	40	5	30
APR	50	50	50	60	80	70	60	30	5	20
MAY	70	70	70	90	90	50	80	20	5	20
JUN	90	110	110	130	190	50	20	30	5	50
JUL	30	30	30	40	40	40	10	5	5	5
AUG	40	5	30	20	30	20	5	5	5	10
SEP	70	50	50	30	30	5	5	5	5	5
OCT	80	60	70	70	100	50	60	10	5	10
NOV	60	180	230	250	190	120	120	20	5	
DEC	20	30	40	100	100	110	100	70	10	30
mean	**64**	**71**	**87**	**96**	**102**	**67**	**53**	**23**	**5**	**18**
std dev	26	48	62	62	54	39	38	19	1	14
median	65	60	70	95	100	55	55	20	5	10
max	100	180	230	250	190	120	120	70	10	50
min	20	5	30	20	30	5	5	5	5	5

month	NC11	AC	DP	IC	NCF6
JAN	50	80	50	50	130
FEB	20	70	90	60	50
MAR	40	190	100	40	20
APR	50	80	80	50	30
MAY	100	150	130	90	80
JUN	40	180	190	110	50
JUL	70	340	60	20	20
AUG	100	110	80	70	30
SEP	70	100	100	40	30
OCT	40	50	50	50	30
NOV	40	50	60	50	20
DEC	70	50	70	50	30
mean	**58**	**121**	**88**	**57**	**43**
std dev	25	85	40	24	32
median	60	50	30	50	30
max	100	340	190	110	130
min	20	50	50	20	20

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	20	10	10	20	80	20	340	60	60
FEB	5	20	10	40	130	10	40	40	30
MAR	10	10	5	10	380	10	30	180	40
APR	80	50	50	40	120	170	70	90	110
MAY	230	130	120	130	20	50	70	110	120
JUN	170	200	210	190	40	80	90	180	710
JUL	40	70	460	140	20	20	40	40	260
AUG	20	80	520	30	40	190	60	80	70
SEP	5	5	20	110	650	40	40	70	290
OCT	60	40	40	70	120	70	40	50	80
NOV	210	20	10	40	110	20	30	40	30
DEC	80	90	5	10	70	80	30	60	5
mean	**78**	**60**	**122**	**69**	**148**	**63**	**73**	**83**	**150**
std dev	81	58	183	59	185	60	86	50	198
median	50	45	30	40	95	45	40	65	75
max	230	200	520	190	650	190	340	180	710
min	5	5	5	10	20	10	30	40	5

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	70	30	20	5	30	5
FEB	40	20	20	10	20	5
MAR	20	20	10	10	30	20
APR	80	30	50	20	30	70
MAY	60	60	30	60	40	50
JUN	70	70	90	450	140	170
JUL	30	30	60	100	20	30
AUG	50	50	70	50	40	60
SEP	10	5	10	40	5	50
OCT	70	20	40	70	20	30
NOV	30	10	40	10	5	5
DEC	60	30	30	20	10	510
mean	**49**	**31**	**39**	**70**	**33**	**84**
std dev	23	20	25	123	36	142
median	55	30	35	30	25	40
max	80	70	90	450	140	510
min	10	5	10	5	5	5

month	NCF117	B210	COL	LVC2
JAN	30	10	10	590
FEB	50	5	5	1,070
MAR	20	5	40	310
APR	60	50	5	270
MAY	50	30	30	750
JUN	80	100	120	390
JUL	10	30		1,810
AUG	5	20	50	1,300
SEP	20	5	30	390
OCT	50	20	20	210
NOV	50	10	10	230
DEC	20	10	5	790
mean	**37**	**25**	**30**	**676**
std dev	23	27	34	499
median	40	15	20	490
max	80	100	120	1,810
min	5	5	5	210

Table 2.12 Total Kjeldahl Nitrogen (µg/l) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	600	400	700	600	200	300	300	200	50	100
FEB	700	500	800	600	800	800	200	500	100	400
MAR	1,700	1,400	1,300	1,100	1,000	1,000	900	200	200	500
APR	900	1,200	1,200	500	700	500	600	300	200	300
MAY	640	770	590	720	550	490	450	50	50	50
JUN	740	810	540	670	590	350	330	160	150	600
JUL	700	700	500	700	600	6,200	400	200	200	200
AUG	600	700	500	700	800	600	600	500	300	700
SEP	600	400	500	400	500	500	1,000	200	200	200
OCT	500	700	700	800	700	500	400	300	200	300
NOV	900	50	200	500	300	200	50	600	500	400
DEC	400	400	500	500	600	300	300	300	100	200
mean	**748**	**669**	**669**	**649**	**612**	**978**	**461**	**293**	**188**	**329**
std dev	318	351	297	176	208	1,589	264	156	117	190
median	670	700	565	635	600	500	400	250	200	300
max	1,700	1,400	1,300	1,100	1,000	6,200	1,000	600	500	700
min	400	50	200	400	200	200	50	50	50	50

month	NC11	AC	DP	IC	NCF6
JAN	500	1,000	600	600	400
FEB	700	600	700	600	900
MAR	1,700	1,600	900	700	1,000
APR	700	600	700	1,100	1,200
MAY	700	800	800	600	700
JUN	580	990	790	710	470
JUL	1,200	1,300	1,600	1,200	400
AUG	500	700	900	900	600
SEP	800	500	700	500	500
OCT	700	300	900	400	400
NOV	500	700	600	800	1,000
DEC	1,000	900	1,300	700	800
mean	**798**	**833**	**874**	**734**	**734**
std dev	338	342	283	225	225
median	705	700	650	700	650
max	1,700	1,600	1,600	1,200	1,200
min	500	300	600	400	400

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	400	500	100	700	400	500	800	400	800
FEB	2,100	800	800	700	1,000	400	400	900	800
MAR	9,200	1,000	100	1,100	1,200	800	1,000	1,000	800
APR	1,800	1,100	1,100	1,000	1,000	1,600	1,500	1,200	1,100
MAY	1,500	1,100	1,000	900	1,000	900	1,100	1,400	1,100
JUN	1,260	1,440	1,730	1,500	1,190	660	1,000	50	1,920
JUL	800	800	1,900	1,000	1,300	400	1,000	50	1,400
AUG	900	1,900	2,300	900	1,100	600	1,400	1,500	400
SEP	800	1,200	1,600	1,100	2,600	600	1,300	1,100	1,200
OCT	1,400	1,000	1,000	1,000	600	900	800	200	600
NOV	1,500	600	500	700	900	1,000	800	400	400
DEC	1,200	500	500	400	600	700	700	600	400
mean	**1,905**	**995**	**1,053**	**917**	**1,074**	**755**	**983**	**733**	**910**
std dev	2,245	388	679	264	529	316	300	495	441
median	1,330	1,000	1,000	950	1,000	680	1,000	750	800
max	9,200	1,900	2,300	1,500	2,600	1,600	1,500	1,500	1,920
min	400	500	100	400	400	400	400	50	400

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	200	700	800	500	300	500
FEB	400	600	900	1,000	500	700
MAR	300	800	900	900	600	600
APR	2,100	700	1,600	1,900	1,100	1,500
MAY	790	830	840	920	420	470
JUN	600	700	1,300	1,800	400	400
JUL	300	800	1,000	1,100	300	200
AUG	700	1,800	2,600	1,100	1,100	700
SEP	1,000	1,100	1,000	1,200	800	900
OCT	1,000	900	500	600	400	400
NOV	600	500	600	300	500	300
DEC	700	500	400	500	600	1,000
mean	**724**	**828**	**1,037**	**985**	**585**	**639**
std dev	485	334	566	472	266	344
median	650	750	900	960	500	550
max	2,100	1,800	2,600	1,900	1,100	1,500
min	200	500	400	300	300	200

month	NCF117	B210	COL	LVC2
JAN	500	400	500	700
FEB	900	500	600	1,600
MAR	200	700	900	1,100
APR	700	700	1,200	900
MAY	800	700	600	1,200
JUN	790	690	1,010	980
JUL	700	600		3,200
AUG	500	800	800	1,400
SEP	600	900	1,200	1,000
OCT	1,000	1,100	1,000	1,000
NOV	900	500	600	700
DEC	500	400	600	1,100
mean	**674**	**666**	**819**	**1,240**
std dev	216	197	245	640
median	700	695	800	1,050
max	1,000	1,100	1,200	3,200
min	200	400	500	700

Table 2.13 Total Phosphorus (µg/l) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	120	90	100	70	80	70	50	40	10	40
FEB	190	170	170	100	100	80	70	50	50	50
MAR	160	190	200	160	150	100	70	50	40	50
APR	110	90	100	80	80	70	60	40	40	40
MAY	120	100	110	90	70	70	60	50	30	50
JUN	180	110	110	90	110	70	80	60	50	60
JUL	270	190	160	130	90	80	70	60	40	30
AUG	150	160	130	110	120	110	60	30	30	30
SEP	120	120	130	110	100	120	120	40	40	30
OCT	110	100	110	80	70	50	50	30	20	30
NOV	190	110	100	80	70	60	60	50	50	
DEC	70	70	60	60	80	60	50	40	40	10
mean	**149**	**125**	**123**	**97**	**93**	**78**	**67**	**45**	**37**	**38**
std dev	51	40	36	27	23	20	18	10	12	13
median	135	110	110	90	85	70	60	45	40	40
max	270	190	200	160	150	120	120	60	50	60
min	70	70	60	60	70	50	50	30	10	10

month	NC11	AC	DP	IC	NCF6
JAN	160	150	100	100	80
FEB	160	130	150	100	200
MAR	130	170	140	80	100
APR	110	110	110	130	120
MAY	160	150	130	120	80
JUN	120	160	140	140	90
JUL	160	220	230	270	100
AUG	160	180	160	170	130
SEP	170	160	140	110	130
OCT	100	100	110	100	120
NOV	120	130	130	140	190
DEC	360	320	220	120	110
mean	**159**	**165**	**147**	**132**	**132**
std dev	65	56	39	48	48
median	130	120	115	120	115
max	360	320	230	270	270
min	100	100	100	80	80

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	30	40	40	70	70	100	260	3,550	230
FEB	80	70	70	80	150	50	170	1,770	240
MAR	90	80	70	160	180	40	140	400	130
APR	230	100	100	130	130	150	130	250	130
MAY	160	160	170	220	140	100	250	730	170
JUN	150	330	400	490	220	80	380	3,400	370
JUL	100	150	510	380	230	70	380	3,860	400
AUG	50	880	370	330	230	60	650	680	160
SEP	40	110	90	500	370	70	360	1,670	350
OCT	230	180	170	320	170	40	250	1,340	180
NOV	170	90	80	70	180	70	150	790	70
DEC	140	60	60	50	80	40	110	470	60
mean	**123**	**188**	**178**	**233**	**179**	**73**	**269**	**1,576**	**208**
std dev	66	221	152	159	76	31	148	1,260	109
median	120	105	95	190	175	70	250	1,065	175
max	230	880	510	500	370	150	650	3,860	400
min	30	40	40	50	70	40	110	250	60

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	40	20	170	20	40	80
FEB	50	40	280	30	50	90
MAR	60	40	190	40	60	80
APR	140	200	260	70	120	100
MAY	110	70	390	90	100	180
JUN	130	110	1,160	210	120	200
JUL	150	120	660	160	80	210
AUG	150	130	1,720	90	260	230
SEP	130	60	200	110	160	170
OCT	130	70	80	60	100	160
NOV	80	30	150	40	80	150
DEC	80	30	50	10	80	110
mean	**104**	**77**	**443**	**78**	**104**	**147**
std dev	38	51	485	57	57	51
median	120	65	230	65	90	155
max	150	200	1,720	210	260	230
min	40	20	50	10	40	80

month	NCF117	B210	COL	LVC2
JAN	90	40	10	10
FEB	810	40	20	40
MAR	70	40	20	30
APR	160	80	30	40
MAY	110	100	20	50
JUN	120	130	50	80
JUL	90	130		70
AUG	80	140	70	60
SEP	170	130	90	50
OCT	140	110	10	20
NOV	90	60	10	10
DEC	40	10	10	30
mean	**164**	**84**	**31**	**41**
std dev	198	43	26	21
median	100	90	20	40
max	810	140	90	80
min	40	10	10	10

Figure 2.5 Total Phosphorus at the Lower Cape Fear River program manistem stations, 1995-2007 versus 2008.

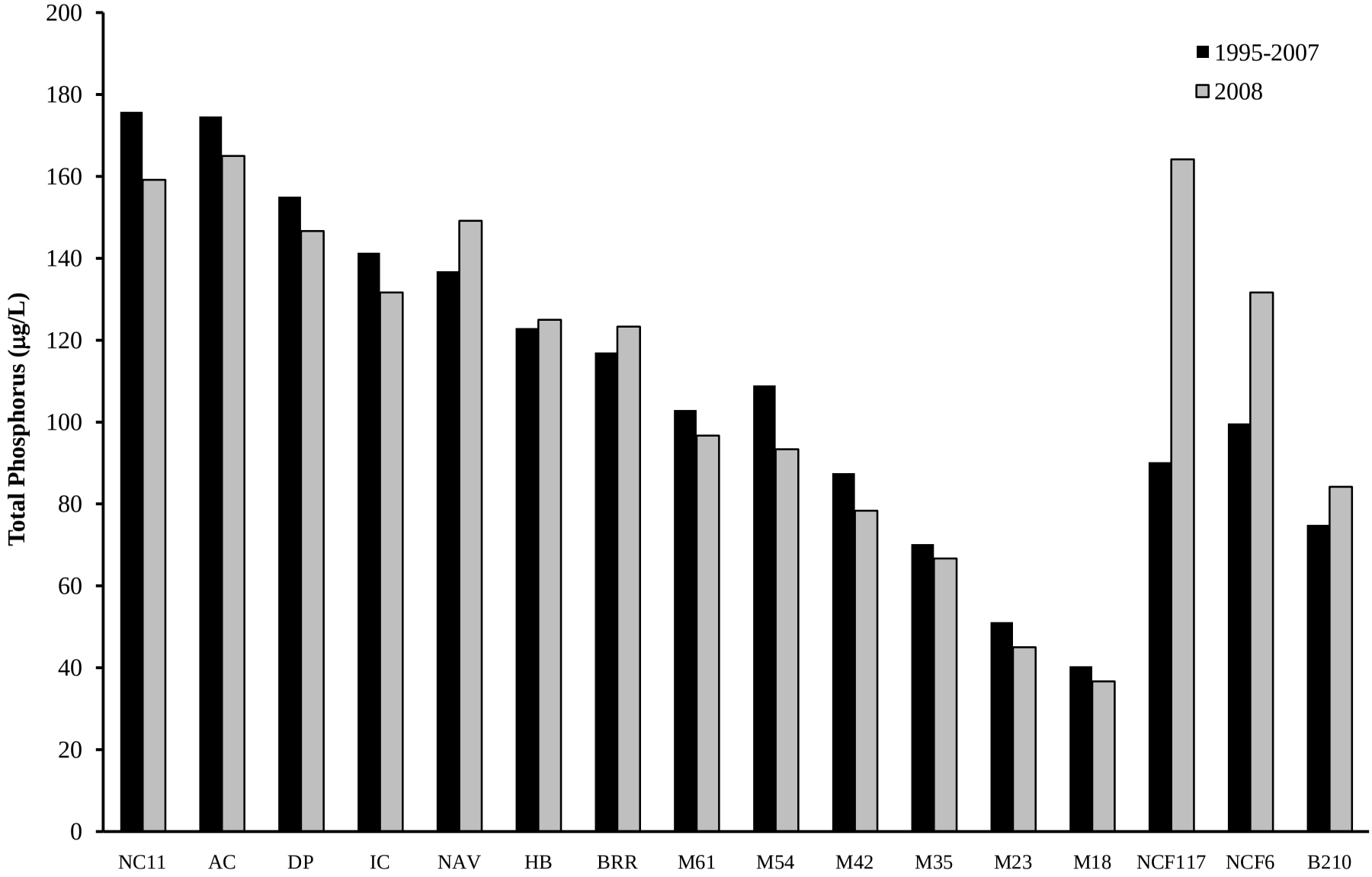


Table 2.14 Orthophosphate (µg/l) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	30	20	40	40	50	40	30	30	0	20
FEB	90	80	70	50	40	40	30	10	10	10
MAR	60	60	80	60	40	40	30	10	10	20
APR	40	30	30	40	30	30	20	10	10	20
MAY	50	50	50	50	50	40	40	40	30	30
JUN	30	30	20	30	20	20	10	10	10	20
JUL	60	60	50	40	30	20	20	10	10	20
AUG	70	80	70	60	40	20	10	10	0	10
SEP	50	50	50	40	50	40	30	10	0	10
OCT	40	40	40	40	30	30	20	10	10	10
NOV	70	60	40	40	40	40	30	20	10	10
DEC	20	30	30	30	30	30	30	20	20	10
mean	**51**	**49**	**48**	**43**	**38**	**33**	**25**	**16**	**10**	**16**
std dev	19	19	17	9	9	8	9	10	8	6
median	50	50	45	40	40	35	30	10	10	15
max	90	80	80	60	50	40	40	40	30	30
min	20	20	20	30	20	20	10	10	0	10

month	NC11	AC	DP	IC	NCF6	BBT
JAN	80	70	30	30	30	30
FEB	60	70	60	30	50	30
MAR	70	90	70	20	40	20
APR	30	40	40	30	40	30
MAY	70	70	60	50	50	40
JUN	40	70	50	50	30	40
JUL	40	60	70	70	30	50
AUG	80	100	80	100	60	70
SEP	50	50	50	50	40	40
OCT	40	50	40	30	50	40
NOV	60	50	60	80	50	30
DEC	80	80	70	40	30	50
mean	**58**	**67**	**57**	**48**	**42**	**39**
std dev	17	17	14	23	10	13
median	50	45	40	45	40	40
max	80	100	80	100	60	70
min	30	40	30	20	30	20

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	10	10	10	30	10	20	140	430	50
FEB	10	20	20	40	30	10	120	1770	120
MAR	20	20	10	80	30	10	40	360	50
APR	120	20	20	40	20	20	40	1730	30
MAY	100	20	20	40	30	10	60	550	50
JUN	60	60	40	60	40	40	130	1770	60
JUL	30	40	30	50	20	20	200	2820	90
AUG	10	40	20	110	30	20	300	450	60
SEP	0	20	20	130	10	10	150	1170	60
OCT	130	50	60	120	50	10	100	830	40
NOV									
DEC	90	20	10	30	20	0	50	310	20
mean	**53**	**29**	**24**	**66**	**26**	**15**	**121**	**1,108**	**57**
std dev	47	15	14	36	11	10	75	779	26
median	30	20	20	50	30	10	120	830	50
max	130	60	60	130	50	40	300	2,820	120
min	0	10	10	30	10	0	40	310	20

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	10	10	120	0	10	20
FEB	20	10	250	0	20	20
MAR	10	10	190	0	20	30
APR	40	80	120	10	20	20
MAY	30	20	220	10	20	40
JUN	50	40	60	40	50	60
JUL	50	40	300	20	20	60
AUG	40	20		10	40	70
SEP	60	10	100	20	70	60
OCT	30	10	40	10	40	50
NOV	20	10	80	10	20	60
DEC	20	10	30	0	20	30
mean	**32**	**23**	**137**	**11**	**29**	**43**
std dev	16	20	86	11	17	18
median	30	10	120	10	20	45
max	60	80	300	40	70	70
min	10	10	30	0	10	20

month	NCF117	B210	COL	LVC2
JAN	30	20	0	0
FEB	30	20	0	10
MAR	20	10	0	10
APR	70	30	0	0
MAY	30	30	0	0
JUN	50	60	30	40
JUL	20	40		10
AUG	20	50	40	10
SEP	60	50	50	0
OCT	60	30	0	0
NOV	30	20	0	0
DEC	20	10	0	0
mean	**37**	**31**	**11**	**7**
std dev	17	16	18	11
median	30	30	0	0
max	70	60	50	40
min	20	10	0	0

Table 2.15 Chlorophyll *a* (µg/l) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	2.8	3.1	4.5	2.7	2.8	3.9	4.1	1.0	4.5	5.3
FEB	3.5	3.1	4.0	3.7	6.2	6.6	7.0	10.8	12.2	7.0
MAR	4.4	3.7	3.7	4.0	5.2	6.8	4.2	6.5	5.7	5.2
APR	5.7	3.8	5.1	3.3	2.5	2.5	4.5	3.5	4.5	4.1
MAY	3.3	3.3	6.8	4.8	3.4	5.2	3.8	3.4	5.0	3.9
JUN	8.8	10.1	16.1	19.3	23.9	25.2	29.5	13.0	8.5	6.8
JUL	9.4	9.0	11.4	21.4	26.7	21.4	15.9	4.9	5.7	9.4
AUG	8.8	7.8	24.5	18.6	24.0	39.8	23.7	9.0	8.3	9.5
SEP	3.0	5.0	9.0	7.0	11.0	35.0	40.0	13.0	11.0	16.0
OCT	1.0	1.0	1.0	1.0	2.0	3.0	3.0	4.0	2.0	3.0
NOV	3.4	1.4	2.7	2.4	2.4	2.7	3.1	4.9	4.3	3.3
DEC	1.0	1.0	1.1	1.2	1.3	1.8	1.8	3.3	3.6	2.9
mean	**4.6**	**4.4**	**7.5**	**7.5**	**9.3**	**12.8**	**11.7**	**6.4**	**6.3**	**6.4**
std dev	2.8	2.9	6.6	7.3	9.4	13.2	12.2	3.9	2.9	3.6
median	3.5	3.5	4.8	3.9	4.3	5.9	4.4	4.9	5.4	5.3
max	9.4	10.1	24.5	21.4	26.7	39.8	40.0	13.0	12.2	16.0
min	1.0	1.0	1.0	1.0	1.3	1.8	1.8	1.0	2.0	2.9

month	NC11	AC	DP	BBT	IC	NCF6
JAN	1.2	1.1	1.3	1.4	1.9	2.7
FEB	3.5	3.4	2.8	1.2	1.5	3.4
MAR	2.5	1.6	1.6	1.0	1.4	2.2
APR	2.7	2.8	2.8	1.0	1.4	1.4
MAY	2.0	1.2	1.1	1.0	1.2	1.5
JUN	12.8	4.9	3.0	3.1	6.3	9.6
JUL	24.1	11.1	4.4	3.1	3.9	12.0
AUG	34.2	22.9	14.7	11.7	13.4	31.7
SEP	2.0	2.0	2.0	1.0	1.0	5.0
OCT	1.0	0.5	1.0	1.0	1.0	1.0
NOV	1.1	1.1	1.2	0.9	0.6	1.5
DEC	5.0	4.3	3.2	2.7	1.7	1.5
mean	**7.7**	**4.7**	**3.3**	**2.4**	**2.9**	**6.1**
std dev	10.3	6.1	3.6	2.9	3.5	8.4
median	2.6	2.6	2.4	2.4	1.1	1.5
max	34.2	22.9	14.7	11.7	13.4	31.7
min	1.0	0.5	1.0	0.9	0.6	1.0

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	3.8	1.2	2.6	6.5	8.8	5.7	0.8	0.8	6.7
FEB	84.3	2.1	7.2	3.1	8.0	2.8	0.9	1.8	7.7
MAR	17.1	3.5	2.5	8.4	4.6	4.1	2.4	9.9	1.5
APR	2.2	1.7	2.2	1.7	2.3	2.6	1.0	2.7	1.1
MAY	2.7	1.5	2.4	5.2	12.0	14.3	2.8	4.6	1.3
JUN	19.4	1.4	118.3	100.9	43.0	2.3	0.9	3.7	376.0
JUL	11.4	7.2	36.1	39.6	79.9	12.5	24.0	5.8	113.8
AUG	81.5	58.7	281.4	56.3	173.3	7.0	16.3	14.4	14.6
SEP	15.0	3.0	3.0	12.0	163.0	9.0	1.0	7.0	4.0
OCT	4.0	2.0	2.0	8.0	4.0	2.0	1.0	3.0	1.0
NOV	1.2	0.5	0.6	1.3	1.1	59.3	0.7	0.7	0.2
DEC	0.8	0.5	1.0	1.9	2.3	30.4	1.4	1.0	0.5
mean	**20.3**	**6.9**	**38.3**	**20.4**	**41.9**	**12.7**	**4.4**	**4.6**	**44.0**
std dev	28.7	15.7	80.1	29.3	60.7	16.0	7.2	4.0	104.6
median	7.7	1.9	2.6	7.3	8.4	6.4	1.0	3.4	2.8
max	84.3	58.7	281.4	100.9	173.3	59.3	24.0	14.4	376.0
min	0.8	0.5	0.6	1.3	1.1	2.0	0.7	0.7	0.2

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.8	0.7	1.8	2.0	1.5	2.6
FEB	3.1	1.3	1.6	3.4	3.1	32.4
MAR	1.2	1.0	1.6	1.2	1.5	3.8
APR	2.0	2.2	3.3	5.6	3.4	1.9
MAY	0.7	0.7	1.1	2.3	0.9	0.5
JUN	3.3	0.7	1.6	104.1	1.5	1.6
JUL	0.9	1.2	1.2	14.3	8.1	7.3
AUG	5.8	12.6	42.9	22.0	32.0	40.3
SEP	1.0	0.0	1.0	3.0	1.0	2.0
OCT	1.0	0.5	1.0	2.0	1.0	1.0
NOV	0.4	0.4	1.7	1.3	1.1	0.5
DEC	1.3	0.8	1.4	2.3	1.5	1.5
mean	**1.8**	**1.8**	**5.0**	**13.6**	**4.7**	**8.0**
std dev	1.5	3.3	11.4	27.9	8.5	12.9
median	1.1	0.8	1.6	2.7	1.5	2.0
max	5.8	12.6	42.9	104.1	32.0	40.3
min	0.4	0.0	1.0	1.2	0.9	0.5

month	NCF117	B210	COL	LVC2
JAN	0.5	0.4	0.7	1.2
FEB	0.9	1.3	1.2	2.9
MAR	1.1	1.4	1.1	1.0
APR	0.9	1.2	3.3	3.8
MAY	0.5	0.5	0.8	1.6
JUN	1.3	1.2	6.7	4.4
JUL	4.3	2.2		7.7
AUG	32.1	6.4	18.9	27.6
SEP	2.0	0.0	1.0	6.0
OCT	1.0	1.0	1.0	1.0
NOV	0.3	0.7	0.2	0.3
DEC	0.2	0.4	0.3	2.3
mean	**3.8**	**1.4**	**3.2**	**5.0**
std dev	8.6	1.6	5.3	7.1
median	1.0	1.1	1.0	2.6
max	32.1	6.4	18.9	27.6
min	0.2	0.0	0.2	0.3

Figure 2.6 Chlorophyll *a* at the Lower Cape Fear River program mainstem stations, 1995-2007 versus 2008.

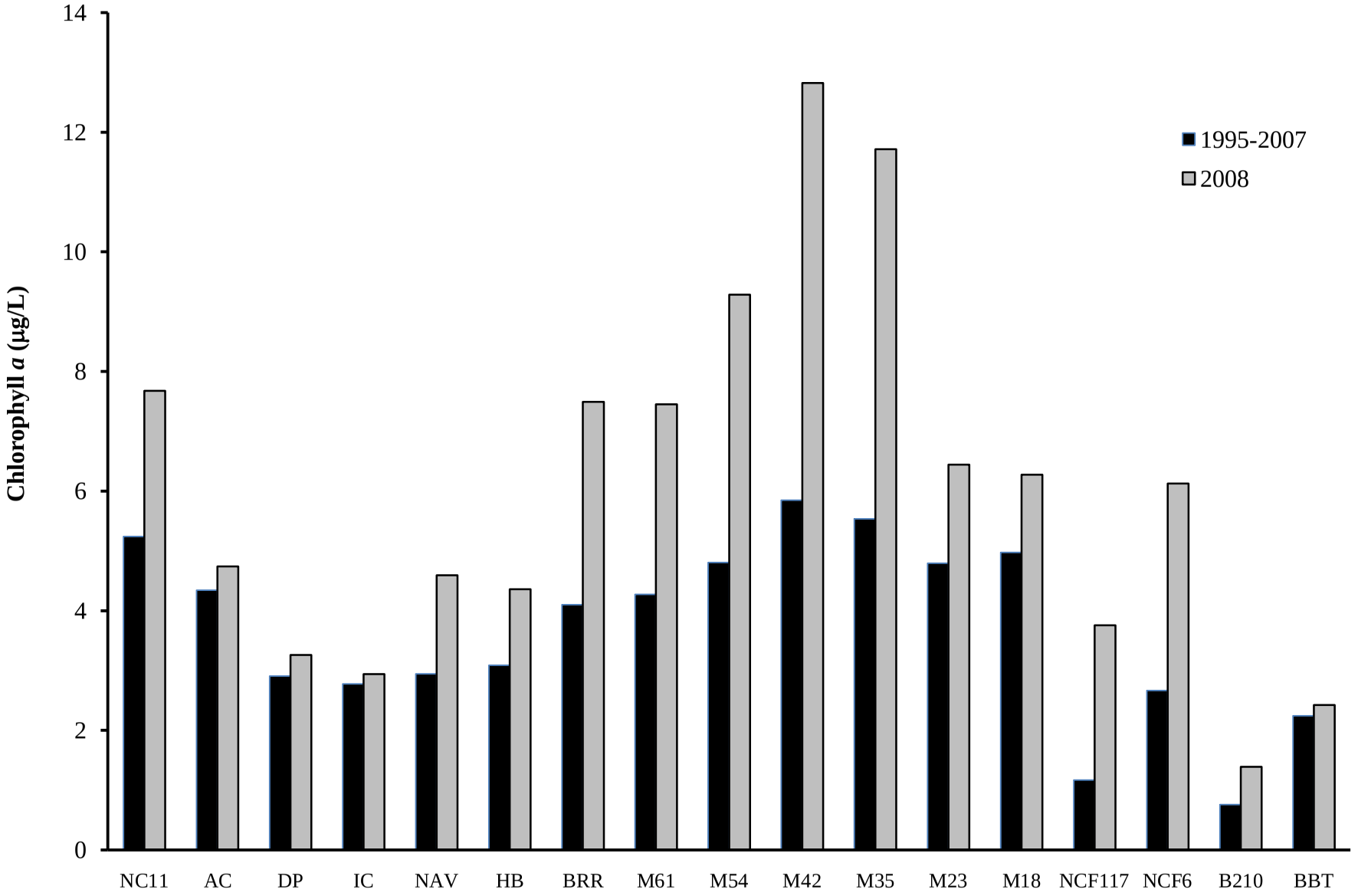


Table 2.16 Biochemical Oxygen Demand (mg/l) during 2008 at the Lower Cape Fear River Program stations.

5-Day Biochemical Oxygen Demand

month	NC11	AC	ANC	SAR	GS	N403	ROC	BC117	NCF117	B210	LVC2	BBT
JAN	1.2	1.2	1.4	0.8	0.6	0.7	0.8	1.0	1.0	1.0	1.2	1.1
FEB			4.9	0.6	0.8	0.6	0.5	0.9	0.4	0.2	1.0	
MAR	0.8	1.8	2.0	1.3	0.8	1.2	1.7	1.8	1.3	0.9	2.2	1.1
APR	0.9	1.0	2.1	1.6	1.5	1.2	1.5	1.5	2.4	1.8	2.3	0.9
MAY	1.2	1.3	1.4	1.8	1.6	2.2	2.8	2.3	1.1	1.3	3.3	1.1
JUN	2.1	1.3	4.4	0.8	8.9	7.8	0.9	1.6	0.9	1.0	1.3	0.9
JUL	2.3	2.1	1.9	0.8	4.6	2.9	2.8	0.8	0.6	1.4	2.9	
AUG	2.0	1.5	2.1	0.9	6.4	1.8	1.2	1.5	0.7	1.0	3.3	2.0
SEP	1.5	1.6	2.2	1.2	1.6	2.3	1.3	1.3	0.7	2.5	1.6	1.4
OCT	1.0	0.7	1.8	1.7	1.2	1.4	1.4	2.1	1.3	2.1	1.7	1.3
NOV												
DEC			1.3	2.0	2.4	1.3	1.1	1.0				
median	1.2	1.3	2.0	1.2	1.6	1.4	1.3	1.5	1.0	1.2	2.0	1.1
mean	1.4	1.4	2.3	1.2	2.8	2.1	1.5	1.4	1.0	1.3	2.1	1.2
max	2.3	2.1	4.9	2.0	8.9	7.8	2.8	2.3	2.4	2.5	3.3	2.0
min	0.8	0.7	1.3	0.6	0.6	0.6	0.5	0.8	0.4	0.2	1.0	0.9
stdev	0.6	0.4	1.2	0.5	2.7	2.0	0.7	0.5	0.6	0.7	0.9	0.4

20-Day Biochemical Oxygen Demand

month	NC11	AC	ANC	SAR	GS	N403	ROC	BC117	NCF117	B210	LVC2	BBT
JAN	3.6	4	2.8	1.9	1.6	1.8	3.3	2.5	2.6	1.9	4.4	3.1
FEB			9.5	2.4	2.5	2.2	2.3	3.2	2.4	1.2	8.5	
MAR	2.9	5.7	5.1	4.1	3.2	3.5	4.5	6.6	3.3	1.5	5.7	2.2
APR	2.5	2.9		5.2	5.3	3.1	4.1	3.7	5.6	3.9	5.7	2.5
MAY	3.9	3.9	4.9	4.0	3.7	4.9	5.6	5.2	3.2	3.3	9.1	3.5
JUN	4.5	4.9	>8.9	3.2	>9.1	>9.0	3.3	4.5	2.8	3.1	3.9	3.5
JUL	5.3	7.3	4.5	2.8	7.8	8.0	6.0	2.3	1.5	3.2	8.3	
AUG	3.0	3.1	4.6	3.2	14.8	5.5	4.6	4.7	2.0	3.3	8.7	3.3
SEP	4.0	4.3	5.5	4.6	4.4	5.4	4.4	3.9	2.3	5.4	5.5	3.9
OCT	3.1	2.4	5.6	4.8	3.4	4.0	4.4	5.5	4.0	4.3	4.8	3.9
NOV												
DEC												
median	3.6	4.0	5.0	3.6	3.7	4.0	4.4	4.2	2.7	3.3	5.7	3.4
mean	3.6	4.3	5.3	3.6	5.2	4.3	4.3	4.2	3.0	3.1	6.5	3.2
max	5.3	7.3	9.5	5.2	14.8	8.0	6.0	6.6	5.6	5.4	9.1	3.9
min	2.5	2.4	2.8	1.9	1.6	1.8	2.3	2.3	1.5	1.2	3.9	2.2
stdev	0.9	1.5	1.9	1.1	4.0	1.9	1.1	1.4	1.2	1.3	2.0	0.6

Table 2.17 Fecal Coliform (cfu/100 ml) during 2008 at the Lower Cape Fear River Program stations.

month	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	30	21	27	19	14	8	5	2	2	2
FEB	52	52	46	31	31	25	16	8	1	10
MAR	460	30	35	40	50	35	12	4	4	9
APR	26	33	28	37	15	8	8	4	6	6
MAY	36	80	114	63	41	23	6	9	3	8
JUN	8	37	72	42	22	10	20	16	6	2
JUL	11	15	13	32	16	10	2	2	< 1	3
AUG	48	84	48	20	13	4	< 2	4	< 2	< 2
SEP	23	58	91	57	19	11	3	< 1	1	1
OCT	54	164	48	44	37	19	4	4	< 2	11
NOV	98	104	40	33	19	8	19	2	29	4
DEC	45	5	19	8	13	28	4	24	52	13
mean	**74**	**57**	**48**	**36**	**24**	**16**	**9**	**7**	**12**	**6**
std dev	119	43	29	15	12	9	6	7	16	4
max	460	164	114	63	50	35	20	24	52	13
min	8	5	13	8	13	4	2	2	1	1
Geomean	40	41	41	32	22	13	7	5	5	5

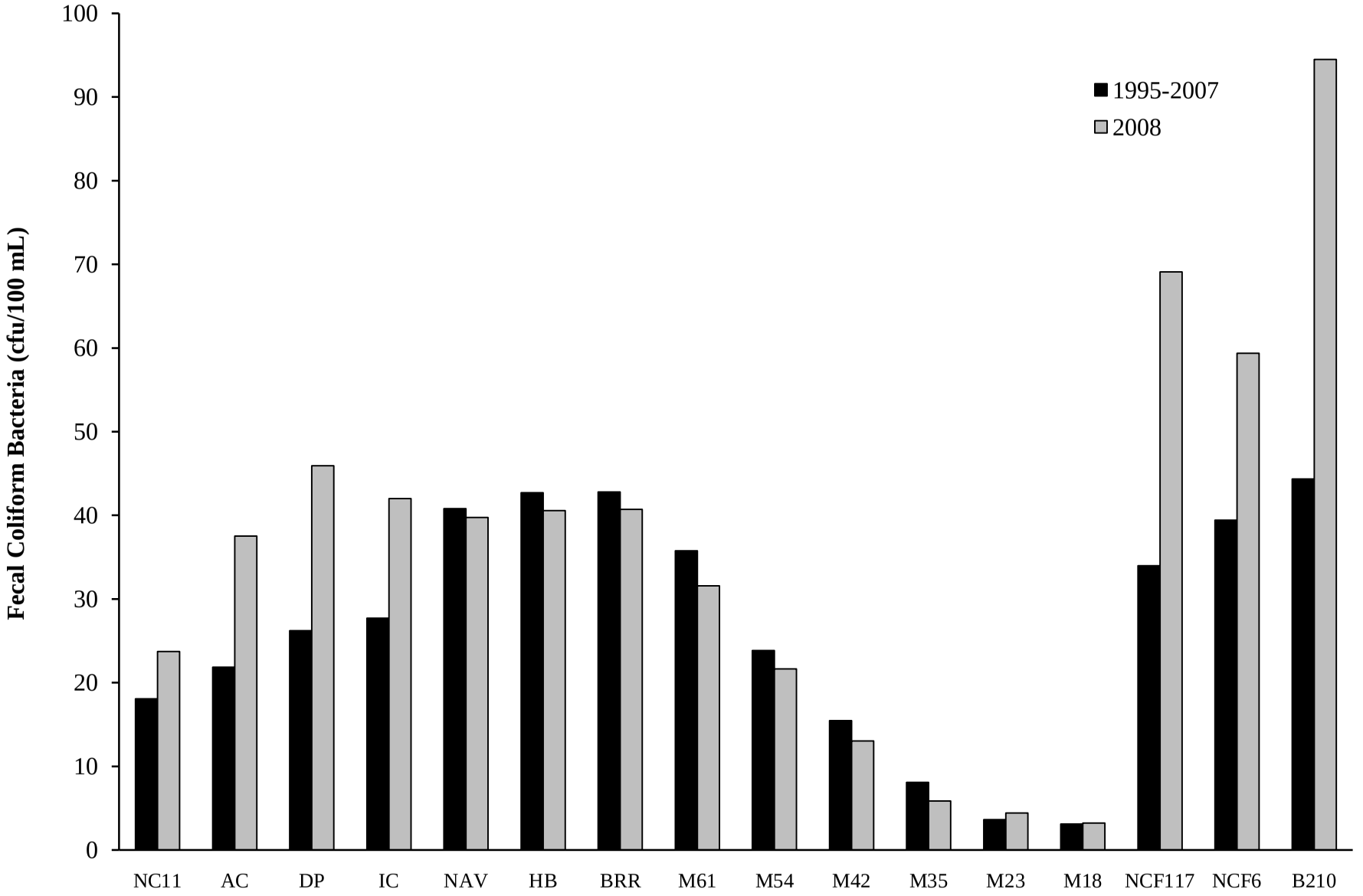
month	NC11	AC	DP	IC	NCF6
JAN	36	40	64	26	36
FEB	31	40	20	27	82
MAR	11	15	12	22	13
APR	8	13	37	68	29
MAY	7	27	64	46	100
JUN	4	17	31	40	163
JUL	4	2	17	15	28
AUG	15	19	38	40	58
SEP	48	164	94	44	100
OCT	31	20	31	26	34
NOV	260	2,000	220	420	580
DEC	500	219	188	54	33
mean	**80**	**215**	**68**	**69**	**105**
std dev	144	542	65	107	149
max	500	2,000	220	420	580
min	4	2	12	15	13
Geomean	24	38	46	42	59

month	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	51	90	100	64	840	82	119	430	146
FEB	120	700	570	28	109	17	28	240	75
MAR	104	118	73	64	480	14	240	1,200	490
APR	56	144	46	98	28	36	118	1,455	109
MAY	560	96	73	114	182	134	500	819	1,550
JUN	110	80	100	400	115	110	100	637	46
JUL	208	773	540	144	28	682	46	1,364	91
AUG	100	520	204	1,091	30,000	1,050	591	1,819	9,400
SEP	32	150	185	172	130	5	135	550	2,000
OCT	290	300	145	280	5,100	127	270	910	2,273
NOV	55	1,091	155	210	455	195	210	1,000	145
DEC	91	546	82	82	127	546	181	490	181
mean	**148**	**384**	**189**	**229**	**3,133**	**250**	**212**	**910**	**1,376**
std dev	142	322	170	279	8,213	317	166	455	2,542
max	560	1,091	570	1,091	30,000	1,050	591	1,819	9,400
min	32	80	46	28	28	5	28	240	46
Geomean	106	258	139	142	311	94	154	788	357

month	6RC	LCO	GCO	SR	BRN	HAM
JAN	119	110	119	110	42	240
FEB	64	28	20	108	35	192
MAR	430	32	32	100	82	108
APR	2,300	600	230	80	230	240
MAY	162	34	164	29	72	65
JUN	230	28	73	819	1,000	84
JUL	82	64	76	235	66	52
AUG	195	146	120	109	637	176
SEP	273	104	86	285	455	2,350
OCT	305	100	80	92	546	500
NOV	120	48	74	182	620	760
DEC	1,600	260	148	216	270	819
mean	**490**	**130**	**102**	**197**	**338**	**466**
std dev	676	156	56	200	299	621
max	2,300	600	230	819	1,000	2,350
min	64	28	20	29	35	52
Geomean	254	80	85	141	197	244

month	NCF117	B210	COL	LVC2	SC-CH
JAN	46	58	116	44	88
FEB	22	33	17	25	46
MAR	19	47	48	146	37
APR	64	91	33	84	64
MAY	118	58	128	85	137
JUN	4	31	96	32	78
JUL	146	24		45	37
AUG	182	58	73	135	37
SEP	5,500	2,200	319	230	419
OCT	95	104	48	120	56
NOV	64	773	50	95	51
DEC	23	140	223	593	196
mean	**524**	**301**	**105**	**136**	**104**
std dev	1,501	606	87	149	105
max	5,500	2,200	319	593	419
min	4	24	17	25	37
Geomean	69	95	76	92	75

Figure 2.7 Fecal Coliform Bacteria at the Lower Cape Fear River program mainstem stations, 1995-2007 versus 2008.



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 2008 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 a statewide fish consumption advisory 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:

Standard exceeded in < 10% of samples = Supporting
Standard exceeded in > 10% of samples = Impaired Less than
10 samples collected = Not Rated DO and pH standard
exceeded in swamps = 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 status 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.

Our system lists a sampling location as having good quality (G) if the standard is exceeded in none or 1 sample out of 12 measurements (<10%), fair quality (F) if standard is exceeded in 2 or 3 or 12 of measurements (11-25%), or poor quality (P) if 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 2008 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 present.

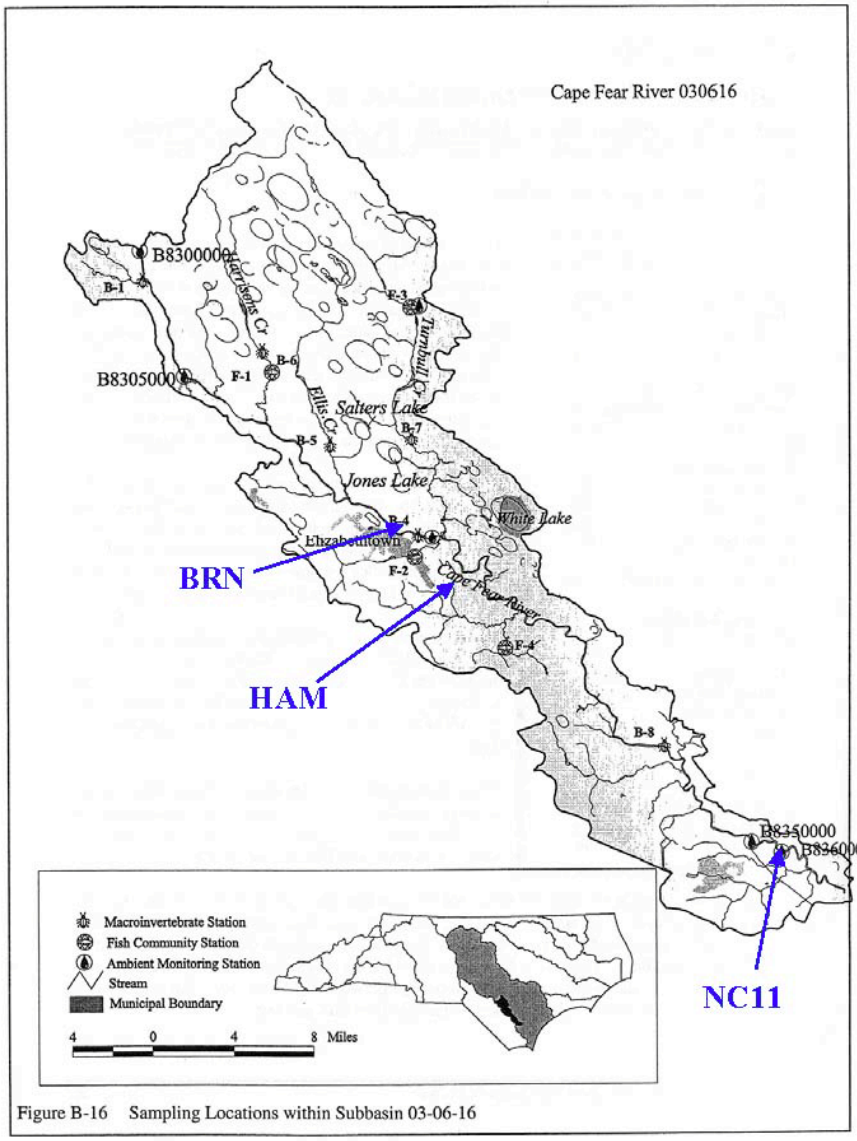


Figure B-16 Sampling Locations within Subbasin 03-06-16

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* of 40 µg/L was not exceeded at any station during 2008. Of note is that chlorophyll *a* concentrations at all three stations was greater than 30 µg/L during August.

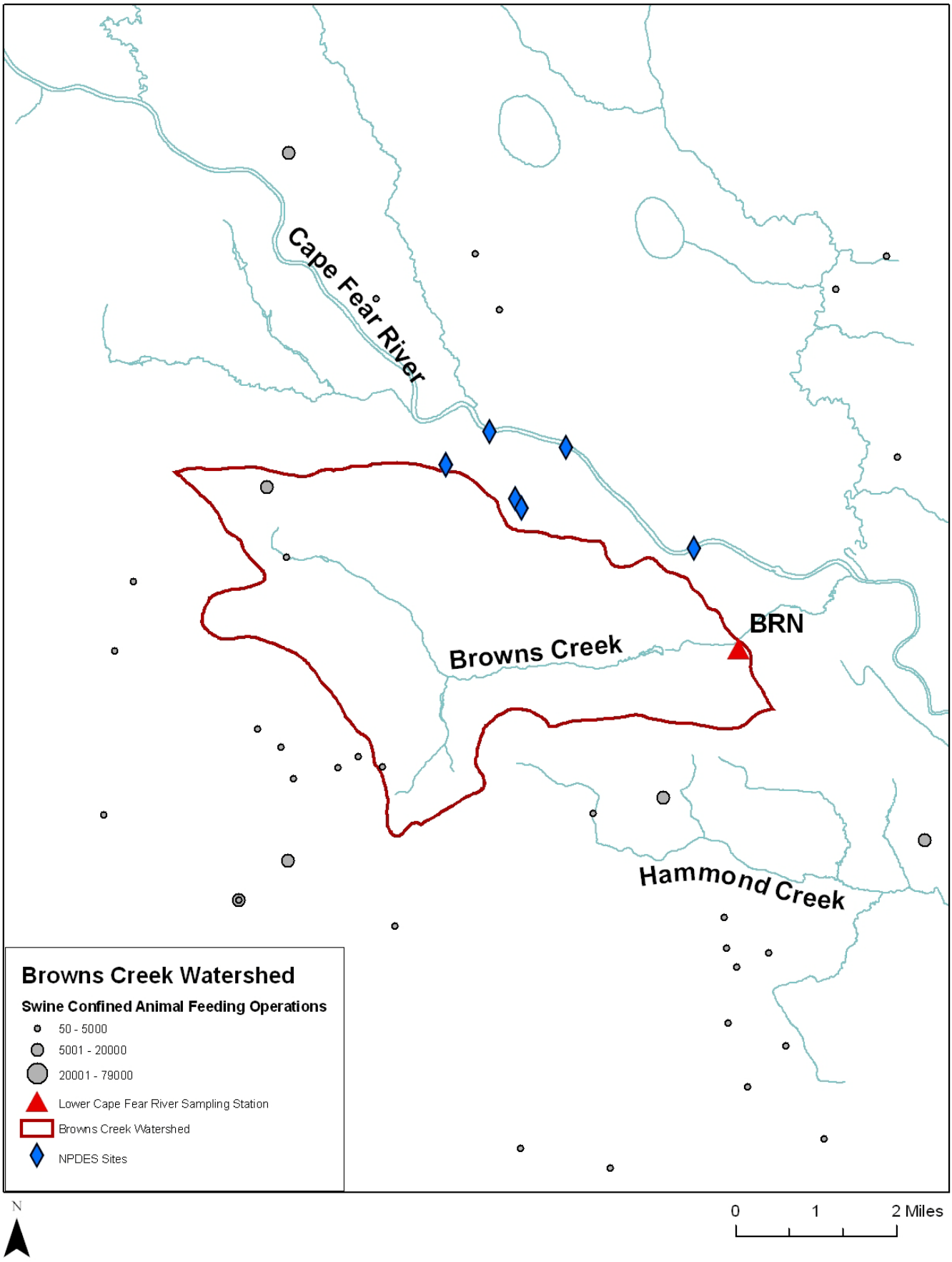
For fecal coliform bacteria concentrations NC11 had a fair rating with concentrations exceeding the NC State Standard in 17% of twelve samples (Table 3.3.1). BRN and HAM received a poor rating exceeding the standard 58% and 50% of the time, respectively.

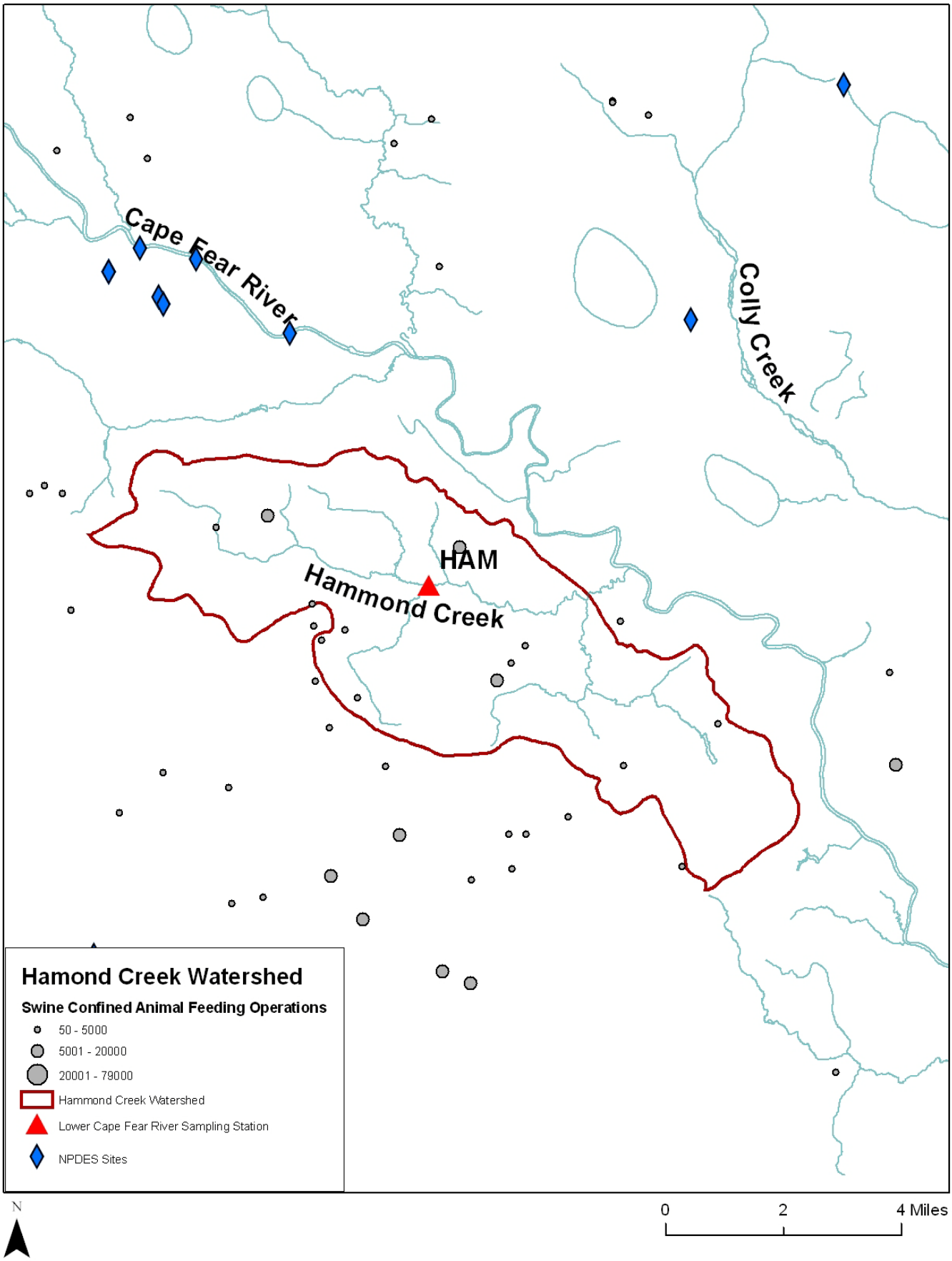
For field turbidity, all stations were rated good (Table 3.3.1). The NC State Standard of 50 NTU was exceeded once at NC11 in December.

For nitrate, BRN rated as poor (above standard 42% of the time) and HAM rated as fair (above the standard 25% of the time). A good rating was found at NC11 for both nutrient species and for total phosphorus at BRN and HAM.

Table 3.3.1 UNCW AEL 2008 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	F	G
NC11	G	G	F	G	G	G


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


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

3.4 Cape Fear River Subbasin 03-06-17

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

LCFRP monitoring stations (DWQ #):

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

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

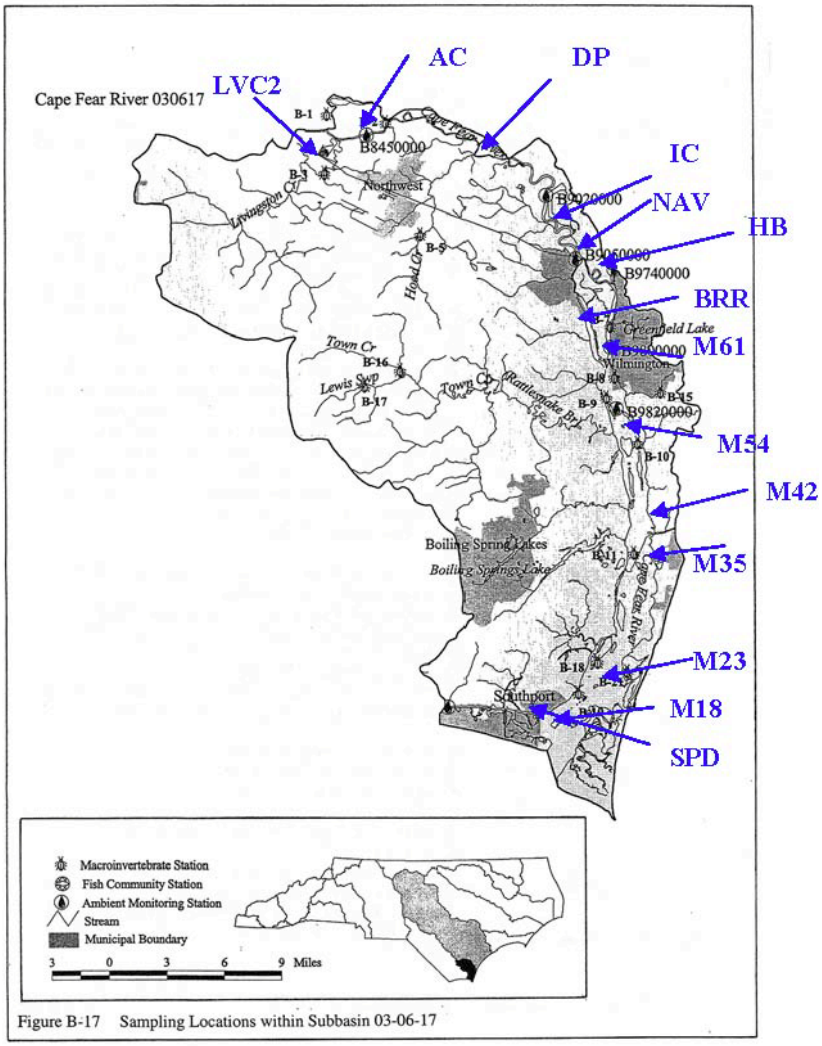


Figure B-17 Sampling Locations within Subbasin 03-06-17

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

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

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

UNCW Aquatic Ecology Laboratory Evaluation

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

AC – representative of riverine system channel

HB- upper estuary, upstream of Wilmington

M35 – represents wide estuary

Sites given a good rating for dissolved oxygen include AC, DP, IC, M54, 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 NAV (17%), HB (25%), BRR (25%), and M61 (25%). LVC2 was rated poor with samples below the standard 42% of the time.

All sites within this subbasin had a good rating in terms of chlorophyll *a* concentrations (Table 3.4.1). None of the sampled locations exceeded the 40 µg/L North Carolina State standard on any sample occasion during 2008, although there were several that were at or near 40 µg/L in the middle estuary during the summer.

All but two sites within this subbasin had a good rating for fecal coliform bacteria concentrations (Table 3.4.1). LVC2 and AC each had two samples (17%) exceed the 200 cfu/100mL North Carolina State human contact standard during 2008.

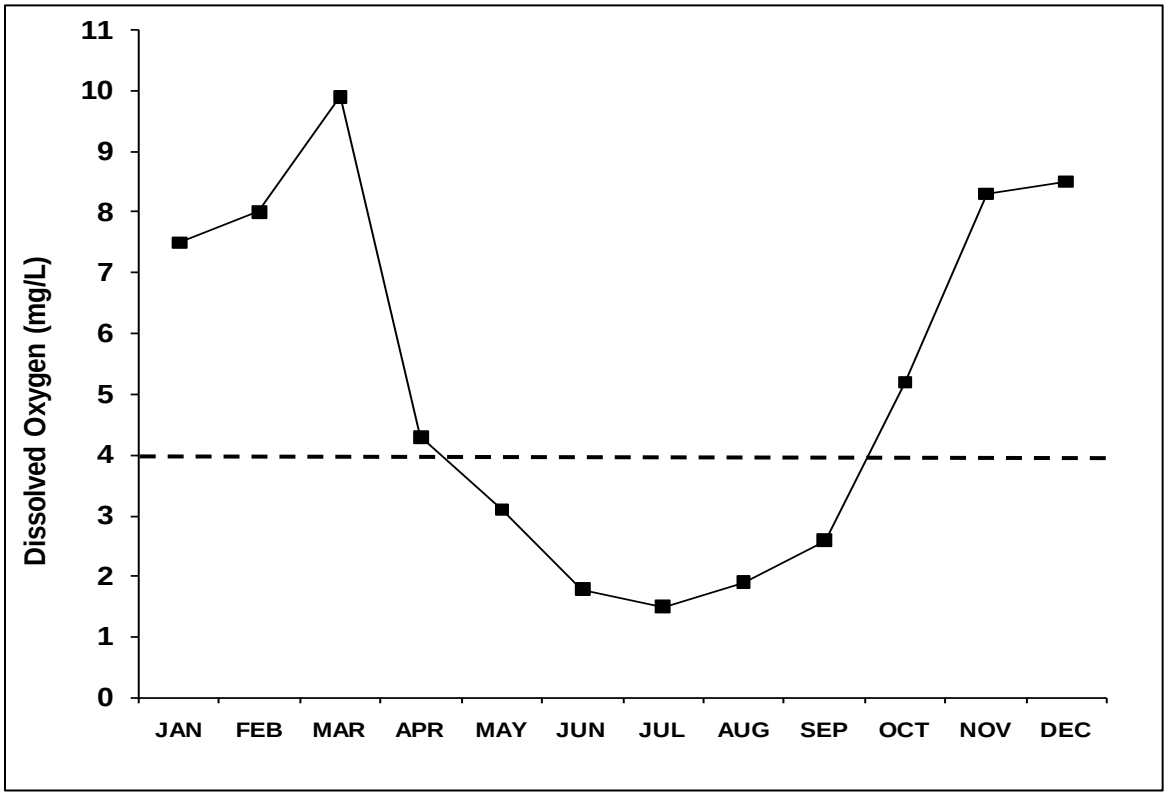
All the LCFRP sites in this subbasin had a good rating for field turbidity. The station NAV and those upstream were evaluated using the NC State Standard for freshwater of 50 NTU while all stations downstream of NAV were evaluated with the NC State Standard for brackish waters of 25 NTU.

AC and IC were both rated fair for nitrate, exceeding the recommended UNCW-AEL standard 17% of the time (Table 3.4.1) LVC2 was rated poor for nitrate, exceeding the UNCW-AEL recommended standard (200 mg/L) 75% of the time. All stations rated good for total phosphorus.

Table 3.4.1 UNCW AEL 2008 evaluation for subbasin 03-06-17

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

Figure 3.4.1 Dissolved oxygen concentrations at LVC2, rated poor for 2008. The dashed line shows the NC State Standard for swampwater, 4.0 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

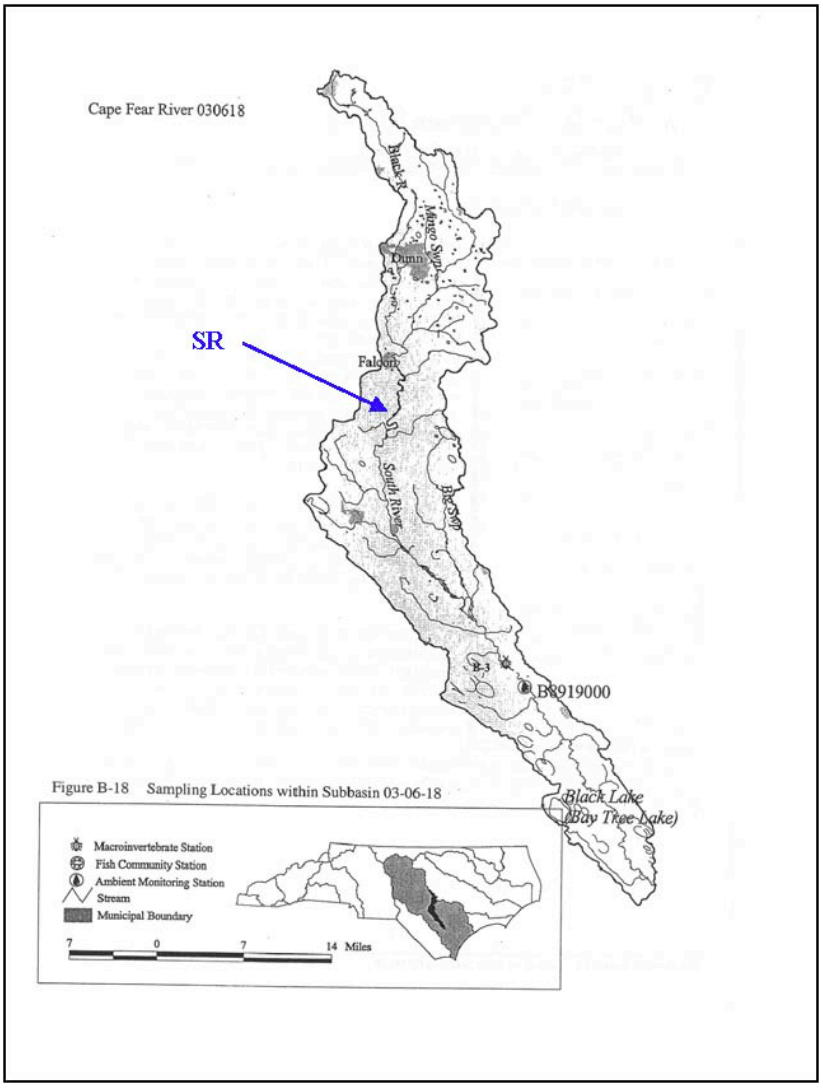


Figure B-18 Sampling Locations within Subbasin 03-06-18

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 was found to have a poor rating for dissolved oxygen concentrations in 2008 (Table 3.5.1). The North Carolina State Standard for swampwater of 4.0 mg/L was not met 33% 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, Figure 3.5.1).

SR had a poor water quality status 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 June (819 CFU/100mL).

SR had a good rating for field turbidity, nitrate and total phosphorus (Table 3.5.1).

Table 3.5.1 UNCW AEL 2008 evaluation for subbasin 03-06-18						
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
SR	P	G	P	G	G	G

Figure 3.5.1 Dissolved oxygen (mg/L) at SR during 2008. The dashed line shows the NC State Standard for swampwater DO of 4.0 mg/L.

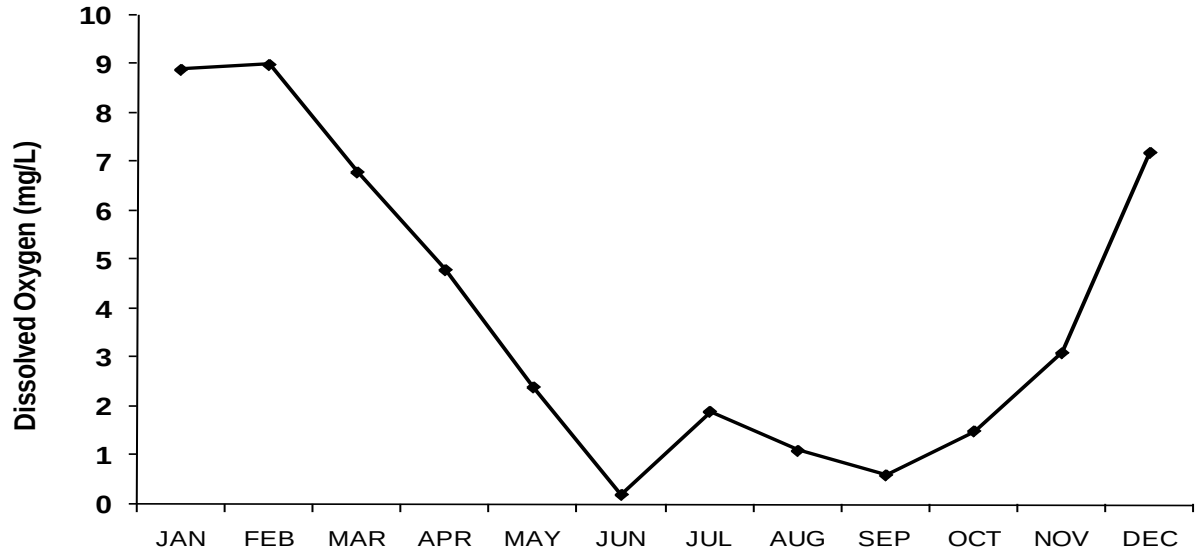
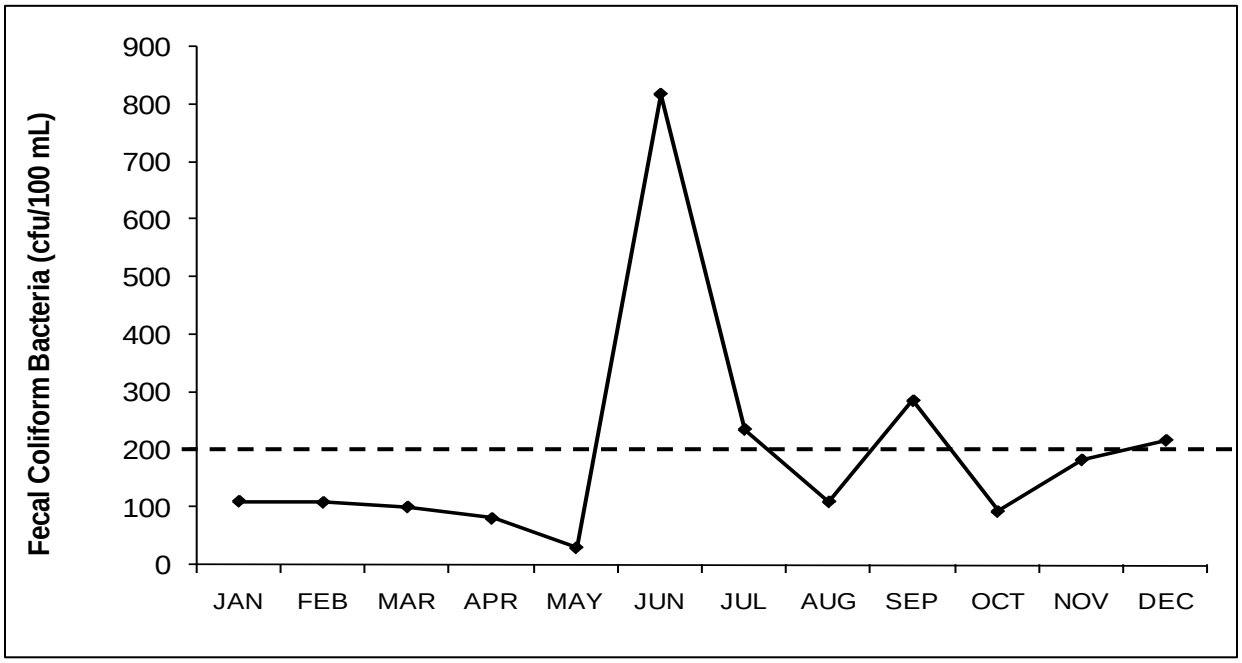
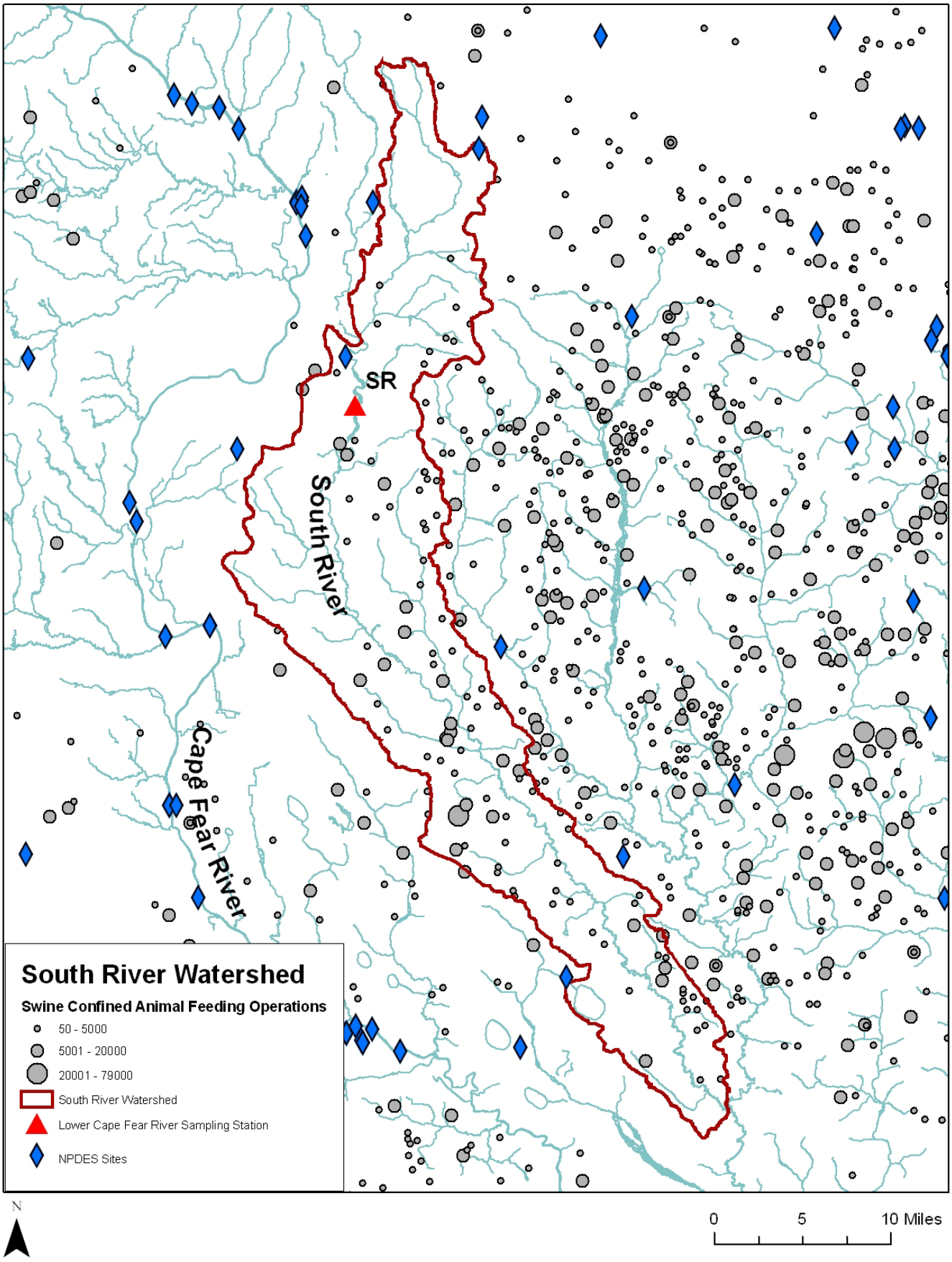


Figure 3.5.2 Fecal Coliform Bacteria (cfu/100 mL) at SR during 2008. The dashed line shows the NC State Standard of 200 cfu/100 mL.




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

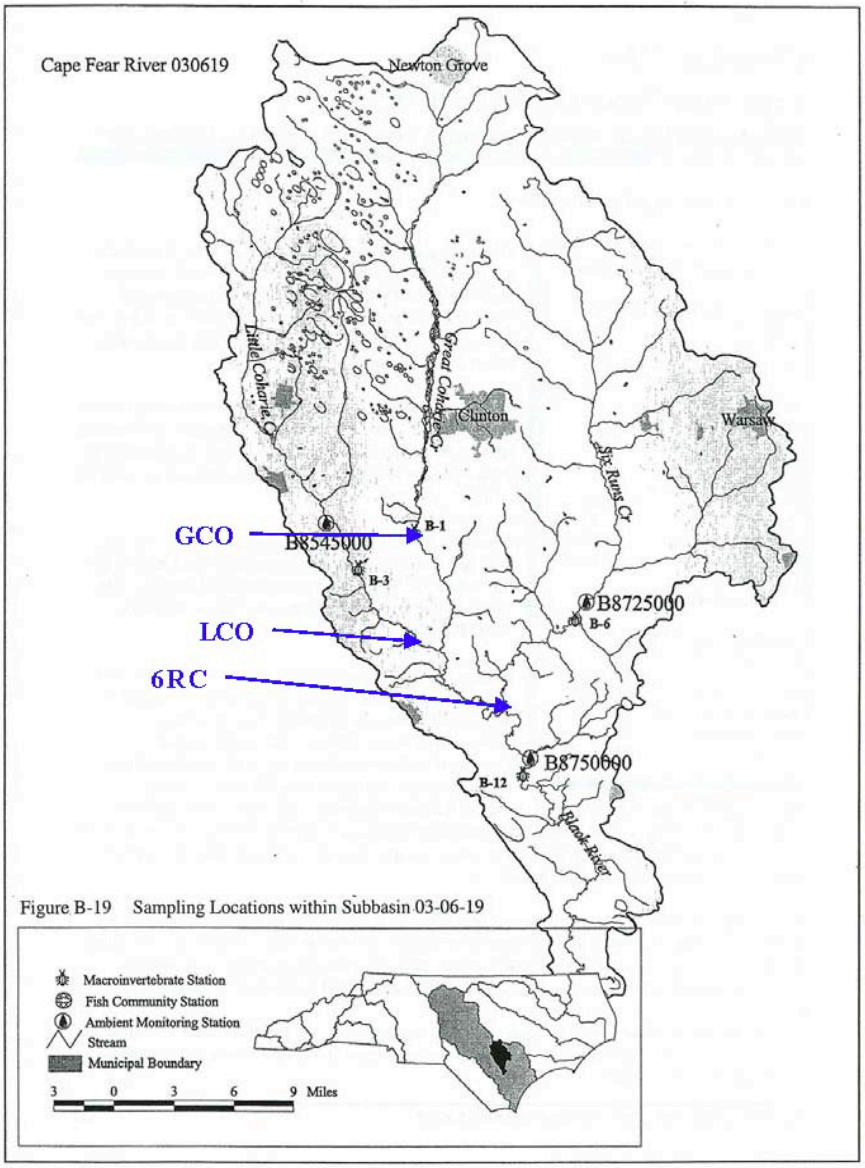


Figure B-19 Sampling Locations within Subbasin 03-06-19

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 and LCO had a good rating for dissolved oxygen concentrations during 2008 (Table 3.6.1). GCO was rated fair with two samples (17%) below the NC State Standard of 4.0 mg/L.

All sites within this subbasin had a good rating for chlorophyll *a* and field turbidity concentrations (Table 3.6.1).

6RC had a poor rating for fecal coliform bacteria with 50% of samples exceeding the NC State human contact standard of 200 CFU/100mL (Table 3.6.1). LCO had a fair rating with a 17% rate and GCO had a good rating for fecal coliform bacteria.

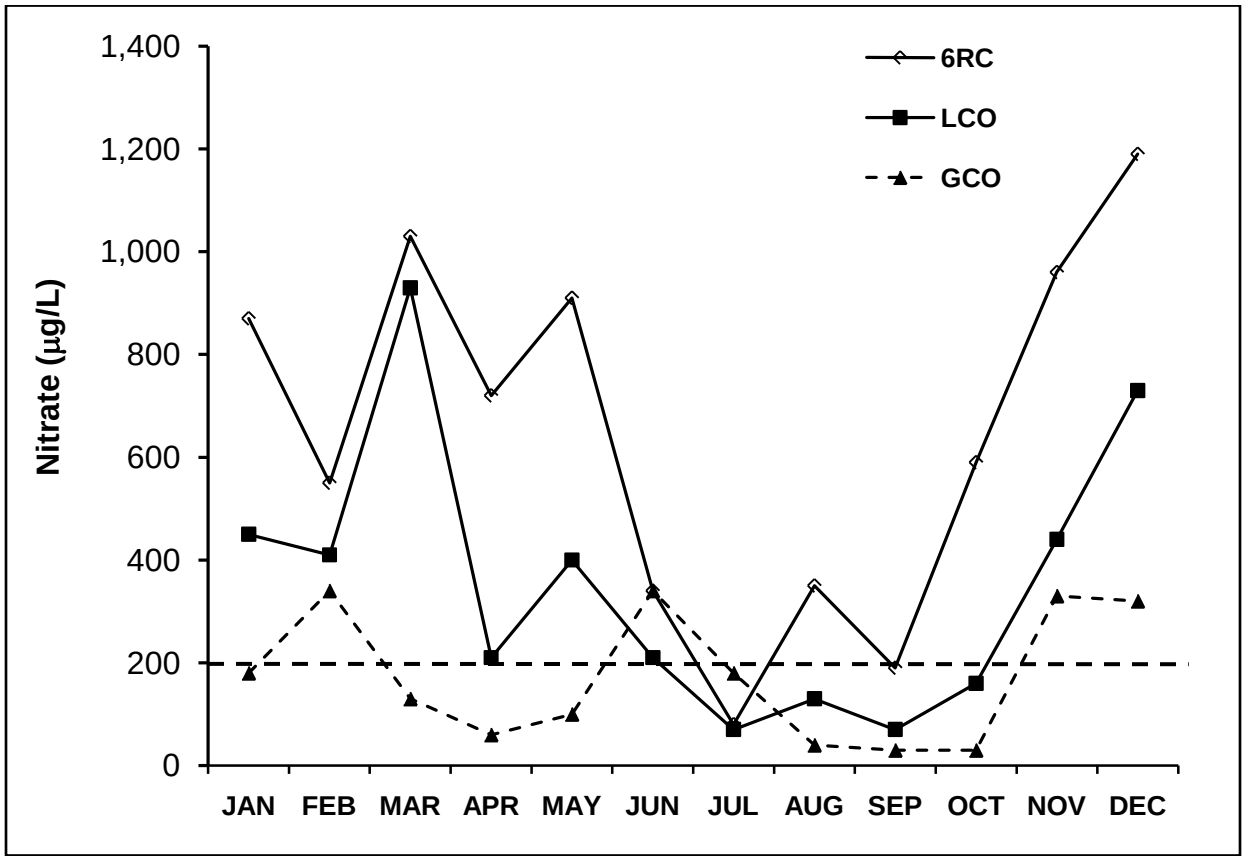
Nitrate levels were rated poor at 6RC, LCO and GCO, exceeding 200 µg/L in 83%, 67%, and 33% of the samples, respectively (Table 3.6.1, Figure 3.6.1).

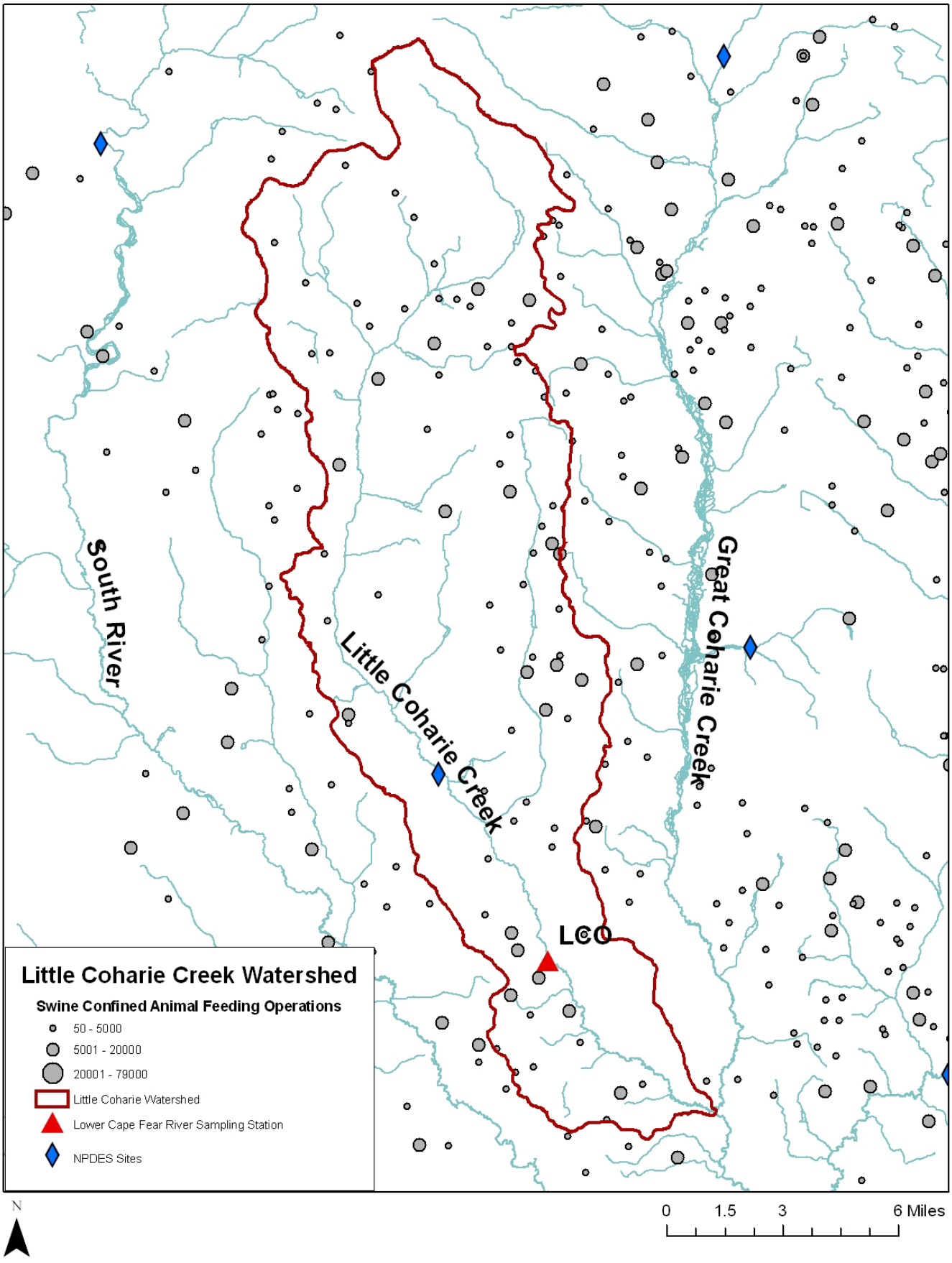
Total phosphorus was rated good at 6RC and LCO and rated fair at GCO with levels above 500 µg/L 25% of the time (Table 3.6.1).

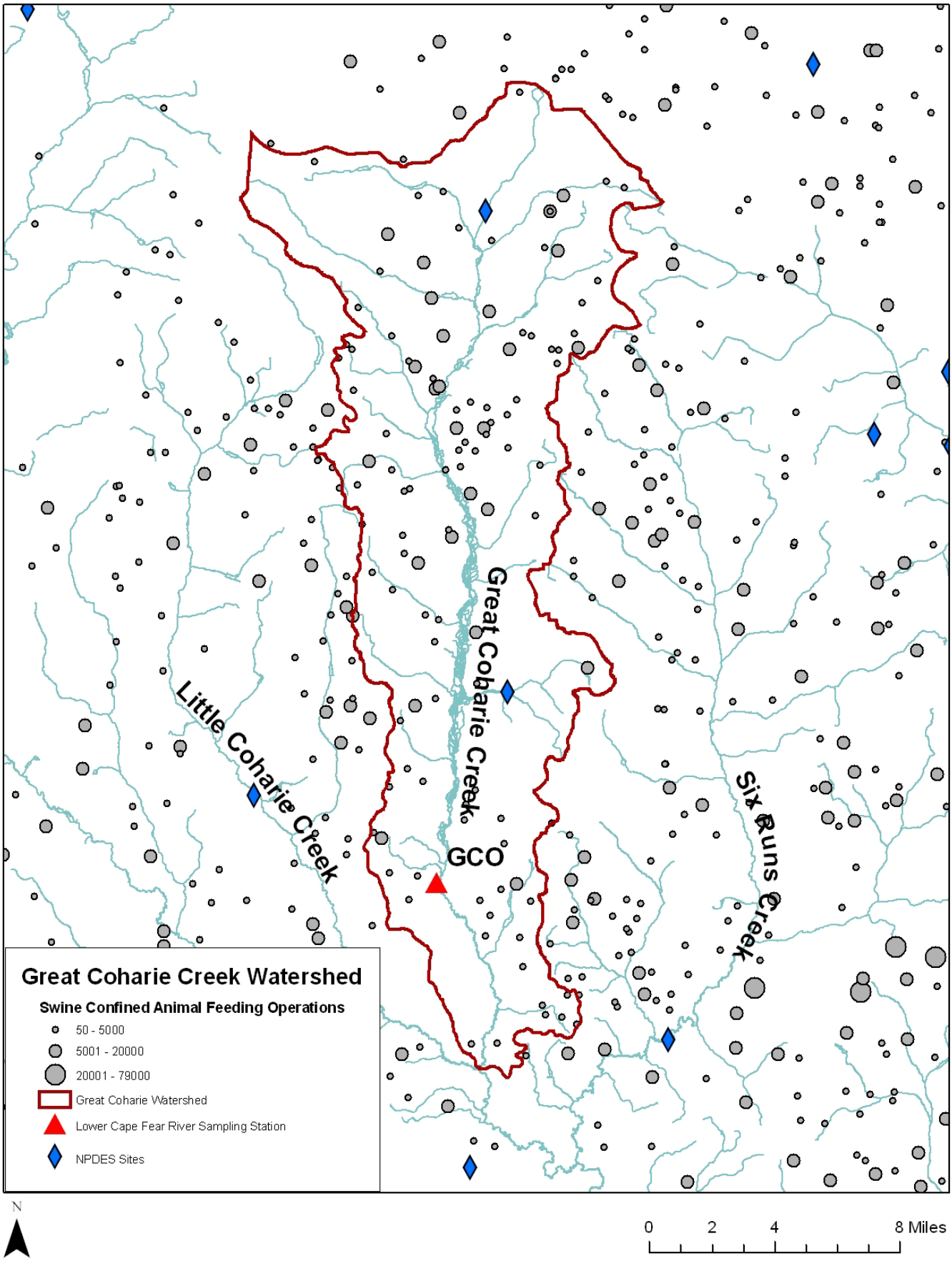
Table 3.6.1 UNCW AEL 2008 evaluation for subbasin 03-06-19

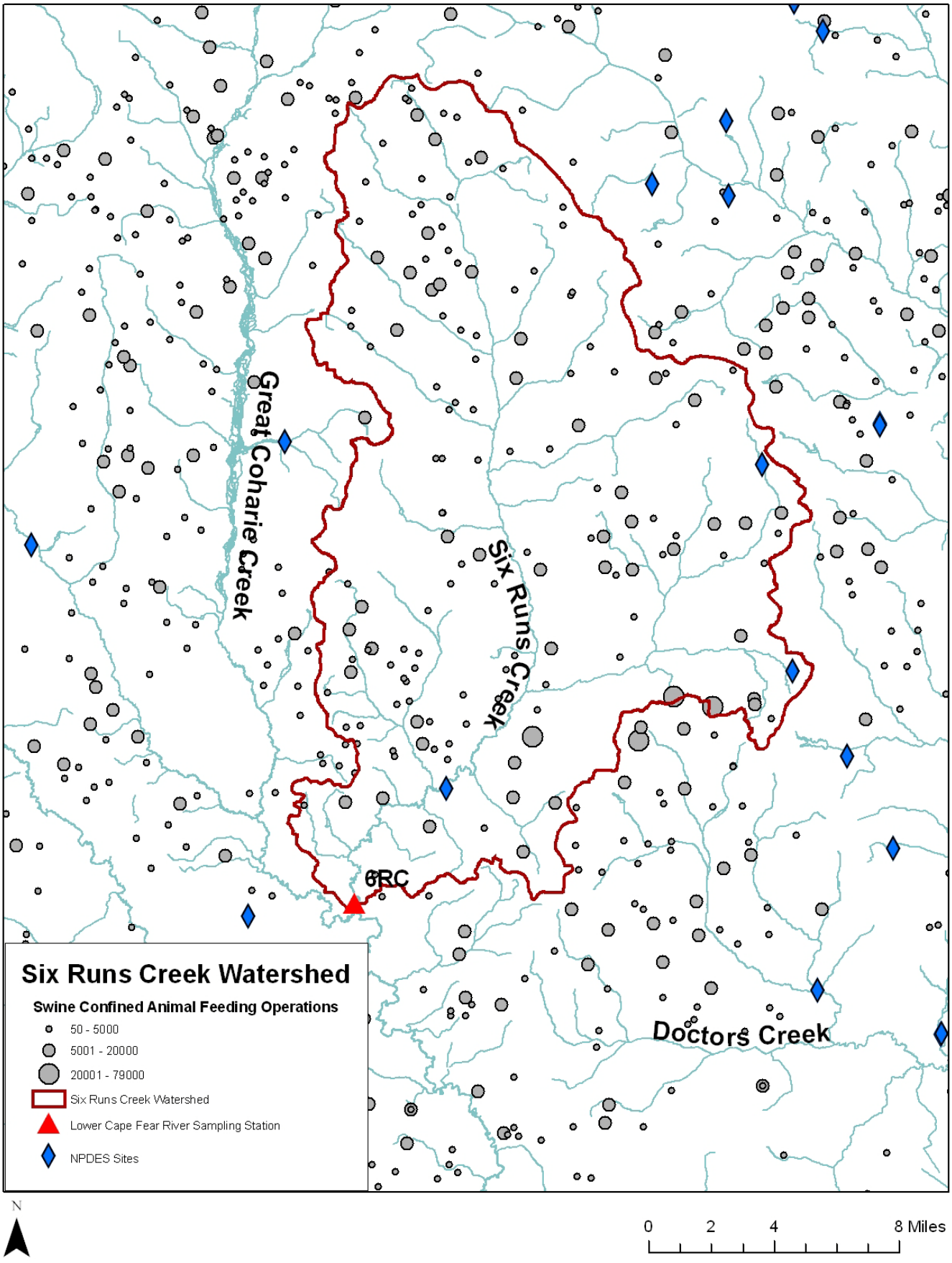
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
6RC	G	G	P	G	P	G
LCO	G	G	F	G	P	G
GCO	F	G	G	G	P	F

Figure 3.6.1 Nitrate concentrations (µg/L) at 6RC, LCO, and GCO during 2008. 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

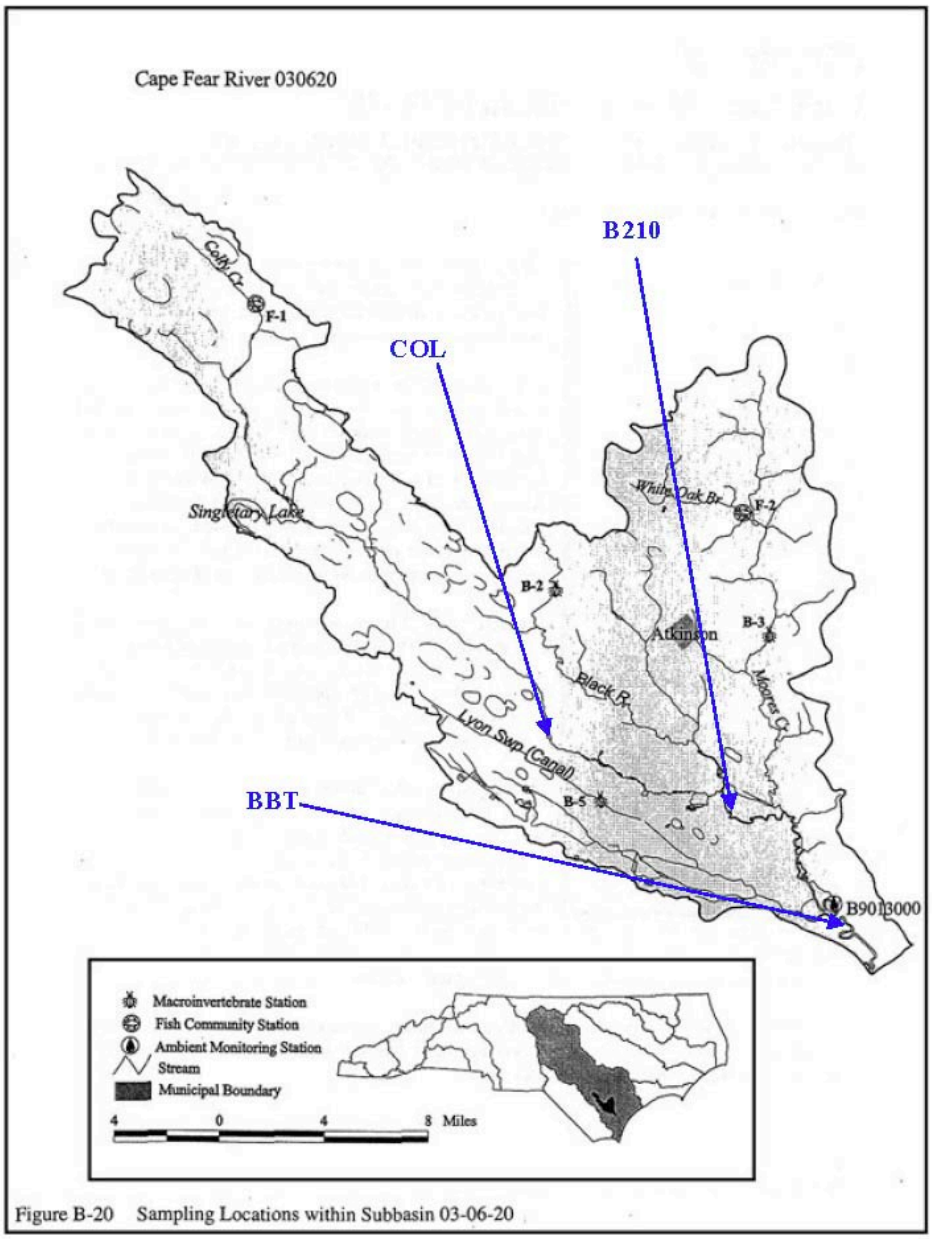


Figure B-20 Sampling Locations within Subbasin 03-06-20

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).

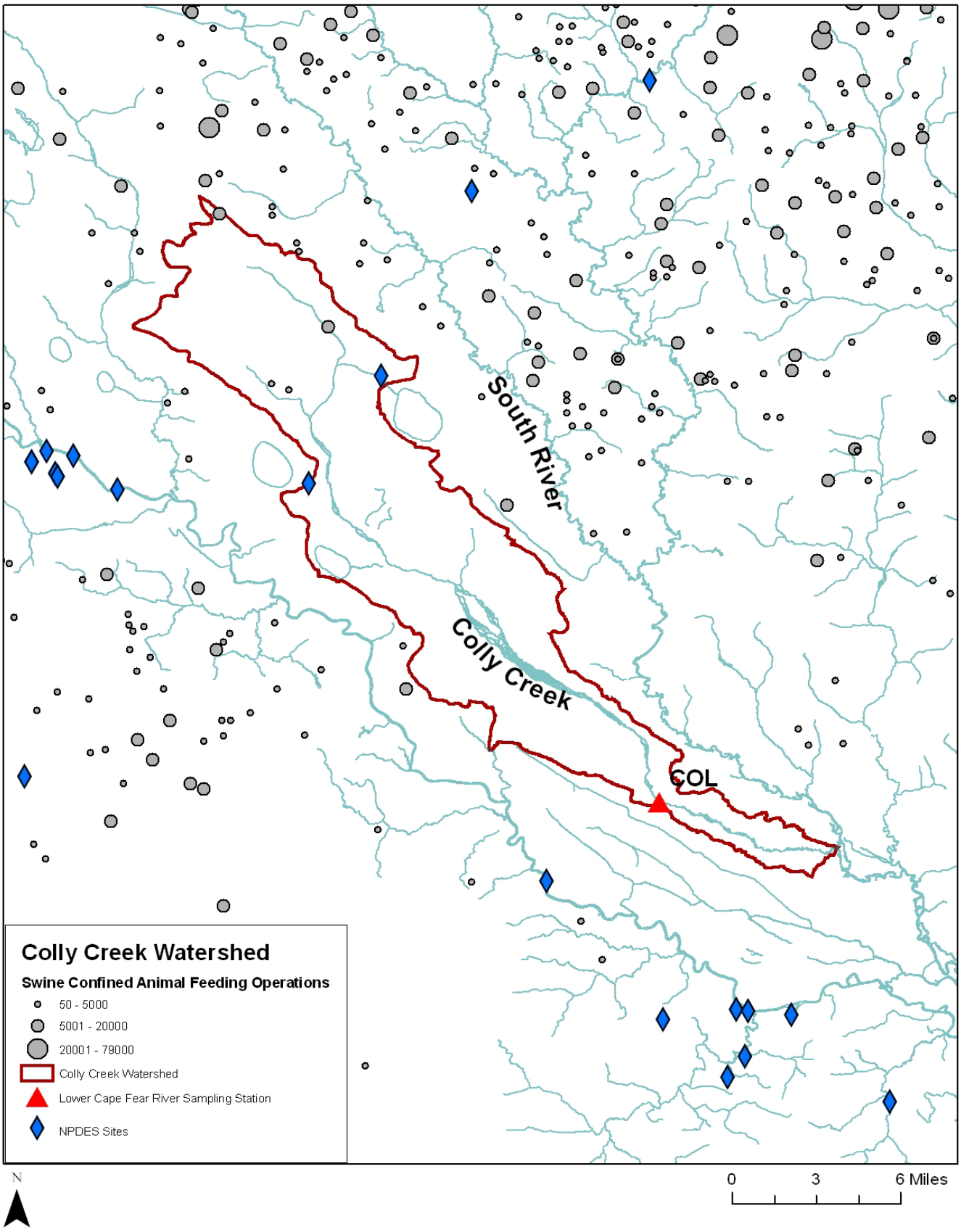
Chlorophyll *a* and field turbidity concentrations were low for each site within this subbasin and all sites had a good rating for these parameters (Table 3.7.1).

Fecal coliform bacteria concentrations were generally low with B210 and COL rating as fair with samples exceeding the NC State standard 17% and 18% of the time respectively (Table 3.7.1). BBT samples were not analyzed for fecal coliform bacteria.

All stations rated good for both nutrient species. BBT samples were not analyzed for nutrients.

Table 3.7.1 UNCW AEL 2008 evaluation for subbasin 03-06-20

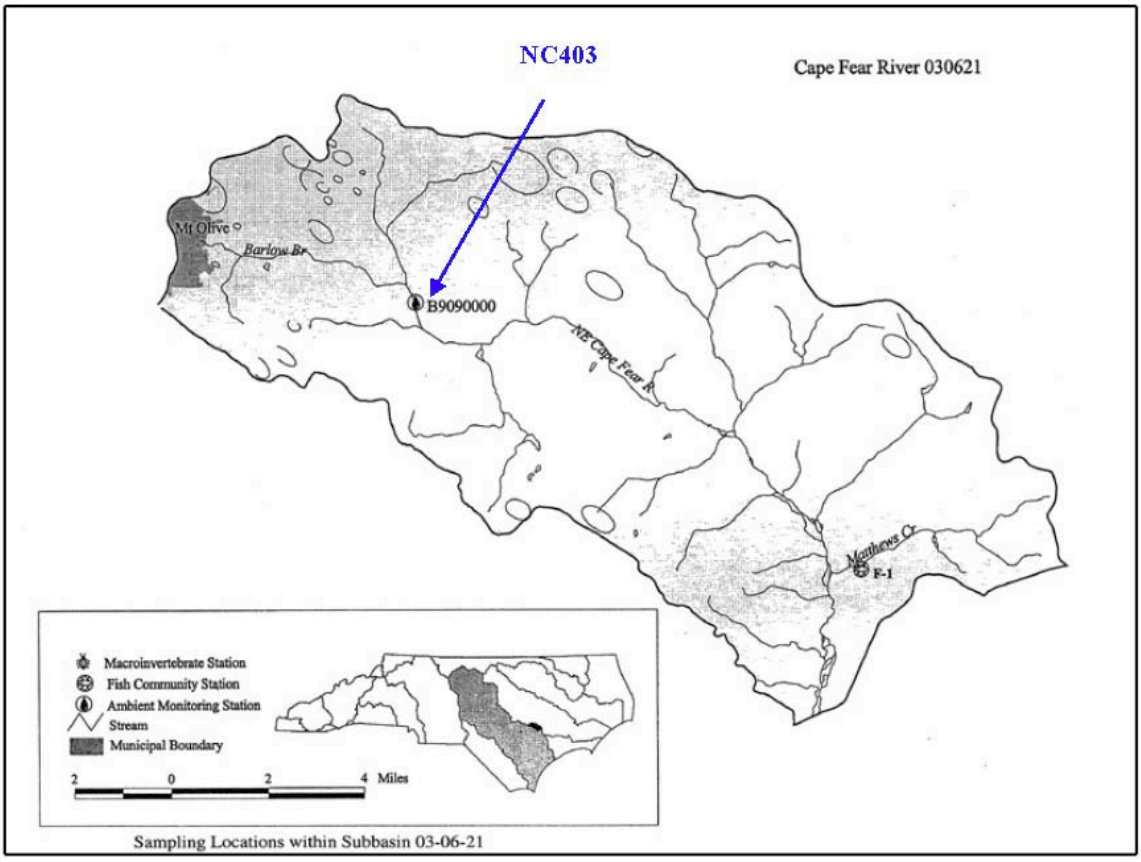
Station	Dissolved Oxygen	Chlorophyll a	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
B210	G	G	F	G	G	G
COL	G	G	F	G	G	G
BBT	G	G		G		


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 fair rating for chlorophyll *a* and 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.

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

NC403 had a poor rating for fecal coliform bacteria with samples exceeding the NC State standard for human contact (200 cfu/100 mL) 33% of the time.

High nitrate levels at NC403 led to a poor rating, with nitrate concentrations >200 µg/L for 50% of the samples (Table 3.8.1, Figure 3.8.1). UNCW AEL researchers are concerned

about the elevated nitrate levels that are periodically found at this site since these levels increase the likelihood of algal blooms and excessive aquatic macrophyte growth. Total phosphorus had a good rating at this location for 2008.

Table 3.8.1 UNCW AEL 2008 evaluation for subbasin 03-06-21

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

Figure 3.8.1 Dissolved oxygen (mg/L) and nitrate (µg/L) concentrations at NC403 during 2008. 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.

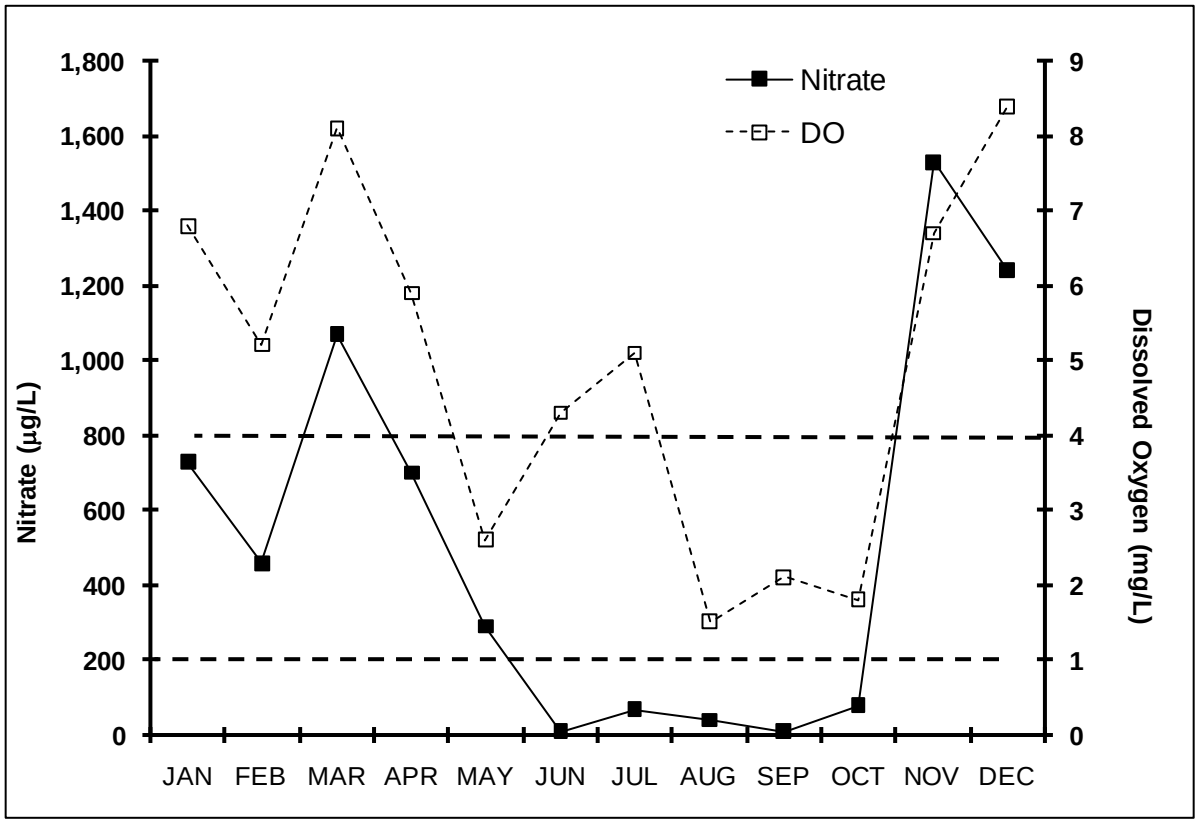
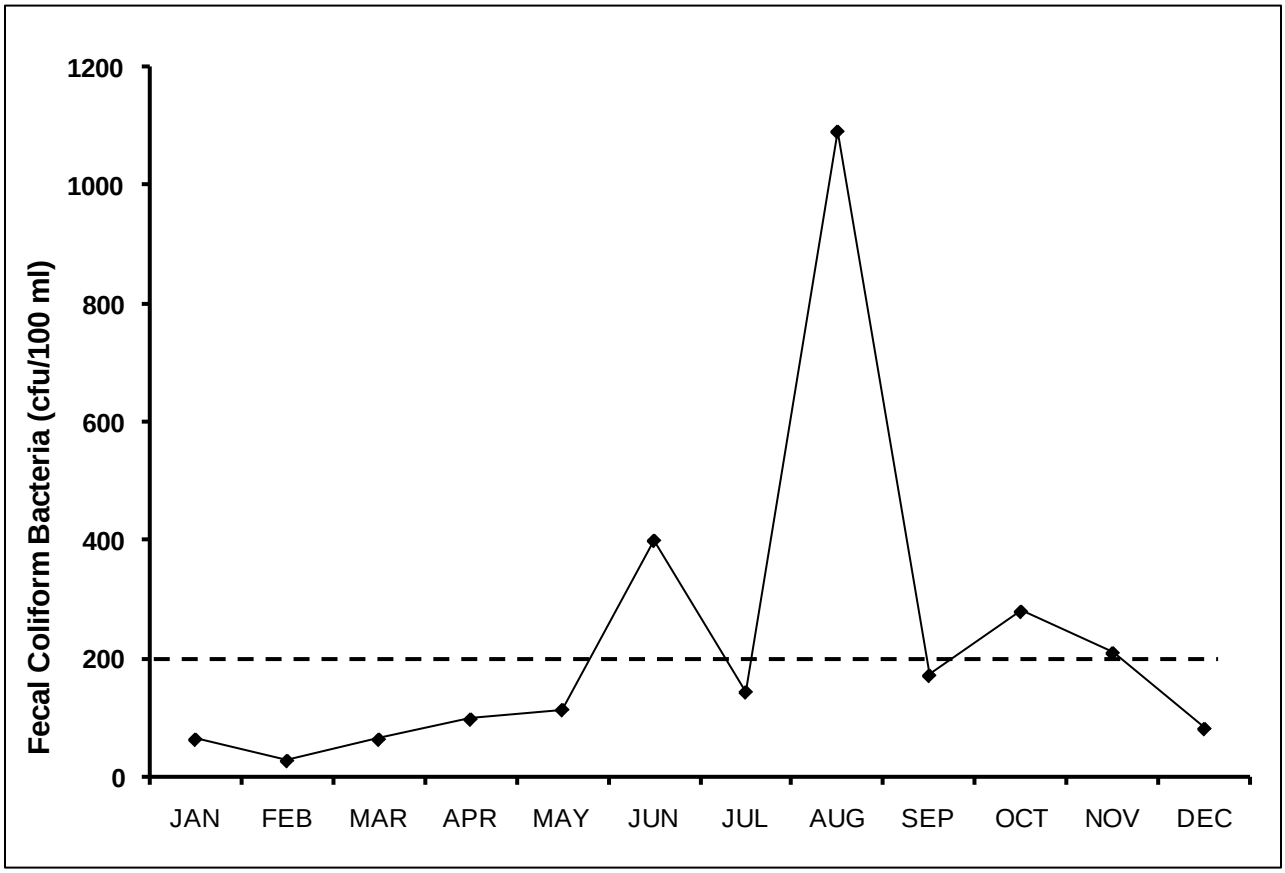


Figure 3.9.1 Fecal Coliform Bacteria concentrations (cfu/100 mL) at NC403 during 2008. The dashed line shows the NC State standard of 200 cfu/100 mL.



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

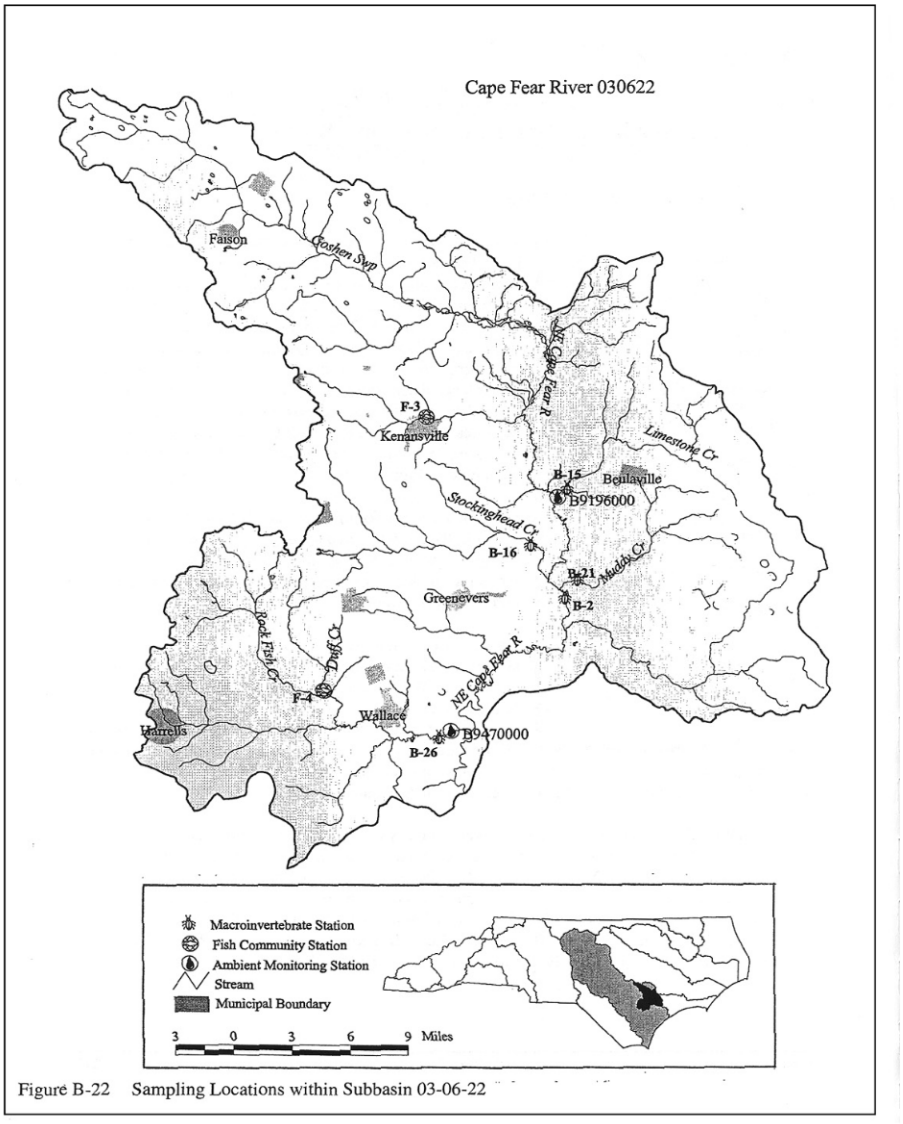


Figure B-22 Sampling Locations within Subbasin 03-06-22

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 25% of the time.

For chlorophyll *a* concentrations SAR, LRC and ROC had a good rating (Table 3.9.1). GS was rated fair with samples exceeding the NC State Standard 17% of the time. PB was rated poor, exceeding the standard 33% of the time.

Fecal coliform bacteria concentrations were rated using the NC State standard of 200 CFU/100 mL for human contact. GS and LRC each had a fair rating with both exceeding the standard 25% of the time (Table 3.9.1). SAR, PB and ROC each had a poor rating with 50%, 42% and 42% of samples above the standard, respectively. Fecal coliform bacteria concentrations are shown graphically in Figure
3.9.1.

All sites had a good rating for field turbidity concentrations (Table 3.9.1). Mean levels were less than 15 NTU for all sites within this subbasin for 2008.

For nitrate GS and LRC had a good rating (Table 3.9.1). SAR, PB, and ROC all had a poor rating with levels exceeding the UNCW AEL standard (200 µg/L) 50%, 58%, 33% and 92% of the time, respectively. Nitrate levels for SAR, PB and ROC are shown graphically in Figure 3.9.2.

For total phosphorus all stations were rated good (Table 3.9.1).

Table 3.9.1 UNCW AEL 2008 evaluation for subbasin 03-06-22

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

Figure 3.9.1 Fecal coliform bacteria at SAR, PB and ROC (cfu/100mL) during 2008. The dashed line is the NC State Standard for human contact of 200 cfu/100mL).

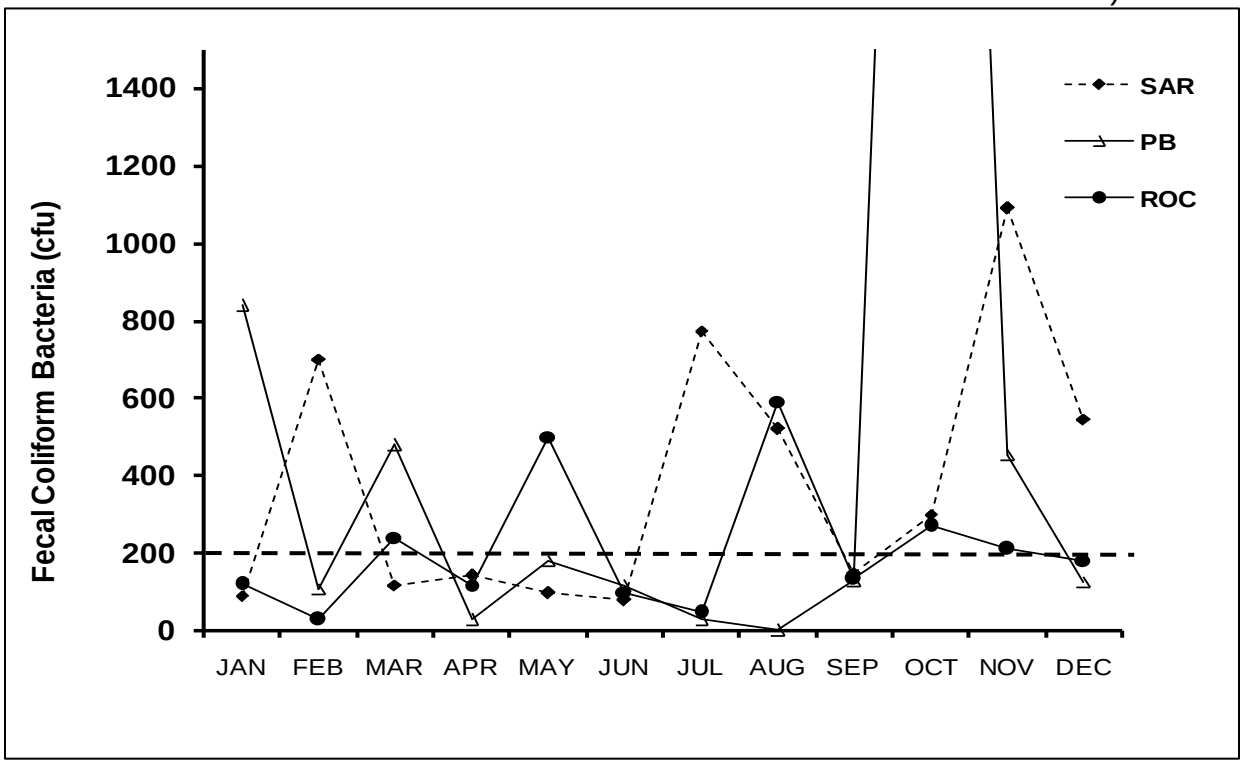
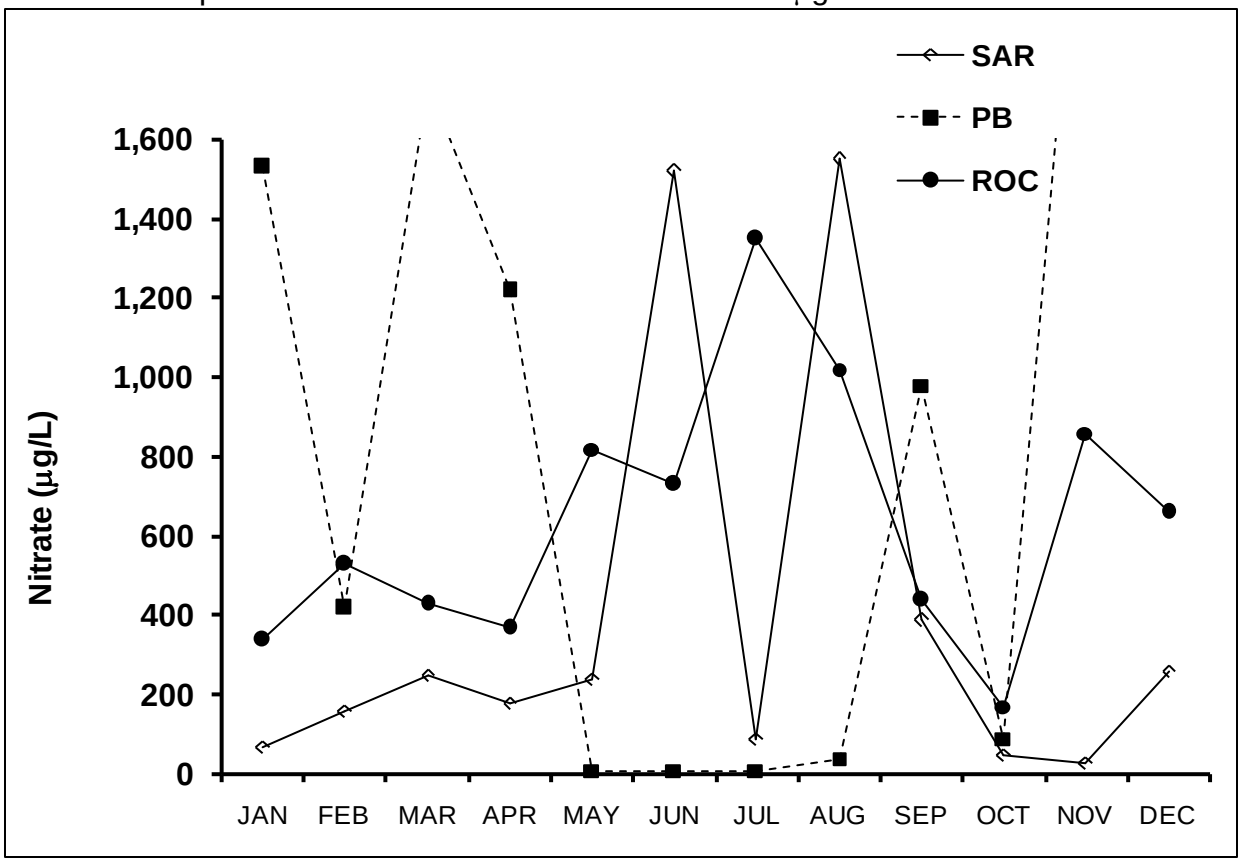
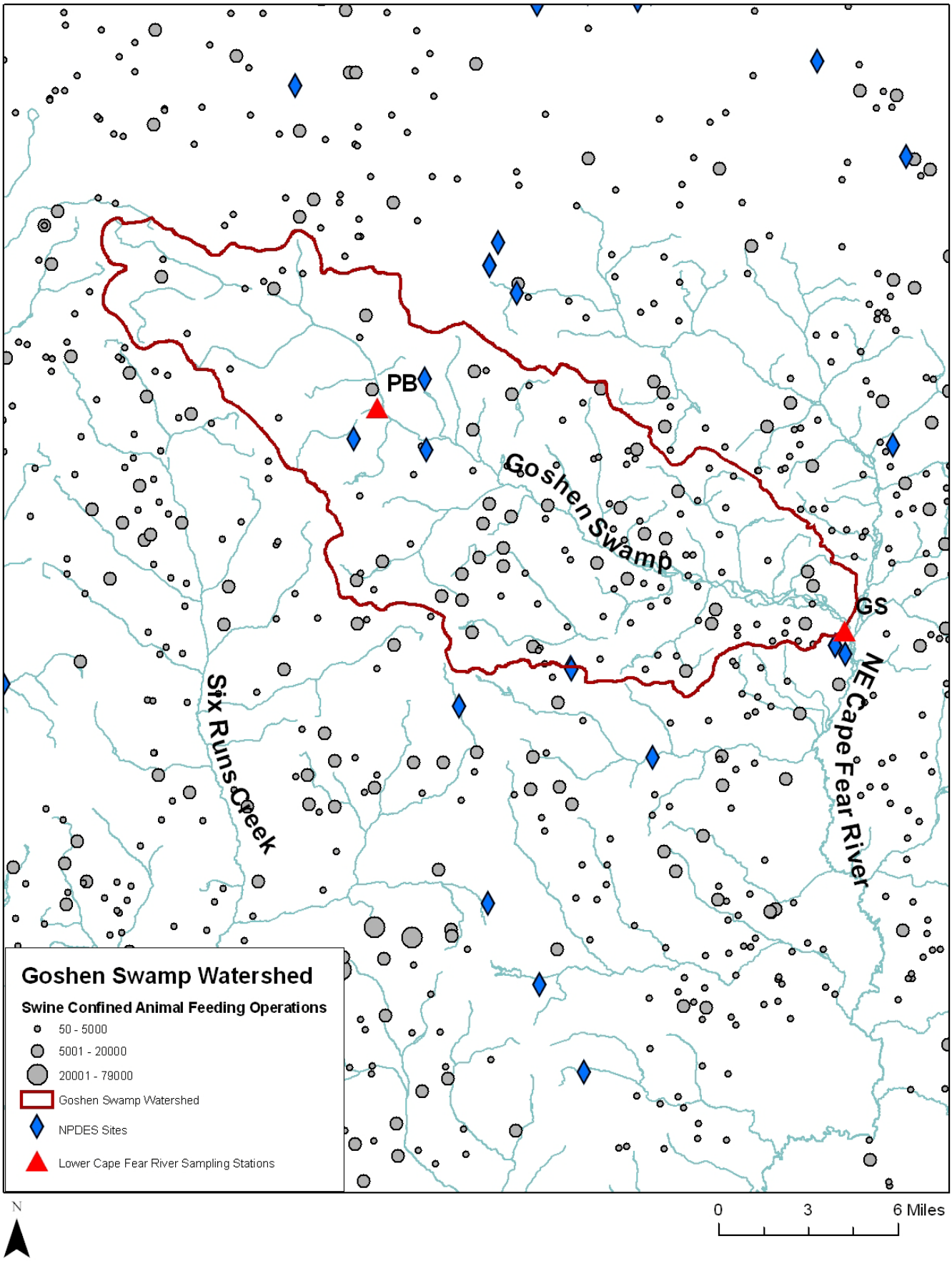
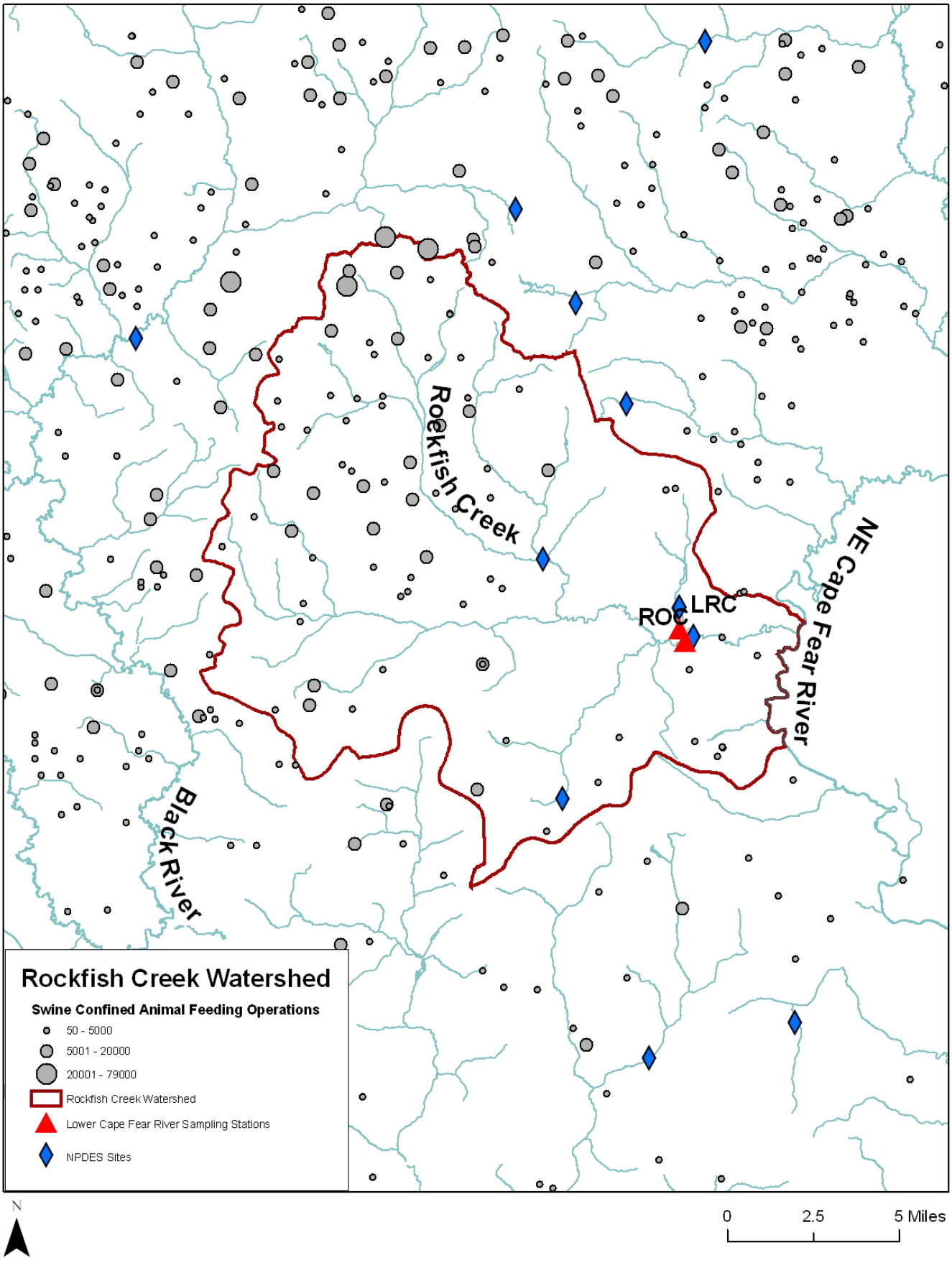


Figure 3.9.2 Nitrate-N concentrations (µg/L) at SAR, PB and ROC during 2008. The dashed line represents the UNCW AEL standard of 200 µg/L.




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


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

3.10 Cape Fear River Subbasin 03-06-23

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

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

DWQ monitoring stations: NCF117

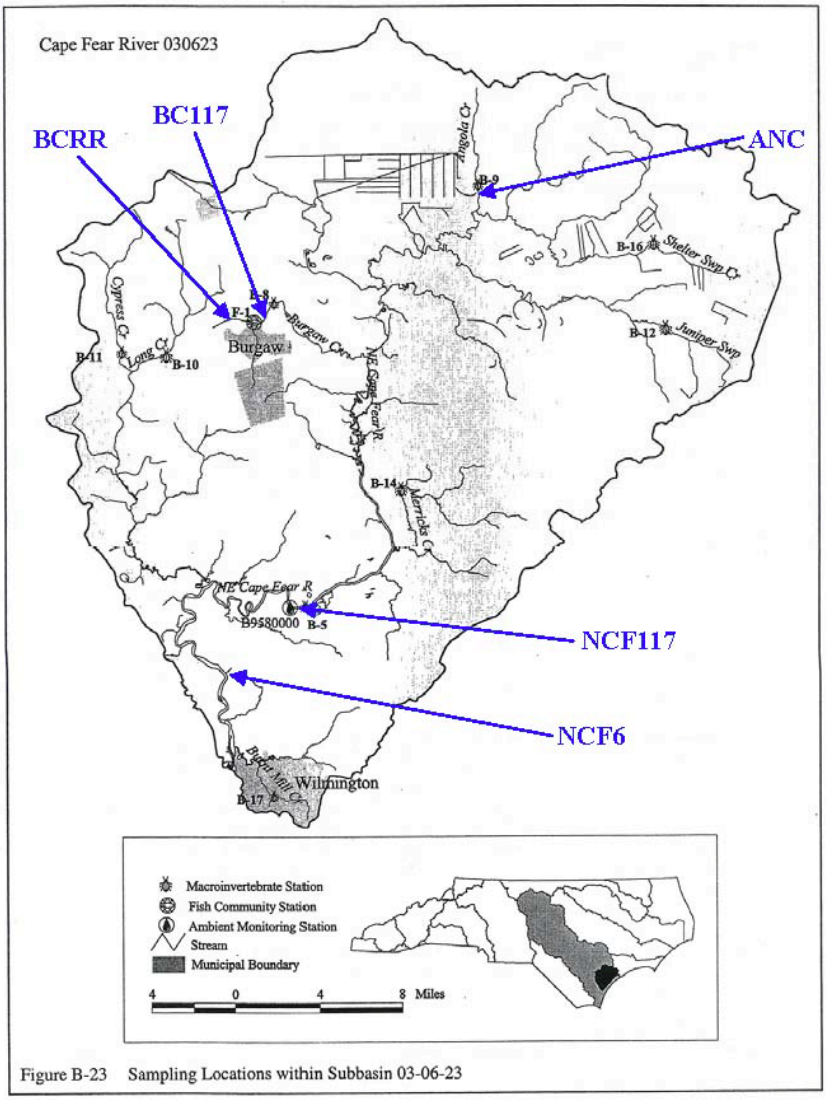


Figure B-23 Sampling Locations within Subbasin 03-06-23

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

forested with some agriculture and increasing human development.

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

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

UNCW Aquatic Ecology Laboratory Evaluation

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


ANC - Angola Creek


BC117 - Burgaw Canal at US 117


NCF117 - Northeast Cape Fear River at US117

For dissolved oxygen BC117, NCF117 and NCF6 had a good rating when using the 4.0 mg/L standard (Table 3.10.1). ANC had a fair rating with sub-standard samples 25% of the time. SC-CH and BCRR had a poor rating with substandard samples 33% and 58% of the time. DO levels for ANC, BCRR and SC-CH are seen in Figure 3.10.1.

For chlorophyll *a* BC117, NCF117 and NCF6 rated good (Table 3.10.1). ANC and BCRR rated fair exceeding the NC State Standard of 40 µg/L 17% of the time at both sites. Chlorophyll *a* was not analyzed at SC-CH.

For fecal coliform bacteria NCF117, NCF6 and SC-CH had a good rating (Table 3.10.1). ANC had a fair rating, exceeding the standard 25% of the time. BC117 and BCRR each had a poor rating exceeding the human contact standard 100% and 42% of the time, respectively. Fecal coliform bacteria concentrations for BC117 and BCRR are shown in Figure 3.10.2.

All stations were rated good for field turbidity except SC-CH which had field turbidity values exceeding the NC State Standard for tidal waters of 25 NTU 33% of the time. (Table 3.10.1).

Nutrient loading of nitrate and total phosphorus was problematic at BC117 which had a poor rating for both (Table 3.10.1). Nitrate levels exceeded the UNCW AEL standard 100% of the time and total phosphorus levels exceeded the UNCW AEL standard 75% of the time. BC117 had the highest nitrate and TP levels seen in the LCFRP system. These levels were far above the concentrations known to lead to algal bloom formation, bacterial increases and increased biochemical oxygen demand (BOD) in blackwater streams (Mallin et al. 2001, Mallin et al. 2002). ANC and BC117 were both rated poor for nitrate as well, exceeding the UNCW AEL standard 33% and 42% of the time, respectively.

Table 3.10.1 UNCW AEL 2008 evaluation for subbasin 03-06-23

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

Figure 3.10.1 Dissolved oxygen concentrations (mg/L) at BCRR, SC-CH and ANC for 2008. The dashed line shows the NC State Standard for swampwater, 4.0 mg/L.

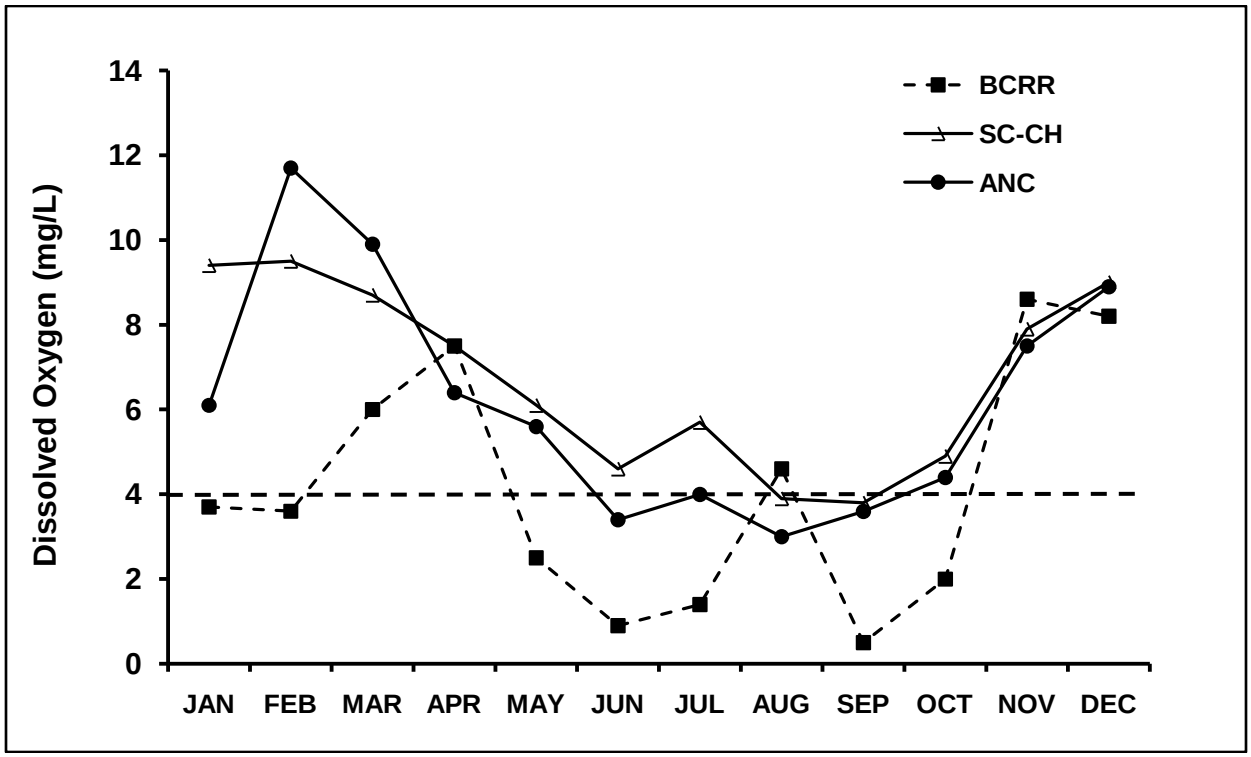
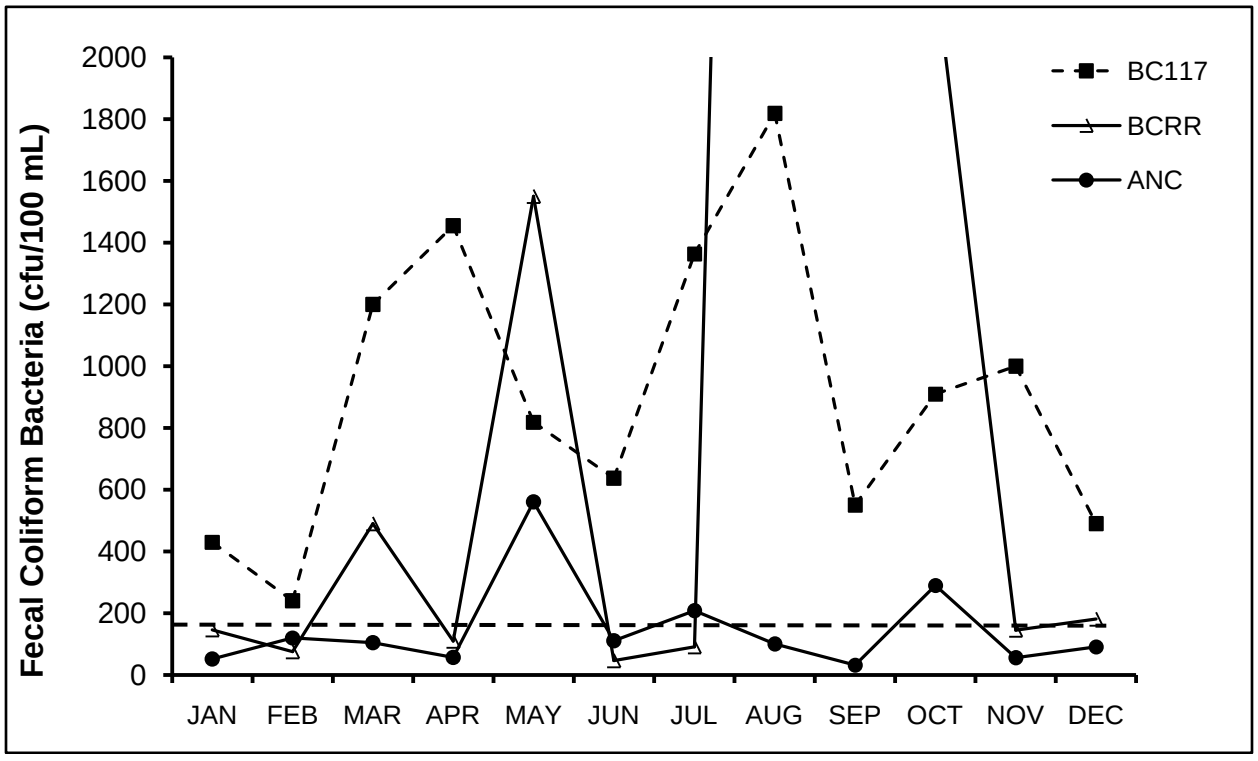
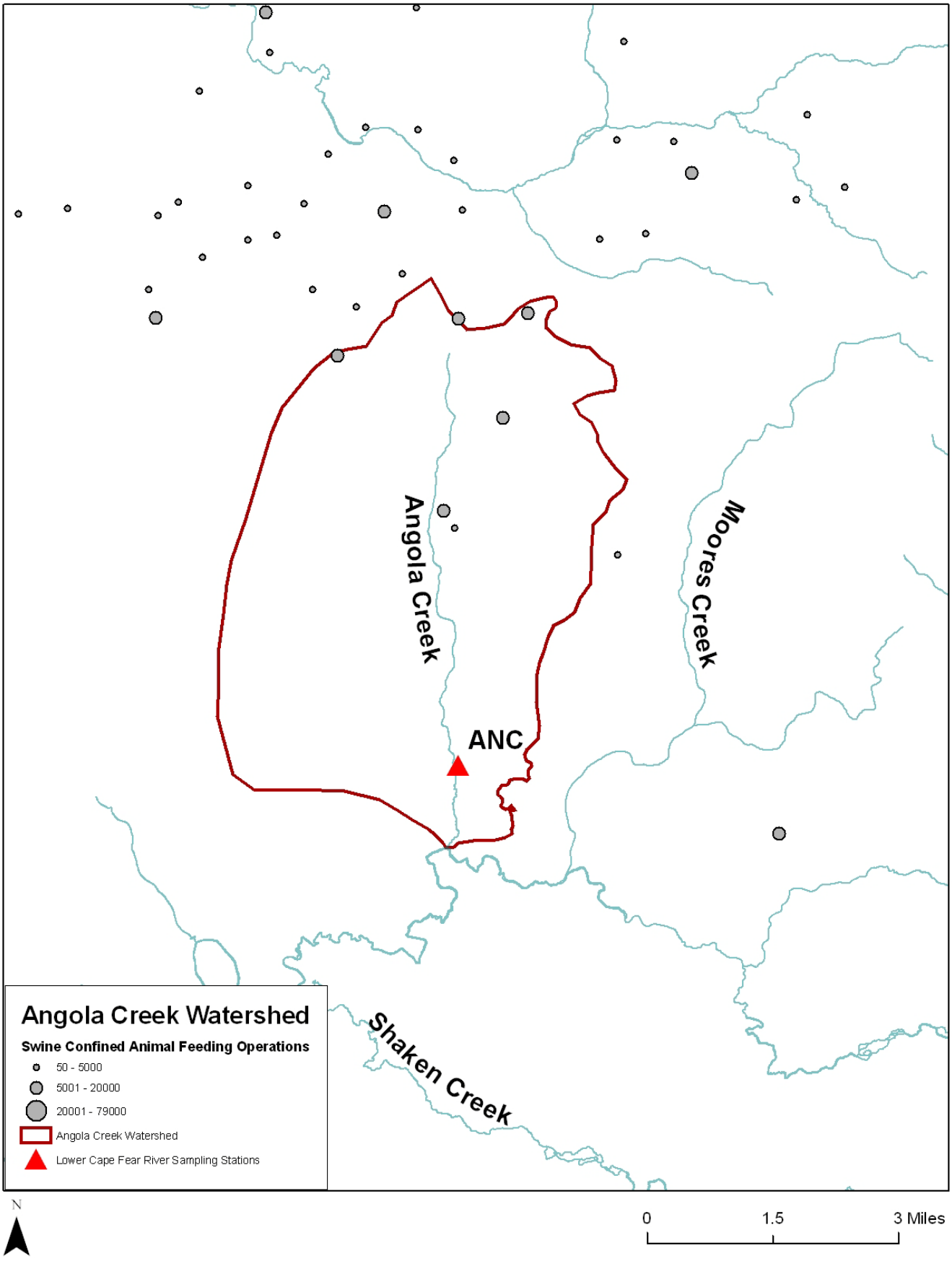
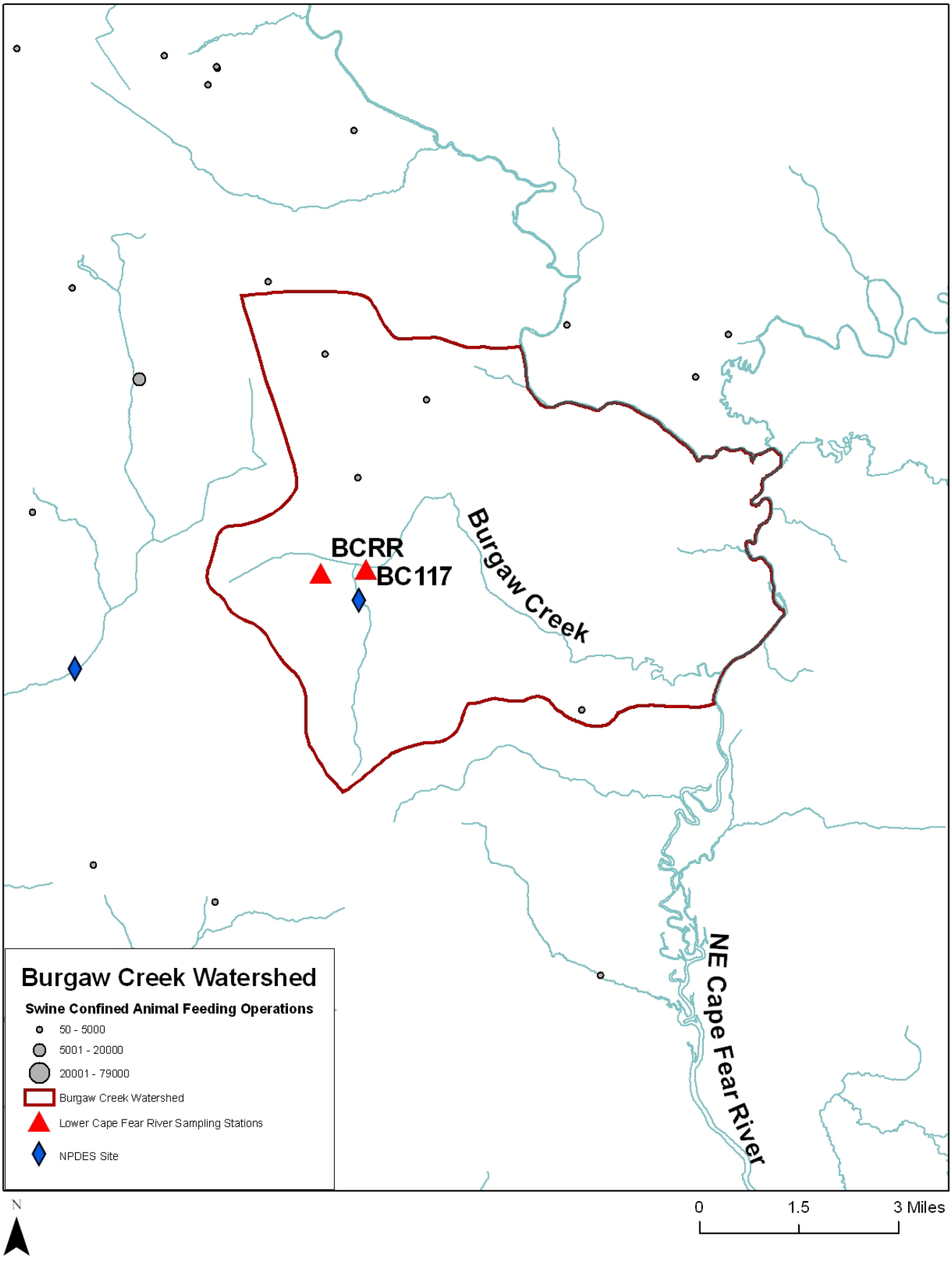


Figure 3.10.2 Fecal coliform bacteria concentrations (cfu/100mL) at BC117, BCRR and ANC during 2008. The dashed line shows the NC State Standard for human contact, 200 cfu/100 mL.




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


BCRR
BC117
Burgaw Creek
NE Cape Fear River
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
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.