Environmental Assessment of the Lower Cape Fear River System, 2011

By

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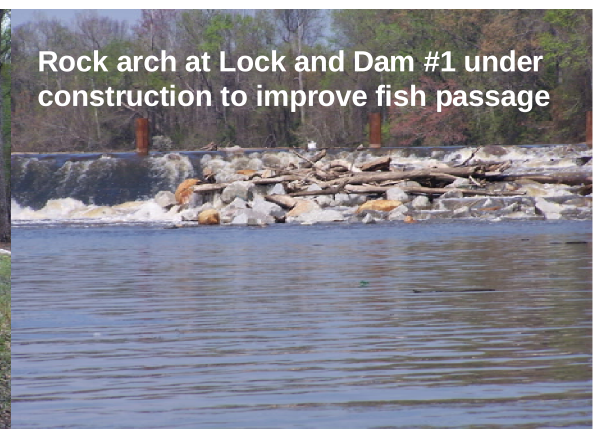
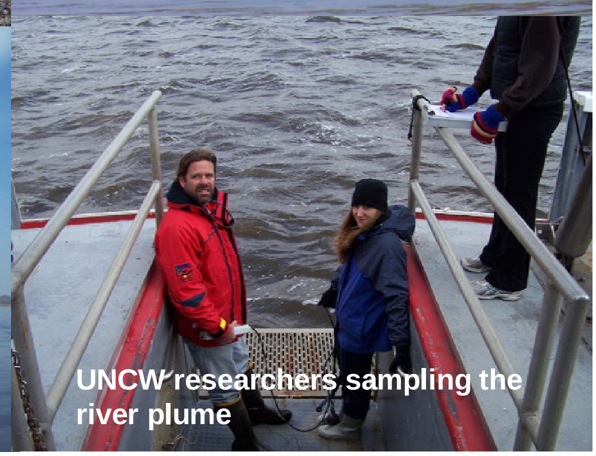
Spring 2012 UNCW Estuarine Biology class


Rock arch at Lock and Dam #1 under construction to improve fish passage


Dredging the shipping channel


UNCW researchers sampling the river plume

Executive Summary

Multiparameter water sampling for the Lower Cape Fear River Program (LCFRP) has been ongoing since June 1995. Scientists from the University of North Carolina Wilmington's (UNCW) Aquatic Ecology Laboratory perform the sampling effort. The LCFRP currently encompasses 36 water sampling stations throughout the lower Cape Fear, Black, and Northeast Cape Fear River watersheds. The LCFRP sampling program includes physical, chemical, and biological water quality measurements and analyses of the benthic and epibenthic macroinvertebrate communities, and has in the past included assessment of the fish communities. Principal conclusions of the UNCW researchers conducting these analyses are presented below, with emphasis on water quality of the period January - December 2011. The opinions expressed are those of UNCW scientists and do not necessarily reflect viewpoints of individual contributors to the Lower Cape Fear River Program.

The mainstem lower Cape Fear River is a 6th order stream characterized by periodically turbid water containing moderate to high levels of inorganic nutrients. It is fed by two large 5th order blackwater rivers (the Black and Northeast Cape Fear Rivers) that have low levels of turbidity, but highly colored water with less inorganic nutrient content than the mainstem. While nutrients are reasonably high in the river channels, major algal blooms have until recently been rare because light is attenuated by water color or turbidity, and flushing is usually high (Ensign et al. 2004). During periods of low flow (as in 2008-2010) algal biomass as chlorophyll *a* increases in the river because lower flow causes settling of more solids and improves light conditions for algal growth. Periodically major algal blooms are seen in the tributary stream stations, some of which are impacted by point source discharges. Below some point sources, nutrient loading can be high and fecal coliform contamination occurs. Other stream stations drain blackwater swamps or agricultural areas, some of which periodically show elevated pollutant loads or effects (Mallin et al. 2001).

Average annual dissolved oxygen (DO) levels at the river channel stations for 2011 were similar to the average for 1995-2010. Dissolved oxygen levels were lowest during the summer and early fall, often falling below the state standard of 5.0 mg/L at several river and upper estuary stations. There is a dissolved oxygen sag in the main river channel that begins at Station DP below a paper mill discharge and near the Black River input, and persists into the mesohaline portion of the estuary. Mean oxygen levels were highest at the upper river stations NC11 and AC and in the middle to lower estuary at stations M42 to M18. Lowest mainstem average 2011 DO levels occurred at the lower river and upper estuary stations DP, IC, NAV, HB, BRR and M61 (6.8-7.6 mg/L). As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River. These rivers are classified as blackwater systems because of their tea colored water. The Northeast Cape Fear River often seems to be more oxygen stressed than the Black River; as such, in 2011 Stations NCF117 and B210,

representing those rivers, had average DO concentrations of 5.3 and 6.9 mg/L, respectively. Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2011. Station BCRR (upper Burgaw Creek) had DO levels below 4.0 mg/L 75% of the occasions sampled, with SR (South River) and GS (Goshen Swamp) 58%, LVC2 (Livingston Creek) 42%, ANC (Angola Creek) 50% and NC403 (Northeast Cape Fear River headwaters) 67% below standard. Considering all sites sampled in 2011, we rated 17% as poor for dissolved oxygen, 28% as fair, and 55% as good, a slight improvement from 2010

Annual mean turbidity levels for 2011 were lower than the long-term average in all river and estuary stations. Highest mean turbidities were at the river sites NC11 (17 NTU) and AC (15 NTU) and the upper estuary sites NAV (21 NTU) and HB (17 NTU), with turbidities gradually decreasing downstream through the estuary. Turbidity was much lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river, and were low in general in the lower order streams.

Regarding stream stations, chronic or periodic high nitrate levels were found at a number of sites, including BC117 (Burgaw Creek below Burgaw), ROC (Rockfish Creek), 6RC (Six Runs Creek), SAR (Sarecta), and GCO (Great Coharie Creek) and LCO (Little Coharie Creek). Average chlorophyll *a* concentrations were larger than usual, particularly from June through August 2011; during this same period river flow as measured by USGS at Lock and Dam #1 was lower for 2011 compared with the 1995-2010 long-term average (1,210 CFS compared with 3,580 CFS). Low discharge allows for settling of suspended solids and more light penetration into the water column, where the relatively high nutrient levels and slow moving waters support algal bloom formation. Stream algal blooms exceeding the State standard of 40 µg/L in 2011 occurred at ANC, NC403, PB and SR. The most troublesome occurrence was the recurrence of cyanobacteria (i.e. blue-green algal blooms) in the Cape Fear River during summer centered in the river near NC11. These consisted largely of *Microcystis aeruginosa*, which produce toxins, and their occurrence in bloom formation has occurred every summer since 2009. We note that fish kills were not reported related to the blooms.

Several stream stations, particularly BC117, BCRR, PB, BRN (Browns Creek), HAM (Hammond Creek), 6RC, LRC and SC-CH showed high fecal coliform bacteria counts on a number of occasions. On rare occasions biochemical oxygen demand (BOD) concentrations at a few Cape Fear River watershed stations (NC11, NCF117 and LVC2 were elevated (BOD5 2.8 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 2011 sampling year. The UNCW-AEL utilizes ratings that consider a water body to be of poor quality if the water quality standard for a given parameter is in violation > 25% of the time, of fair quality if the standard is in violation between 11 and 25% of the time, and good quality if the standard is violated no more than 10% of the time. UNCW also considerers nutrient loading in water quality assessments, based on published experimental and field scientific findings.

For the 2010 period UNCW rated 97% of the stations as good and 3% fair in terms of chlorophyll *a*. For turbidity 92% of the sites were rated good and 8% fair. Fecal coliform bacteria counts showed slightly worse water quality in 2011 compared to 2009, with 49% of the sites rated as poor to fair compared with 43% in 2010. 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, 45% of the sites were rated poor or fair for dissolved oxygen, about the same as in 2010. 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 2011.

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 16-year (1995-2011) data base that is available to the public, and is used as a teaching tool for programs like UNCW's River Run. Using this monitoring data as a framework the program goals also include focused scientific projects and investigation of pollution episodes. The scientific aspects of the program are carried out by investigators from the University of North Carolina Wilmington Center for Marine Science. The monitoring program was developed by the Lower Cape Fear River Program Technical Committee, which consists of representatives from UNCW, the North Carolina Division of Water Quality, The NC Division of Marine Fisheries, the US Army Corps of Engineers, technical representatives from streamside industries, the City of Wilmington Wastewater Treatment Plants, Cape Fear Community College, Cape Fear River Watch, the North Carolina Cooperative Extension Service, the US Geological Survey, forestry and agriculture organizations, and others. This integrated and cooperative program was the first of its kind in North Carolina.

Broad-scale monthly water quality sampling at 16 stations in the estuary and lower river system began in June 1995 (UNCW Aquatic Ecology Laboratory, directed by Dr. Michael Mallin). Sampling was increased to 34 stations in February of 1996, 35 stations in February 1998, and 36 stations in 2005. The Lower Cape Fear River Program added another component concerned with studying the benthic macrofauna of the system in 1996. This component is directed by Dr. Martin Posey and Mr. Troy Alphin of the UNCW Biology Department and includes the benefit of additional data collected by the Benthic Ecology Laboratory under Sea Grant and NSF sponsored projects in the Cape Fear Estuary. These data are collected and analyzed depending upon the availability of funding. The third major biotic component (added in January 1996) was an extensive fisheries program directed by Dr. Mary Moser of the UNCW Center for Marine Science Research, with subsequent (1999) overseeing by Mr. Michael Williams and Dr. Thomas Lankford of UNCW-CMS. This program involved cooperative sampling with the North Carolina Division of Marine Fisheries and the North Carolina Wildlife Resources Commission. The fisheries program ended in December 1999, but was renewed with additional funds from the Z. Smith Reynolds Foundation from spring – winter 2000. The regular sampling that was conducted by UNCW biologists was assumed by the North Carolina Division of Marine Fisheries.

1.1. Site Description

The mainstem of the Cape Fear River is formed by the merging of the Haw and the Deep Rivers in Chatham County in the North Carolina Piedmont. However, its drainage basin reaches as far upstream as the Greensboro area (Fig. 1.1). The mainstem of the river has been altered by the construction of several dams and water control structures. In the coastal plain, the river is joined by two major tributaries, the Black and the Northeast Cape Fear Rivers (Fig. 1.1). These 5th order blackwater streams drain extensive riverine swamp forests and add organic color to the mainstem. The watershed (about 9,164 square miles) is the most heavily industrialized in North Carolina with 203 permitted wastewater discharges with a permitted flow of approximately 429 million gallons per day, and (as of 2010) over 2.07 million people residing in the basin (NCDENR Basinwide Information Management System (BIMS) & 2010 Census). Approximately 23% of the land use in the watershed is devoted to agriculture and livestock production (2006 National Land Cover Dataset), 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). We note that after July 2011 sampling was discontinued at stations M42 and SPD, per agreement with the North Carolina Division of Water Quality. Riverine stations sampled by boat include NC11, AC, DP, IC, and BBT (Table 1.1; Fig. 1.1). NC11 is located upstream of any major point source discharges in the lower river and estuary system, and is considered to be representative of water quality entering the lower system (we note that the City of Wilmington and portions of Brunswick County get their drinking water from the river just upstream of Lock and Dan #1). Station BBT is located on the Black River between Thoroughfare (a stream connecting the Cape Fear and Black Rivers) and the mainstem Cape Fear, and is influenced by both rivers. We consider B210 and NCF117 to represent water quality entering the lower Black and Northeast Cape Fear Rivers, respectively. Data has also been collected at stream and river stations throughout the Cape Fear, Northeast Cape Fear, and Black River watersheds (Table 1.1; Fig. 1.1; Mallin et al. 2001). There is one station, SC-CH, sampled for selected parameters on Smith Creek at Castle Hayne Road (Table 1.1).

1.2. Report Organization

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

The LCFRP has a website that contains maps and an extensive amount of past water quality, benthos, and fisheries data gathered by the Program available at: www.uncw.edu/cms/aelab/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, 2011, 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

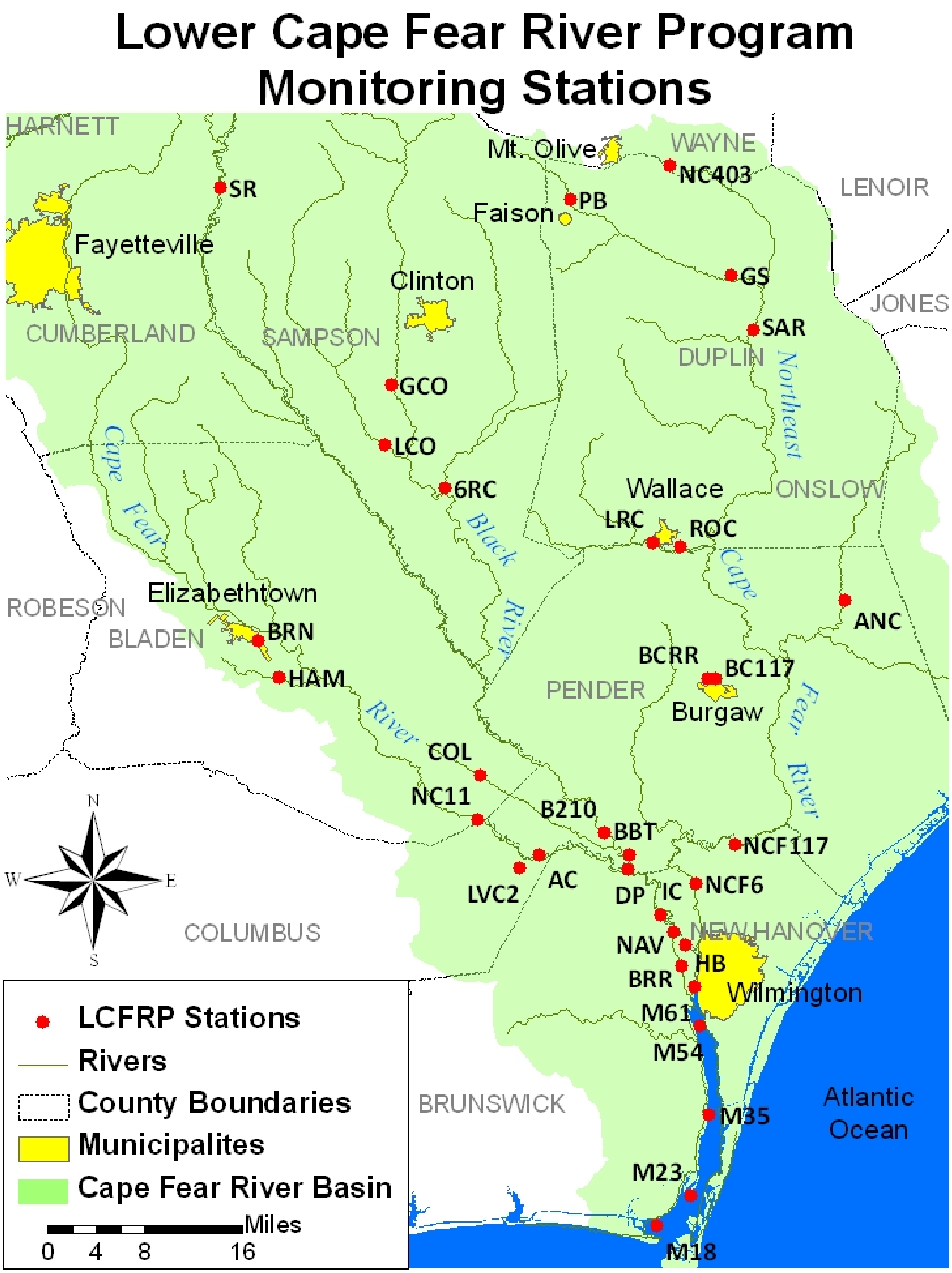
M54	B7950000	Channel Marker 54, 5 km downstream of Wilmington	
GPS	N	34.13933	W 77.94595
M42	B9845100	Channel Marker 42 near Keg Island	
GPS	N	34.09017	W 77.93355
M35	B9850100	Channel Marker 35 near Olde Brunswick Towne	
GPS	N	34.03408	W 77.93943
M23	B9910000	Channel Marker 23 near CP&L intake canal	
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 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 2011 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. By agreement with N.C. Division of Water Quality, after June 2011 sampling was discontinued at stations M42 and SPD.

<u>Physical Parameters</u>

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 (i.e. from bridges or docks) 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.

<u>Chemical Parameters</u>

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.

<u>Biological Parameters</u>

Fecal Coliform Bacteria

Fecal coliform bacteria were analyzed by 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. After August 2011 the fecal coliform analysis was changed to *Enterococcus* in the estuarine stations downstream of NAV and HB.

Chlorophyll a

The analytical method used to measure chlorophyll *a* is described in Welschmeyer (1994) and US EPA (1997) and was performed by CMS personnel. Chlorophyll *a* concentrations were determined utilizing the 1.0 micron filters used for filtering samples for orthophosphate analysis. All filters were wrapped individually in foil, placed in airtight containers and stored in the freezer. During analysis each filter was immersed in 10 mL of 90% acetone for 24 hours, which extracts the chlorophyll *a* into solution. Chlorophyll *a* concentration of each solution was measured on a Turner 10-AU fluorometer. The fluorometer uses an optimal combination of excitation and emission bandwidth filters which reduces the errors inherent in the acidification technique. The Aquatic Ecology Laboratory at the CMS is State-certified by the N.C. Division of Water Quality for the analysis of chlorophyll *a*.

Biochemical Oxygen Demand (BOD)

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

2.3 - Results and Discussion

This section includes results from monitoring of the physical, biological, and chemical parameters at all stations for the time period January-December 2011. Discussion of the data focuses both on the river channel stations and stream stations, which sometimes reflect poorer water quality than mainstem stations. The contributions of the two large blackwater tributaries, the Northeast Cape Fear River and the Black River, are represented by conditions at NCF117 and B210, respectively. The Cape Fear Region did not experience any significant hurricane activity during this monitoring period (after major hurricanes in 1996, 1998, and 1999). Therefore this report reflects low to medium flow conditions for the Cape Fear River and Estuary.

Physical Parameters

Water temperature

Water temperatures at all stations ranged from 0.8 to 32.2^{o}C, and individual station annual averages ranged from 15.9 to 21.8^{o}C (Table 2.1). Highest temperatures occurred during July and August and lowest temperatures during January. Stream stations were generally cooler than river stations, most likely because of shading and lower nighttime air temperatures affecting the shallower waters. Colly Creek was dry June-August so no data were collected from that site in summer.

Salinity

Salinity at the estuarine stations (NAV through SPD) ranged from 0.1 to 35.1 practical salinity units (psu) and station annual means ranged from 4.5 to 30.3 psu (Table 2.2). Lowest salinities occurred in early spring and December and highest salinities occurred in mid-summer. The annual mean salinity for 2011 was higher than that of the fifteen-year average for 1995-2010 for all of the estuarine stations (Figure 2.1). Two stream stations, NC403 and PB, had occasional oligohaline conditions due to discharges from pickle production facilities. SC-CH is a tidal creek that enters the Northeast Cape Fear River upstream of Wilmington and salinity there ranges widely, from freshwater to salinity exceeding 18 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.17 to 53.24 mS/cm and from 0.07 to 10.43 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. Conductivity at PB was exacerbated in June and July following a May 10 waste pond spill at Bay Valley Foods. Smith Creek (SC-CH) is an estuarine tidal creek and the conductivity values reflect this (Table 2.3).

pH

pH values ranged from 3.8 to 8.7 and station annual means ranged from 3.9 to 8.0 (Table 2.4). pH was typically lowest upstream due to acidic swamp water inputs and highest downstream as alkaline seawater mixes with the river water. Low pH values at COL predominate because of naturally acidic blackwater inputs at this near-pristine stream station. PB had the highest maximum pH concentration in 2011 (8.7); this was the result of a waste pond spill at Bay Valley Foods in May. We also note that LRC had unusually high pH levels (8.3) in June and August 2011 (Table 2.3).

Dissolved Oxygen

Dissolved oxygen (DO) problems have been a major water quality concern in the lower Cape Fear River and its estuary, and several of the tributary streams (Mallin et al. 1999; 2000; 2001a; 2001b; 2002a; 2002b; 2003; 2004; 2005a; 2006a; 2006b; 2007; 2008; 2009; 2010; 2011). Surface concentrations for all sites in 2011 ranged from 0.2 to 14.5 mg/L and station annual means ranged from 4.5 to 9.9 mg/L (Table 2.5). Average annual DO levels at the river channel and estuarine stations for 2011 were mostly higher than the average for 1995-2010 (Figure 2.2). River dissolved oxygen levels were lowest during the summer and early fall (Table 2.5), often falling below the state standard of 5.0 mg/L at several river and upper estuary stations. Working synergistically to lower oxygen levels are two factors: lower oxygen carrying capacity in warmer water and increased bacterial respiration (or biochemical oxygen demand, BOD), due to higher temperatures in summer. Unlike other large North Carolina estuaries (the Neuse, Pamlico and New River) the Cape Fear estuary rarely suffers from dissolved oxygen stratification. This is because despite salinity stratification the oxygen remains well mixed due to strong estuarine gravitational circulation and high freshwater inputs (Lin et al. 2006). Thus, hypoxia in the Cape Fear is present throughout the water column.

There is a dissolved oxygen sag in the main river channel that begins at DP below a paper mill discharge and persists into the mesohaline portion of the estuary (Fig. 2.2). Mean oxygen levels were highest at the upper river stations NC11 and AC and in the low-to-middle estuary at stations M35 to M23 (note that DO concentrations are higher at M42 due to cessation of sampling during mid-to-late summer). Lowest mainstem mean 2011 DO levels occurred at the river and upper estuary stations IC, NAV, HB, BRR and M61 (6.8-7.2 mg/L). NAV, HB and IC were both below 5.0 mg/L on 25% of occasions sampled and M61, BRR, DP and BBT were below on 17%, an improvement from 2010. Based on number of occasions the river stations were below 5 mg/L UNCW rated IC, NAV, HB, BRR and M61 as fair for 2011; the mid to lower estuary stations were rated as good. Discharge of high BOD waste from the paper/pulp mill just above the AC station (Mallin et al. 2003), as well as inflow of blackwater from the Northeast Cape Fear and Black Rivers, helps to diminish oxygen in the lower river and upper estuary. Additionally, algal blooms periodically form behind Lock and Dam #1, and the chlorophyll *a* they produce is strongly correlated with BOD at Station NC11 (Mallin et al. 2006b); thus the blooms do contribute to lower DO in the river. As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River (NCF117 2011 mean = 5.3, NCF6 = 6.3, B210 2011 mean = 6.9), a worsening from 2010 . These rivers are classified as blackwater systems because of their tea colored water. As the water passes through swamps en route to the river channel, tannins from decaying vegetation leach into the water, resulting in the observed color. Decaying vegetation on the swamp floor has an elevated biochemical oxygen demand and usurps oxygen from the water, leading to naturally low dissolved oxygen levels. Runoff from concentrated animal feeding operations (CAFOs) may also contribute to chronic low dissolved oxygen levels in these blackwater rivers (Mallin et al. 1998; 1999; 2006; Mallin 2000). We note that phosphorus and nitrogen (components of animal manure) levels have been positively correlated with BOD in the blackwater rivers and their major tributaries (Mallin et al. 2006b).

Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2011. Station BCRR had DO levels below 4.0 mg/L 75% of the occasions sampled, with NC403 67%, SR and GS 58% and ANC and LVC2 42% (Table 2.5). Some of this can be attributed to low summer water conditions and some potentially to CAFO runoff; however point-source discharges also likely contribute to low dissolved oxygen levels at NC403 and possibly SR, especially via nutrient loading (Mallin et al. 2001a; 2002a; 2004). Hypoxia is thus a continuing and widespread problem, with 45% of the sites impacted in 2011.

Field Turbidity

Field turbidity levels ranged from 1 to 61 Nephelometric turbidity units (NTU) and station annual means ranged from 2 to 21 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Annual mean turbidity levels for 2011 were lower than the long-term average at all estuary sites (Fig. 2.3). Highest mean and median turbidities were at NAV and HB (16-21 NTU) with turbidities generally low in the middle to lower estuary (Figure 2.3). Station HB and Station SC-CH each exceeded the turbidity standard on two occasions. Turbidity was considerably lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river. Average turbidity levels were low in the freshwater streams, with the exception of PB, SR and to a lesser extent BCRR and BC117. The State standard for freshwater turbidity is 50 NTU.

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

Total Suspended Solids

Total suspended solid (TSS) values system wide ranged from 1 to 157 mg/L with station annual means from 2 to 27 mg/L (Table 2.7). The overall highest river values were at NAV and SPD. In the stream stations TSS was generally considerably lower than the river and estuary, except for Station PB with unusually high values, prompted at least in some cases by the May waste pond spill at Bay Valley Foods. 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. The fine silt and clay in the upper to middle estuary sediments are most likely derived from the Piedmont and carried downstream to the estuary, while the sediments in the lowest portion of the estuary are marine-derived sands (Benedetti et al. 2006).

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 0.81 to 5.99/m and station annual means ranged from 1.41 at M18 to 3.95 /m at NCF6 (Table 2.8). Elevated mean and median light attenuation occurred from AC downstream to IC; the estuary from NAV-M54 also had high attenuation (Table 2.8). In the Cape Fear system, light is attenuated by both turbidity and water color.

High light attenuation did not always coincide with high turbidity. Blackwater, though low in turbidity, will attenuate light through absorption of solar irradiance. At NCF6 and BBT, blackwater stations with moderate turbidity levels, light attenuation was high. Compared to other North Carolina estuaries the Cape Fear has high average light attenuation. The high average light attenuation is a major reason why phytoplankton production in the major rivers and the estuary of the LCFR is generally low. Whether caused by turbidity or water color this attenuation tends to limit light availability to the phytoplankton (Mallin et al. 1997; 1999; 2004; Dubbs and Whalen 2008).

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 70 to 31,650 μg/L and station annual means ranged from 334 to 20,305 μg/L (Table 2.9). Mean total nitrogen in 2011 was slightly less than the fifteen-year mean at most river and estuary stations, except the uppermost ones NC11-IP (Figure 2.4). Previous research (Mallin et al. 1999) has shown a positive correlation between river flow and TN in the Cape Fear system. In the main river total nitrogen concentrations were highest between NC11 and DP, entering the system, then declined into the lower estuary, most likely reflecting uptake of nitrogen into the food chain through algal productivity and subsequent grazing by planktivores as well as through dilution and marsh denitrification. One stream station, BC117, had a very high median of 24,825 μg/L, likely from the upstream Town of Burgaw wastewater discharge. PB, ROC, LVC2, SAR, ANC, GCO and 6RC also had comparatively high TN values among the stream stations.

Nitrate+Nitrite

Nitrate+nitrite (henceforth referred to as nitrate) is the main species of inorganic nitrogen in the Lower Cape Fear River. Concentrations system wide ranged from 10 (detection limit) to 31,600 µg/L and station annual means ranged from 26 to 20,034 µg/L (Table 2.10). The highest average riverine nitrate levels were at NC11 and AC (889 and 897 µg/L, respectively) indicating that much of this nutrient is imported from upstream. Moving downstream, nitrate levels decrease most likely as a result of uptake by primary producers, microbial denitrification in riparian marshes and tidal dilution. Despite this, the rapid flushing of the estuary (Ensign et al. 2004) permits sufficient nitrate to enter the coastal ocean in the plume and contribute to offshore productivity (Mallin et al. 2005b). Nitrate can limit phytoplankton production in the lower estuary in summer (Mallin et al. 1999). The blackwater rivers carried lower concentrations of nitrate compared to the mainstem Cape Fear stations; i.e. the Northeast Cape Fear River (NCF117 mean = 275 µg/L) and the Black River (B210 = 218 µg/L). Lowest river nitrate occurred during summer, along with lowest flows and lowest dissolved oxygen concentrations.

Several stream stations showed high levels of nitrate on occasion including BC117, ROC, 6RC, GCO, SAR, LVC2 and NC403. LVC2 and NC403 are downstream of industrial wastewater discharges and 6RC, ROC, GCO and SAR 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 4,670 µg/L and station annual means ranged from 7 to 721 µg/L (Table 2.11). River areas with the highest mean ammonium levels this monitoring period included AC and DP, which are downstream of a pulp mill discharge, and M54, located downstream of the Wilmington South Side Wastewater Treatment Plant discharge. Ocean dilution and biological uptake accounts for decreasing levels in the lower estuary. At the stream stations, areas with highest levels of ammonium were PB, LVC2, ANC, BCRR and ROC (Table 2.11). PB had the highest mean and median concentrations in 2011; these were the result of a waste pond spill at bay Valley Foods in May that impacted stream water quality through September.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of the total concentration of organic nitrogen plus ammonium. TKN ranged from 50 to 7,200 μg/L and station annual means ranged from 271 to 1,833 μg/L (Table 2.12). TKN concentration decreases ocean-ward through the estuary, likely due to ocean dilution and food chain uptake of nitrogen. One notably elevated peak of 7,200 μg/L of TN was seen at PB in August. Station PB had the highest mean and median concentrations; other sites with elevated TKN included ANC, GS, BCRR, SR and ROC.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from below detection limit to 5,080 μg/L and station annual means ranged from 25 to 2,893 μg/L (Table 2.13). Mean TP for 2011 was somewhat below the fifteen-year mean in the estuary and lower river stations, but higher in the blackwater rivers (Figure 2.5). In the river TP is highest at the upper riverine channel station AC and declines downstream into the estuary. Some of this decline is attributable to the settling of phosphorus-bearing suspended sediments, yet incorporation of phosphorus into bacteria and algae is also responsible.

The experiments discussed above in the nitrate subsection also involved additions of phosphorus, either as inorganic orthophosphate or a combination of inorganic plus organic P. The experiments showed that additions of P exceeding 0.5 mg/L led to significant increases in bacterial counts, as well as significant increases in BOD over control. Thus, we consider concentrations of phosphorus above 0.5 mg/L (500 μg/L) to be potentially problematic to blackwater streams (Mallin et al. 1998; 2004). Streams periodically exceeding this critical concentration included BC117, GCO, ROC and PB. Some of these stations (BC117, PB) are downstream of industrial or wastewater discharges, while GCO and ROC are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from undetectable to 3,750 μg/L and station annual means ranged from 6 to 2,048 μg/L (Table 2.14). Much of the orthophosphate load is imported into the Lower Cape Fear system from upstream areas, as NC11 or AC typically have high levels; there are also inputs of orthophosphate from the paper mill above AC (Table 2.14). The Northeast Cape Fear River had higher orthophosphate levels than the Black River. Orthophosphate can bind to suspended materials and is transported downstream via particle attachment; thus high levels of turbidity at the uppermost river stations may be an important factor in the high orthophosphate levels. Turbidity declines toward the lower estuary because of settling, and orthophosphate concentration also declines. In the estuary, primary productivity helps reduce orthophosphate concentrations by assimilation into biomass. Orthophosphate levels typically reach maximum concentrations during summertime, when anoxic sediment releases bound phosphorus. Also, in the Cape Fear Estuary, summer algal productivity is limited by nitrogen, thereby allowing the accumulation of orthophosphate (Mallin et al. 1997; 1999). In spring, productivity in the estuary is usually limited by phosphorus (Mallin et al. 1997; 1999).

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

Chemical Parameters - EPA Priority Pollutant Metals

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

Biological Parameters

Chlorophyll a

During this monitoring period in most locations chlorophyll *a* was low, except for periodic elevated concentrations in summer at a few locations (Table 2.15). At many of the river and estuarine stations chlorophyll *a* for 2011 was considerably higher than the fifteen-year mean for those sites (Figure 2.6). Highest chlorophyll *a* concentrations on the river occurred at Station NC11. We note that at this site it has been demonstrated that chlorophyll *a* biomass is significantly correlated with biochemical oxygen demand (BOD5 – Mallin et al. 2006b). What is of human health as well as ecological interest was that blooms of cyanobacteria (blue-green algae) called *Microcystis aeruginosa* began occurring in 2009 and continued to occur in summer 2010 and 2011. This species contains many strains long known to produce toxins, both as a threat to aquatic life and to humans as well (Burkholder 2002). At least some of the blooms in the main stem of the Cape Fear have produced toxins. The North Carolina Division of Public Health had a 2009 bloom sample from Lock and Dam #1 tested and it came out positive for 73 ppb (μg/L) of microcystin (Dr. Mina Shehee, NC Division of Public Health, memo September 25, 2011), resulting in an advisory to keep children and dogs from swimming in the waters. For comparison, the World Health Organization has a guideline of < 1.0 μg/L of microcystin-LR for drinking water. Additionally, a UNCW Marine Science student directed by chemist Dr. Jeff Wright isolated two hepatotoxins, microcystin LR and microcystin RR, from Cape Fear *Microcystis aeruginosa* blooms in 2010 (Isaacs 2011). We note that the City of Wilmington receives their drinking water from the river above Lock and Dam #1.

The 2011 bloom persisted for a number of weeks before dissipating. In 2011 there was also a series of blooms on the Northeast Cape Fear River upstream of our sampling sites reported by NC DWQ (Stephanie Petter Garrett, personal communication); these blooms led to local hypoxia in the affected waters. These blooms are primarily a surface phenomenon, thus not captured by the required sampling technique (photic zone. Presently (summer 2012) there are special projects ongoing by two UNCW researchers, Dr. Mike Mallin and Dr. Larry Cahoon, aimed at gaining further understanding of how these blooms affect the river's ecology.

System wide, chlorophyll *a* ranged from undetectable to 91 µg/L and station annual means ranged from 2-20 µg/L, lower than in 2010. Production of chlorophyll *a* biomass is usually low to moderate in the rivers and estuary primarily because of light limitation by turbidity in the mainstem and high organic color and low inorganic nutrients in the blackwater rivers.

Spatially, besides Station NC11 along the mainstem high values are normally found in the mid-to-lower estuary stations because light becomes more available downstream of the estuarine turbidity maximum (Fig. 2.6). On average, flushing time of the Cape Fear estuary is rapid, ranging from 1-22 days with a median of 6.7 days (Ensign et al. 2004). This does not allow for much settling of suspended materials, leading to light limitation of phytoplankton production. However, under lower-than-average flows there is generally clearer water through less suspended material and less blackwater swamp inputs. For the growing season May-September, long-term (1995-2010) average monthly flow at Lock and Dam #1 was approximately 3,580 CFS (USGS data; (http://nc.water.usgs.gov/realtime/real_time_cape_fear.html), whereas for 2011 it was well below that at approximately 1,210 CFS. Thus, chlorophyll *a* concentrations in the river and estuary were greater than the average for the preceding fifteen years (Figure 2.6).

Substantial phytoplankton blooms occasionally occur at the stream stations, with a few occurring summer-fall in 2011 (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). In particular, Station SR had three blooms exceeding the state standard 40 µg/L in 2011 (46, 83 and 91 µg/L); single blooms exceeding the standard also occurred at ANC, NC 403 and PB (Table 2.15).

Biochemical Oxygen Demand

For the mainstem river, median annual five-day biochemical oxygen demand (BOD5) concentrations were approximately equivalent between NC11 and AC, suggesting that in 2011 (as was the case with 2007 through 2010) there was little discernable effect of BOD loading from the nearby pulp/paper mill inputs (Table 2.16). BOD5 values between 1.0 and 2.0 mg/L are typical for the rivers in the Cape Fear system (Mallin et al. 2006b) and in 2011 BOD5 values ranged from 0.5 – 4.5 mg/L. NCF117 mean BOD5 was 1.8 mg/L, considerably higher than the 1.2 mg/L mean at Black River B210. Stations LVC2 had the highest mean and median BOD5 and BOD20 concentrations in 2011. BOD20 values showed similar patterns to BOD5 in 2011.

Fecal Coliform Bacteria

Fecal coliform (FC) bacterial counts ranged from 1 to 60,000 CFU/100 mL and station annual geometric means ranged from 6 to 875 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded at the mainstem sites only rarely in 2011, once in June at DP, once in July at NAV, and once in November at AC. Geometric mean fecal coliform counts in 2011 in the Cape Fear, Black, and Northeast Cape Fear Rivers as well as the estuary were somewhat lower compared with the fifteen-year average (Figure 2.7). *Enterococcus* counts, initiated in the estuary in mid-2011, were generally low in 2011.

During 2011 PB exceeded 200 CFU/100 mL 83% of the time; HAM 67%, BCRR and BC117 58%, BRN 50%, LRC 45%, and 6RC and SC-CH 33% 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. PB in particular had counts of 60,000 CFU/100 mL on two occasions, May and August. Overall, elevated fecal coliform counts are problematic in this system, with 49% of the stations impacted in 2011, slightly higher than the previous year 2010.

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Table 2.1 Water temperature (^{o}C) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	5.2	5.8	5.9	6.1	6.3	6.6	7.1	7.2	7.2	7.1
FEB	6.8	7.0	7.3	7.4	7.3	7.5	7.7	8.0	8.0	8.6
MAR	14.3	14.4	14.0	14.1	14.4	13.9	14.3	13.9	13.0	13.7
APR	20.1	21.8	20.9	20.6	20.7	20.7	20.5	20.1	19.5	19.7
MAY	23.9	25.1	24.0	24.1	23.8	24.0	23.6	23.6	23.1	23.1
JUN	29.3	28.6	29.2	29.3	28.6	28.4	28.2	27.3	27.0	27.8
JUL	29.4	29.5	29.6	29.6	29.6		29.5	29.3	29.3	
AUG	31.3	31.1	31.1	31.2	31.0		30.8	30.3	30.4	
SEP	27.3	27.5	27.7	27.6	27.7		28.1	28.0	27.8	
OCT	22.7	22.9	22.5	22.0	22.3		23.0	22.8	22.9	
NOV	16.1	16.6	16.8	16.5	16.5		17.0	16.8	16.6	
DEC	12.3	12.6	13.2	13.7	14.0		14.3	14.7	14.7	
mean	**19.9**	**20.2**	**20.2**	**20.2**	**20.2**	**16.9**	**20.3**	**20.2**	**20.0**	**16.7**
std dev	8.9	8.8	8.7	8.6	8.5	9.0	8.3	8.1	8.1	8.2
median	21.4	22.4	21.7	21.3	21.5	17.3	21.8	21.5	21.2	16.7
max	31.3	31.1	31.1	31.2	31.0	28.4	30.8	30.3	30.4	27.8
min	5.2	5.8	5.9	6.1	6.3	6.6	7.1	7.2	7.2	7.1

	NC11	AC	DP	BBT	IC	NCF6
JAN	5.0	5.7	5.1	5.1	5.0	6.1
FEB	8.6	8.6	8.5	8.8	8.8	9.2
MAR	13.0	13.3	13.8	14.0	14	15.0
APR	14.2	14.3	15.1	15.7	16.8	17.1
MAY	22.7	22.6	22.4	22.4	23	23.4
JUN	29.3	29.3	29.2	28.9	29.5	29.1
JUL	30.0	30.2	30.1	30.1	30.1	29.7
AUG	32.2	31.2	31.0	31.1	31.4	31.0
SEP	28.4	28.1	27.3	27.3	28.2	27.4
OCT	22.4	22.3	22.4	20.6	22.1	22.2
NOV	15.8	16.2	16.2	15.5	16.5	17.3
DEC	13.5	13.8	13.8	13.4	13.7	14.9
mean	**19.6**	**19.6**	**19.6**	**19.4**	**19.9**	**20.2**
std dev	9.1	8.8	8.7	8.7	8.8	8.2
median	19.1	19.3	19.3	18.2	19.5	19.8
max	32.2	31.2	31.0	31.1	31.4	31.0
min	5.0	5.7	5.1	5.1	5.0	6.1

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	4.6	3.3	4.1	4.4	4.1	5.3	3.4	6.1	3.5
FEB	10.7	10.5	10.3	10.9	8.9	10.6	11.8	10.1	10.8
MAR	9.8	8.8	9.5	9.9	8.7	9.9	8.7	9.1	8.4
APR	22.8	23.3	23.9	23.4	24.0	22.4	21.6	20.5	18.9
MAY	19.1	19.6	19.7	20.3	23.7	24.7	20.0	21.8	18.2
JUN	27.6	28.1	29.0	26.8	31.6	28.8	26.5	25.1	23.2
JUL	27.0	28.2	30.1	27.4	31.1		27.7	27.2	25.2
AUG	24.7	25.6	25.3	24.8	27.8	26.3	25.1	24.3	23.5
SEP	21.0	20.6	20.9	20.5	21.1	21.1	20.2	22.7	20.3
OCT	15.8	15.2	15.3	14.5	15.3	14.6	14.6	17.9	15.9
NOV	17.3	17.8	19.7	16.8	19.0	19.8	15.5	20.1	13.9
DEC	8.1	7.2	6.9	7.0	5.2	6.3	6.7	9.7	8.4
mean	**17.4**	**17.4**	**17.9**	**17.2**	**18.4**	**17.3**	**16.8**	**17.9**	**15.9**
std dev	7.7	8.4	8.7	7.9	9.8	8.3	8.0	7.2	6.9
median	18.2	18.7	19.7	18.6	20.1	19.8	17.8	20.3	17.1
max	27.6	28.2	30.1	27.4	31.6	28.8	27.7	27.2	25.2
min	4.6	3.3	4.1	4.4	4.1	5.3	3.4	6.1	3.5

	6RC	LCO	GCO	SR	BRN	HAM
JAN	2.2	1.8	1.3	0.8	2.8	2.4
FEB	7.7	7.6	7.3	7.3	7.6	7.7
MAR	11.6	11.6	11.0	10.6	12.1	11.4
APR	17.1	17.3	17.3	17.0	17.3	16.5
MAY	19.2	19.4	20.1	18.5	19.2	18.0
JUN	23.8	23.5	24.6	24.8	23.5	22.5
JUL	27.2	27.5	28.7	28.7	26.2	25.6
AUG	27.7	27.5	29.0	31.3	26.8	28.0
SEP	23.3	23.1	22.7	24.3	22.3	21.9
OCT	15.8	16.1	16.0	17.2	15.7	15.4
NOV	10.8	10.5	10.7	12.3	11.3	10.7
DEC	12.9	12.9	12.9	12.7	12.2	11.3
mean	**16.6**	**16.6**	**16.8**	**17.1**	**16.4**	**16.0**
std dev	8.0	8.0	8.6	9.0	7.5	7.6
median	16.5	16.7	16.7	17.1	16.5	16.0
max	27.7	27.5	29.0	31.3	26.8	28.0
min	2.2	1.8	1.3	0.8	2.8	2.4

	NCF117	B210	COL	LVC2	SC-CH
JAN		5.2	5.1	4.8	6.4
FEB		11.4	10.2	12.3	11.9
MAR	14.9	14.4	12.6	14.6	14.8
APR	16.0	15.2	13.6	16.0	16.6
MAY	23.1	21.7	19.8	22.2	23.6
JUN	28.6	28.7		26.9	28.9
JUL	30.7	30.8		28.6	30.8
AUG	30.8	30.0		28.3	30.5
SEP	25.5	26.1	24.2	25.4	27.5
OCT	20.7	18.3	15.2	18.1	21.0
NOV	15.6	13.0	9.5	13.2	15.8
DEC	12.1	9.7	8.2	9.7	12.4
mean	**21.8**	**18.7**	**13.2**	**18.3**	**20.0**
std dev	7.0	8.6	5.9	7.9	8.2
median	21.9	16.8	12.6	17.1	18.8
max	30.8	30.8	24.2	28.6	30.8
min	12.1	5.2	5.1	4.8	6.4

Table 2.2 Salinity (psu) during 2011 at the Lower Cape Fear River Program estuarine stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD	NCF6	SC-CH
JAN	5.2	8.8	7.9	13.7	15.7	18.9	23.9	26.3	31.6	29.5	3.4	1.2
FEB	1.2	5.0	4.8	10.1	10.4	12.7	15.5	24.1	28.2	28.1	0.1	0.3
MAR	0.1	2.3	4.9	7.6	9.3	10.3	13.3	22.0	25.2	27.9	0.1	1.6
APR	0.1	0.5	1.3	2.6	6.6	10.9	18.4	25.9	31.7	25.9	0.1	0.3
MAY	0.1	1.7	2.1	5.1	7.7	11.6	16.5	23.1	28.2	26.6	0.8	2.2
JUN	10.1	15.9	12.8	16.5	19.6	22.2	26.3	32.4	33.9	31.4	7.2	9.2
JUL	12.3	13.6	14.5	18.5	21.3		25.8	31.8	33.0		13.5	15.3
AUG	9.0	12.5	16.5	20.2	22.4		27.6	33.1	35.0		19.4	18.5
SEP	0.1	0.4	1.3	3.6	4.3		8.9	18.1	23.3		3.9	0.5
OCT	14.1	14.8	15.9	20.3	21.5		28.3	35.1	35.1		0.3	1.4
NOV	6.3	10.4	9.4	16.0	17.7		25.4	30.1	34.5		4.1	8.4
DEC	0.1	0.2	2.6	7.3	7.5		14.3	21.0	23.8		1.6	6.6
mean	**4.9**	**7.2**	**7.8**	**11.8**	**13.7**	**14.4**	**20.4**	**26.9**	**30.3**	**28.2**	**4.5**	**5.5**
std dev	5.3	6.1	5.8	6.5	6.7	4.9	6.6	5.5	4.4	2.0	6.1	6.2
median	3.2	6.9	6.4	11.9	13.1	12.2	21.2	26.1	31.7	28.0	2.5	1.9
max	14.1	15.9	16.5	20.3	22.4	22.2	28.3	35.1	35.1	31.4	19.4	18.5
min	0.1	0.2	1.3	2.6	4.3	10.3	8.9	18.1	23.3	25.9	0.1	0.3

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations, 1995-2010 versus 2011.

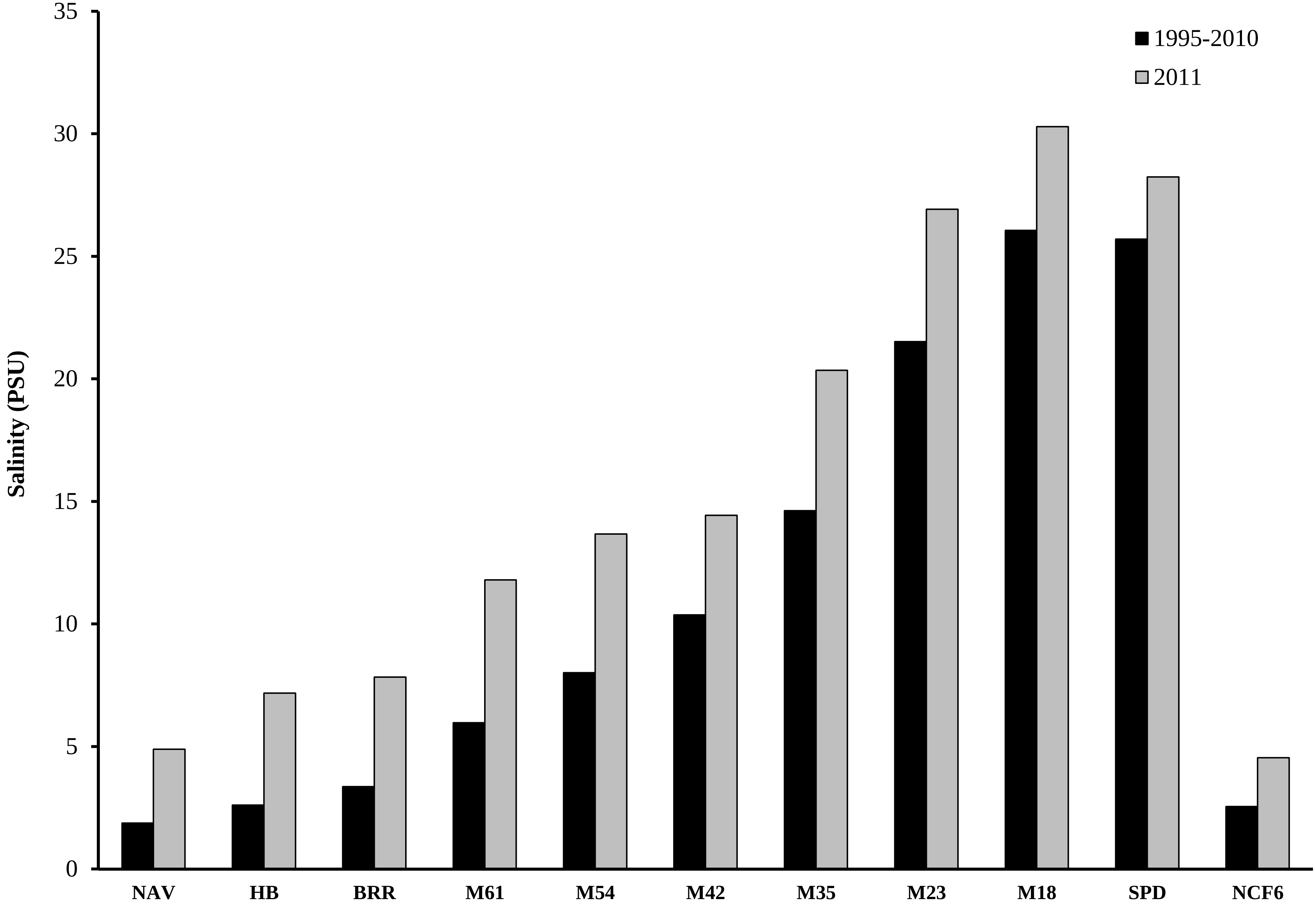


Table 2.3 Conductivity (mS/cm) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	9.03	15.27	13.72	22.96	25.87	30.67	38.04	41.60	49.00	46.09
FEB	2.39	9.04	8.62	17.11	17.63	21.32	25.54	38.28	44.16	43.90
MAR	0.23	4.28	8.75	13.17	15.84	17.40	22.06	34.96	39.51	43.24
APR	0.27	0.89	2.43	4.84	11.53	18.35	29.69	40.45	48.48	40.49
MAY	0.27	3.19	4.00	9.16	13.40	19.43	26.89	36.64	43.61	41.54
JUN	17.16	26.15	21.49	27.00	31.62	35.43	41.19	49.62	51.63	48.30
JUL	21.61	22.61	24.10	30.09	34.10		40.47	48.83	50.51	
AUG	15.57	21.01	27.03	32.58	35.71		43.12	50.62	53.24	
SEP	0.28	0.79	2.50	6.60	7.86		15.36	29.37	36.86	
OCT	23.22	24.39	25.99	32.26	34.31		43.86	48.26	53.15	
NOV	11.07	17.54	16.04	26.09	28.66		39.57	46.24	52.37	
DEC	0.17	0.46	4.78	12.67	12.93		23.63	33.49	37.52	
mean	**8.44**	**12.13**	**13.29**	**19.54**	**22.45**	**23.77**	**32.45**	**41.53**	**46.67**	**43.93**
std dev	9.04	10.08	9.43	10.17	10.26	7.46	9.68	7.14	6.12	2.89
median	5.71	12.16	11.23	20.03	21.75	20.37	33.86	41.03	48.74	43.57
max	23.22	26.15	27.03	32.58	35.71	35.43	43.86	50.62	53.24	48.30
min	0.17	0.46	2.43	4.84	7.86	17.40	15.36	29.37	36.86	40.49

	NC11	AC	DP	BBT	IC	NCF6
JAN	0.15	0.18	0.21	0.20	0.22	6.41
FEB	0.14	0.17	0.16	0.09	0.12	0.13
MAR	0.17	0.22	0.21	0.14	0.18	0.22
APR	0.12	0.13	0.13	0.12	0.14	0.20
MAY	0.14	0.15	0.16	0.15	0.16	1.57
JUN	0.15	0.16	0.30	0.20	0.25	12.68
JUL	0.13	0.11	0.27	0.26	0.35	25.43
AUG	0.20	0.32	0.34	0.34	2.52	31.32
SEP	0.18	0.37	0.23	0.23	0.34	7.22
OCT	0.16	0.29	0.29	0.16	0.23	0.54
NOV	0.21	0.33	0.37	0.24	0.30	7.32
DEC	0.16	0.20	0.23	0.22	0.25	3.05
mean	**0.16**	**0.22**	**0.24**	**0.20**	**0.42**	**8.01**
std dev	0.03	0.09	0.08	0.07	0.66	10.35
median	0.15	0.19	0.23	0.20	0.24	4.73
max	0.21	0.37	0.37	0.34	2.52	31.32
min	0.12	0.11	0.13	0.09	0.12	0.13

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	0.11	0.19	0.18	0.59	2.16	0.17	0.15	0.44	0.30
FEB	0.08	0.19	0.18	0.50	1.71	0.13	0.14	0.42	0.15
MAR	0.09	0.20	0.21	0.71	0.97	0.14	0.15	0.43	0.26
APR	0.11	0.20	0.21	0.56	1.89	0.25	0.13	0.87	0.29
MAY	0.10	0.19	0.17	0.70	2.72	0.16	0.13	0.84	0.30
JUN	0.18	0.28	0.24	0.86	6.07	0.18	0.26	1.16	0.28
JUL	0.17	0.29	0.26	0.50	10.43		0.33	1.29	0.37
AUG	0.15	0.30	0.34	2.09	5.95	0.29	0.23	0.74	0.19
SEP	0.10	0.24	0.25	0.92	3.99	0.17	0.14	1.15	0.24
OCT	0.13	0.22	0.23	1.11	2.60	0.17	0.22	0.95	0.23
NOV	0.12	0.24	0.23	0.92	1.87	0.19	0.16	1.14	0.25
DEC	0.14	0.29	0.22	0.83	1.47	0.18	0.23	1.14	0.27
mean	**0.12**	**0.23**	**0.22**	**0.86**	**3.49**	**0.18**	**0.19**	**0.88**	**0.26**
std dev	0.03	0.04	0.05	0.43	2.75	0.05	0.07	0.31	0.06
median	0.12	0.23	0.22	0.77	2.38	0.17	0.15	0.91	0.26
max	0.18	0.30	0.34	2.09	10.43	0.29	0.33	1.29	0.37
min	0.08	0.19	0.17	0.50	0.97	0.13	0.13	0.42	0.15

	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.14	0.10	0.17	0.09	0.15	0.20
FEB	0.11	0.09	0.12	0.08	0.13	0.11
MAR	0.13	0.09	0.13	0.09	0.13	0.16
APR	0.13	0.08	0.12	0.08	0.11	0.16
MAY	0.13	0.09	0.14	0.09	0.12	0.18
JUN	0.15	0.10	0.44	0.14	0.12	0.23
JUL	0.14	0.10	0.43	0.33	0.13	0.19
AUG	0.17	0.12	0.51	0.34	0.10	0.28
SEP	0.15	0.10	0.23	0.35	0.17	0.18
OCT	0.15	0.10	0.22	0.51	0.15	0.19
NOV	0.15	0.10	0.32	0.51	0.15	0.21
DEC	0.15	0.11	0.20	0.21	0.16	0.22
mean	**0.14**	**0.10**	**0.25**	**0.24**	**0.13**	**0.19**
std dev	0.02	0.01	0.14	0.17	0.02	0.04
median	0.15	0.10	0.21	0.17	0.13	0.19
max	0.17	0.12	0.51	0.51	0.17	0.28
min	0.11	0.08	0.12	0.08	0.10	0.11

	NCF117	B210	COL	LVC2	SC-CH
JAN		0.10	0.07	0.14	2.29
FEB		0.09	0.07	0.10	0.59
MAR	0.14	0.10	0.07	0.12	3.03
APR	0.13	0.08	0.07	0.10	0.64
MAY	0.13	0.09	0.07	0.15	4.20
JUN	0.29	0.12		0.17	15.75
JUL	4.35	0.14		0.17	22.58
AUG	4.81	0.13		0.21	30.10
SEP	0.15	0.13	0.10	0.15	1.01
OCT	0.19	0.12	0.09	0.14	2.72
NOV	0.23	0.15	0.09	0.18	14.40
DEC	0.22	0.14	0.10	0.17	11.56
mean	**1.06**	**0.12**	**0.08**	**0.15**	**9.07**
std dev	1.86	0.02	0.01	0.03	9.81
median	0.21	0.12	0.07	0.15	3.62
max	4.81	0.15	0.10	0.21	30.10
min	0.13	0.08	0.07	0.10	0.59

Table 2.4 pH during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	7.6	7.6	7.6	7.8	7.9	8.0	8.1	8.2	8.1	8.0
FEB	7.3	7.4	7.5	7.7	7.8	8.1	8.2	8.3	8.2	8.0
MAR	7.4	7.0	7.4	7.4	7.6	7.7	7.8	8.1	8.0	7.8
APR	6.9	6.9	7.1	7.1	7.5	7.7	7.9	8.0	8.1	8.0
MAY	7.0	7.0	7.0	7.1	7.4	7.6	7.9	8.0	8.0	7.9
JUN	7.3	7.5	7.6	7.9	8.0	8.1	8.1	8.0	8.1	8.0
JUL	7.1	7.2	7.1	7.4	7.7		8.0	7.9	8.0	
AUG	7.0	7.1	7.1	7.3	7.5		7.8	7.9	8.0	
SEP	6.7	6.7	6.8	7.0	7.1		7.3	7.7	7.9	
OCT	7.3	7.2	7.4	7.6	7.7		7.9	8.0	8.0	
NOV	7.3	7.3	7.3	7.5	7.6		7.9	7.9	7.9	
DEC	7.1	7.2	7.2	7.3	7.5		7.7	7.9	7.9	
mean	**7.2**	**7.2**	**7.3**	**7.4**	**7.6**	**7.9**	**7.9**	**8.0**	**8.0**	**8.0**
std dev	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1
median	7.2	7.2	7.3	7.4	7.6	7.9	7.9	8.0	8.0	8.0
max	7.6	7.6	7.6	7.9	8.0	8.1	8.2	8.3	8.2	8.0
min	6.7	6.7	6.8	7.0	7.1	7.6	7.3	7.7	7.9	7.8

	NC11	AC	DP	BBT	IC	NCF6
JAN	6.4	7.1	7.0	6.9	6.9	7.1
FEB	6.4	6.7	6.9	6.3	6.5	6.5
MAR	7.2	7.2	7.2	6.9	7.0	6.7
APR	7.0	7.0	7.0	6.8	6.9	6.8
MAY	6.8	6.8	6.7	6.6	6.7	6.9
JUN	6.9	6.8	7.0	6.7	6.9	7.0
JUL	7.0	6.5	7.0	6.9	6.9	7.1
AUG	6.8	7.0	6.9	6.9	7.0	7.1
SEP	6.8	7.1	6.7	6.7	6.7	6.5
OCT	6.9	7.2	7.2	6.7	6.9	6.6
NOV	6.6	7.2	7.2	7.0	7.0	6.9
DEC	7.2	7.2	7.3	7.1	7.2	7.0
mean	**6.8**	**7.0**	**7.0**	**6.8**	**6.9**	**6.9**
std dev	0.3	0.2	0.2	0.2	0.2	0.2
median	6.9	7.1	7.0	6.9	6.9	6.9
max	7.2	7.2	7.3	7.1	7.2	7.1
min	6.4	6.5	6.7	6.3	6.5	6.5

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	6.1	6.8	6.9	6.9	6.7	7.0	7.0	6.8	6.3
FEB	5.1	6.7	6.9	6.8	6.6	7.1	6.9	6.8	6.3
MAR	5.7	7.0	6.9	6.7	6.7	7.4	7.2	7.3	6.8
APR	6.3	6.9	6.6	6.4	6.9	7.4	7.1	7.6	6.9
MAY	6.3	6.9	6.5	6.3	6.8	8.0	7.0	7.8	7.0
JUN	6.8	7.2	6.6	6.4	6.8	8.3	7.1	7.7	6.9
JUL	6.7	7.3	7.3	6.5	8.7		7.2	7.9	7.0
AUG	6.6	6.7	6.3	6.6	7.1	8.3	7.0	7.6	6.7
SEP	5.7	6.5	6.5	6.6	6.9	7.4	7.1	7.7	6.7
OCT	6.5	6.7	6.7	6.6	6.8	7.3	6.7	7.7	7.0
NOV	6.1	6.5	6.4	6.6	6.8	7.3	7.0	7.6	6.7
DEC	6.4	6.7	6.6	6.6	6.7	7.5	7.1	7.6	6.5
mean	**6.2**	**6.8**	**6.7**	**6.6**	**7.0**	**7.5**	**7.0**	**7.5**	**6.7**
std dev	0.5	0.2	0.3	0.2	0.6	0.5	0.1	0.4	0.3
median	6.3	6.8	6.6	6.6	6.8	7.4	7.1	7.6	6.8
max	6.8	7.3	7.3	6.9	8.7	8.3	7.2	7.9	7.0
min	5.1	6.5	6.3	6.3	6.6	7.0	6.7	6.8	6.3

	6RC	LCO	GCO	SR	BRN	HAM
JAN	6.2	6.3	6.4	6.5	6.6	6.7
FEB	6.0	5.9	6.2	6.2	6.4	6.4
MAR	6.6	6.6	6.5	6.8	6.8	6.8
APR	6.9	6.6	6.5	6.1	6.8	6.9
MAY	7.1	6.8	6.7	6.2	7.0	7.1
JUN	7.2	6.8	7.2	6.3	7.0	7.6
JUL	7.1	6.8	7.0	6.5	6.7	7.1
AUG	6.8	6.7	7.1	7.2	6.9	7.3
SEP	6.1	6.1	6.2	6.3	6.8	7.0
OCT	6.8	6.7	6.5	6.1	7.0	7.2
NOV	6.7	6.6	6.7	6.1	6.9	7.2
DEC	6.8	6.6	6.5	5.8	6.7	7.0
mean	**6.7**	**6.5**	**6.6**	**6.3**	**6.8**	**7.0**
std dev	0.4	0.3	0.3	0.4	0.2	0.3
median	6.8	6.6	6.5	6.3	6.8	7.1
max	7.2	6.8	7.2	7.2	7.0	7.6
min	6.0	5.9	6.2	5.8	6.4	6.4

	NCF117	B210	COL	LVC2	SC-CH
JAN		6.2	3.9	6.9	6.4
FEB		5.9	3.9	6.8	6.3
MAR	6.6	6.4	4.0	6.8	6.8
APR	6.6	6.2	4.0	6.8	7.0
MAY	6.6	6.4	4.0	6.8	6.9
JUN	6.8	6.7		6.8	7.1
JUL	6.9	6.8		6.6	7.1
AUG	6.8	6.8		6.8	7.1
SEP	6.0	6.0	3.8	6.5	6.9
OCT	6.4	6.4	3.9	6.7	6.8
NOV	6.7	6.3	4.1	7.5	6.9
DEC	6.8	6.3	3.9	6.9	7.2
mean	**6.6**	**6.4**	**3.9**	**6.8**	**6.9**
std dev	0.3	0.3	0.1	0.2	0.3
median	6.7	6.4	3.9	6.8	6.9
max	6.9	6.8	4.1	7.5	7.2
min	6.0	5.9	3.8	6.5	6.3

Table 2.5 Dissolved Oxygen (mg/l) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	11.4	11.3	11.1	11.0	11.1	11.2	11.3	11.5	10.7	10.6
FEB	10.8	10.8	10.9	11.1	11.3	11.6	11.9	11.8	11.2	10.2
MAR	9.2	9.2	9.2	9.2	9.4	9.5	9.8	10.1	10.0	9.0
APR	6.7	6.9	7.1	7.4	7.4	7.8	7.9	8.0	8.2	7.7
MAY	5.9	6.4	6.0	6.3	6.8	7.0	7.4	7.5	7.3	6.7
JUN	5.4	5.0	7.0	7.5	8.1	7.7	7.1	6.2	6.4	6.6
JUL	3.8	4.7	4.0	5.2	6.0		6.9	6.1	6.2	
AUG	3.1	3.3	3.7	3.9	5.0		6.1	5.6	5.5	
SEP	3.7	3.5	3.7	3.2	3.5		4.9	5.8	5.9	
OCT	5.6	5.4	6.0	6.5	6.8		7.1	7.1	7.1	
NOV	7.2	7.3	7.3	7.3	7.5		8.2	8.1	7.8	
DEC	8.7	8.8	8.4	8.1	8.4		8.3	8.5	8.5	
mean	**6.8**	**6.9**	**7.0**	**7.2**	**7.6**	**9.1**	**8.1**	**8.0**	**7.9**	**8.5**
std dev	2.8	2.7	2.6	2.5	2.3	1.9	2.0	2.1	1.9	1.7
median	6.3	6.7	7.1	7.4	7.5	8.7	7.7	7.8	7.6	8.4
max	11.4	11.3	11.1	11.1	11.3	11.6	11.9	11.8	11.2	10.6
min	3.1	3.3	3.7	3.2	3.5	7.0	4.9	5.6	5.5	6.6

	NC11	AC	DP	BBT	IC	NCF6
JAN	13.2	12.9	12.1	12.1	11.9	11.1
FEB	12.3	12.0	11.9	10.5	11.0	10.1
MAR	10.0	9.7	9.5	9.0	9.2	7.8
APR	10.1	9.5	9.4	8.8	9.1	8.1
MAY	6.9	6.6	5.5	5.4	5.4	6.1
JUN	7.3	6.1	5.0	4.7	5.4	5.7
JUL	7.9	5.3	5.1	5.1	4.7	4.4
AUG	7.3	5.1	3.9	3.4	3.2	3.0
SEP	6.1	5.3	3.7	3.8	3.2	1.7
OCT	7.3	6.8	6.6	5.1	5.8	3.4
NOV	8.5	7.8	6.8	6.6	6.5	6.9
DEC	9.7	9.4	9.2	7.8	8.5	7.8
mean	**8.9**	**8.0**	**7.4**	**6.9**	**7.0**	**6.3**
std dev	2.2	2.6	2.9	2.8	2.9	2.9
median	8.2	7.3	6.7	6.0	6.2	6.5
max	13.2	12.9	12.1	12.1	11.9	11.1
min	6.1	5.1	3.7	3.4	3.2	1.7

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	10.6	11.6	10.9	10.0	10.4	11.5	12.3	10.6	8.7
FEB	9.9	8.5	9.4	8.5	10.5	11.3	9.3	9.5	7.8
MAR	10.9	10.6	9.9	8.7	8.4	11.3	10.7	9.0	6.8
APR	3.1	5.4	1.7	2.4	5.5	6.1	6.4	4.4	0.2
MAY	5.0	6.5	3.3	2.4	4.4	10.5	7.3	8.8	0.8
JUN	2.6	5.8	3.0	3.5	7.4	9.4	5.1	4.8	1.6
JUL	0.6	5.9	6.9	1.6	14.5	*	6.0	5.0	0.4
AUG	1.2	5.4	1.0	1.6	1.2	9.5	3.6	4.7	0.8
SEP	3.3	4.0	1.6	1.7	6.5	8.2	5.7	4.7	1.4
OCT	5.1	7.3	3.1	3.5	7.9	10.5	7.0	7.6	2.6
NOV	3.5	5.7	2.1	3.7	7.6	7.1	6.9	5.1	0.3
DEC	7.6	10.1	7.9	6.7	8.0	13.2	9.2	7.7	3.0
mean	**5.3**	**7.2**	**5.1**	**4.5**	**7.7**	**9.9**	**7.5**	**6.8**	**2.9**
std dev	3.6	2.4	3.7	3.1	3.3	2.1	2.5	2.3	3.1
median	4.3	6.2	3.2	3.5	7.8	10.5	7.0	6.4	1.5
max	10.9	11.6	10.9	10.0	14.5	13.2	12.3	10.6	8.7
min	0.6	4.0	1.0	1.6	1.2	6.1	3.6	4.4	0.2

	6RC	LCO	GCO	SR	BRN	HAM
JAN	13.8	13.1	12.7	11.8	13.6	12.5
FEB	10.3	10.4	9.2	9.5	10.7	10.7
MAR	9.9	9.1	7.2	5.5	7.1	7.1
APR	8.4	8.3	6.1	4.4	8.8	7.7
MAY	8.0	7.9	6.4	3.0	7.9	6.7
JUN	6.5	5.8	6.5	2.5	7.4	9.5
JUL	5.2	5.5	4.0	3.2	5.9	5.1
AUG	5.7	4.8	4.2	8.4	6.2	6.8
SEP	4.1	6.0	2.9	2.9	7.1	5.9
OCT	8.4	8.6	5.1	0.6	8.8	8.2
NOV	10.0	10.3	8.8	2.9	9.9	8.8
DEC	9.4	9.5	7.0	2.2	9.6	8.0
mean	**8.3**	**8.3**	**6.7**	**4.7**	**8.6**	**8.1**
std dev	2.7	2.4	2.7	3.4	2.2	2.1
median	8.4	8.5	6.5	3.1	8.4	7.9
max	13.8	13.1	12.7	11.8	13.6	12.5
min	4.1	4.8	2.9	0.6	5.9	5.1

	NCF117	B210	COL	LVC2	SC-CH
JAN		11.7	9.9	10.5	10.1
FEB		9.5	8.0	8.9	9.2
MAR	8.1	8.4	7.1	7.7	8.2
APR	8.1	7.5	6.9	6.9	8.2
MAY	4.3	5.2	5.4	2.0	6.1
JUN	4.5	4.6		2.5	4.8
JUL	5.3	4.3		1.9	4.2
AUG	5.5	4.1		1.6	3.2
SEP	0.3	3.0	4.4	2.1	3.6
OCT	3.2	6.1	6.8	4.3	4.5
NOV	5.7	8.1	8.3	6.0	6.9
DEC	8.0	10.0	8.6	6.4	8.6
mean	**5.3**	**6.9**	**7.3**	**5.1**	**6.5**
std dev	2.5	2.7	1.7	3.1	2.4
median	5.4	6.8	7.1	5.2	6.5
max	8.1	11.7	9.9	10.5	10.1
min	0.3	3.0	4.4	1.6	3.2

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations, 1995-2010 versus 2011.

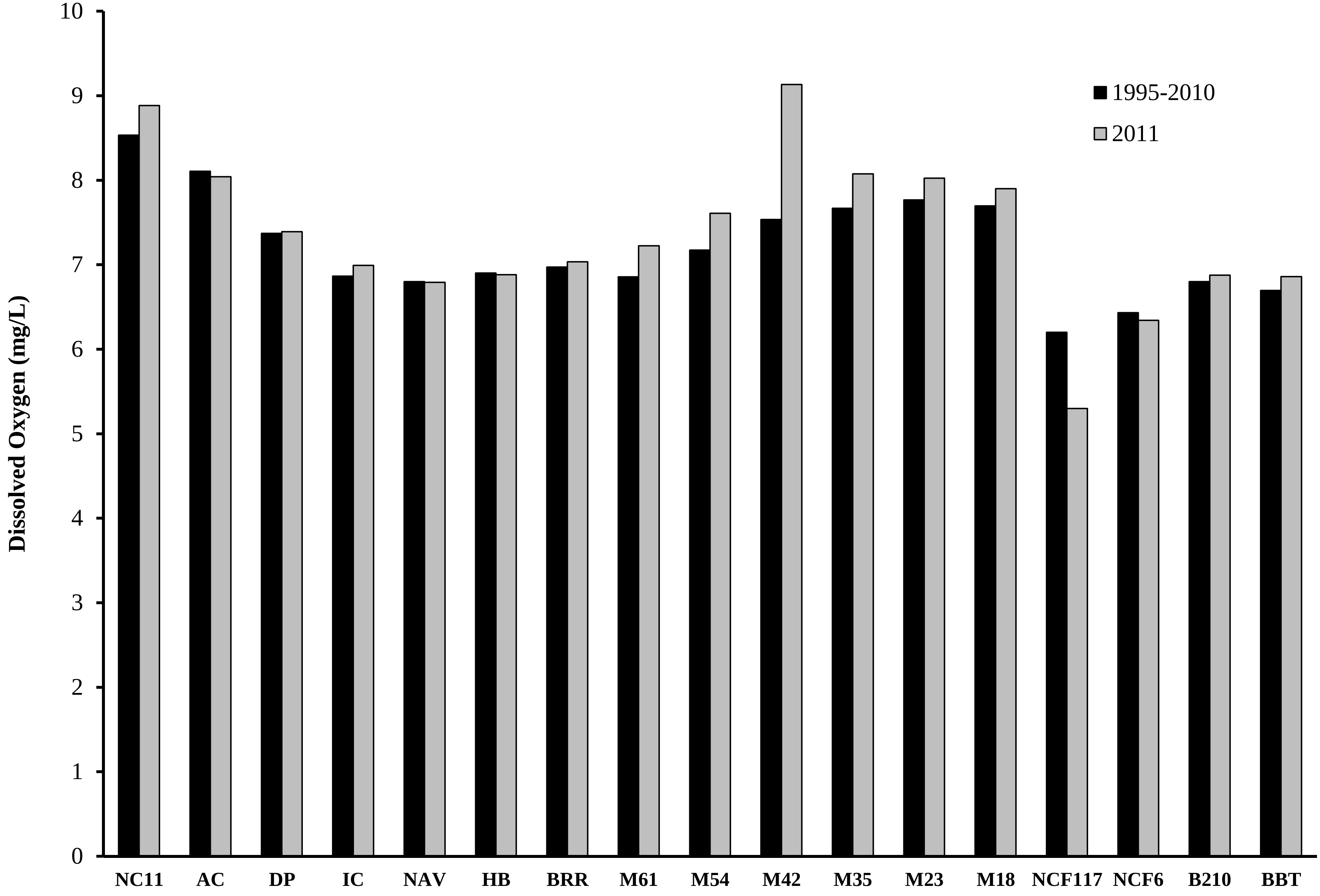


Table 2.6 Field Turbidity (NTU) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	15	16	13	7	8	9	6	5	6	8
FEB	44	17	10	8	7	7	6	6	7	4
MAR	17	17	19	12	12	10	9	10	14	8
APR	17	16	13	9	22	8	8	7	7	17
MAY	14	13	10	7	11	8	5	5	9	8
JUN	4	7	7	5	5	4	3	4	5	5
JUL	22	16	18	10	19		14	8	7	
AUG	8	10	9	6	6		6	4	4	
SEP	17	10	11	6	6		6	4	4	
OCT	23	31	15	12	12		8	7	13	
NOV	24	18	13	11	10		8	8	16	
DEC	44	34	24	15	10		6	4	5	
mean	**21**	**17**	**14**	**9**	**11**	**8**	**7**	**6**	**8**	**8**
std dev	12	8	5	3	5	2	3	2	4	5
median	17	16	13	9	10	8	6	6	7	8
max	44	34	24	15	22	10	14	10	16	17
min	4	7	7	5	5	4	3	4	4	4

	NC11	AC	DP	BBT	IC	NCF6
JAN	3	4	5	5	7	12
FEB	38	31	27	8	12	6
MAR	27	29	32	18	21	17
APR	16	12	10	8	7	6
MAY	8	9	7	7	6	10
JUN	5	5	6	4	5	6
JUL	20	7	8	8	15	16
AUG	9	5	7	7	3	16
SEP	6	8	5	5	5	6
OCT	5	8	5	2	5	2
NOV	3	6	7	3	3	4
DEC	60	61	22	6	9	23
mean	**17**	**15**	**12**	**7**	**8**	**10**
std dev	17	17	10	4	5	6
median	9	8	7	7	7	8
max	60	61	32	18	21	23
min	3	4	5	2	3	2

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	6	2	2	2	7	20	3	7	4
FEB	7	4	3	2	5	4	4	6	6
MAR	9	5	3	4	10	6	8	12	14
APR	7	5	6	3	13	4	7	10	7
MAY	12	4	3	2	13	2	5	5	4
JUN	5	2	12	9	44	4	5	12	10
JUL	3	1	22	15	13		2	6	21
AUG	3	2	9	15	17	1.0	2	5	5
SEP	2	2	5	11	9	2	4	6	5
OCT	5	4	4	5	11	2	4	7	11
NOV	4	3	2	3	19	2	3	11	8
DEC	5	4	3	3	19	4	5	8	5
mean	**6**	**3**	**6**	**6**	**15**	**5**	**4**	**8**	**8**
std dev	3	1	6	5	10	5	2	3	5
median	5	4	4	4	13	4	4	7	7
max	12	5	22	15	44	20	8	12	21
min	2	1	2	2	5	1	2	5	4

	6RC	LCO	GCO	SR	BRN	HAM
JAN	4	3	2	1	3	5
FEB	11	7	3	2	10	26
MAR	10	12	5	4	7	7
APR	5	5	3	1	5	5
MAY	6	6	5	3	6	8
JUN	2	1	5	14	2	5
JUL	2	3	2	10	6	19
AUG	3	4	3	10	3	11
SEP	3	5	10	16	2	3
OCT	3	2	5	45	2	3
NOV	4	3	4	48	6	5
DEC	3	1	2	3	1	2
mean	**5**	**4**	**4**	**13**	**4**	**8**
std dev	3	3	2	16	3	7
median	4	4	4	7	4	5
max	11	12	10	48	10	26
min	2	1	2	1	1	2

	NCF117	B210	COL	LVC2	SC-CH
JAN		2	3	11	13
FEB		2	2	3	15
MAR	4	4	4	5	20
APR	4	4	2	14	26
MAY	6	6	2	4	18
JUN	4	2		3	10
JUL	4	1		2	7
AUG	6	1		3	33
SEP	4	1	2	1	17
OCT	3	4	3	3	8
NOV	5	3	2	3	10
DEC	5	3	2	5	19
mean	**5**	**3**	**2**	**5**	**16**
std dev	1	2	1	4	8
median	4	3	2	3	16
max	6	6	4	14	33
min	3	1	2	1	7

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2010 versus 2011.

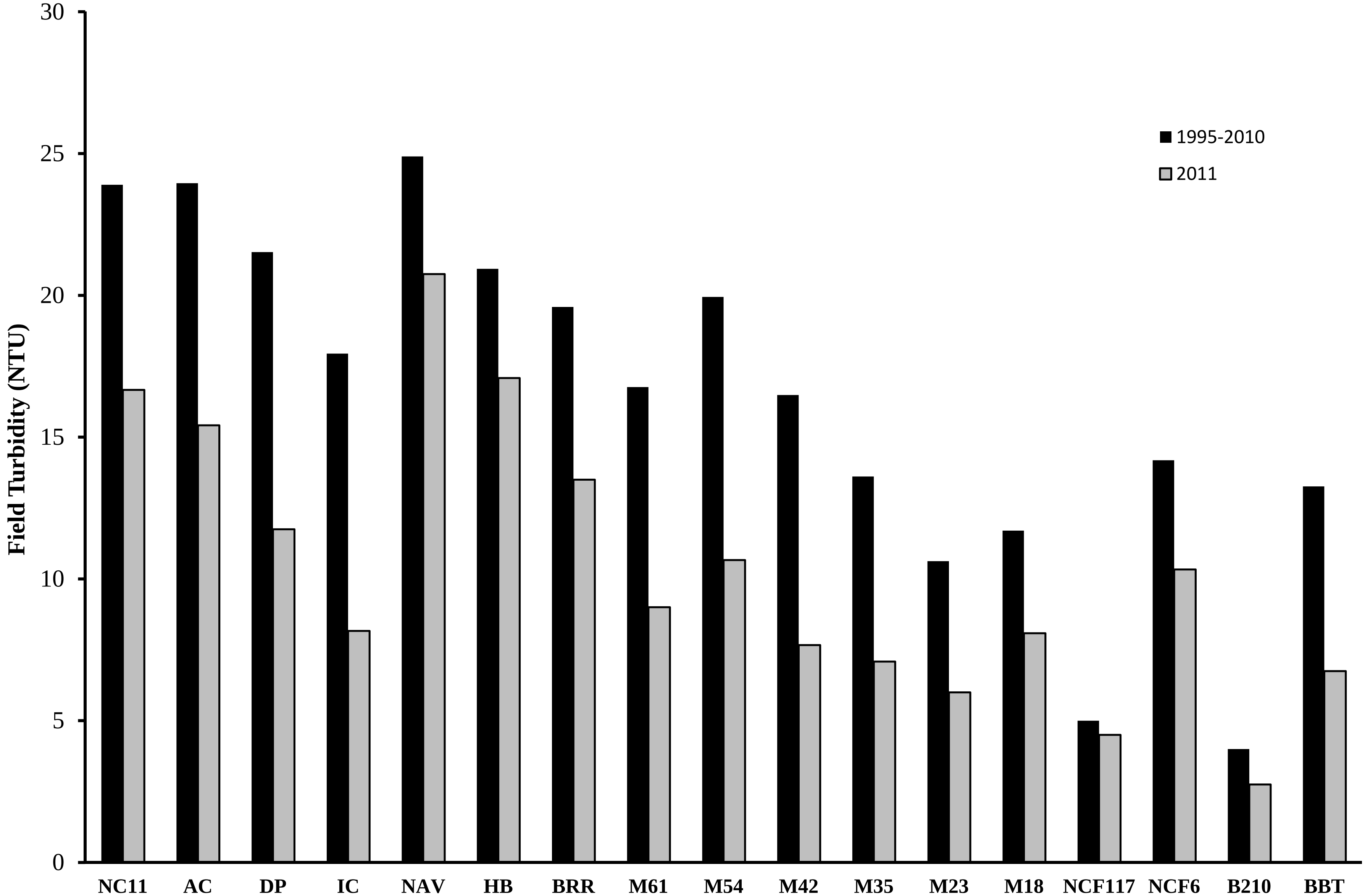


Table 2.7 Total Suspended Solids (mg/L) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	20	25	21	15	19	21	19	12	18	21
FEB	78	14	13	14	14	15	16	17	23	16
MAR	19	23	22	18	17	18	17	24	34	21
APR	19	15	14	11	40	14	18	18	24	28
MAY	16	11	15	8	14	15	12	9	10	20
JUN	18	34	19	14	19	18	15	18	17	18
JUL	27	23	17	20	29		28	21	20	
AUG	20	18	25	28	18		25	18	24	
SEP	31	10	11	8	8		11	14	18	
OCT	20	14	12	9	11		11	8	14	
NOV	21	13	15	12	14		13	10	12	
DEC	24	16	14	12	10		7	9	12	
mean	**26**	**18**	**16**	**14**	**18**	**17**	**16**	**15**	**19**	**21**
std dev	17	7	4	6	9	3	6	5	7	4
median	20	15	15	13	16	16	16	15	18	20
max	78	34	25	28	40	21	28	24	34	28
min	16	10	11	8	8	14	7	8	10	16

	NC11	AC	DP	IC	NCF6
JAN	4	4	7	6	13
FEB	30	25	23	8	4
MAR	18	24	17	15	17
APR	12	15	8	5	7
MAY	7	7	7	5	10
JUN	6	7	15	6	11
JUL	15	5	9	23	48
AUG	9	8	10	21	37
SEP	7	6	7	6	7
OCT	6	8	10	5	5
NOV	4	3	10	6	8
DEC	56	62	19	6	23
mean	**14**	**14**	**12**	**9**	**16**
std dev	15	17	5	6	14
median	8	8	10	6	10
max	56	62	23	23	48
min	4	3	7	5	4

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	2	3	2	2	6	17	2	5	3
FEB	2	3	2	2	9	2	3	3	8
MAR	3	3	2	2	28	5	2	6	6
APR	7	8	12	2	17	2	4	10	10
MAY	7	5	5	2	14	9	3	4	6
JUN	37	2	157	12	45	3	2	12	6
JUL	16	4	16	14	27		3	5	20
AUG	5	2	21	6	25	2	2	12	9
SEP		5		3	6	2	4	8	9
OCT		2		2	5	2	2	4	4
NOV		2		2	11	2	2	4	5
DEC		1		1	10	1	1	4	17
mean	**10**	**3**	**27**	**4**	**17**	**4**	**2**	**6**	**8**
std dev	12	2	53	4	12	5	1	3	5
median	6	3	8	2	12	2	2	5	7
max	37	8	157	14	45	17	4	12	20
min	2	1	2	1	5	1	1	3	3

	6RC	LCO	GCO	SR	BRN	HAM
JAN	2	2	2	2	2	2
FEB	9	6	3	2	12	32
MAR	7	10	4	2	3	2
APR	6	7	4	5	6	4
MAY	3	3	3	3	2	2
JUN	2	2	55	19	4	3
JUL	2	2	4	15	5	21
AUG	2	2	3	9	2	7
SEP			23			
OCT			6			
NOV			3			
DEC			2			
mean	**4**	**4**	**9**	**7**	**4**	**9**
std dev	3	3	15	7	3	11
median	2	2	3	4	4	3
max	9	10	55	19	12	32
min	2	2	2	2	2	2

	NCF117	B210	COL	LVC2
JAN		2	2	2
FEB		2	2	2
MAR	2	2	2	3
APR	3	3	2	4
MAY	4	5	2	5
JUN	7	2		2
JUL	4	2		3
AUG	7	2		2
SEP	10	2		2
OCT	4	2		2
NOV	5	2		2
DEC	4	2		1
mean	**5**	**2**	**2**	**3**
std dev	2	1	0	1
median	4	2	2	2
max	10	5	2	5
min	2	2	2	1

Table 2.8 Light Attenuation (k) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	3.13	3.04	3.00	2.21	2.35	2.11	1.84	1.87	1.11	1.56
FEB	5.99	3.58	3.68	5.07	2.32	2.22	2.16	1.57	1.60	1.33
MAR	3.61	3.79	3.85	3.57	3.13	2.92	2.58	2.31	2.42	1.82
APR	3.63	3.90	3.09	2.63	4.12	2.11	1.62	1.31	1.18	2.23
MAY	3.76	3.2	3.11	2.56	3.1	1.95	1.75	1.32	1.54	1.66
JUN	3.20	2.49	2.33	1.96	2.15	1.62	1.19	1.04	0.81	1.22
JUL			2.72	1.73	2.89		2.06	1.27	1.05	
AUG	2.27	2.32	2.13	2.10	1.79		1.19	1.28	1.15	
SEP	4.56	4.36	4.31	4.32	3.47		2.87	2.02	1.88	
OCT	3.43	3.30		2.49	2.28		1.77	1.30	1.27	
NOV	3.39	2.99	2.79	2.12	2.16		1.63	1.27	1.60	
DEC	5.16	4.18	3.76	2.74	2.02		1.76	1.36	1.31	
mean	**3.83**	**3.38**	**3.16**	**2.79**	**2.65**	**2.16**	**1.87**	**1.49**	**1.41**	**1.64**
std dev	1.04	0.66	0.67	1.02	0.70	0.43	0.50	0.38	0.43	0.36
max	5.99	4.36	4.31	5.07	4.12	2.92	2.87	2.31	2.42	2.23
min	2.27	2.32	2.13	1.73	1.79	1.62	1.19	1.04	0.81	1.22

	NC11	AC	DP	BBT	IC	NCF6
JAN	1.48	1.61	1.99	1.80	2.54	3.87
FEB	3.41	3.78	3.06	3.13	3.06	3.39
MAR	2.43	2.57	3.52	2.62	2.70	4.90
APR	2.43	2.58	2.09	2.44	2.24	3.72
MAY	2.10	2.06	3.14	3.40	3.32	3.67
JUN	1.73	1.65	2.65	2.44	2.29	2.79
JUL	2.89	1.80	2.35	2.48	2.41	3.29
AUG	2.07	2.21	2.25	2.32	2.94	2.69
SEP	1.88	2.25	3.12	2.71	2.96	4.32
OCT	1.85	2.55	2.05	3.39	2.24	5.27
NOV	1.55	1.95	2.75	2.85	2.88	3.84
DEC	5.56	5.57	2.70	2.64	2.48	5.60
mean	**2.45**	**2.55**	**2.64**	**2.69**	**2.67**	**3.95**
std dev	1.13	1.12	0.50	0.46	0.36	0.92
max	5.56	5.57	3.52	3.40	3.32	5.60
min	1.48	1.61	1.99	1.80	2.24	2.69

Table 2.9 Total Nitrogen (μg/l) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	940	720	740	600	540	460	350	210	120	150
FEB	1,930	1,610	1,330	1,000	970	890	650	150	110	110
MAR	1,420	1,750	990	1,370	1,000	990	770	740	580	720
APR	640	640	660	620	670	660	760	540	630	620
MAY	1,240	1,020	930	750	850	680	520	540	240	470
JUN	920	870	790	640	620	430	410	410	310	310
JUL	930	780	750	750	730		510	310	310	
AUG	710	860	1,080	1,270	930		690	420	510	
SEP	1,070	950	940	930	870		760	560	290	
OCT	1,270	1,420	1,340	1,010	1,120		920	640	310	
NOV	1,400	1,290	1,200	1,040	880		680	360	250	
DEC	950	1,100	780	760	810		640	1,130	350	
mean	**1,118**	**1,084**	**961**	**895**	**833**	**685**	**638**	**501**	**334**	**397**
std dev	342	343	223	242	161	205	157	251	157	227
median	1,010	985	935	845	860	670	665	480	310	390
max	1,930	1,750	1,340	1,370	1,120	990	920	1,130	630	720
min	640	640	660	600	540	430	350	150	110	110

	NC11	AC	DP	IC	NCF6
JAN	1,410	1,420	1,070	1,130	560
FEB	1,750	1,700	1,700	1,230	1,040
MAR	1,740	2,300	1,280	1,580	890
APR	1,370	1,080	1,310	1,120	810
MAY	1,650	1,460	1,280	1,160	790
JUN	1,030	1,040	1,250	1,210	800
JUL	1,180	1,350	1,360	1,530	1,010
AUG	1,390	1,300	1,540	1,160	990
SEP	1,170	1,250	1,210	980	1,230
OCT	920	1,100	1,400	1,140	990
NOV	2,160	2,140	2,310	2,030	920
DEC	1,300	970	1,100	860	560
mean	**1,423**	**1,426**	**1,401**	**1,261**	**883**
std dev	336	407	321	300	186
median	1,380	1,325	1,295	1,160	905
max	2,160	2,300	2,310	2,030	1,230
min	920	970	1,070	860	560

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1,390	1,520	510	2,120	1,360	1,330	1,360	5,820	1,150
FEB	1,270	1,570	810	1,700	1,920	1,250	1,810	6,050	590
MAR	1,100	890	510	810	1,670	570	920	5,140	1,570
APR	2,350	1,500	1,140	950	1,550	640	1,180	24,200	1,340
MAY	920	820	630	610	1,180	440	840	18,250	730
JUN	1,240	2,210	950	950	2,250	410	5,540	27,950	850
JUL	710	840	1,520	1,010	3,510		610	31,650	2,240
AUG	810	2,400	2,380	910	7,230	210	2,660	17,100	1,070
SEP	1,540	1,290	1,030	800	2,190	690	1,480	28,150	1,130
OCT	1,050	1,020	710	540	760	440	3,140	26,050	570
NOV	820	550	510	570	830	210	830	25,450	350
DEC	840	700	510	700	1,060	820	2,600	27,850	690
mean	**1,170**	**1,276**	**934**	**973**	**2,126**	**637**	**1,914**	**20,305**	**1,023**
std dev	433	563	529	453	1,701	356	1,346	9,299	499
median	1,075	1,155	760	860	1,610	570	1,420	24,825	960
max	2,350	2,400	2,380	2,120	7,230	1,330	5,540	31,650	2,240
min	710	550	510	540	760	210	610	5,140	350

	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,830	1,070	550	230	550	290
FEB	2,050	1,610	780	470	1,460	1,880
MAR	2,050	1,720	1,250	1,250	1,090	1,080
APR	810	380	400	230	270	430
MAY	1,010	720	720	620	560	520
JUN	670	1,170	4,070	2,010	660	480
JUL	550	1,040	1,730	1,010	880	720
AUG	2,010	760	940	1,320	330	320
SEP	810	890	1,740	910	570	430
OCT	1,410	900	1,260	1,650	700	360
NOV	1,430	1,100	1,800	1,140	950	420
DEC	750	210	250	610	230	70
mean	**1,282**	**964**	**1,291**	**954**	**688**	**583**
std dev	560	417	980	530	345	457
median	1,210	970	1,095	960	615	430
max	2,050	1,720	4,070	2,010	1,460	1,880
min	550	210	250	230	230	70

	NCF117	B210	COL	LVC2
JAN		1,250	930	2,730
FEB		1,240	1,010	660
MAR	950	630	710	580
APR	1,210	730	630	430
MAY	1,030	870	850	1,460
JUN	1,500	1,150		1,570
JUL	640	590		2,230
AUG	630	460		4,020
SEP	1,250	970	760	1,280
OCT	1,040	1,000	950	560
NOV	1,120	720	720	1,240
DEC	680	600	510	610
mean	**1,005**	**851**	**786**	**1,448**
std dev	273	258	154	1,035
median	1,035	800	760	1,260
max	1,500	1,250	1,010	4,020
min	630	460	510	430

Figure 2.4 Total Nitrogen at the Lower Cape Fear River Program mainstem stations, 1995-2010 versus 2011.

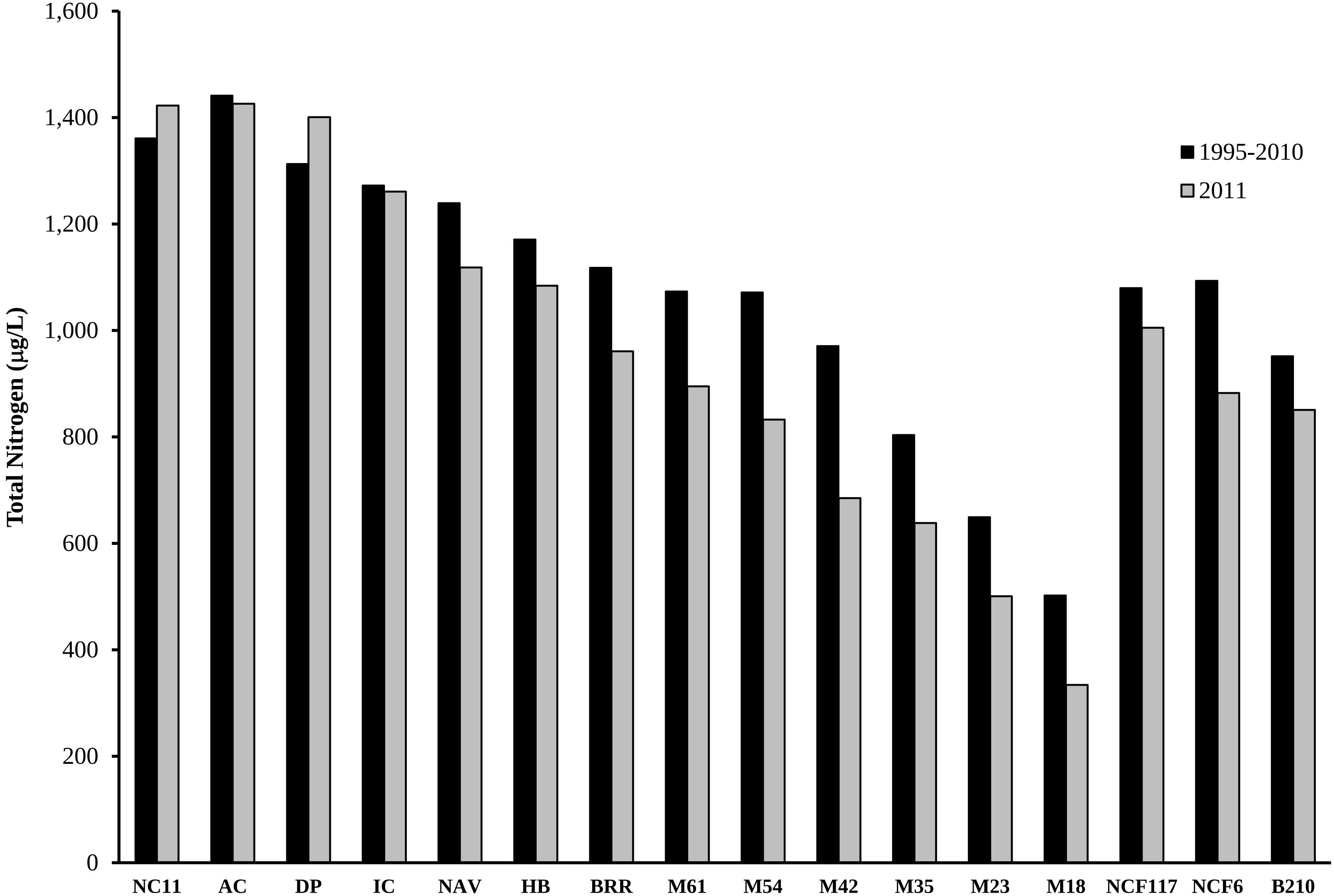


Table 2.10 Nitrate/Nitrite (µg/l) during 2011 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	840	620	640	500	440	360	250	110	20	50
FEB	730	510	530	400	370	290	250	50	10	10
MAR	520	450	390	370	300	290	270	140	80	20
APR	540	540	560	520	470	360	260	140	30	120
MAY	440	420	430	350	350	280	220	140	40	70
JUN	520	270	290	240	120	30	10	10	10	10
JUL	430	380	350	250	130		10	10	10	
AUG	610	560	480	470	330		90	20	10	
SEP	470	450	340	230	270		260	160	90	
OCT	570	520	540	410	420		220	140	10	
NOV	800	690	700	540	480		280	160	50	
DEC	750	800	480	560	610		590	430	300	
mean	**602**	**518**	**478**	**403**	**358**	**268**	**226**	**126**	**55**	**47**
std dev	137	136	119	114	136	112	145	108	79	39
median	555	515	480	405	360	290	250	140	25	35
max	840	800	700	560	610	360	590	430	300	120
min	430	270	290	230	120	30	10	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	1310	1320	970	1030	460
FEB	1150	1100	1100	730	340
MAR	840	800	780	780	290
APR	770	680	810	720	210
MAY	850	860	680	560	290
JUN	730	740	850	910	400
JUL	380	850	760	930	410
AUG	690	600	540	460	390
SEP	870	850	610	480	130
OCT	620	600	900	740	190
NOV	1560	1440	1510	1330	320
DEC	900	920	1050	810	260
mean	**889**	**897**	**880**	**790**	**308**
std dev	304	255	249	233	95
median	845	850	830	760	305
max	1,560	1,440	1,510	1,330	460
min	380	600	540	460	130

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	290	720	10	1320	260	430	760	5020	350
FEB	70	570	10	800	1020	450	1010	4950	90
MAR	200	390	10	410	670	70	420	4640	270
APR	150	600	40	250	50	40	380	24100	240
MAY	120	320	30	210	180	40	440	18200	30
JUN	40	1510	50	50	50	10	4940	27900	50
JUL	10	40	20	10	210		10	31600	40
AUG	10	1100	80	10	30	10	1260	16700	270
SEP	40	90	30	100	890	90	380	28100	130
OCT	50	220	10	40	60	40	1640	26000	170
NOV	20	150	10	170	30	10	230	25400	150
DEC	40	200	10	300	60	20	1100	27800	190
mean	**87**	**493**	**26**	**306**	**293**	**110**	**1,048**	**20,034**	**165**
std dev	83	424	21	373	343	157	1,259	9,602	99
median	45	355	15	190	120	40	600	24,750	160
max	290	1,510	80	1,320	1,020	450	4,940	31,600	350
min	10	40	10	10	30	10	10	4,640	30

	6RC	LCO	GCO	SR	BRN	HAM
JAN	1730	970	450	130	450	190
FEB	1350	1010	380	170	960	1080
MAR	1150	620	150	150	290	180
APR	710	280	200	130	170	130
MAY	510	320	220	120	260	120
JUN	70	170	2970	10	360	80
JUL	150	240	930	10	480	120
AUG	1410	160	140	20	230	20
SEP	110	90	40	10	170	30
OCT	710	200	60	50	300	60
NOV	830	300	1000	40	250	20
DEC	700	160	150	110	180	20
mean	**786**	**377**	**558**	**79**	**342**	**171**
std dev	517	303	789	59	210	280
median	710	260	210	80	275	100
max	1,730	1,010	2,970	170	960	1,080
min	70	90	40	10	170	20

	NCF117	B210	COL	LVC2
JAN		350	30	230
FEB		440	10	60
MAR	250	230	10	80
APR	610	230	30	30
MAY	430	270	50	360
JUN	300	250		670
JUL	240	90		1230
AUG	130	60		920
SEP	50	70	60	180
OCT	340	200	50	160
NOV	220	220	20	440
DEC	180	200	10	210
mean	**275**	**218**	**30**	**381**
std dev	151	106	18	360
median	245	225	30	220
max	610	440	60	1,230
min	50	60	10	30

Table 2.11 Ammonium (μg/l) during 2011 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	50	60	70	60	70	40	10	10	5	5
FEB	40	50	40	40	20	40	5	5	5	5
MAR	90	80	80	80	60	70	60	10	10	5
APR	60	60	10	70	80	50	10	10	5	10
MAY	90	100	110	80	100	50	30	10	10	10
JUN	50	80	5	5	5	5	5	5	5	5
JUL	20	5	10	5	10		5	10	5	
AUG	5	10	5	10	10		5	5	5	
SEP	30	40	60	80	70		30	10	10	
OCT	40	5	10	10	40		10	20	10	
NOV	90	90	100	90	100		40	20	10	
DEC	70	80	90	100	110		100	60	50	
mean	**53**	**55**	**49**	**53**	**56**	**43**	**26**	**15**	**11**	**7**
std dev	28	34	40	36	38	21	29	15	13	3
median	50	60	50	65	65	45	10	10	8	5
max	90	100	110	100	110	70	100	60	50	10
min	5	5	5	5	5	5	5	5	5	5

	NC11	AC	DP	IC	NCF6
JAN	30	10	20	40	70
FEB	20	10	60	40	10
MAR	80	120	40	70	40
APR	30	40	80	60	30
MAY	120	70	80	50	30
JUN	60	100	130	30	20
JUL	20	90	50	30	5
AUG	100	190	60	50	10
SEP	50	160	70	60	150
OCT	60	170	90	70	30
NOV	30	100	120	50	10
DEC	70	110	110	90	20
mean	**56**	**98**	**76**	**53**	**35**
std dev	32	59	33	18	40
median	55	100	75	50	25
max	120	190	130	90	150
min	20	10	20	30	5

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	5	5	10	40	170	150	20	50	110
FEB	10	30	20	20	80	10	60	50	60
MAR	120	10	10	10	150	10	10	150	170
APR	2,320	140	160	130	320	30	40	110	300
MAY	180	50	70	100	460	20	80	100	460
JUN	130	60	40	250	1,570	10	70	110	230
JUL	10	30	180	300	60		20	90	550
AUG	5	40	50	150	4,670	10	40	30	280
SEP	180	130	10	70	560	90	50	70	360
OCT	50	20	40	120	210	10	910	60	90
NOV	20	40	20	60	220	10	10	50	20
DEC	20	10	10	30	180	5	900	70	30
mean	**254**	**47**	**52**	**107**	**721**	**32**	**184**	**78**	**222**
std dev	654	44	59	91	1,309	46	337	34	173
median	35	35	30	85	215	10	45	70	200
max	2,320	140	180	300	4,670	150	910	150	550
min	5	5	10	10	60	5	10	30	20

	6RC	LCO	GCO	SR	BRN	HAM
JAN	40	40	10	10	10	10
FEB	50	30	40	5	5	5
MAR	20	10	10	10	10	20
APR	20	50	20	20	20	50
MAY	50	50	60	20	50	90
JUN	20	30	40	50	40	40
JUL	50	30	90	70	70	140
AUG	50	30	50	20	30	20
SEP	40	10	70	50	30	20
OCT	40	5	40	320	30	20
NOV	20	5	30	10	5	5
DEC	40	10	20	20	20	10
mean	**37**	**25**	**40**	**50**	**27**	**36**
std dev	13	17	24	87	20	41
median	40	30	40	20	25	20
max	50	50	90	320	70	140
min	20	5	10	5	5	5

	NCF117	B210	COL	LVC2
JAN		20	10	1,360
FEB		5	10	100
MAR	40	10	20	100
APR	40	20	20	110
MAY	130	100	110	960
JUN	10	40		90
JUL	5	10		5
AUG	20	30	80	2,950
SEP	100	10	80	610
OCT	100	10	40	80
NOV	20	20	10	330
DEC	20	10	5	180
mean	**49**	**24**	**39**	**573**
std dev	45	26	38	858
median	30	15	20	145
max	130	100	110	2,950
min	5	5	5	5

Table 2.12 Total Kjeldahl Nitrogen (µg/l) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	100	100	100	100	100	100	100	100	100	100
FEB	1200	1100	800	600	600	600	400	100	100	100
MAR	900	1300	600	1000	700	700	500	600	500	700
APR	100	100	100	100	200	300	500	400	600	500
MAY	800	600	500	400	500	400	300	400	200	400
JUN	400	600	500	400	500	400	400	400	300	300
JUL	500	400	400	500	600		500	300	300	
AUG	100	300	600	800	600		600	400	500	
SEP	600	500	600	700	600		500	400	200	
OCT	700	900	800	600	700		700	500	300	
NOV	600	600	500	500	400		400	200	200	
DEC	200	300	300	200	200		50	700	50	
mean	**517**	**567**	**483**	**492**	**475**	**417**	**413**	**375**	**279**	**350**
std dev	339	359	219	263	196	195	180	174	168	214
median	550	550	500	500	550	400	450	400	250	350
max	1,200	1,300	800	1,000	700	700	700	700	600	700
min	100	100	100	100	100	100	50	100	50	100

	NC11	AC	DP	IC	NCF6
JAN	100	100	100	100	100
FEB	600	600	600	500	700
MAR	900	1500	500	800	600
APR	600	400	500	400	600
MAY	800	600	600	600	500
JUN	300	300	400	300	400
JUL	800	500	600	600	600
AUG	700	700	1000	700	600
SEP	300	400	600	500	1,100
OCT	300	500	500	400	800
NOV	600	700	800	700	600
DEC	400	50	50	50	300
mean	**533**	**529**	**521**	**471**	**575**
std dev	239	355	250	224	238
median	600	500	550	500	600
max	900	1,500	1,000	800	1,100
min	100	50	50	50	100

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	1100	800	500	800	1100	900	600	800	800
FEB	1200	1000	800	900	900	800	800	1100	500
MAR	900	500	500	400	1000	500	500	500	1300
APR	2200	900	1100	700	1500	600	800	100	1100
MAY	800	500	600	400	1000	400	400	50	700
JUN	1200	700	900	900	2200	400	600	50	800
JUL	700	800	1500	1000	3300		600	50	2200
AUG	800	1300	2300	900	7200	200	1400	400	800
SEP	1500	1200	1000	700	1300	600	1100	50	1000
OCT	1000	800	700	500	700	400	1500	50	400
NOV	800	400	500	400	800	200	600	50	200
DEC	800	500	500	400	1000	800	1500	50	500
mean	**1,083**	**783**	**908**	**667**	**1,833**	**527**	**867**	**271**	**858**
std dev	404	273	512	225	1,764	226	386	342	501
median	950	800	750	700	1,050	500	700	50	800
max	2,200	1,300	2,300	1,000	7,200	900	1,500	1,100	2,200
min	700	400	500	400	700	200	400	50	200

	6RC	LCO	GCO	SR	BRN	HAM
JAN	100	100	100	100	100	100
FEB	700	600	400	300	500	800
MAR	900	1100	1100	1100	800	900
APR	100	100	200	100	100	300
MAY	500	400	500	500	300	400
JUN	600	1000	1100	2000	300	400
JUL	400	800	800	1000	400	600
AUG	600	600	800	1300	100	300
SEP	700	800	1700	900	400	400
OCT	700	700	1200	1600	400	300
NOV	600	800	800	1100	700	400
DEC	50	50	100	500	50	50
mean	**496**	**588**	**733**	**875**	**346**	**413**
std dev	265	339	473	570	230	240
median	600	650	800	950	350	400
max	900	1,100	1,700	2,000	800	900
min	50	50	100	100	50	50

	NCF117	B210	COL	LVC2
JAN		900	900	2500
FEB		800	1000	600
MAR	700	400	700	500
APR	600	500	600	400
MAY	600	600	800	1100
JUN	1200	900		900
JUL	400	500		1000
AUG	500	400		3100
SEP	1200	900	700	1100
OCT	700	800	900	400
NOV	900	500	700	800
DEC	500	400	500	400
mean	**730**	**633**	**756**	**1,067**
std dev	269	201	150	825
median	650	550	700	850
max	1,200	900	1,000	3,100
min	400	400	500	400

Table 2.13 Total Phosphorus (µg/l) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	100	90	90	100	70	50	50	60	40	60
FEB	210	110	130	90	80	70	90	80	50	40
MAR	110	90	60	60	50	50	40	10	30	20
APR	110	90	90	80	80	50	60	40	30	40
MAY	90	120	110	90	100	60	30	10	10	10
JUN	80	70	90	80	40	10	20	10	10	10
JUL	140	110	120	90	120		50	20	10	
AUG	70	90	100	90	60		50	50	10	
SEP	180	150	160	120	100		90	60	30	
OCT	100	120	100	80	90		60	20	40	
NOV	160	100	80	80	80		110	10	30	
DEC	160	150	80	80	120	50	50	50	10	
mean	**126**	**108**	**101**	**87**	**83**	**49**	**58**	**35**	**25**	**30**
std dev	42	23	25	14	24	17	25	24	14	18
median	110	105	95	85	80	50	50	30	30	30
max	210	150	160	120	120	70	110	80	50	60
min	70	70	60	60	40	10	20	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	150	140	140	160	50
FEB	210	200	220	140	90
MAR	80	220	110	120	100
APR	110	90	80	90	60
MAY	130	110	110	120	70
JUN	140	140	210	160	70
JUL	160	160	160	190	80
AUG	220	170	230	200	120
SEP	100	200	150	140	150
OCT	120	140	160	140	130
NOV	200	210	380	140	110
DEC	230	320	190	110	150
mean	**154**	**175**	**178**	**143**	**143**
std dev	48	58	75	30	30
median	145	165	160	140	95
max	230	320	380	200	200
min	80	90	80	90	90

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	100	70	70	100	200	100	140	430	40
FEB	90	140	60	170	180	30	290	520	90
MAR	100	80	50	120	410	40	170	820	410
APR	200	180	220	250	610	90	260	2,950	260
MAY	140	130	110	150	350	60	200	2,380	230
JUN	160	280	300	450	410	40	610	5,080	190
JUL	110	490	260	400	380		820	4,770	270
AUG	90	160	640	420	2,430	30	1,440	2,590	340
SEP	170	200	170	270	240	40	700	4,630	360
OCT	120	70	60	140	200	60	810	4,320	240
NOV	100	70	50	120	170	30	290	3,150	320
DEC	40	10	40	30	190	10	220	3,080	150
mean	**118**	**157**	**169**	**218**	**481**	**48**	**496**	**2,893**	**242**
std dev	41	122	166	133	601	26	375	1,576	106
median	105	135	90	160	295	40	290	3,015	250
max	200	490	640	450	2,430	100	1,440	5,080	410
min	40	10	40	30	170	10	140	430	40

	6RC	LCO	GCO	SR	BRN	HAM
JAN	50	30	70	10	60	60
FEB	120	100	110	50	90	140
MAR	70	40	140	130	90	60
APR	170	50	240	40	100	180
MAY	100	50	320	50	70	190
JUN	120	120	670	130	80	160
JUL	210	80	760	110	70	350
AUG	100	130	1,090	150	80	260
SEP	170	80	1,650	110	110	280
OCT	190	40	620	140	100	140
NOV	160	50	340	100	70	240
DEC	130	50	250	130	50	170
mean	**133**	**68**	**522**	**96**	**81**	**186**
std dev	47	32	450	44	17	82
median	125	50	330	110	80	175
max	210	130	1,650	150	110	350
min	50	30	70	10	50	60

	NCF117	B210	COL	LVC2
JAN		70	10	40
FEB		80	100	90
MAR	120	80	10	10
APR	50	40	10	10
MAY	160	120	10	30
JUN	100	130		50
JUL	40	100		40
AUG	30	120		30
SEP	310	100	120	10
OCT	110	140	40	10
NOV	110	130	10	10
DEC	50	30	10	10
mean	**108**	**95**	**36**	**28**
std dev	78	34	41	23
median	105	100	10	20
max	310	140	120	90
min	30	30	10	10

Figure 2.5 Total Phosphorus at the Lower Cape Fear River Program mainstem stations, 1995-2010 versus 2011.

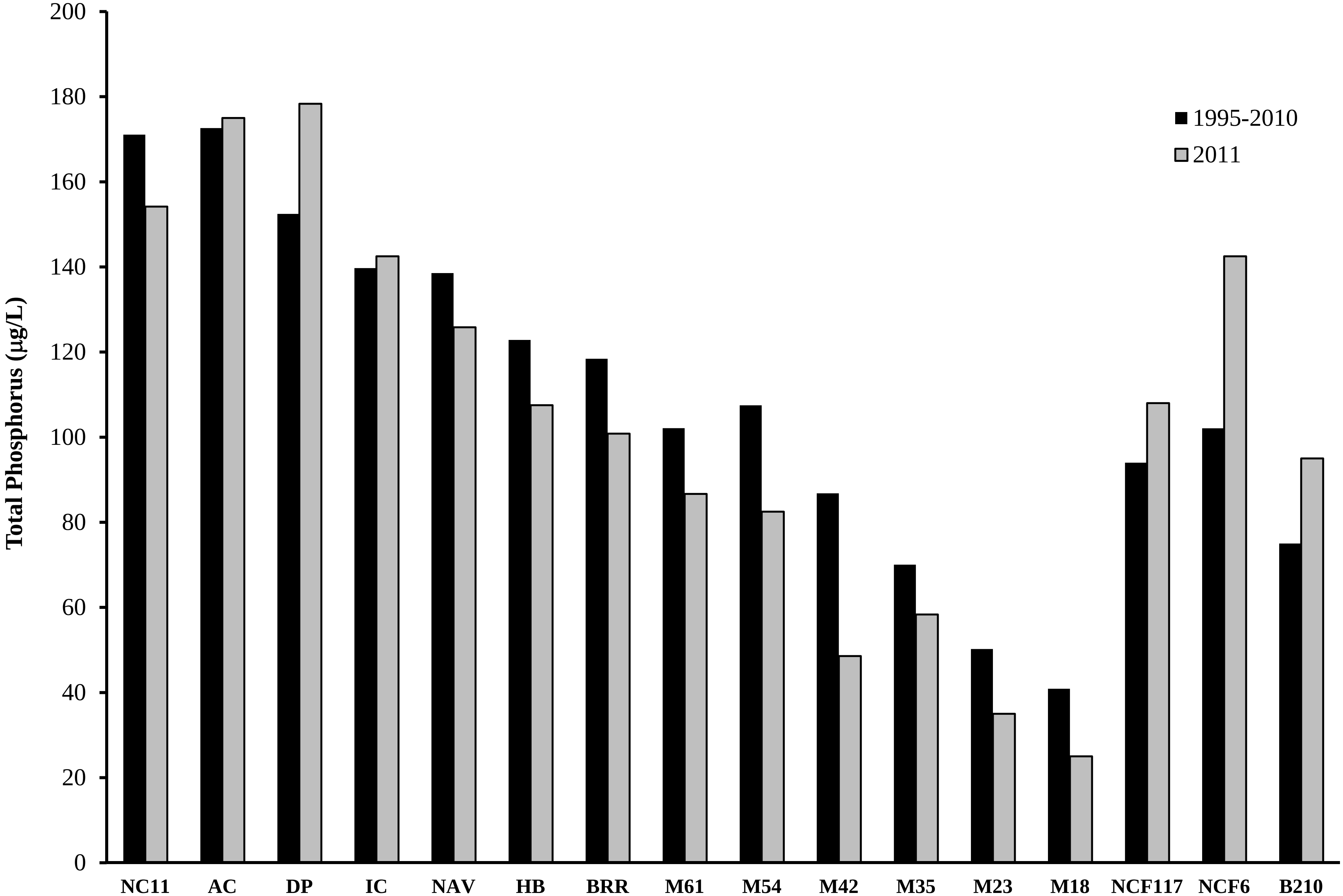


Table 2.14 Orthophosphate (μg/l) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	30	30	30	20	20	10	0	10	0	0
FEB	70	30	30	20	20	10	0	10	0	0
MAR	40	30	20	20	20	20	20	0	10	10
APR	50	50	50	40	30	30	20	10	10	10
MAY	50	60	50	30	20	40	30	20	10	10
JUN	30	30	30	30	20	10	10	0	10	10
JUL	60	50	50	50	50		20	20	10	
AUG	60	70	60	70	50		40	30	20	
SEP	70	80	90	80	80		60	40	30	
OCT	50	50	50	50	50		30	20	20	
NOV	70	70	60	60	50		40	20	20	
DEC	60	60	60	50	40	50	50	40	40	
mean	**53**	**51**	**48**	**43**	**38**	**24**	**27**	**18**	**15**	**7**
std dev	14	18	19	20	19	16	19	13	12	5
median	55	50	50	45	35	20	25	20	10	10
max	70	80	90	80	80	50	60	40	40	10
min	30	30	20	20	20	10	0	0	0	0

	NC11	AC	DP	BBT	IC	NCF6
JAN	60	80	80	60	70	10
FEB	70	60	80	50	30	10
MAR	30	60	80	30	50	30
APR	50	50	50	30	50	30
MAY	80	80	60	50	60	40
JUN	70	80	120	70	90	40
JUL	90	100	90	80	110	50
AUG	110	120	120	110	100	60
SEP	100	120	100	90	90	70
OCT	90	110	120	60	100	70
NOV	150	160	190	80	150	40
DEC	100	100	110	60	90	40
mean	**83**	**93**	**100**	**64**	**83**	**41**
std dev	31	31	37	24	33	20
median	85	90	95	60	90	40
max	150	160	190	110	150	70
min	30	50	50	30	30	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	30	10	0	20	60	30	50	260	10
FEB	60	50	20	40	40	0	80	320	0
MAR	60	30	20	40	80	10	170	610	30
APR	110	50	50	160	70	10	140	2,380	40
MAY	80	30	30	70	70	20	90	1,930	30
JUN	20	40	30	70	40	10	440	3,100	20
JUL	20	30	40	90	40		590	3,750	70
AUG	10	60	50	80	490	20	780	2,020	130
SEP	120	60	40	110	70	10	160	2,760	80
OCT	70	50	20	70	70	10	450	2,710	100
NOV	60	20	20	60	60	20	180	2,140	100
DEC	40	20	20	30	70	10	170	2,590	70
mean	**57**	**38**	**28**	**70**	**97**	**14**	**275**	**2,048**	**57**
std dev	35	17	15	38	125	8	233	1,113	41
median	60	35	25	70	70	10	170	2,260	55
max	120	60	50	160	490	30	780	3,750	130
min	10	10	0	20	40	0	50	260	0

	6RC	LCO	GCO	SR	BRN	HAM
JAN	10	10	30	0	10	20
FEB	30	10	40	30	10	50
MAR	20	10	90	10	30	30
APR	40	10	190	10	20	50
MAY	40	30	150	10	30	50
JUN	50	40	580	10	30	40
JUL	80	50	540	10	30	80
AUG	50	50	760	10	30	40
SEP	60	40	480	10	30	90
OCT	60	20	360	10	40	70
NOV	30	20	220	10	20	70
DEC	20	10	170	20	20	70
mean	**41**	**25**	**301**	**12**	**25**	**55**
std dev	20	16	239	7	9	21
median	40	20	205	10	30	50
max	80	50	760	30	40	90
min	10	10	30	0	10	20

	NCF117	B210	COL	LVC2
JAN		0	10	0
FEB		30	10	0
MAR	30	20	10	0
APR	20	20	10	0
MAY	80	40	20	10
JUN	50	40		20
JUL	20	50		20
AUG	10	50		10
SEP	130	60	100	10
OCT	70	60	40	10
NOV	30	50	10	10
DEC	40	20	0	10
mean	**48**	**37**	**23**	**8**
std dev	36	19	31	7
median	35	40	10	10
max	130	60	100	20
min	10	0	0	0

Table 2.15 Chlorophyll *a* (µg/l) during 2011 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	7	9	8	10	11	13	13	17	14	15
FEB	14	9	9	15	18	18	21	21	16	10
MAR	7	5	4	3	4	3	3	8	12	7
APR	3	4	4	4	5	6	8	7	8	6
MAY	5	3	4	3	6	8	7	8	5	5
JUN	9	8	23	6	7	6	15	7	7	7
JUL	15	29	16	19	38		25	8	8	
AUG	5	8	10	10	18		21	7	7	
SEP	2	3	7	4	4		8	9	7	
OCT	4	10	6	3	3		3	3	5	
NOV	3	3	3	3	4		6	3	3	
DEC	2	2	2	2	2		2	6	6	
mean	**6**	**8**	**8**	**7**	**10**	**9**	**11**	**9**	**8**	**8**
std dev	4	7	6	5	10	5	8	5	4	3
median	5	7	7	4	6	7	8	8	7	7
max	15	29	23	19	38	18	25	21	16	15
min	2	2	2	2	2	3	2	3	3	5

	NC11	AC	DP	BBT	IC	NCF6
JAN	10	14	9	9	8	3
FEB	8	8	7	4	5	3
MAR	7	7	7	5	6	2
APR	4	4	3	2	2	2
MAY	1	1	1	0	1	2
JUN	18	8	12	9	11	18
JUL	13	5	6	4	3	5
AUG	22	8	9	9	13	10
SEP	4	5	2	2	2	2
OCT	2	2	3	1	2	1
NOV	2	1	1	1	1	4
DEC	2	2	1	1	1	3
mean	**8**	**5**	**5**	**4**	**5**	**5**
std dev	7	4	4	3	4	5
median	6	5	5	3	3	3
max	22	14	12	9	13	18
min	1	1	1	0	1	1

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	3	11	7	11	9	13	4	6	2
FEB	2	3	2	5	9	6	1	2	1
MAR	5	1	1	2	3	3	1	2	0
APR	10	1	4	1	39	1	1	1	1
MAY	6	1	2	1	6	1	0	0	1
JUN	74	1	11	5	20	1	0	2	18
JUL	25	30	28	50	67		1	1	36
AUG	15	2	4	5	29	1	3	2	34
SEP	5	4	14	5	4	1	1	1	25
OCT	2	1	2	2	2	1	1	1	6
NOV	2	1	1	3	34	1	1	2	7
DEC	2	1	1	3	3	2	1	1	1
mean	**13**	**5**	**6**	**8**	**19**	**3**	**1**	**2**	**11**
std dev	20	8	8	13	19	4	1	1	13
median	5	1	3	4	9	1	1	2	4
max	74	30	28	50	67	13	4	6	36
min	2	1	1	1	2	1	0	0	0

	6RC	LCO	GCO	SR	BRN	HAM
JAN	4	1	3	2	9	3
FEB	5	3	5	9	5	9
MAR	1	1	1	2	1	1
APR	1	1	2	3	1	1
MAY	0	0	1	1	0	0
JUN	1	0	3	12	0	1
JUL	1	0	1	46	1	7
AUG	1	1	2	34	1	23
SEP	1	1	3	83	0	6
OCT	1	0	2	15	1	1
NOV	1	0	2	91	1	1
DEC	1	1	2	11	1	2
mean	**2**	**1**	**2**	**26**	**2**	**5**
std dev	1	1	1	30	3	6
median	1	1	2	12	1	2
max	5	3	5	91	9	23
min	0	0	1	1	0	0

	NCF117	B210	COL	LVC2
JAN		5	2	2
FEB		4	2	1
MAR	0	1	4	1
APR	1	2	2	1
MAY	1	1	1	13
JUN	1	0		1
JUL	5	3		8
AUG	9	4		9
SEP	1	1	1	1
OCT	1	1	1	1
NOV	1	0	0	1
DEC	1	0	1	1
mean	**2**	**2**	**2**	**3**
std dev	3	2	1	4
median	1	1	1	1
max	9	5	4	13
min	0	0	0	1

Figure 2.6 Chlorophyll *a* at the Lower Cape Fear River Program mainstem stations,1995-2010 versus 2011.

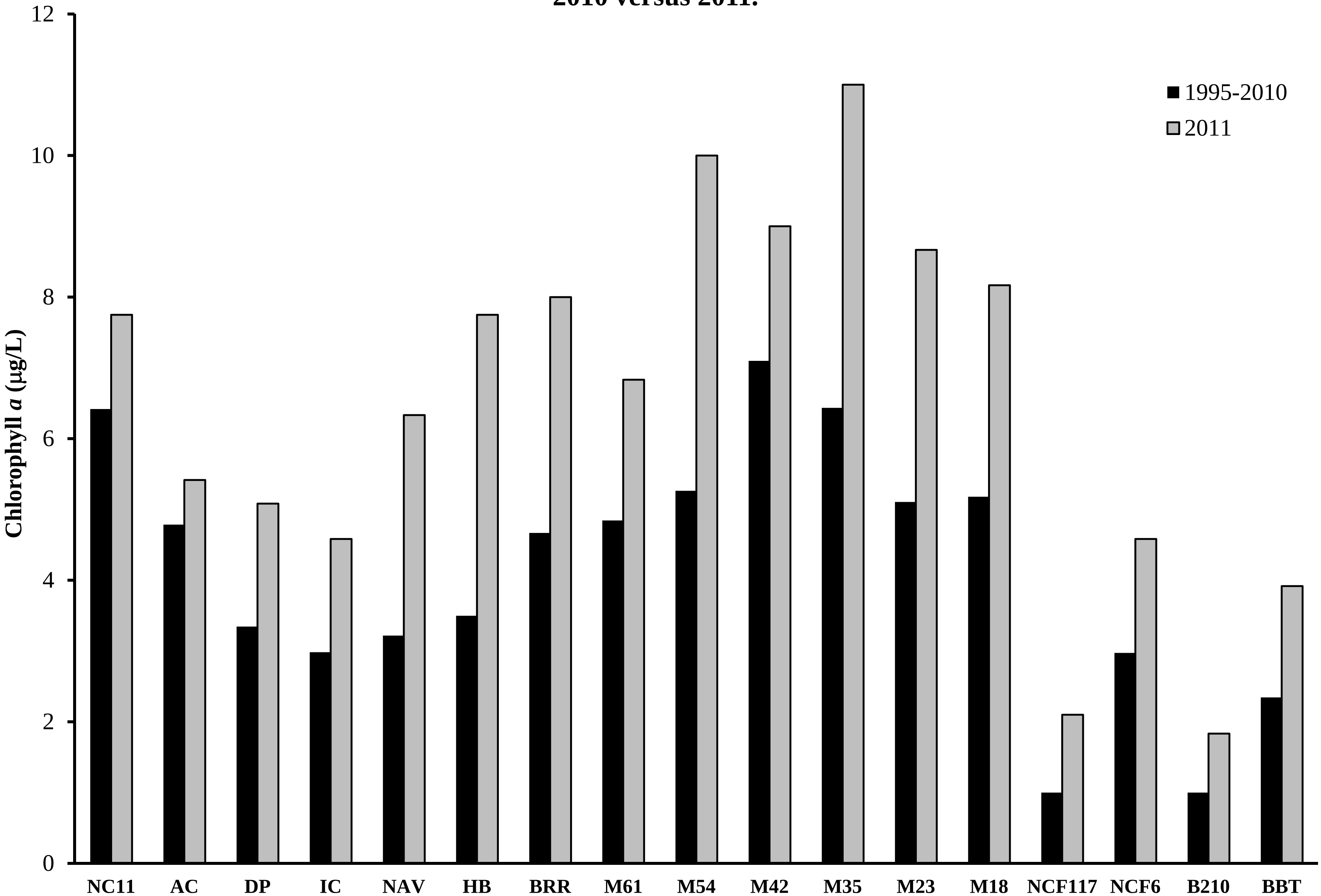


Table 2.16 Biochemical Oxygen Demand (mg/l) during 2011 at the Lower Cape Fear River Program stations.

5-Day Biochemical Oxygen Demand

	NC11	AC	NCF117	B210	LVC2	BBT
JAN	1.5	1.4		1.0	2.6	1.6
FEB	1.8	1.9				1.5
MAR			1.3	1.1	1.4	
APR	1.5	1.2	1.3	1.2	1.5	1.2
MAY	0.9	1.4	4.1	1.6	4.0	1.2
JUN	2.8	1.1	0.5	1.4	1.1	1.1
JUL	1.8	0.9	1.4	1.9	2.7	1.1
AUG	2.1	2.7	0.7	1.1	2.4	1.5
SEP	1.1	1.7	4.5	1.6	1.7	1.5
OCT	1.0	1.5	1.5	0.9	1.3	1.0
NOV	0.7	1.4	1.6	0.9	1.3	0.8
DEC	1.9	1.7	0.9	0.6	0.8	1.2
mean	1.6	1.5	1.8	1.2	1.9	1.2
stdev	0.6	0.5	1.4	0.4	0.9	0.3
median	1.5	1.4	1.4	1.1	1.5	1.2
max	2.8	2.7	4.5	1.9	4.0	1.6
min	0.7	0.9	0.5	0.6	0.8	0.8

20-Day Biochemical Oxygen Demand

	NC11	AC	NCF117	B210	LVC2	BBT
JAN	3.2	3.4		2.2	9.0	4.2
FEB	4.1	4.3				3.6
MAR			4.5	2.7	3.5	
APR	3.7	3.4	4.0	2.8	3.6	3.3
MAY	4.1	3.1	5.6	3.8	8.3	3.2
JUN	5.3	3.0	1.9	2.5	2.9	2.9
JUL	6.8	3.1	3.0	3.6	7.8	3.4
AUG	5.0	7.0	1.6	2.5	8.0	3.7
SEP	3.0	5.3	8.1	4.6	6.8	4.1
OCT						
NOV	1.9	3.8	4.0	2.1	3.6	2.5
DEC	4.0	4.3	2.6	1.9	3.5	3.1
mean	4.1	4.1	3.9	2.9	5.7	3.4
stdev	1.4	1.3	2.0	0.9	2.5	0.5
median	4.1	3.6	4.0	2.6	5.2	3.4
max	6.8	7.0	8.1	4.6	9.0	4.2
min	1.9	3.0	1.6	1.9	2.9	2.5

Table 2.17 Fecal Coliform/Enterococcus (cfu/100 ml) during 2011 at the Lower Cape Fear River Program stations. Enterococcus analysis at saltwater stations began in September, in italics.

	NAV	HB	BRR	M61	M54	M42	M35	M23	M18	SPD
JAN	19	37	5	10	10	5	5	5	5	5
FEB	5	5	5	5	10	10	5	5	5	5
MAR	55	46	46	19	55	28	5	10	5	10
APR	127	118	91	73	19	5	127	19	10	10
MAY	10	28	37	10	10	10	5	5	5	5
JUN	5	19	5	5	10	10	5	5	5	5
JUL	290	118	109	37	37		5	5	5	
AUG	46	5	46	10	5		5	5	10	
SEP	46	28	*55*	*46*	*19*		*10*	*5*	*10*	
OCT	181	181	*82*	*55*	*46*		*10*	*5*	*10*	
NOV	37	5	*37*	*5*	*5*		*5*	*5*	*5*	
DEC	118	46	*10*	*10*	*46*		*10*	*10*	*5*	
mean	**78**	**53**	**44**	**24**	**23**	**11**	**16**	**7**	**7**	**7**
std dev	83	54	34	22	17	8	33	4	2	2
max	290	181	109	73	55	28	127	19	10	10
min	5	5	5	5	5	5	5	5	5	5
Geomean	40	29	27	15	16	9	8	6	6	6

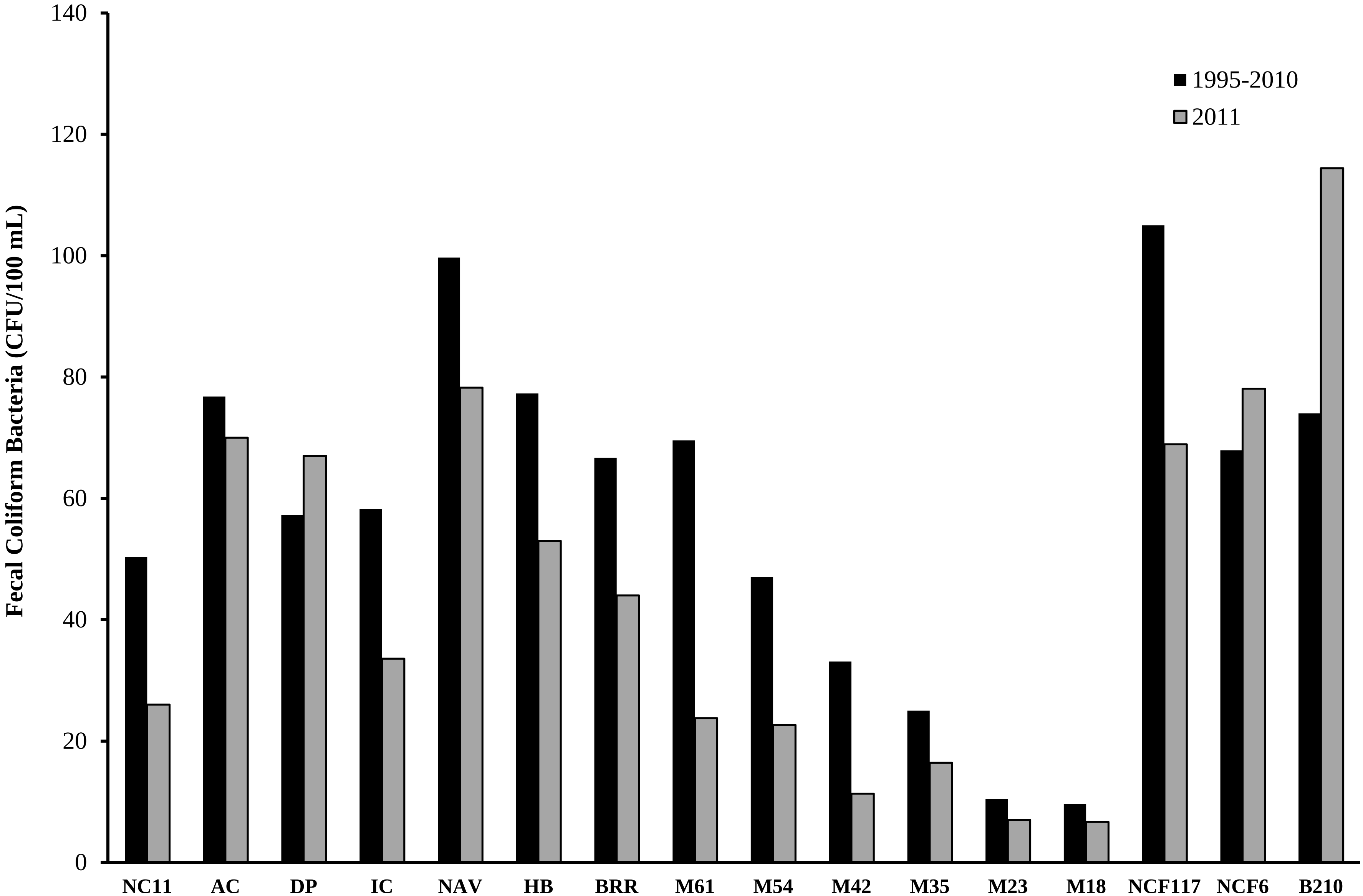
	NC11	AC	DP	IC	NCF6
JAN	5	5	19	28	5
FEB	28	28	10	55	91
MAR	19	1	19	64	55
APR	28	10	10	37	5
MAY	5	19	19	28	154
JUN	37	19	390	10	240
JUL	37	37	136	5	181
AUG	15	29	80	37	22
SEP	5	28	19	10	10
OCT	5	10	19	37	10
NOV	10	590	46	37	10
DEC	118	64	37	55	154
mean	**26**	**70**	**67**	**34**	**78**
std dev	30	158	104	18	80
max	118	590	390	64	240
min	5	1	10	5	5
Geomean	16	21	33	27	34

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	55	82	46	5	82	546	91	220	310
FEB	28	28	19	73	64	28	64	163	220
MAR	109	210	19	28	390	455	118	28	100
APR	46	82	118	64	220	546	136	300	10
MAY	73	46	73	73	60000	230	163	55	82
JUN	273	109	273	273	819	273	127	819	637
JUL	210	2100	728	3900	1360		127	546	819
AUG	136	136	1640	28	60000	190	280	570	9000
SEP	109	127	63	36	1000	63	270	136	27
OCT	118	199	37	37	1000	37	154	250	28
NOV	145	136	19	91	530	28	28	240	5
DEC	81	54	18	63	210	118	154	154	118
mean	**115**	**276**	**254**	**389**	**10,473**	**229**	**143**	**290**	**946**
std dev	67	553	461	1,061	22,153	194	70	226	2,441
max	273	2,100	1,640	3,900	60,000	546	280	819	9,000
min	28	28	18	5	64	28	28	28	5
Geomean	97	122	76	69	875	138	123	204	123

	6RC	LCO	GCO	SR	BRN	HAM
JAN	230	82	19	10	145	270
FEB	240	220	136	28	46	163
MAR	181	290	73	64	127	154
APR	28	55	46	46	109	154
MAY	100	82	19	136	199	410
JUN	91	37	46	82	546	1091
JUL	220	127	91	280	2700	2500
AUG	127	82	240	73	1000	55
SEP	330	135	490	550	260	406
OCT	81	81	54	136	118	350
NOV	100	91	230	460	310	3900
DEC	46	64	55	163	210	580
mean	**148**	**112**	**125**	**169**	**481**	**836**
std dev	88	70	131	166	715	1,126
max	330	290	490	550	2,700	3,900
min	28	37	19	10	46	55
Geomean	120	96	79	100	248	407

	NCF117	B210	COL	LVC2	SC-CH
JAN		82	37	55	73
FEB		19	19	64	73
MAR	46	64	55	46	64
APR	5	100	37	37	100
MAY	46	64	64	91	64
JUN	55	28		10	37
JUL	190	570		580	5300
AUG	82	109		118	55
SEP	199	118	37	390	728
OCT	19	82	73	55	230
NOV	28	91	100	100	390
DEC	19	46	37	28	46
mean	**69**	**114**	**51**	**131**	**597**
std dev	66	140	23	166	1,431
max	199	570	100	580	5,300
min	5	19	19	10	37
Geomean	42	77	46	73	143

Figure 2.7 Fecal Coliform Bacteria at the Lower Cape Fear River Program mainstem stations, 1995-2010 versus 2011.



3.0 Water Quality Evaluation by Subbasin in the Lower Cape Fear River System, 2011

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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 2011 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 next basinwide plan is scheduled to be completed in late 2012.

The goals of the basinwide program are to:
- -Identify water quality problems and restore full use to impaired waters.
- -Identify and protect high value resource waters.
- -Protect unimpaired waters while allowing for reasonable economic growth.

DWQ accomplishes these goals through the following objectives:
- -Collaborate with other agencies to develop appropriate management strategies.
- -Assure equitable distribution of waste assimilative capacity.
- -Better evaluate cumulative effects of pollution.
- -Improve public awareness and involvement.

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

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

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

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

*Some of the NC State Water Quality standards are written with more specific criteria and the reader should refer to http://portal.ncdenr.org/web/wq/ps/csu 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/enterococcus bacteria, field turbidity and the nutrient species nitrate-nitrite (referred to as nitrate) and total phosphorus. For dissolved oxygen, chlorophyll *a* and fecal coliform/enterococcus bacteria LCFRP data is compared to the N.C. State Water Quality Standards which can be found at http://portal.ncdenr.org/web/wq/ps/csu. Fecal coliform/enterococcus bacteria data is compared using human contact standards. A one day value is compared to the standard which is based on a geometric mean of 5 samples over a 30 day period. Entercoccus analysis began in July of 2011 at stations BRR, M61, M54, M35, M23 and M18.

The NC DWQ does not have surface water quality standards for nitrate and total phosphorus. Therefore the AEL water quality standard is based on levels noted to be problematic in the scientific literature and our own published research. Based on data from four years of nutrient addition bioassay experiments using water from the Black and Northeast Cape Fear Rivers, Colly Creek and Great Coharie Creek, the UNCW-AEL considers total phophorus levels of 500 µg/L or greater potentially harmful to water quality in all the waters of the Cape FearRiver watershed. Nitrate levels of 200 µg/L, 500 µg/L and 1,000 µg/L in small streams, mainstem blackwater stations (NCF117, NCF6, B210) and mainstem Cape Fear River stations, respectively, are considered harmful to water quality. These nutrient levels may lead to algal blooms, high bacteria levels and high biochemical oxygen demand (BOD) in blackwater streams (Mallin et al., 2001; 2002; 2004). Water quality status for nutrient species at the mainstem Cape Fear River stations was evaluated with a higher standard for nutrients because its waters are quite different than the blackwater areas and are able to better assimilate higher nutrient levels.

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

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

The 36 stations monitored by the LCFRP by subbasin:

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

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

3.3 Cape Fear River Subbasin 03-06-16

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

LCFRP monitoring stations (DWQ #):
BRN (B8340050), HAM (B8340200), NC11 (B8360000)
NC DWQ monitoring stations (DWQ #):
Six ambient monitoring stations Subbasin 03-06-16 includes the Cape Fear River and many streams that drain coastal plain wetlands and bay lakes. Most of the watershed is forested with some agriculture pres

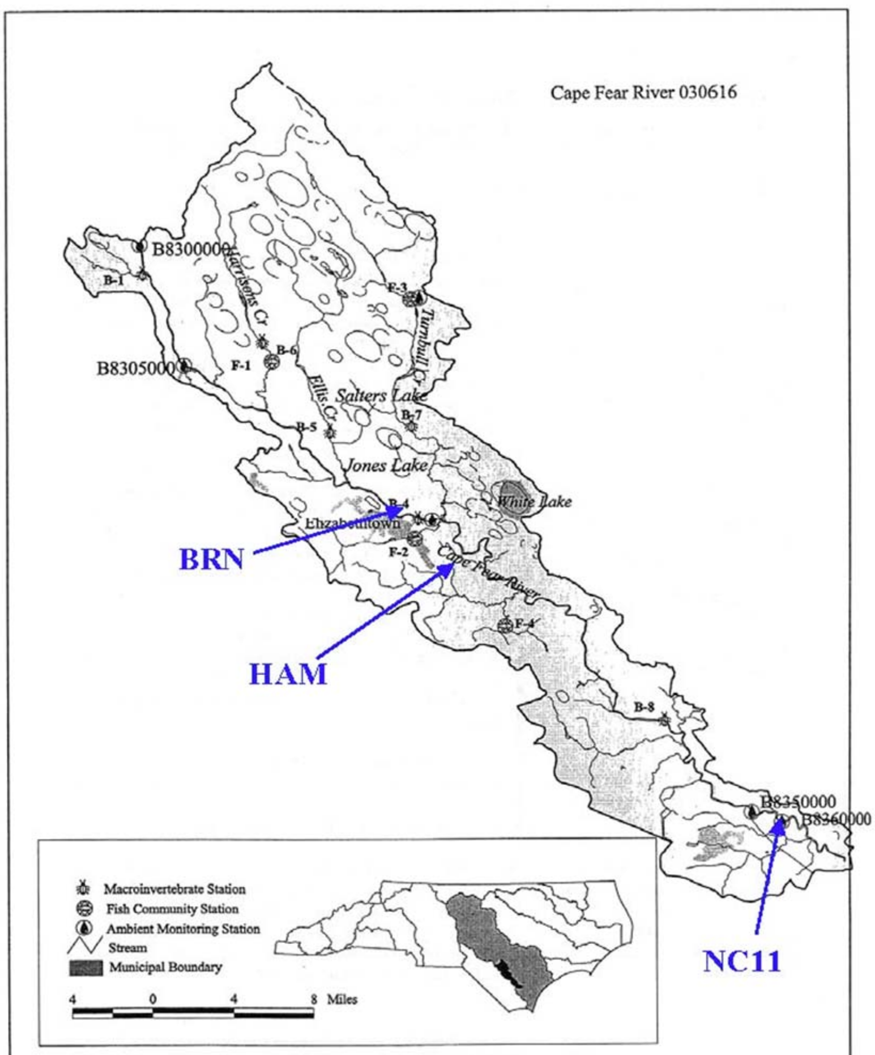


Figure B-16 Sampling Locations within Subbasin 03-06-16

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

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

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

UNCW Aquatic Ecology Laboratory Evaluation

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

BRN - representative of small tributaries

NC11 – Main stem of the Cape Fear River deep channel, freshwater with minor tidal influence

Dissolved oxygen ratings and chlorophyll *a* ratings for BRN, HAM and NC11 were all good for 2011 (Table 3.3.1).

For fecal coliform bacteria concentrations NC11 had a good rating (Table 3.3.1). BRN and HAM received poor ratings exceeding the standard 50% and 67% of the time, respectively (Figure 3.3.1).

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

For nitrate HAM was rated as good with only one sample exceeding the NC State Standard in 2011 (Table 3.3.1). NC11 was rated as fair, exceeding the standard 25% of the time. BRN received a poor rating exceeding the standard 75% of the time (Table, 3.3.1, Figure 3.3.1). All stations rated as good for total phosphorus.

Table 3.3.1 UNCW AEL 2011 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	G	G	P	G	G	G
NC11	G	G G		G	F	G

Figure 3.3.1 Fecal coliform bacteria concentrations at stations BRN and HAM for 2011. The dashed line represents the NC State Standard, 200 cfu/100 mL.

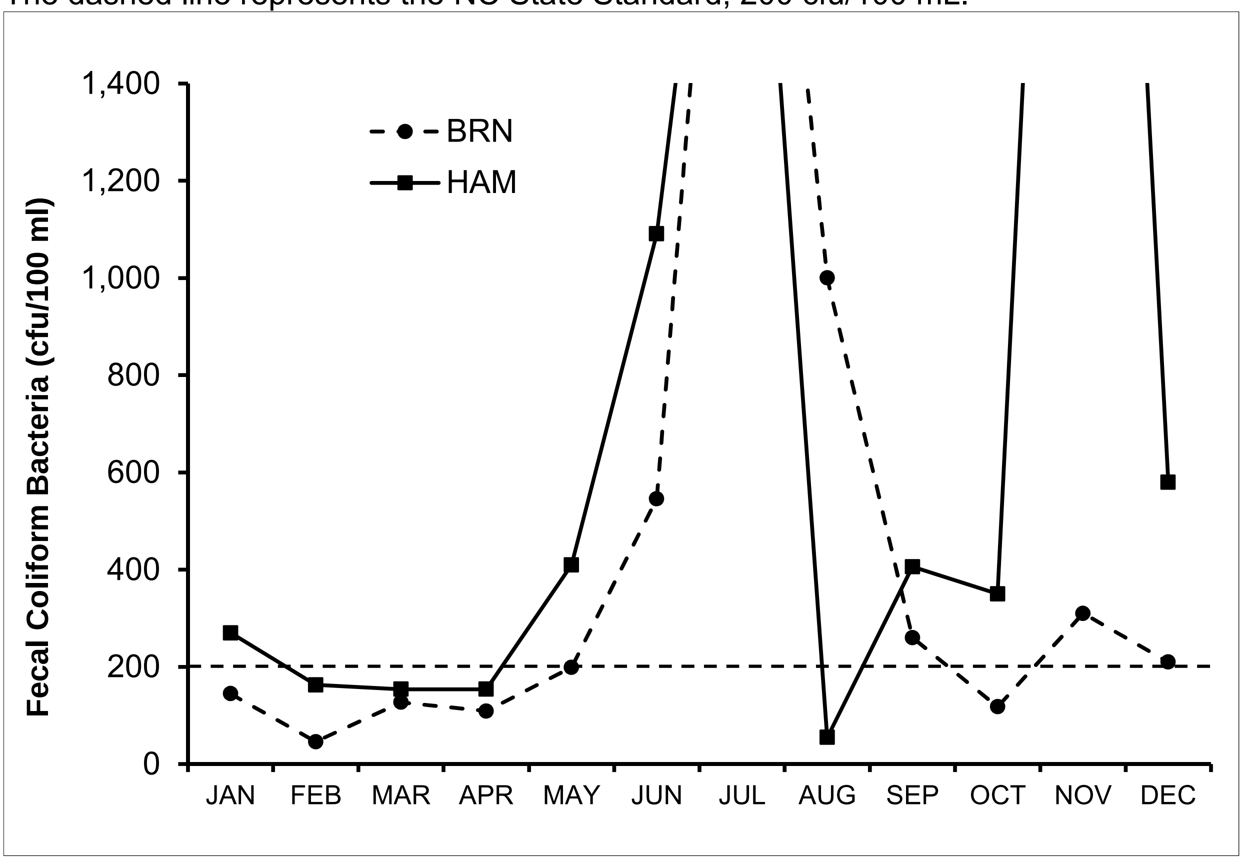
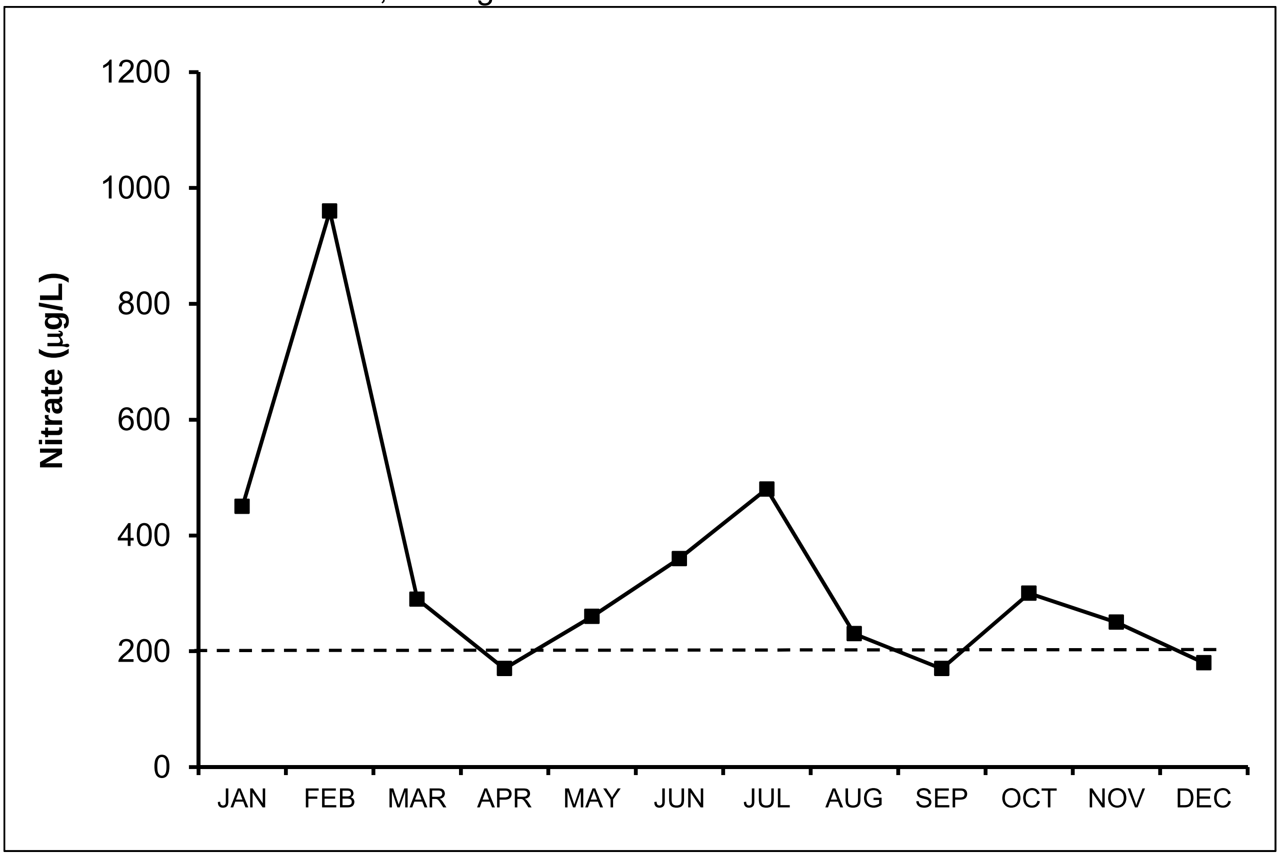
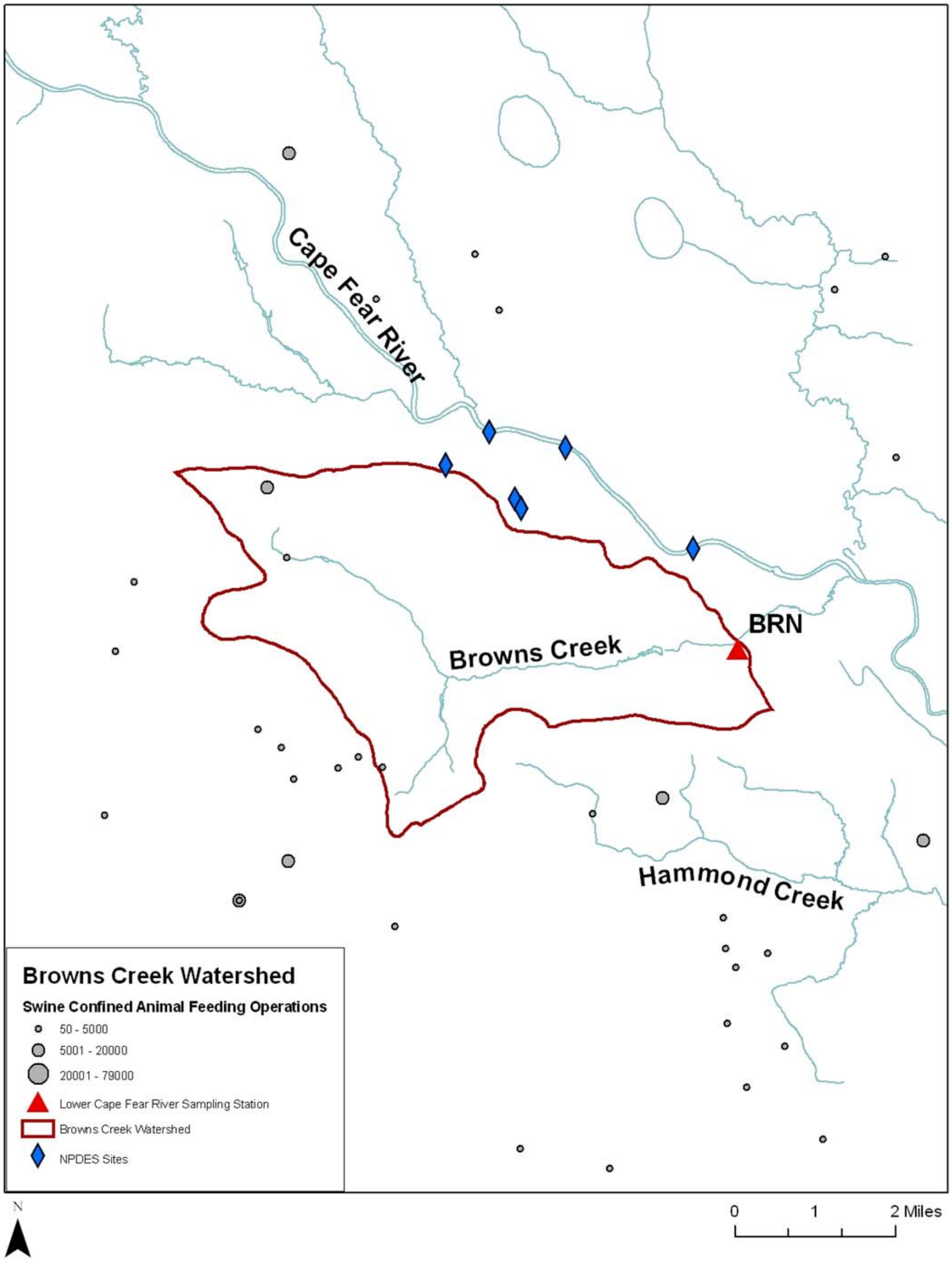
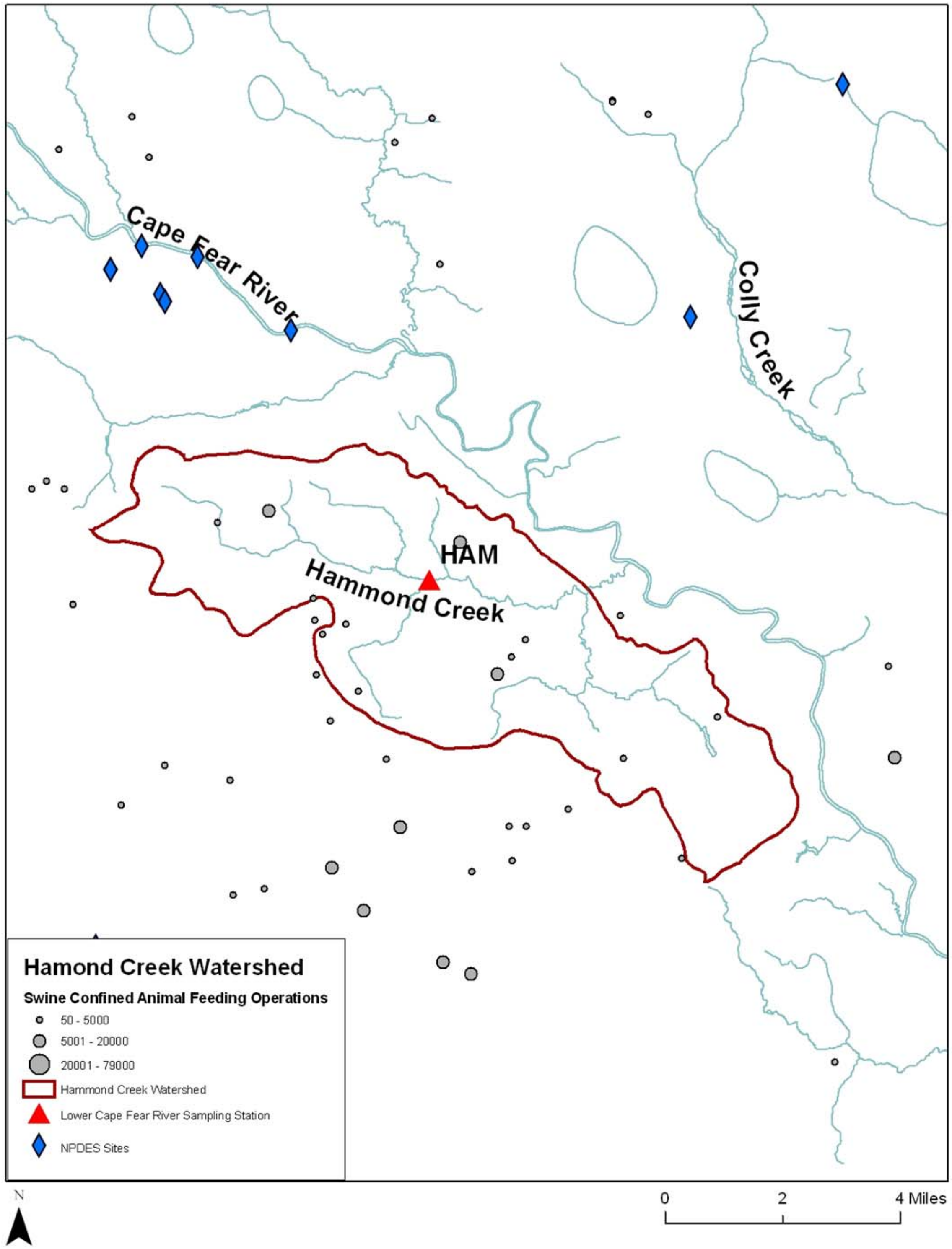


Figure 3.3.2 Nitrate concentrations at BRN for 2011. The dashed line represents the AEL stream standard for nitrate, 200 ug/L.





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


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

3.4 Cape Fear River Subbasin 03-06-17

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

LCFRP monitoring stations (DWQ #):

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

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

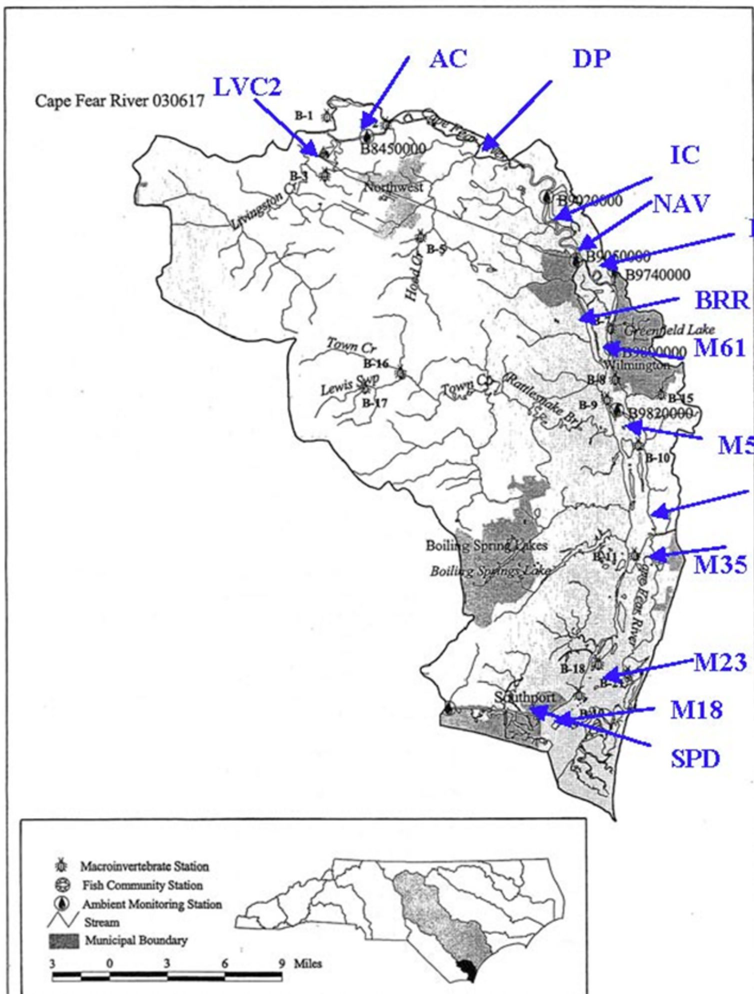


Figure B-17 Sampling Locations within Subbasin 03-06-17

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

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

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

UNCW Aquatic Ecology Laboratory Evaluation

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

AC – representative of riverine system channel

HB- upper estuary, upstream of Wilmington

M35 – represents wide estuary

Sites given a good rating for dissolved oxygen include AC, M54, M42, M35, M23, M18 and SPD (Table 3.4.1). Sites given a fair rating for dissolved oxygen, with the percentage of samples not meeting the standard shown in parentheses, are DP (17%), IC (17%), NAV (25%), HB (25%), M61 (17%) and BRR (25%). LVC2 was rated poor with samples below the standard 42% of the time (Figure 3.4.1).

All sites within this subbasin had a good rating for chlorophyll *a* concentrations (Table 3.4.1). No sample exceeded the 40 µg/L NC State Standard during 2011.

AC, DP, IC, NAV, HB, M42, M35, M23, M18 and SPD rated as good for fecal coliform/entercoccus bacteria (Table 3.4.1). LVC2, BRR, M61 and M54 rated as fair exceeding the NC state standard 17%, 25%, 17% and 17% of the time, respectively.

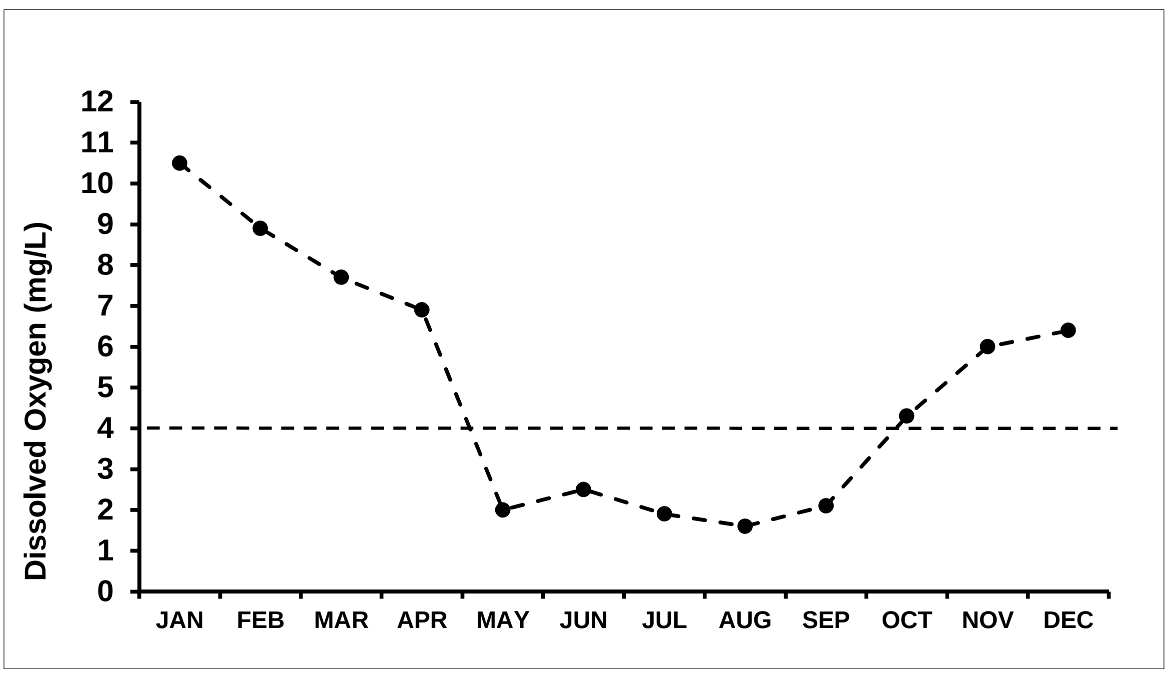
All sites within this subbasin rated good for field turbidity during 2011 except HB which exceeded the NC State Standard 17% of the time giving it a fair rating (Table 3.4.1).

The ten estuary stations were all rated as good for nitrate during 2011 (Table 3.4.1). AC, DP and IC were rated fair exceeding the UNCW-AEL recommended standard (1,000 µg/L for mainstem stations) 25%, 25% and 17% of the time, respectively. LVC2 was rated as poor for nitrate exceeding the UNCW-AEL recommended standard (200 µg/L for stream stations) 58% of the time (Table 3.4.1). All stations rated good for total phosphorus.

Table 3.4.1 UNCW AEL 20011 evaluation for subbasin 03-06-17

Station	Dissolved Oxygen	Chlorophyll *a*	Fec. Coli ECoccus	Field Turbidity	Nitrate	Total Phosphorus
LVC2	P	G	F	G	P	G
AC	G	G	G	G	F	G
DP	F	G	G	G	F	G
IC	F	G	G	G	F	G
NAV	F	G	G	G	G	G
HB	F	G	G	F	G	G
BRR	F	G	F	G	G	G
M61	F	G	F	G	G	G
M54	G	G	F	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

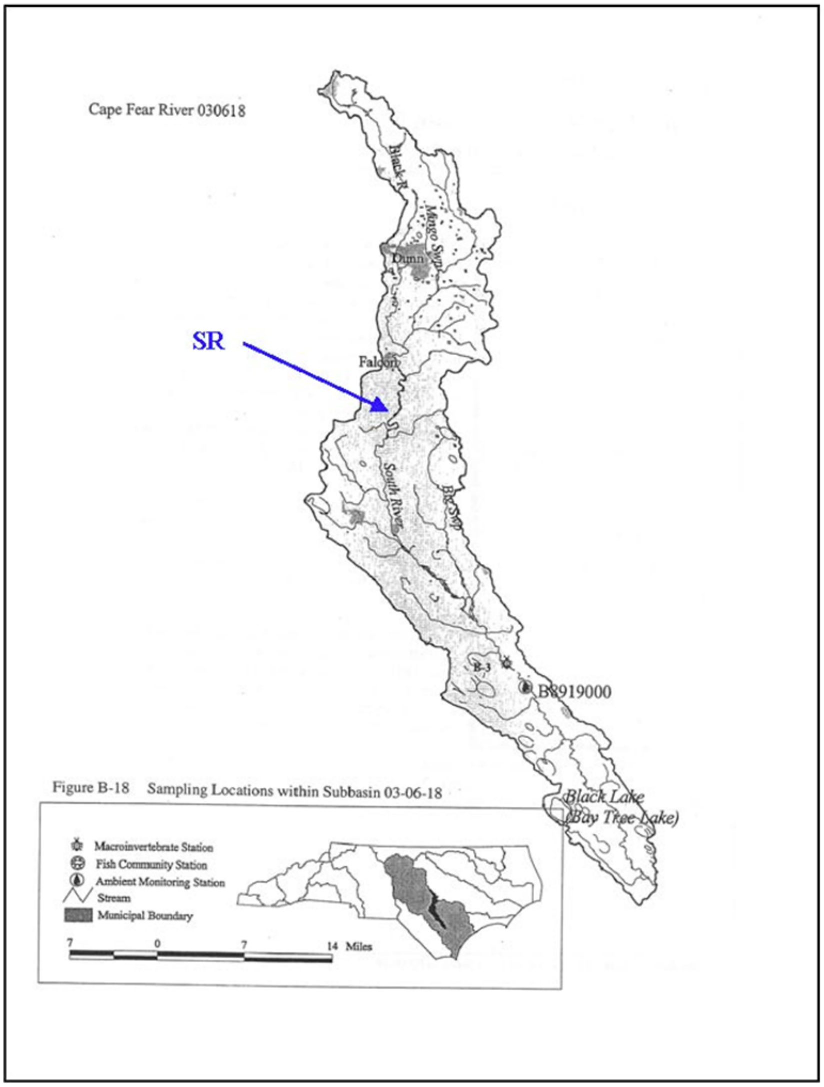
Figure 3.4.1 Dissolved oxygen concentrations at LVC2, rated poor for 2011. The dashed line shows the NC State Standard of 4.0 mg/L.



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



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

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

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

UNCW Aquatic Ecology Laboratory Evaluation

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

SR – a slow black water tributary

SR had a poor rating for dissolved oxygen concentrations in 2011 (Table 3.5.1). The NC State Standard for swampwater of 4.0 mg/L was exceeded 58% of the time (Figure 3.5.1).

SR had a fair rating for chlorophyll *a* exceeding the NC State standard of 40 µg/L 25% of the time (Table 3.5.1).

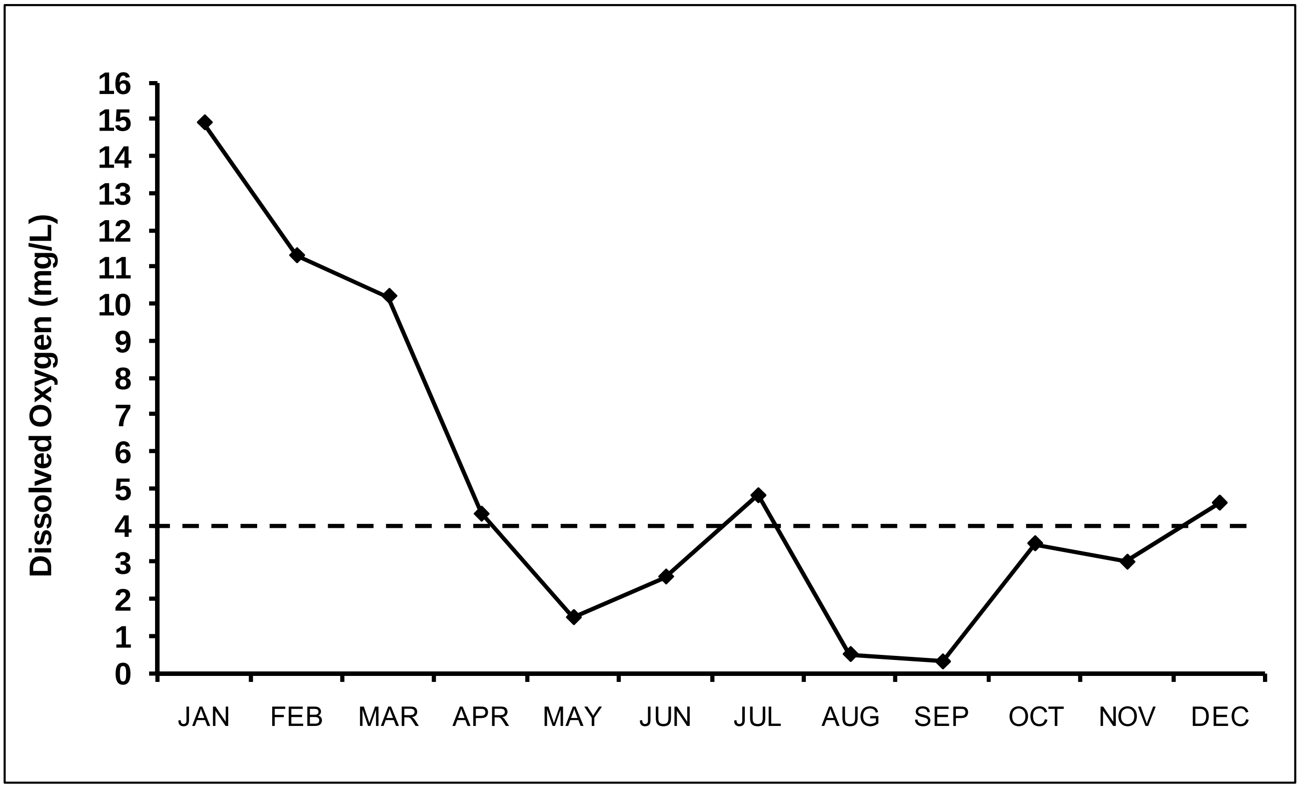
SR had a fair rating for fecal coliform bacteria concentrations exceeding the NC state standard of 200 CFU/100mL in 25% of samples (Table 3.5.1). The highest concentration was in September (550 cfu/100mL).

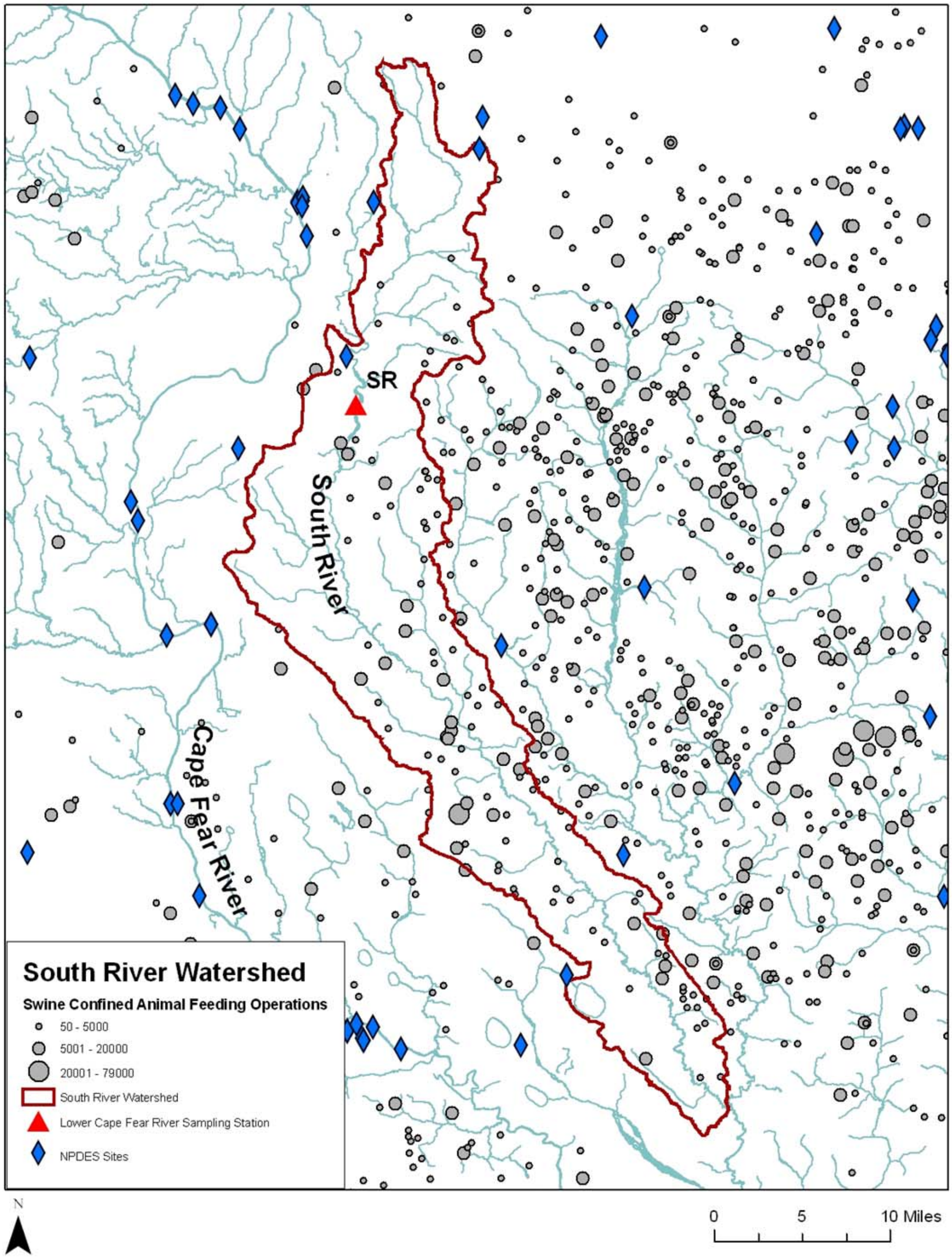
SR had a fair rating for field turbidity exceeding the NC state standard 17% of the time.

Nitrate and total phosphorus were rated as good during 2011 (Table 3.5.1).

Table 3.5.1 UNCW AEL 2011 evaluation for subbasin 03-06-18						
Station	Dissolved Oxygen	Chlorophyll *a*	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
SR	P	F	F	F	G	G

Figure 3.5.1 Dissolved oxygen (mg/L) at SR during 2011. The dashed line shows the NC state standard for swampwater DO of 4.0 mg/L.




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
SR
South River
Cape Fear River
N
0
5
10 Miles

3.6 Cape Fear River Subbasin 03-06-19

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

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

DWQ monitoring stations: none

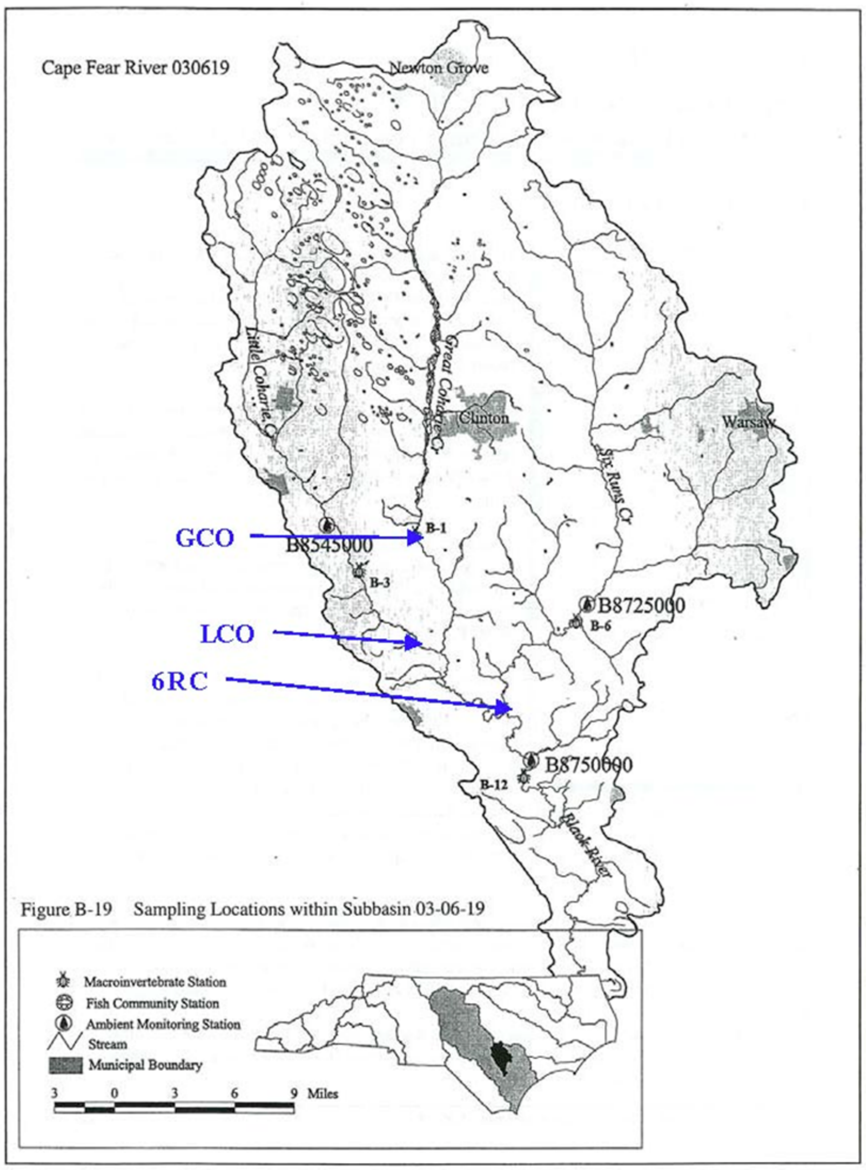


Figure B-19 Sampling Locations within Subbasin 03-06-19

This subbasin is located in the coastal plain within Sampson County. Land adjacent to the Black River is primarily undisturbed forest. There are numerous concentrated swine operations within this subbasin.

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

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

UNCW Aquatic Ecology Laboratory Evaluation

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

GCO - blackwater stream, drains riparian wetlands

6RC, LCO and GCO all had a good rating for dissolved oxygen, chlorophyll *a* and field turbidity concentrations during 2011 (Table 3.6.1).

LCO and GCO had a fair rating for fecal coliform bacteria during 2011exceeding the NC state standard 17% and 25 % of the time, respectively. 6RC had a poor rating for fecal coliform bacteria with 33% of samples exceeding the NC state human contact standard of 200 CFU/100mL (Table 3.6.1, Figure 3.6.1).

Nitrate levels were rated poor at 6RC, LCO and GCO exceeding 200 µg/L in 75%, 58%, and 50% of the samples, respectively (Table 3.6.1, Figure 3.6.1). 6RC and LCO had a good rating for total phosphorus concentrations, while GCO rated as poor with 42% of samples exceeding the UNCW-AEL recommended standard of 500 µg/L (Table 3.6.2).

Table 3.6.1 UNCW AEL 2011 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	G	G	F	G	P	P

Figure 3.6.1 Fecal coliform bacteria concentrations at 6RC during 2011. The dashed line shows the NC state standard of 200 cfu/100 mL.

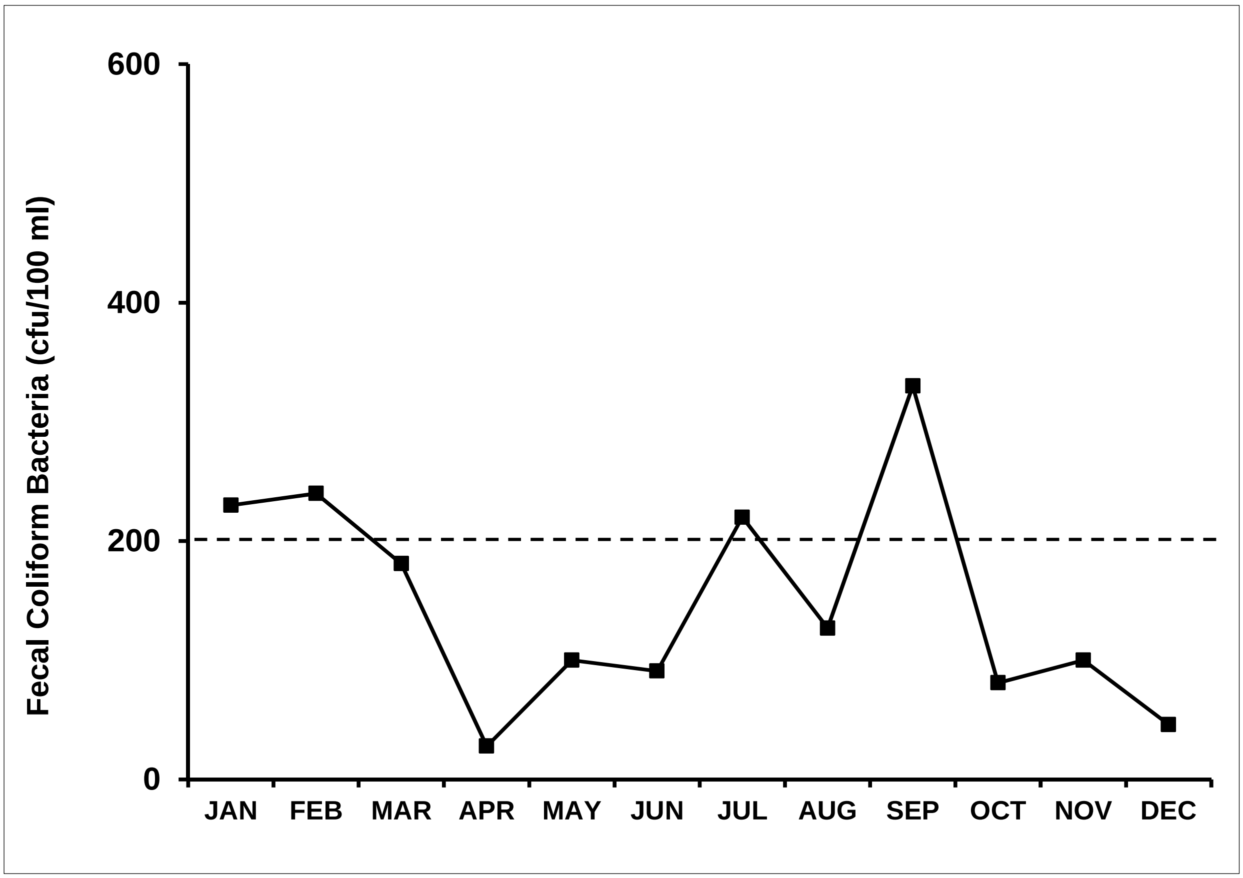
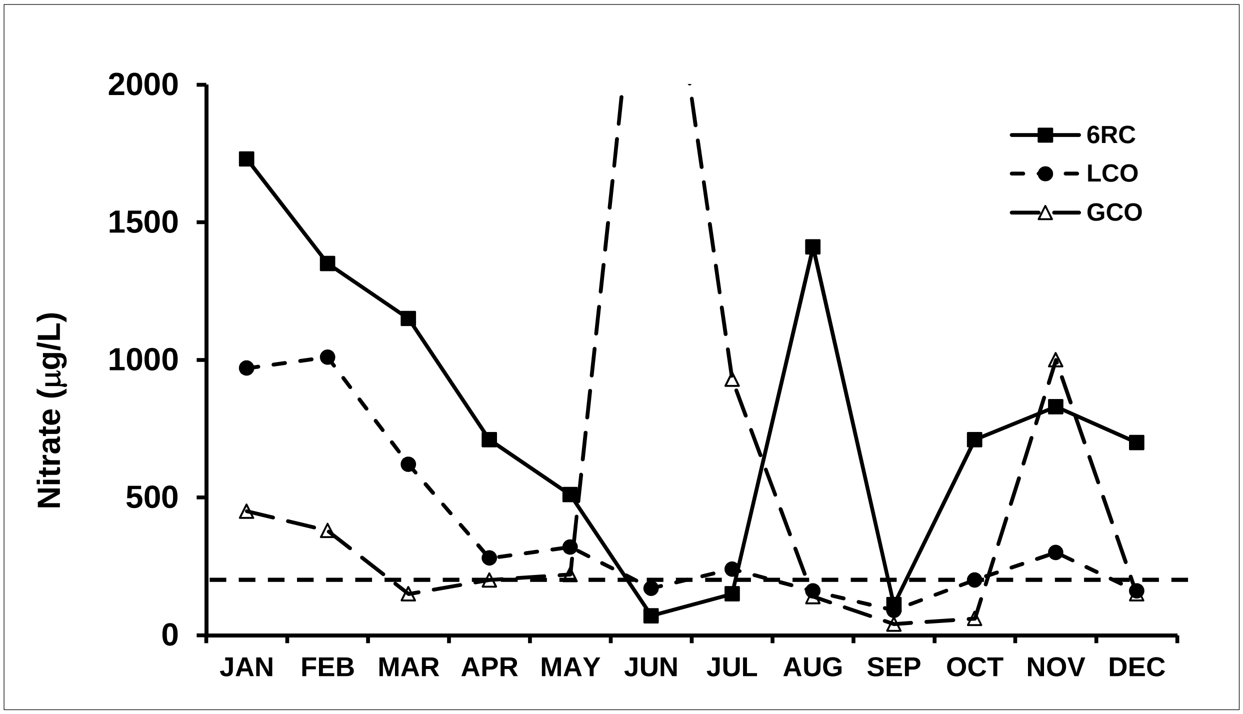
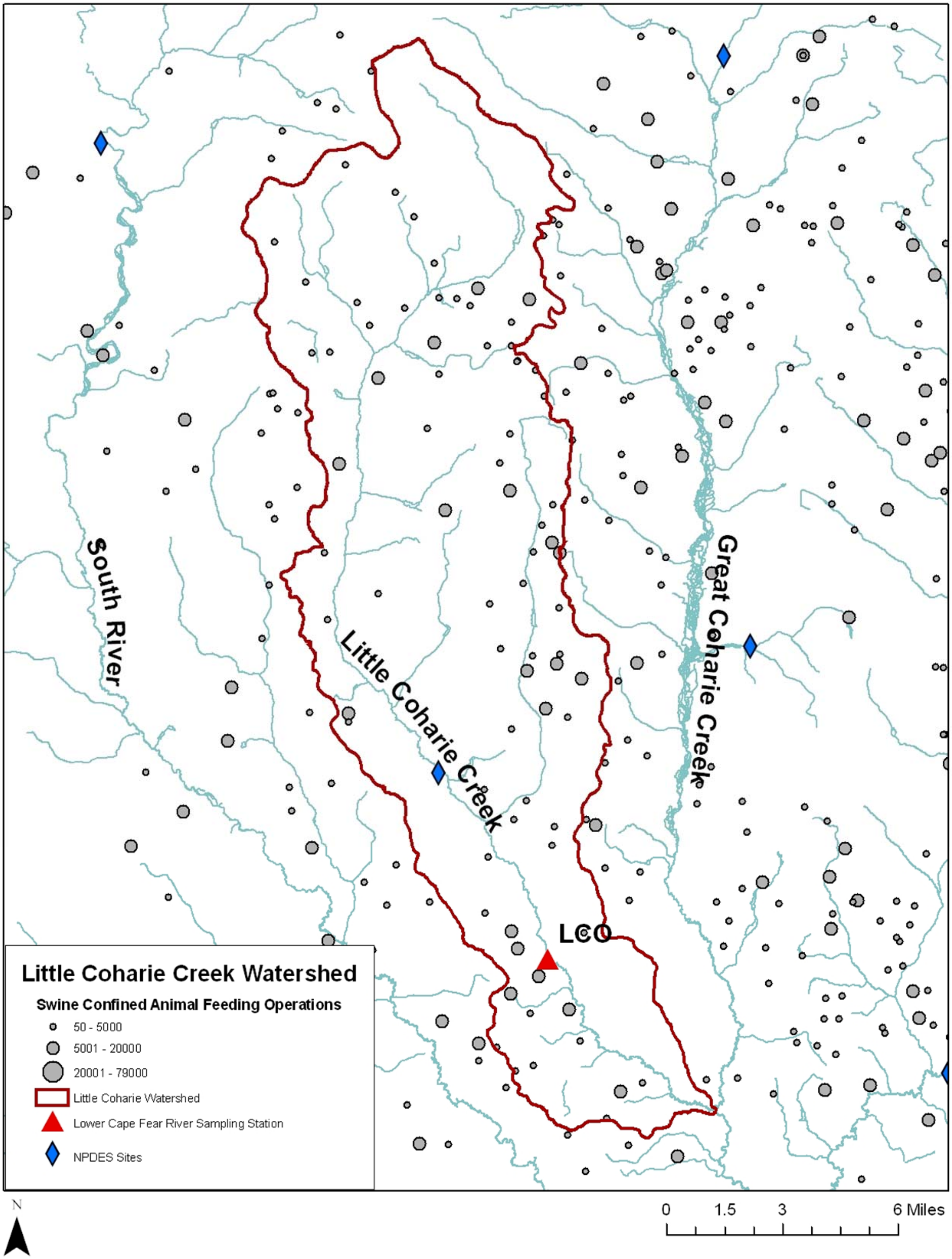
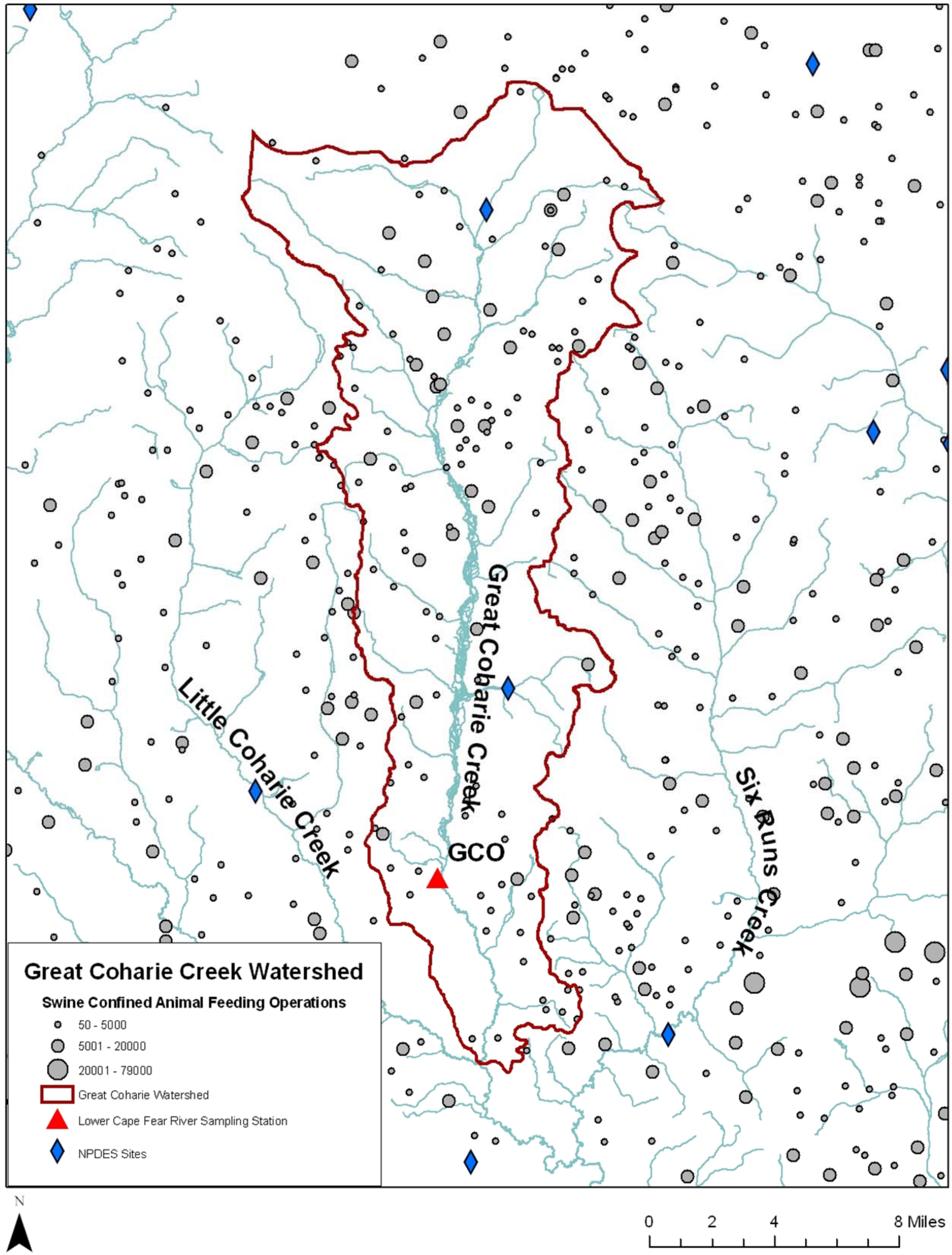
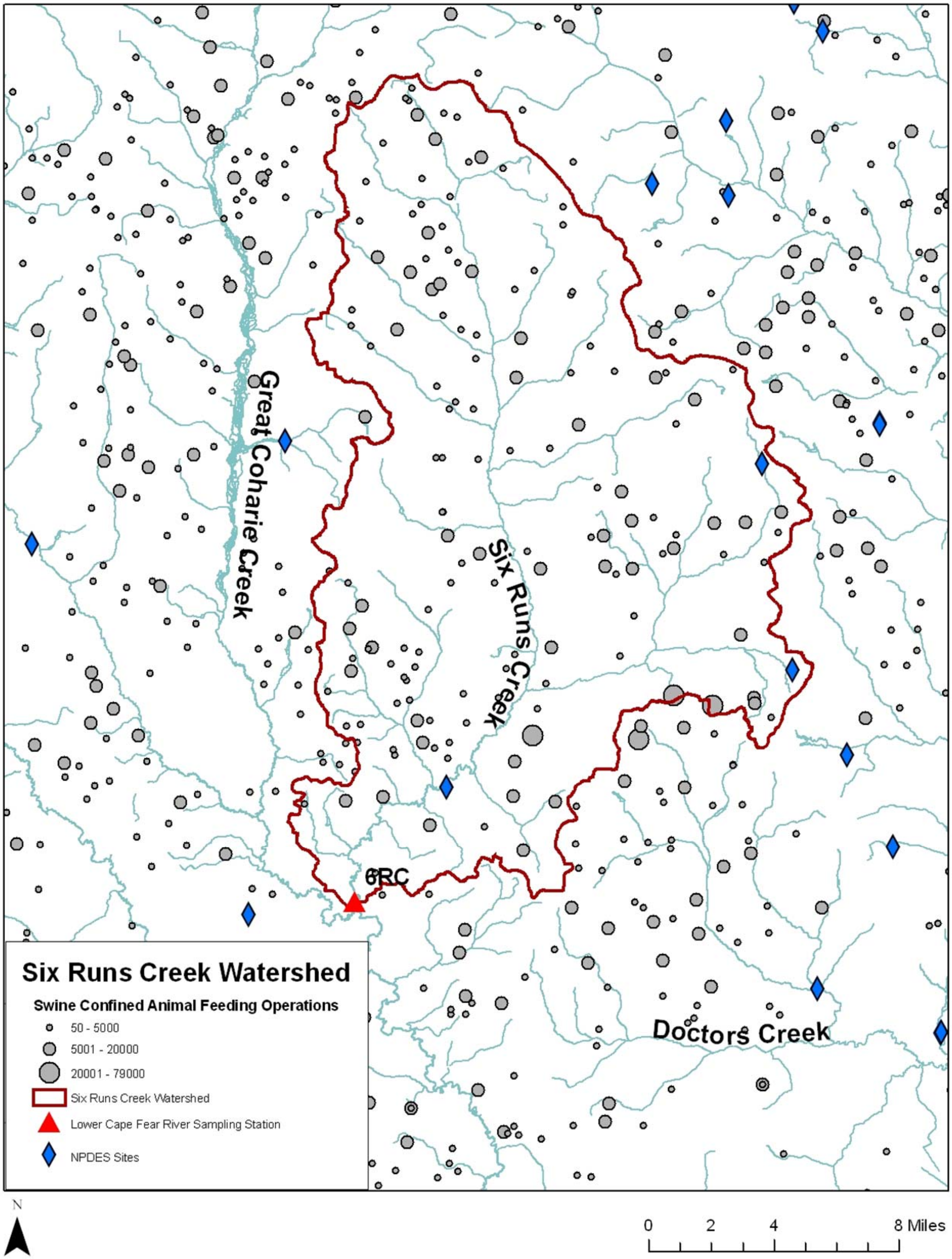


Figure 3.6.2 Nitrate concentrations (µg/L) at 6RC, LCO, and GCO during 2011. The dashed line shows the UNCW-AEL standard of 200 µg/L.




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
Little Coharie Creek
Six Runs Creek
GCO
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
N
0
2
4
8 Miles


Great Coharie Creek
Six Runs Creek
Doctors Creek
6RC
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

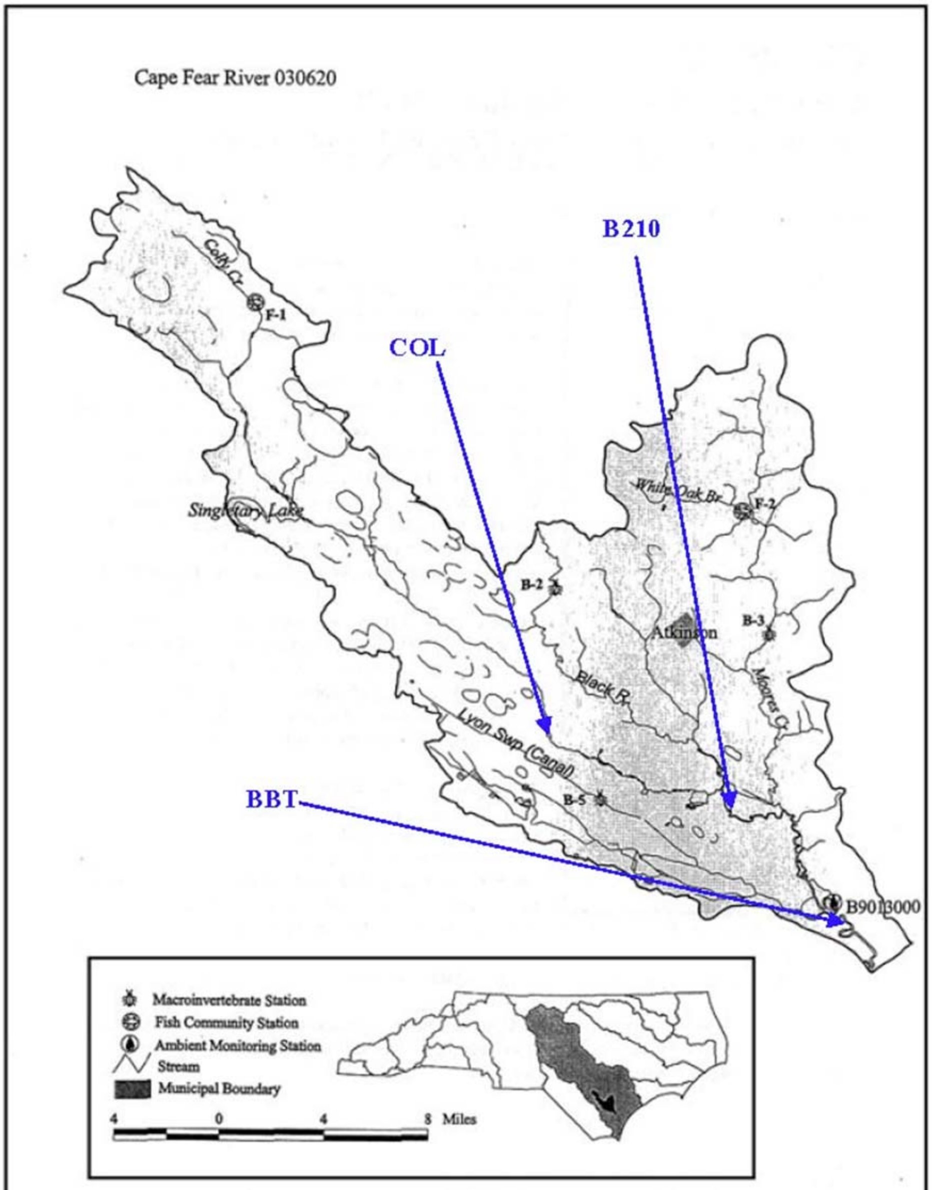


Figure B-20 Sampling Locations within Subbasin 03-06-20

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

B210 and COL had a good rating for dissolved oxygen in 2011. BBT had a fair rating as dissolved oxygen concentration dropped below the NC state standard for swampwaters of 4.0 mg/L 17% of the time (Table 3.7.1).

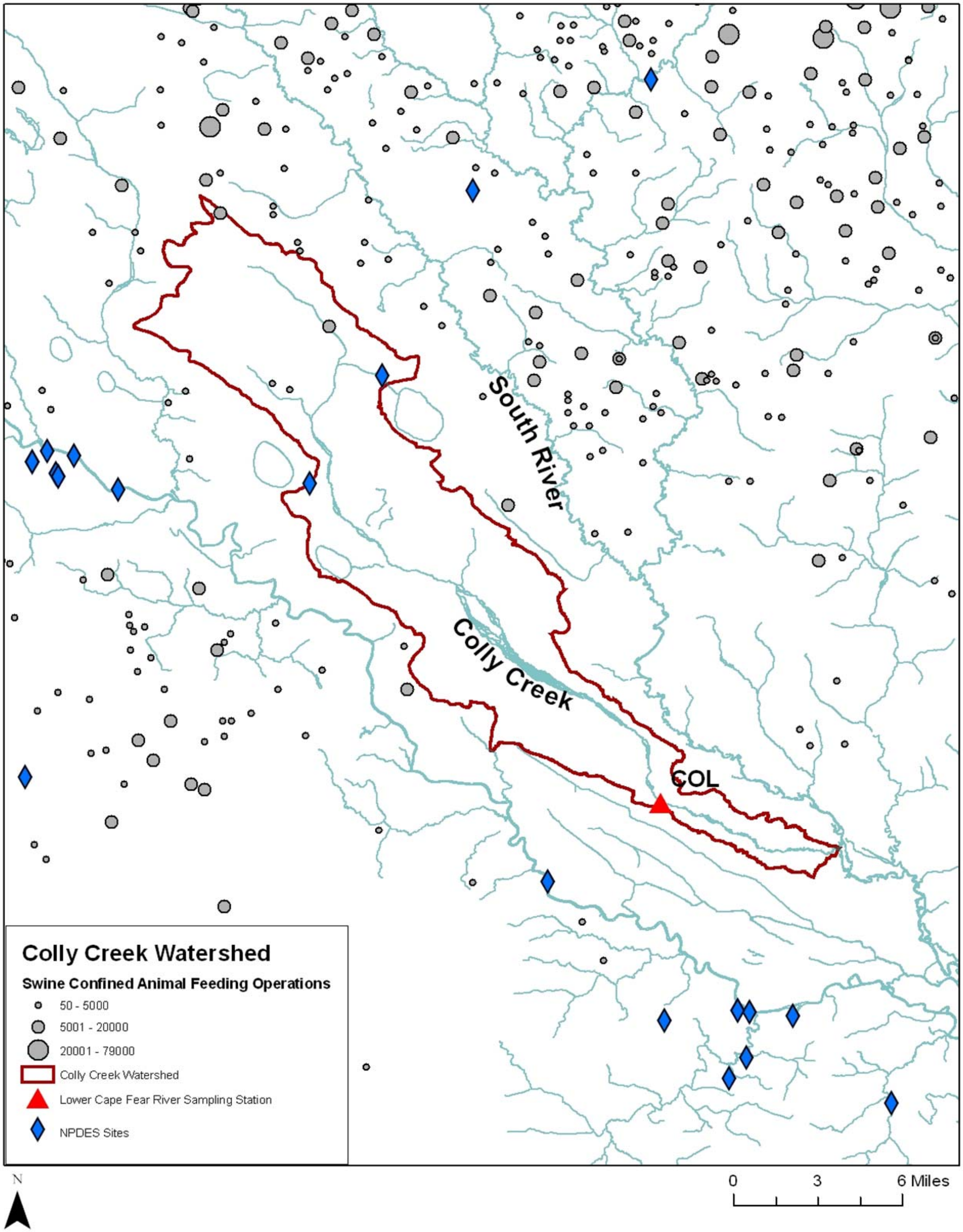
All three sites were rated good for chlorophyll *a*, and field turbidity during 2011(Table 3.7.1).

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

For nitrate and total phosphorus COL and B210 rated as good during 2011 (Table 3.7.1). BBT samples were not analyzed for nutrients.

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

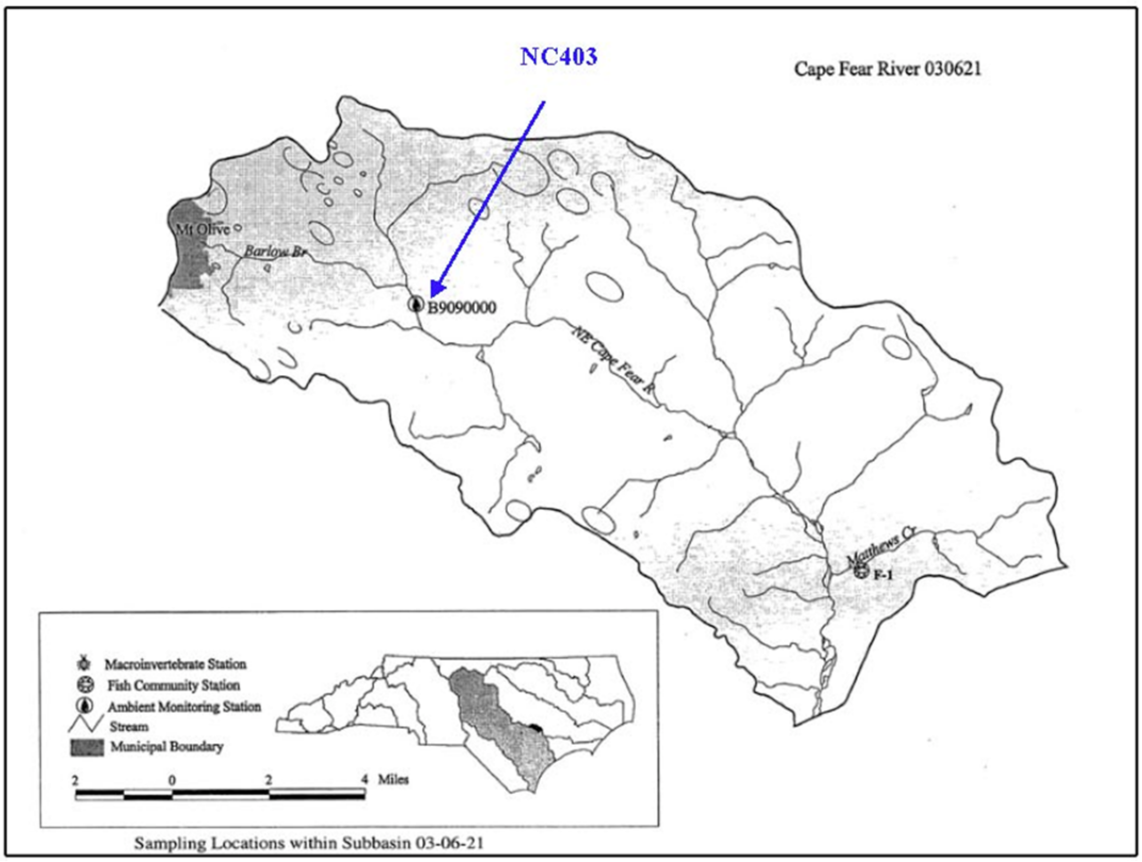
Station	Dissolved Oxygen	Chlorophyll *a*	Fecal Coliform	Field Turbidity	Nitrate	Total Phosphorus
B210	G	G G		G	G	G
COL	G	G G		G	G	G
BBT	F	G		G		


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



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 dropping below the NC state standard for swampwater of 4.0 mg/L in 67% of the samples (Table 3.8.1, Figure 3.8.1)

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

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

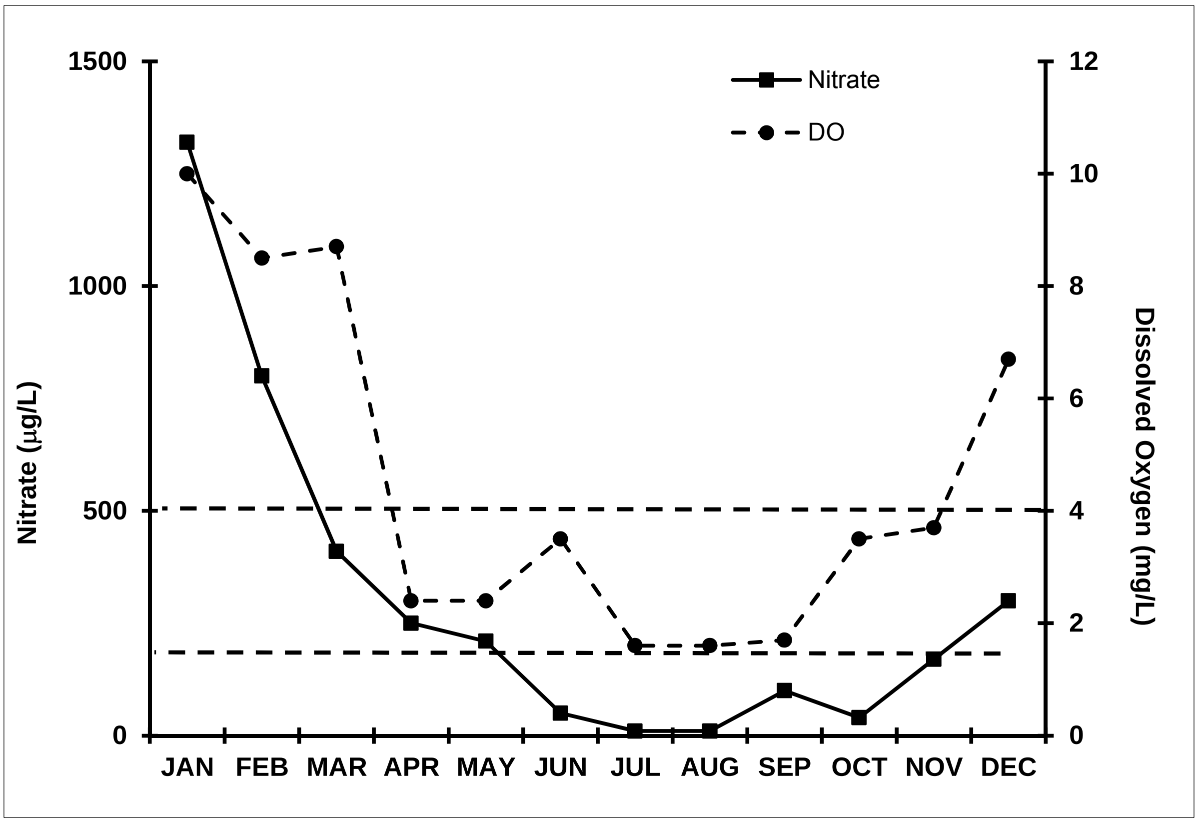
Field turbidity was rated as good at NC 403 (Table 3.8.1).

For nitrate NC403 had a poor rating with 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 at this site since these levels increase the likelihood of algal blooms and excessive aquatic macrophyte growth. Total phosphorus had a good rating for 2011.

Table 3.8.1 UNCW AEL 2011 evaluation for subbasin 03-06-21

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

Figure 3.8.1 Dissolved oxygen (mg/L) and nitrate (µg/L) concentrations at NC403 during 2011. The dashed lines show the NC State DO standard of 4.0 mg/L for swampwater and the UNCW AEL standard for Nitrate of 200 µg/L.



3.9 Cape Fear River Subbasin 03-06-22

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

LCFRP monitoring stations (DWQ #):
PB (B9130000), GS (B9191000), SAR (B9191500), LRC (9460000) ROC (B9430000)

DWQ monitoring stations: none

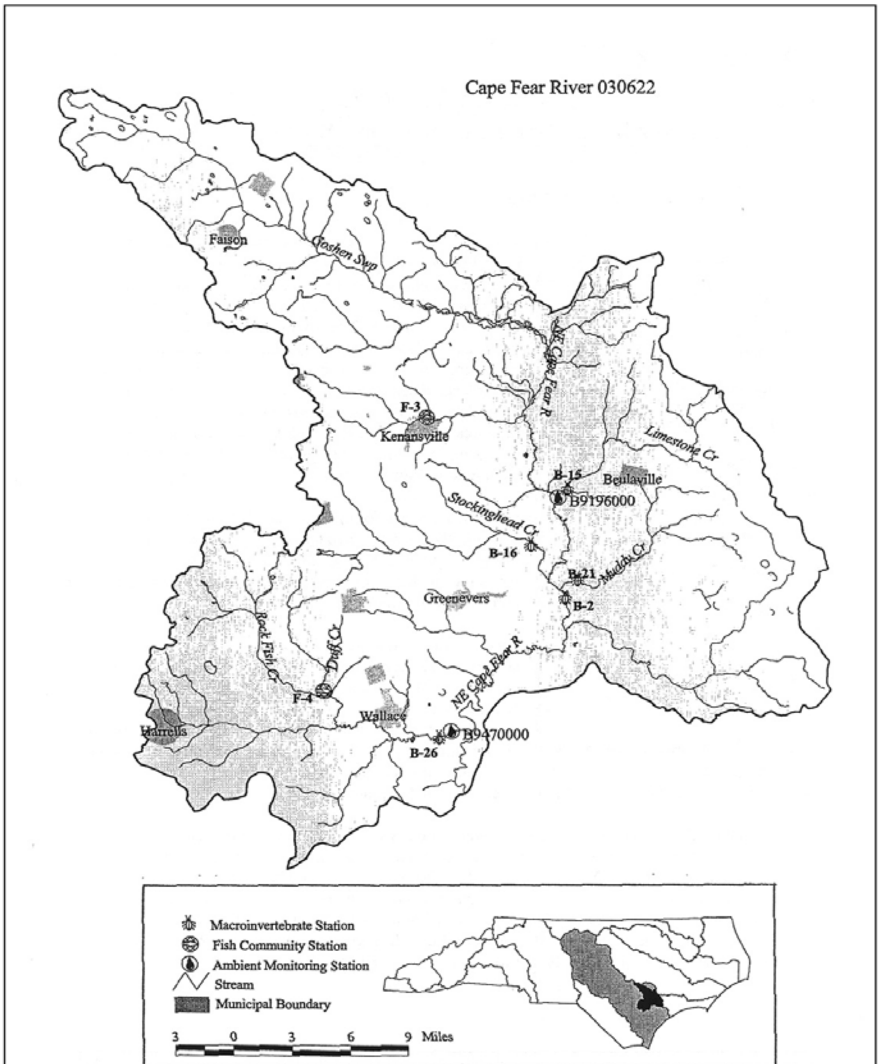


Figure B-22 Sampling Locations within Subbasin 03-06-22

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

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

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

UNCW Aquatic Ecology Laboratory Evaluation

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

PB – slow moving swamp-like stream

ROC - Rockfish Creek below Wallace

All sites in this subbasin were rated using the dissolved oxygen NC State swampwater standard of 4.0 mg/L. SAR, PB, LRC and ROC all had a good rating (Table 3.9.1). GS had a poor rating with DO values dropping below the standard 58% of the time.

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

For fecal coliform bacteria concentrations SAR, GS and ROC each had a fair rating with 17%, 25% and 17% of samples above the standard, respectively (Table 3.9.1, Figure 3.9.1). Sites PB and LRC were rated poor with 83% and 45% of samples above the standard (Figure 3.9.2).

For nitrate GS had a good rating (Table 3.9.1). LRC had a fair rating exceeding the UNCW AEL standard of 200 µg/L 17% of the time. SAR, PB and ROC all had a poor rating with levels exceeding the UNCW AEL standard 67%, 42% and 92% of the time, respectively (Figure 3.9.3).

For total phosphorus SAR, GS and LRC were rated as good (Table 3.9.1). PB was rated as fair, exceeding the UNCW AEL standard of 500 mg/L in 17% of the samples (Table 3.9.1). ROC was rated as poor, exceeding the standard 42% of the time.

Table 3.9.1 UNCW AEL 2011 evaluation for subbasin 03-06-22

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

Figure 3.9.1 Fecal coliform bacteria (cfu/100mL) at SAR, GS and ROC which rated fair during 2011. The dashed line is the NC State Standard for human contact of 200 cfu/100mL).

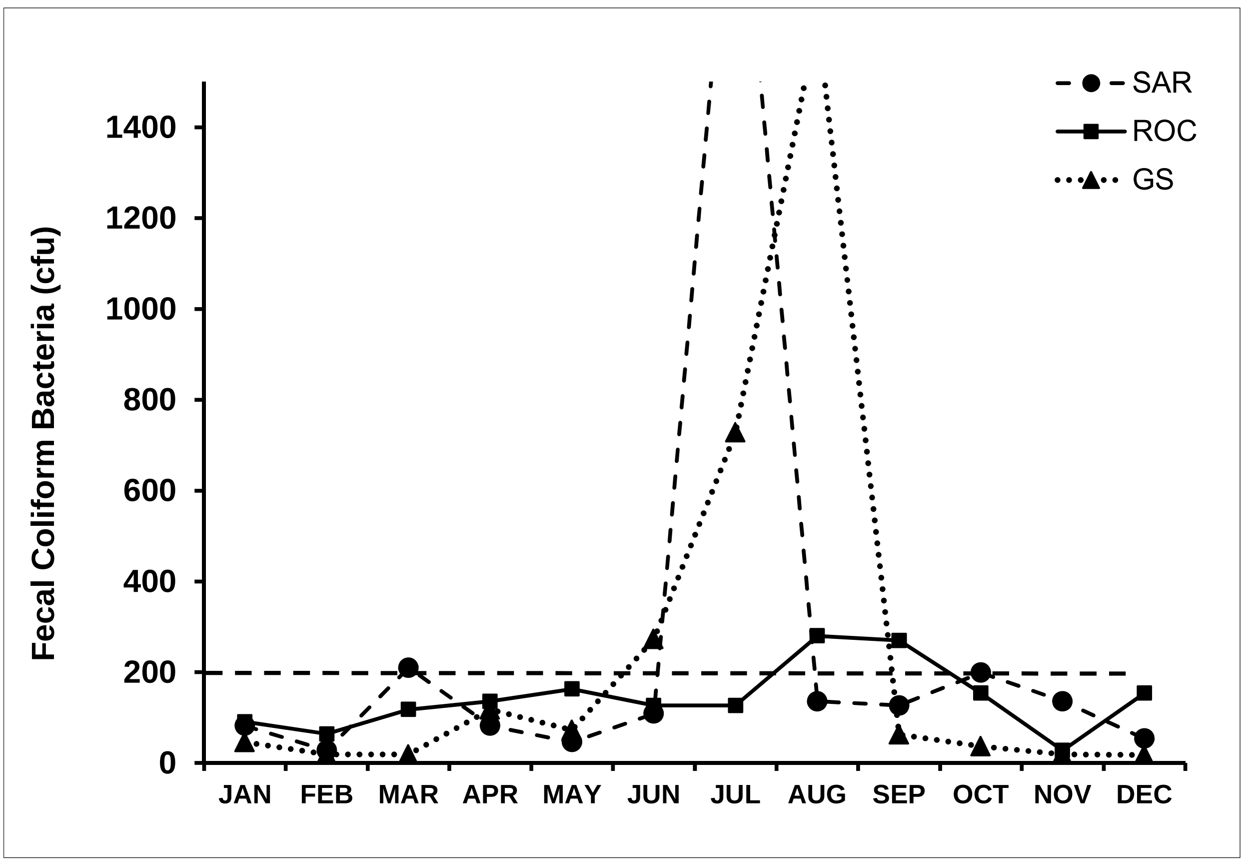


Figure 3.9.2 Fecal coliform bacteria (cfu/100mL) at LRC and PB which rated poor during 2011. The dashed line is the NC State Standard for human contact of 200 cfu/100mL.

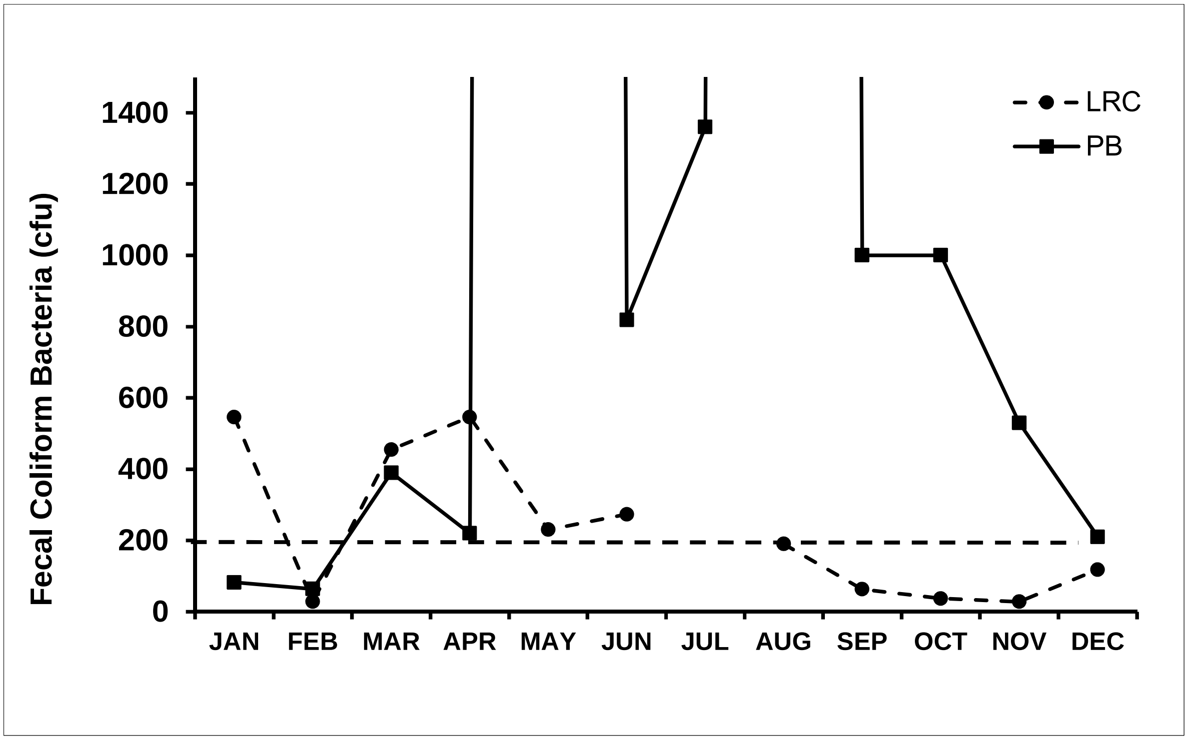
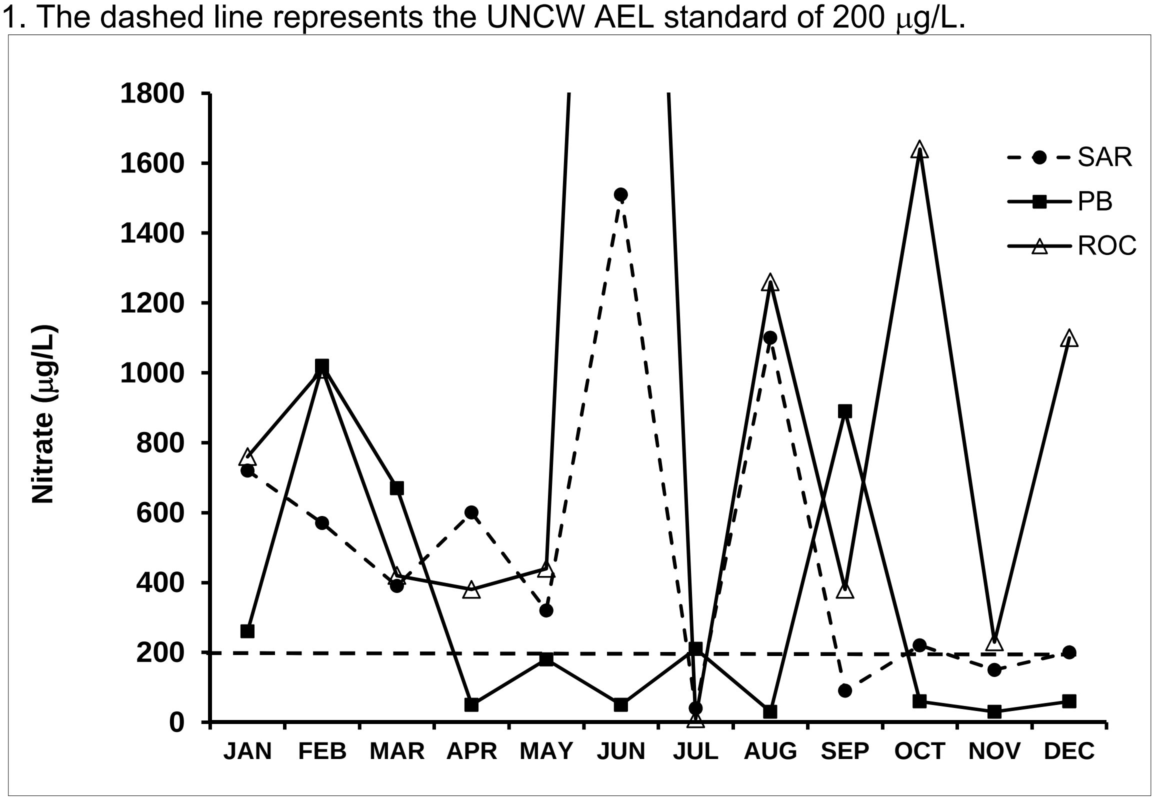
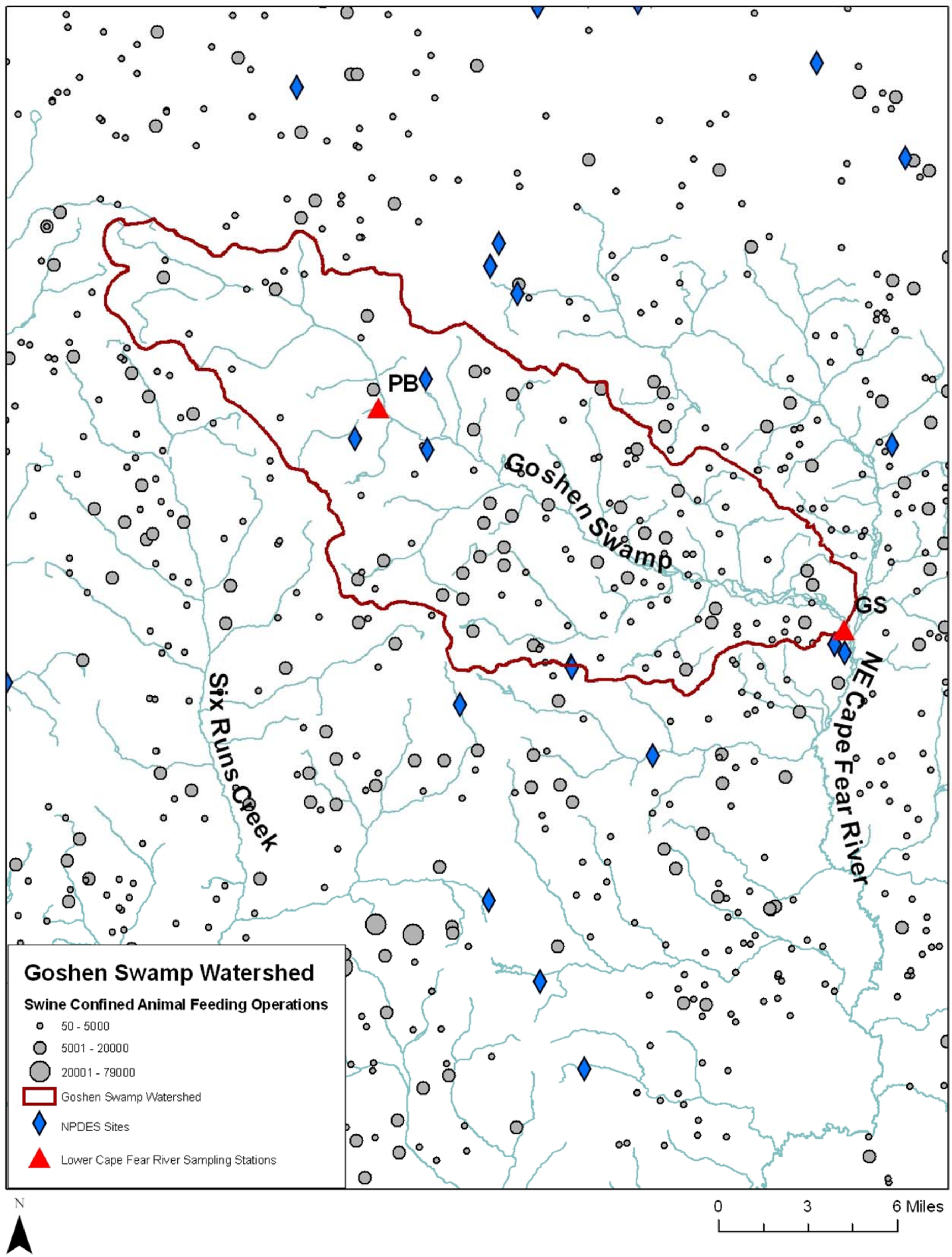
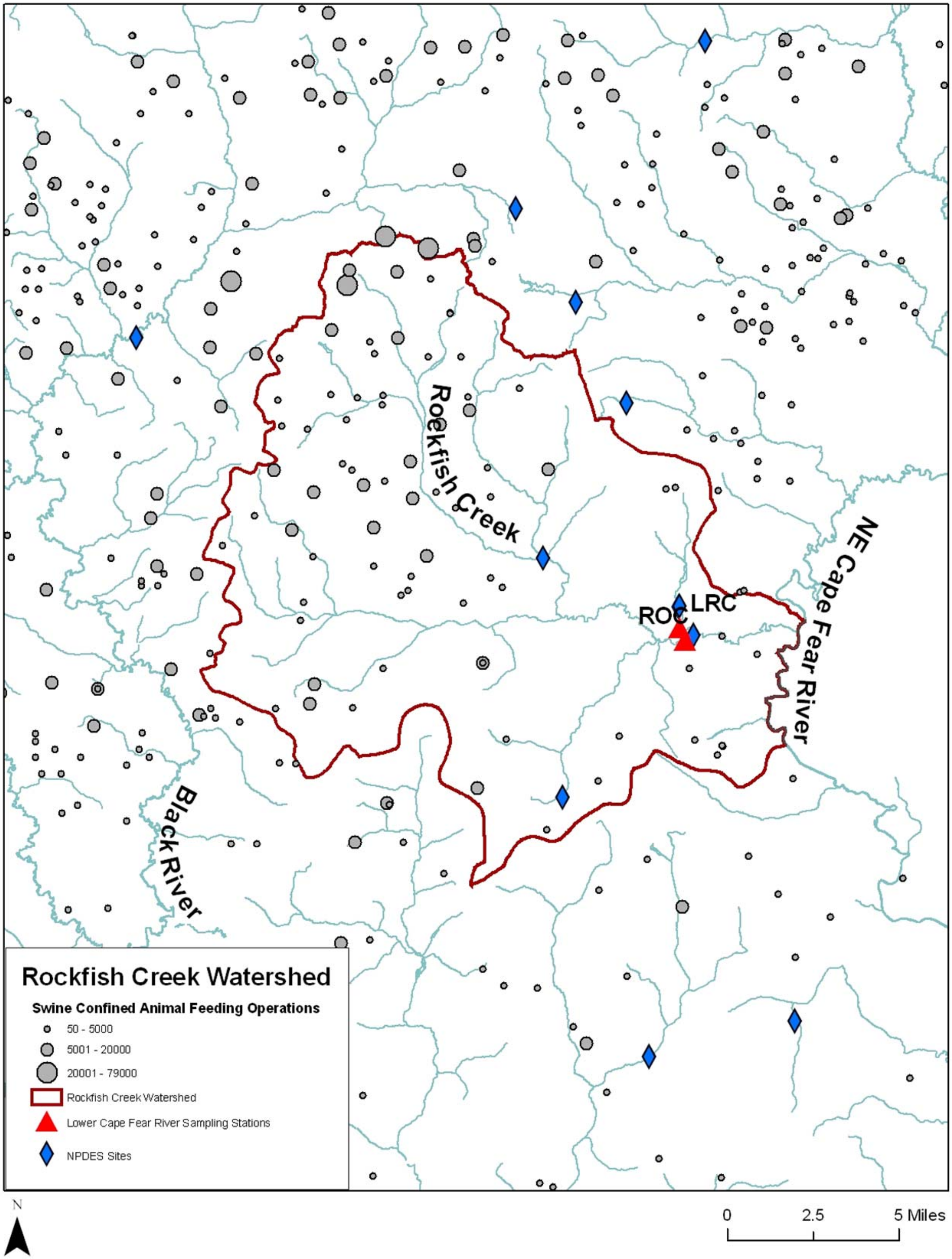


Figure 3.9.3 Nitrate concentrations (µg/L) at SAR, PB and ROC which rated poor during 2011. The dashed line represents the UNCW AEL standard of 200 µg/L.




PB
Goshen Swamp
GS
NE Cape Fear River
Six Runs Creek
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
0
3
6 Miles
N


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

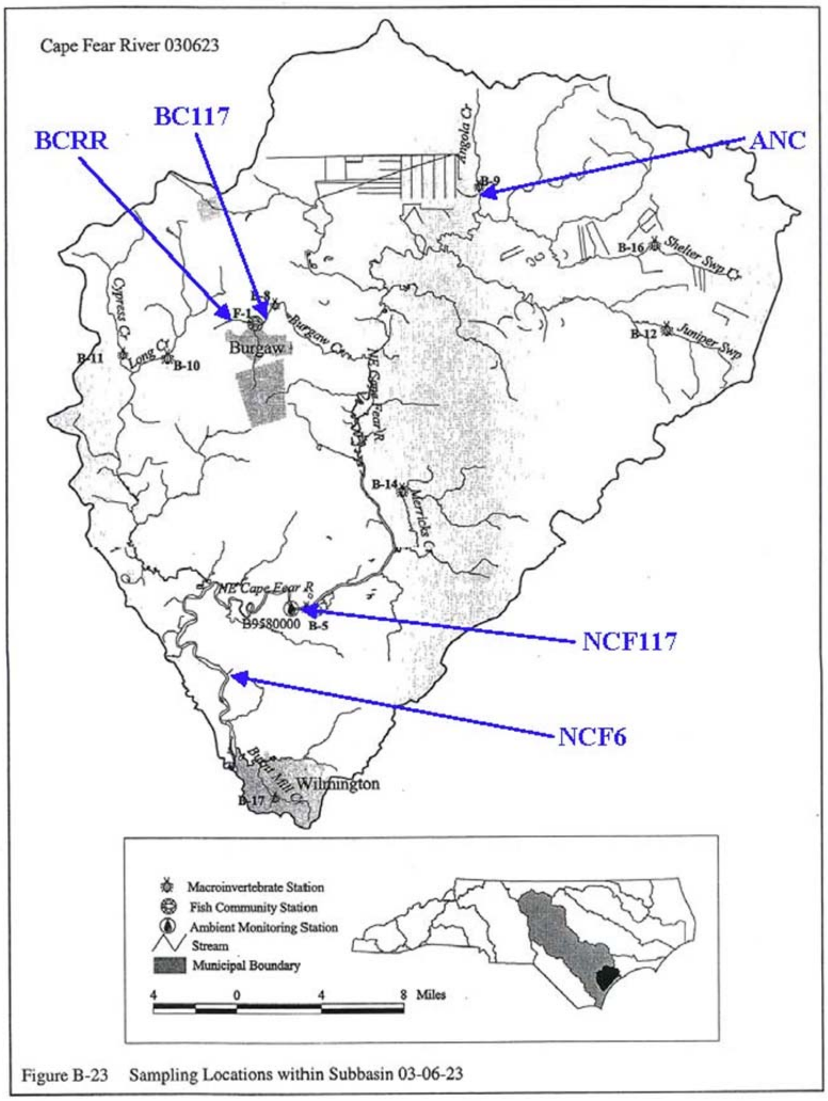


Figure B-23 Sampling Locations within Subbasin 03-06-23

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

All sites were rated for dissolved oxygen using the NC state standard for swampwater of 4.0 mg/L. BC117 had a good rating (Table 3.10.1). NCF117, NCF6 and SC-CH had a fair rating with 17%, 25% and 17% of samples sub-standard, respectively. ANC and BCRR had a poor rating with sub-standard samples 50% and 75% of the time, respectively (Figure 3.10.1).

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

For fecal coliform bacteria NCF117 and NCF6 had a good rating (Table 3.10.1). ANC was rated fair exceeding the standard 17% of the time. BC117, BCRR and SC-CH each had a poor rating, exceeding the human contact standard of 200 cfu/100 mL 58%, 42% and 33% of the time, respectively (Figure 3.10.2).

All six stations were rated good for field turbidity during 2011 (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 92% 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). BCRR was also rated poor for nitrate, exceeding the standard 33% of the time. All other sites were rated good for nitrate and total phosphorus. Nutrients were not analyzed at SC-CH.

Table 3.10.1 UNCW AEL 2011 evaluation for subbasin 03-06-23

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

Figure 3.10.1 Dissolved oxygen concentrations (mg/L) at ANC and BCRR which rated poor during 2011. The dashed line shows the NC state standard for swampwater, 4.0 mg/L.

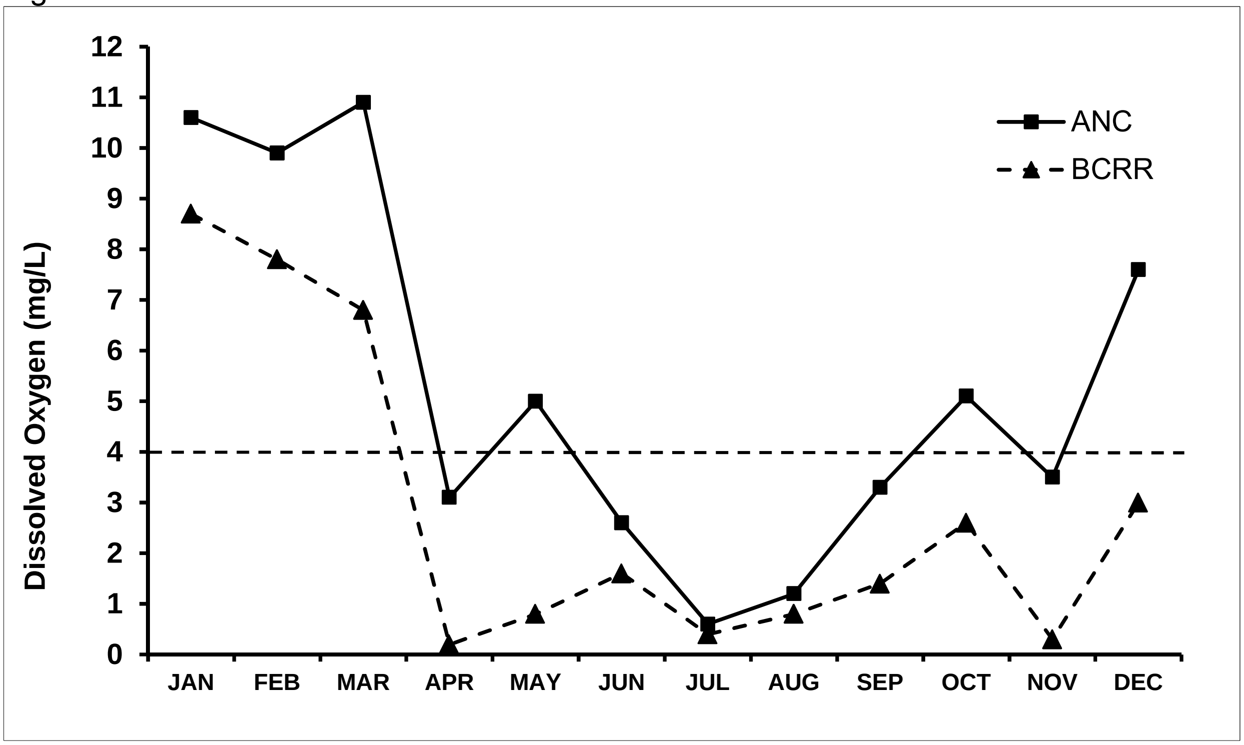
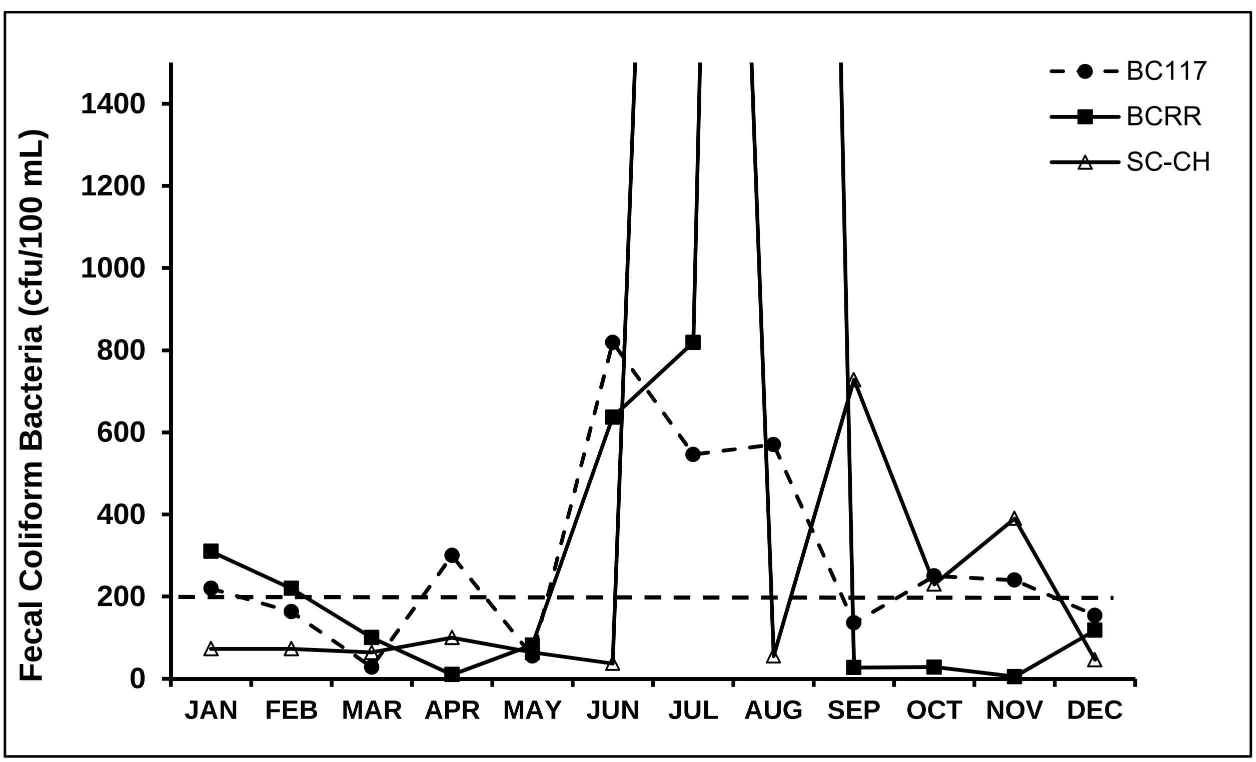
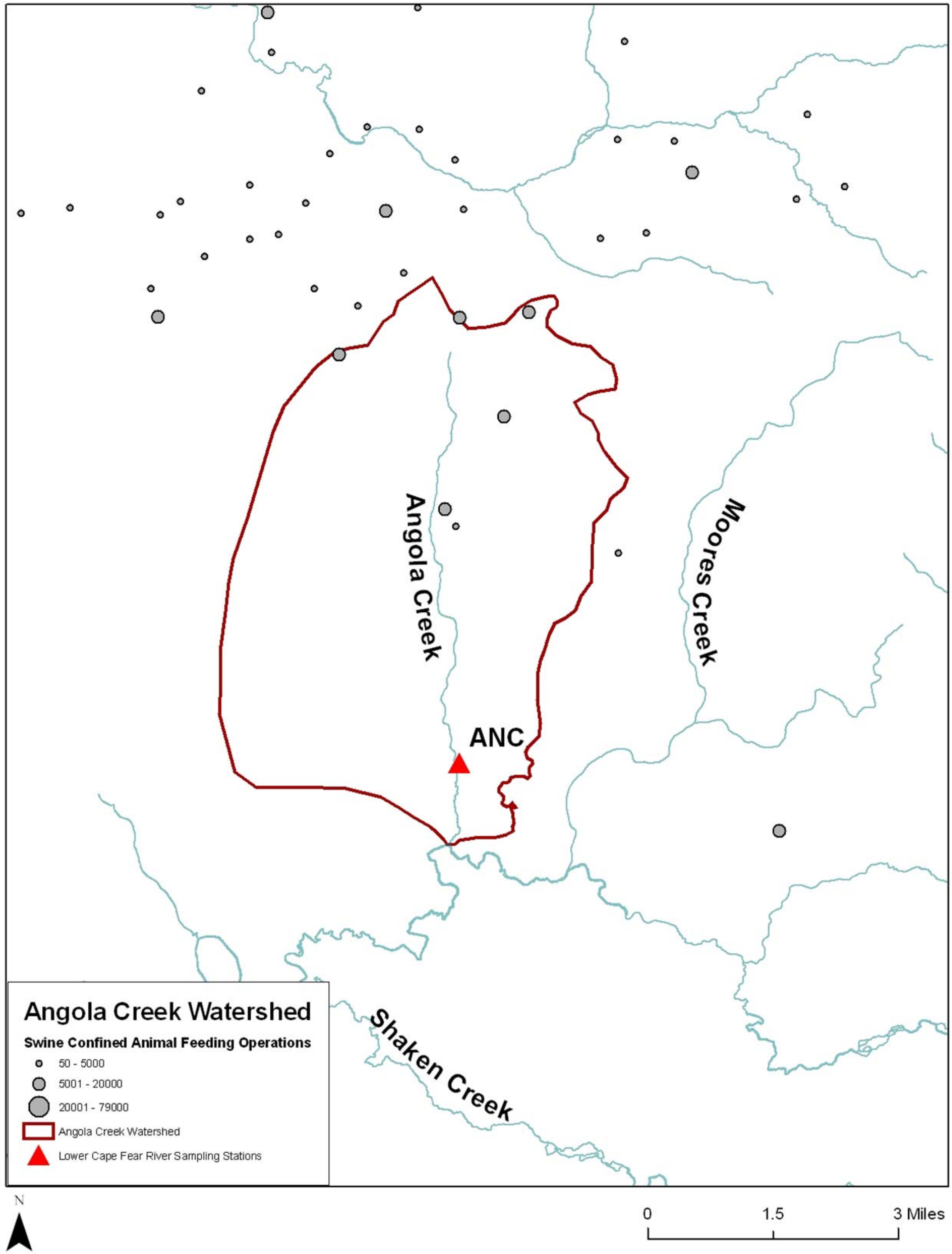
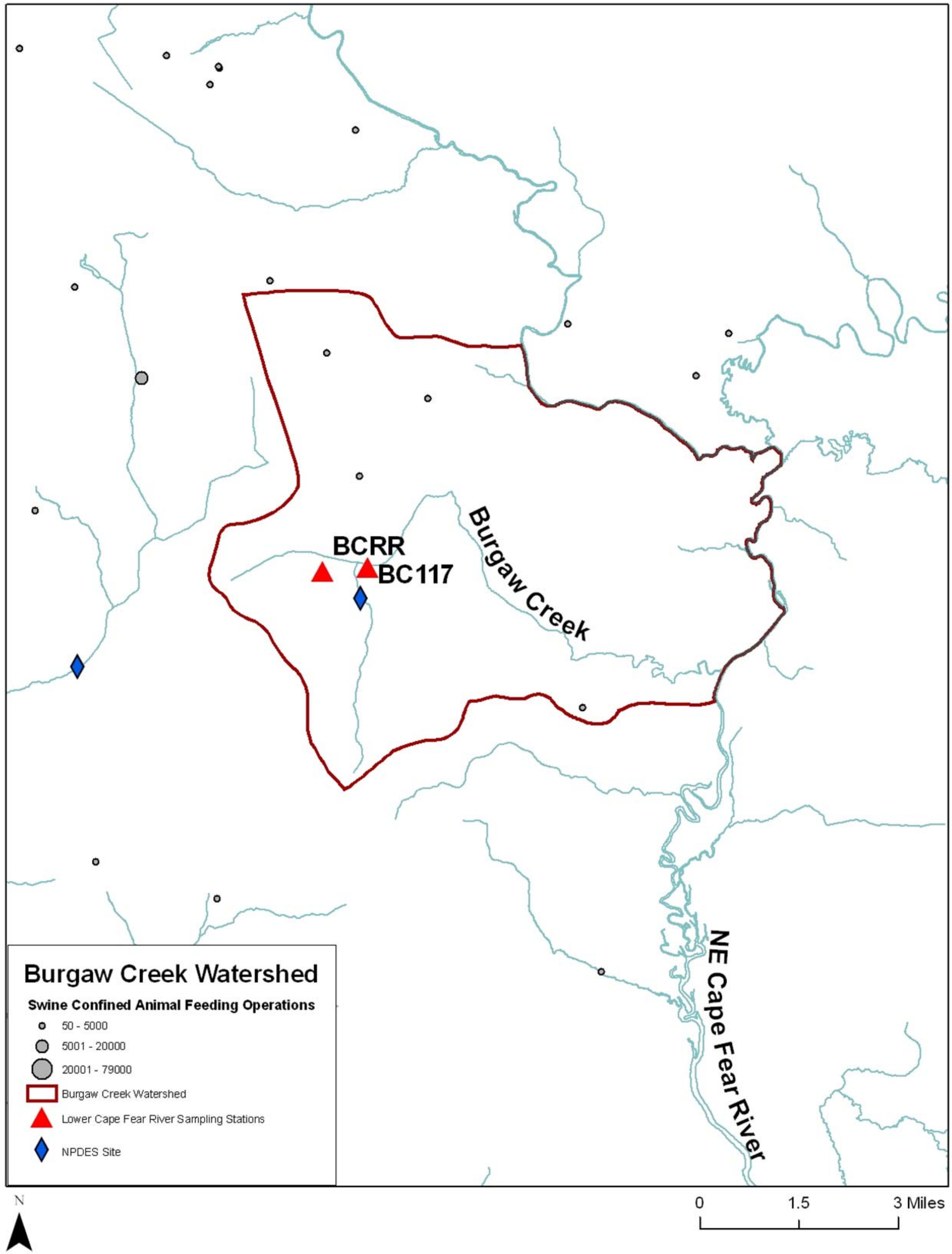


Figure 3.10.2 Fecal coliform bacteria concentrations (cfu/100mL) at BC117, BCRR and SC-CH which rated poor during 2011. The dashed line shows the NC State Standard for human contact, 200 cfu/100 mL.




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 SH. 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.

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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.