Environmental Assessment of the Lower Cape Fear River System, 2012

By

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Center for Marine Science
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Executive Summary

Multiparameter water sampling for the Lower Cape Fear River Program (LCFRP) has been ongoing since June 1995. Scientists from the University of North Carolina Wilmington'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 2012. 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 2008-2011) 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 2012 were slightly lower than the average for 1995-2011. 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 M35 to M18. Lowest mainstem average 2012 DO levels occurred at the lower river and upper estuary stations DP, IC, NAV, HB, BRR and M61 (6.3-6.9 mg/L). As the water reaches the lower estuary higher algal productivity, mixing and ocean dilution help alleviate oxygen problems.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River. These rivers are classified as blackwater systems because of their tea colored water. The Northeast Cape Fear River often seems to be more oxygen stressed than the Black River; as such, in 2012 Stations NCF117 and B210,

representing those rivers, had average DO concentrations of 5.8 and 6.5 mg/L, respectively. Several stream stations were severely stressed in terms of low dissolved oxygen during the year 2012. Stations BCRR and SR had DO levels below 4.0 mg/L 67% of the occasions sampled, with NC403 58%, BC117 50%, LVC2 42%, GS 33% and NCF117 and SC-CH 25%. Considering all sites sampled in 2012, we rated 29% as poor for dissolved oxygen, 18% as fair, and 53% as good, a decrease from 2011

Annual mean turbidity levels for 2012 were lower than the long-term average in all estuary stations. Highest mean turbidities were at NAV and HB (17-20 NTU) with turbidities generally low in the middle to lower estuary. Stations NAV, HB and BRR exceeded the estuarine turbidity standard on four, three and two occasions, respectively. 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 LCO.

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 BRN (Browns Creek). Average chlorophyll *a* concentrations across all sites were similar to long-term average. We note the highest levels in the river and estuary occurred in mid-summer; during the growing season May-September river flow as measured by USGS at Lock and Dam #1 was lower for 2012 compared with the 1995-2011 long-term average (1,719 CFS compared with 3,361 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. The most troublesome occurrence was the recurrence of cyanobacteria (i.e. blue-green algal blooms) in the Cape Fear River during August in the river near NC11 (see report cover). 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. Stream algal blooms exceeding 20 µg/L in 2012 occurred at ANC, NC403, PB and LRC. Several stream stations, particularly BC117, BCRR, PB, BRN, HAM (Hammond Creek), GS, N403, LRC and SC-CH showed high fecal coliform bacteria counts on a number of occasions.

For the 2012 period UNCW rated 100% of the stations as good in terms of chlorophyll *a*. For turbidity 91% of the sites were rated good, 6% fair and 3% poor. Fecal coliform bacteria counts were high in the system in 2012 and the lower estuary had high enterococcus on some occasions. For bacterial water quality overall, 45% of the sites rated as poor, 21% as fiar, and 33% as good in 2012. Using the 5.0 mg/L DO standard for the mainstem river stations, and the 4.0 mg/L “swamp water” DO standard for the stream stations and blackwater river stations, 47% of the sites were rated poor or fair for dissolved oxygen. 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 2012.

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 17-year (1995-2012) 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 Cape Fear Public Utility Authority, 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; and in 2012 sampling was expanded at Smith Creek at the Castle Hayne Road bridge (Table 1.1) and initiated at a new site along the South River (SR-WC). 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).

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

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, 2012, 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

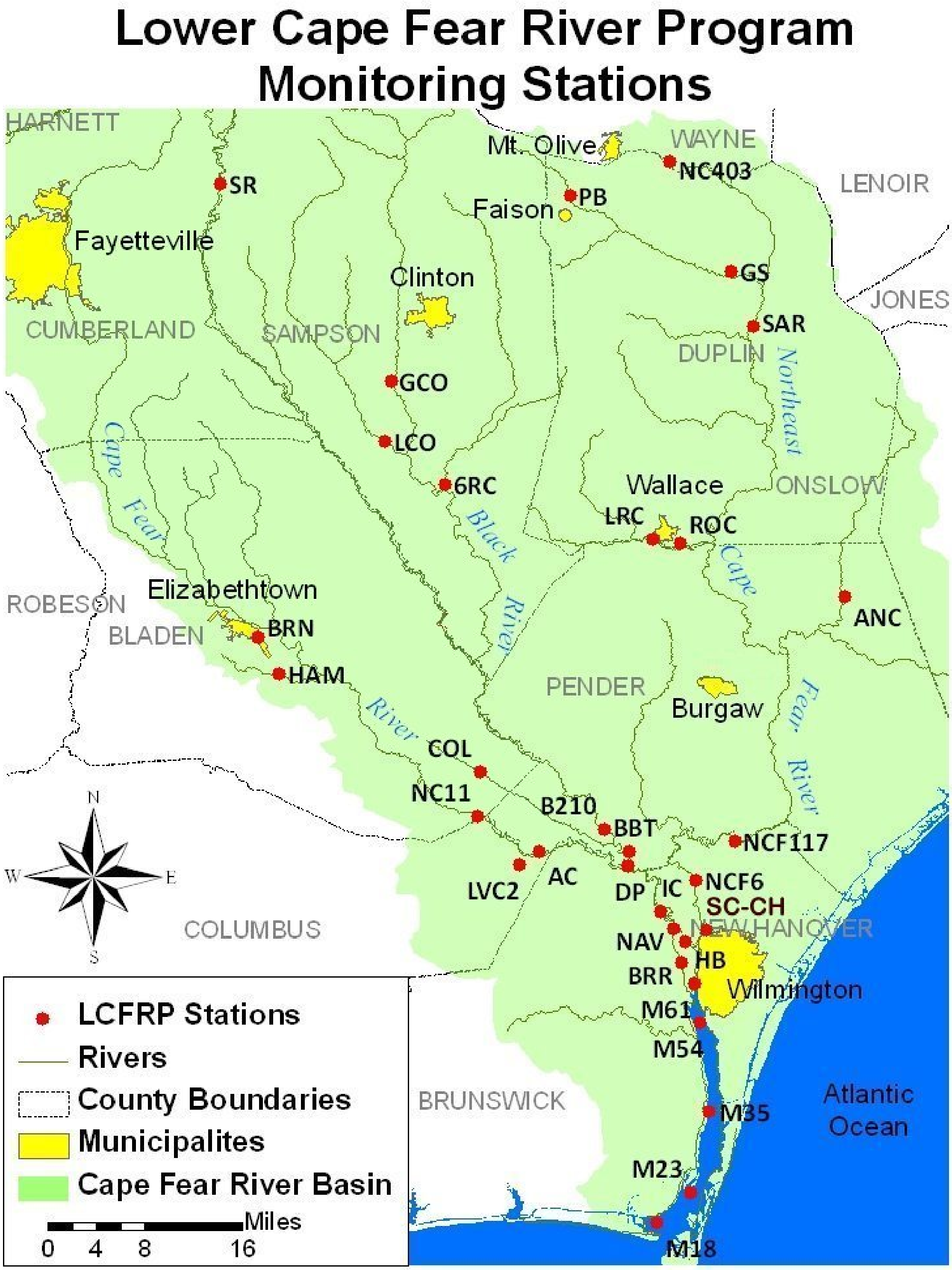
M54	B7950000	Channel Marker 54, 5 km downstream of Wilmington	
GPS		N 34.13933	W 77.94595
M35	B9850100	Channel Marker 35 near Olde Brunswick Towne	
GPS		N 34.03408	W 77.93943
M23	B9910000	Channel Marker 23 near CP&L intake canal	
GPS		N 33.94560	W 77.96958
M18	B9921000	Channel Marker 18 near Southport	
GPS		N 33.91297	W 78.01697

Stream stations collected from land

SR	B8470000	South River at US 13, below Dunn	
GPS		N 35.15600	W 78.64013
GCO	B8604000	Great Coharie Creek at SR 1214	
GPS		N 34.91857	W 78.38873
LCO	B8610001	Little Coharie Creek at SR 1207	
GPS		N 34.83473	W 78.37087
6RC	B8740000	Six Runs Creek at SR 1003 (Lisbon Rd.)	
GPS		N 34.79357	W 78.31192
BRN	B8340050	Browns Creek at NC 87	
GPS		N 34.61360	W 78.58462
HAM	B8340200	Hammonds Creek at SR 1704	
GPS		N 34.56853	W 78.55147
LVC2	B8441000	on Livingston Creek near Acme	
GPS		N 34.33530	W 78.2011
COL	B8981000	Colly Creek at NC 53	
GPS		N 34.46500	W 78.26553
ANC	B9490000	Angola Creek at NC 53	
GPS		N 34.65705	W 77.73485
NC403	B9090000	Northeast Cape Fear below Mt. Olive Pickle at NC403	
GPS		N 35.17838	W 77.98028

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

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



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

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2.1 - Introduction

This section of the report includes a discussion of the physical, chemical, and biological water quality parameters, concentrating on the January-December 2012 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 or enterococcus 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. Analysis methods are listed in Table 2.0.

<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.

Chemical Parameters

Nutrients

A local State-certified analytical laboratory was contracted to conduct all chemical analyses except for orthophosphate, which is performed at CMS. The following methods detail the techniques used by CMS personnel for orthophosphate analysis.

Orthophosphate (PO_4^{-3})

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

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

Biological Parameters

Fecal Coliform Bacteria

Fecal coliform bacteria were analyzed 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 (Stations BRR, M61, M35, M23 and M18).

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 is 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 2012. Discussion of the data focuses both on the river channel stations and stream stations, which sometimes reflect poorer water quality than mainstem stations. The contributions of the two large blackwater tributaries, the Northeast Cape Fear River and the Black River, are represented by conditions at NCF117 and B210, respectively. The Cape Fear Region did not experience any significant hurricane activity during this monitoring period (after major hurricanes in 1996, 1998, and 1999). Therefore this report reflects low to medium flow conditions for the Cape Fear River and Estuary.

Physical Parameters

Water temperature

Water temperatures at all stations ranged from 3.3 to 32.1^{o}C, and individual station annual averages ranged from 15.9 to 20.9^{o}C (Table 2.1). Highest temperatures occurred during July and August and lowest temperatures during January. Stream stations were generally cooler than river stations, most likely because of shading and lower nighttime air temperatures affecting the shallower waters.

Salinity

Salinity at the estuarine stations (NAV through M18; also NCF6 in the Northeast Cape Fear River) ranged from 0.1 to 35.1 practical salinity units (psu) and station annual means ranged from 3.1 to 31.0 psu (Table 2.2). Lowest salinities occurred in spring and also in September and highest salinities occurred in winter. The annual mean salinity for 2012 was higher than that of the fifteen-year average for 1995-2011 for all of the estuarine stations (Figure 2.1), due to reduced river flows. 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 ranged widely, from 0.4 to 10.2 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.14 to 53.3 mS/cm and from 0.07 to 5.50 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. Stations PB and NC403 are below industrial discharges, and often have elevated conductivity. Smith Creek (SC-CH) is an estuarine tidal creek and the conductivity values reflect this (Table 2.3).

pH

pH values ranged from 3.3 to 8.1 and station annual means ranged from 3.7 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. We also note that LRC had an unusually high pH level (7.8) in May 2012 (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; 2012). Surface concentrations for all sites in 2012 ranged from 0.3 to 12.6 mg/L and station annual means ranged from 3.0 to 9.4 mg/L (Table 2.5). Average annual DO levels at the river channel and estuarine stations for 2012 were slightly lower than the average for 1995-2011 (Figure 2.2). River dissolved oxygen levels were lowest during the summer and early fall (Table 2.5), often falling below the state standard of 5.0 mg/L at several river and upper estuary stations. Working synergistically to lower oxygen levels are two factors: lower oxygen carrying capacity in warmer water and increased bacterial respiration (or biochemical oxygen demand, BOD), due to higher temperatures in summer. Unlike other large North Carolina estuaries (the Neuse, Pamlico and New River) the Cape Fear estuary rarely suffers from dissolved oxygen stratification. This is because despite salinity stratification the oxygen remains well mixed due to strong estuarine gravitational circulation and high freshwater inputs (Lin et al. 2006). Thus, hypoxia in the Cape Fear is present throughout the water column.

There is a dissolved oxygen sag in the main river channel that begins at DP below a paper mill discharge and persists into the mesohaline portion of the estuary (Fig. 2.2). Mean oxygen levels were highest at the upper river stations NC11 and AC and in the low-to-middle estuary at stations M35 to M18. Lowest mainstem mean 2012 DO levels occurred at the river and upper estuary stations IC, NAV, HB, BRR and M61 (6.2-6.6 mg/L). HB, BRR, DP and M61 were all below 5.0 mg/L on 33% or more of occasions sampled, BBT was below on 25%, and NCF6 was below on 17% of occasions sampled, a deterioration from 2011. Based on number of occasions the river stations were below 5 mg/L UNCW rated HB, BRR, DP and M61 as poor for 2012; 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 (including the blue-green algal blooms in recent years), 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 2012 mean = 5.8, NCF6 = 6.3, B210 2012 mean = 6.5) . 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 2012. Stations BCRR and SR had DO levels below 4.0 mg/L 67% of the occasions sampled, with NC403 58%, BC117 50%, LVC2 42%, GS 33% and NCF117 and SC-CH 25% (Table 2.5). Some of this can be attributed to low summer water conditions and some potentially to CAFO runoff; however point-source discharges also likely contribute to low dissolved oxygen levels at NC403 and possibly SR, especially via nutrient loading (Mallin et al. 2001a; 2002a; 2004). Hypoxia is thus a continuing and widespread problem, with 47% of the sites impacted in 2012.

Field Turbidity

Field turbidity levels ranged from 0 to 50 Nephelometric turbidity units (NTU) and station annual means ranged from 1 to 20 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Annual mean turbidity levels for 2012 were lower than the long-term average at all estuary sites (Fig. 2.3), due to reduced river flow. Highest mean turbidities were at NAV and HB (17-20 NTU) with turbidities generally low in the middle to lower estuary (Figure 2.3). Stations NAV, HB and BRR exceeded the estuarine turbidity standard on four, three and two occasions, respectively. 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 LCO. 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 51 mg/L with station annual means from 2 to 19 mg/L (Table 2.7). The overall highest river values were at NAV and M18. In the stream stations TSS was generally considerably lower than the river and estuary, except for a few incidents at Station PB and Station ROC. 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 0.77 to 6.08/m and station annual means ranged from 1.29 at M18 to 4.17 /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).

<u>Chemical Parameters – Nutrients</u>

Total Nitrogen

Total nitrogen (TN) is calculated from TKN (see below) plus nitrate; it is not analyzed in the laboratory. TN ranged from 50 (detection limit) to 11,100 μg/L and station annual means ranged from 288 to 2,313 μg/L (Table 2.9). Mean total nitrogen in 2012 was less than the sixteen-year mean at the river and estuary stations (Figure 2.4). Previous research (Mallin et al. 1999) has shown a positive correlation between river flow and TN in the Cape Fear system. In the main river total nitrogen concentrations were highest between NC11 and 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. The highest median TN value at the stream stations was at ROC, with 1,305 μg/L; other elevated TN values were seen at BC117, ANC, GCO and 6RC.

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 11,100 μg/L and station annual means ranged from 27 to 1,671 μg/L (Table 2.10). The highest average riverine nitrate levels were at NC11 and AC (942 and 890 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 = 278 μg/L) and the Black River (B210 = 203 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 BRN. 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/ammonia

Ammonium concentrations ranged from 5 (detection limit) to 3,380 μg/L and station annual means ranged from 5 to 372 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 M61, located just upstream 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, BC117, BCRR and ROC (Table 2.11). ANC had an unusually high peak concentration of 3,380 μg/L in July for unknown reasons.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of the total concentration of organic nitrogen plus ammonium. TKN ranged from 50 (detection limit) to 6,000 μg/L and station annual means ranged from 233 to 1,300 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 6,000 μg/L of TKN was seen at ANC in July; ANC also had the highest median concentrations. Other sites with elevated TKN included ROC, GCO, SR and COL.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from 10 (detection limit) to 1,400 μg/L and station annual means ranged from 32 to 432 μg/L (Table 2.13). Mean TP for 2012 was somewhat higher than the sixteen-year mean in the estuary and river stations (Figure 2.5). In the river TP is highest at the upper riverine channel stations NC11 and 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 NC403. Some of these stations (BC117, NC403) are downstream of industrial or wastewater discharges, while GCO and ROC are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from undetectable to 1,180 μg/L and station annual means ranged from 6 to 328 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 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 elevated concentrations in July and August at the river and upper estuary stations (Table 2.15). The only exceedence of the state standard was for 54 µg/L at Station 61 in August; there was also a bloom or 40 µg/L at AC in July. We note that at the upper site NC11 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 concern 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, 2011 and 2012. 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. Additional algal bloom material from the Cape Fear River collected in September 2009 was analyzed by Dr. Paul Zimba at Texas A&M University-Corpus Christi, who found a water microcystin RR concentration of 391 µg/L. In related work UNCW researchers directed by chemists Dr. Jeff Wright and Dr. Wendy Strangman also isolated the two hepatotoxins, microcystin LR and microcystin RR, from Cape Fear *Microcystis aeruginosa* blooms in 2010 (Isaacs 2011). These researchers also found two new cyanopeptides, micropeptin 1106 and micropeptin 1120 in elevated concentrations; the biological activity of those two compounds is unknown. We note that the City of Wilmington and parts of Brunswick County receive their drinking water from the river above Lock and Dam #1 in the bloom area.

In 2012 a significant *Microcystis aeruginosa* bloom occurred in July in the vicinity of Lock and dam #1. Jared Metheny, a student under the direction of Dr. Mike Mallin found significant correlations between chlorophyll *a* and BOD5 in surface and sub-surface water at Stations NC11 and AC and downstream several miles. Dr. Larry Cahoon, of the UNCW Biology and Marine Biology Department, also collected a variety of chemical samples in association with blooms upstream of L&D#1, with the goal of gaining further understanding of how these blooms affect the river's ecology.

System wide, chlorophyll *a* ranged from undetectable to 54 µg/L and station annual means ranged from 2-8 µg/L, lower than in 2011. 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 (1995-2012) average monthly flow at Lock and Dam #1 was approximately 3,361 CFS (USGS data; (http://nc.water.usgs.gov/realtime/real_time_cape_fear.html), whereas for 2012 it was well below that at approximately 1,719 CFS. Thus, chlorophyll *a* concentrations in the river and estuary were mostly greater than the average for the preceding sixteen years (Figure 2.6).

Phytoplankton blooms occasionally occur at the stream stations, with a few occurring at various months in 2012 (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). Stations LRC, PB, NC403 and ANC all had minor algal blooms in 2012, although not exceeding the state standard of 40 µg/L (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 2012 (as was the case with 2007 through 2011) 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 2012 BOD5 values ranged from 0.3 – 4.2 mg/L. There were no major differences among sites for BOD5 or BOD20 in 2012. BOD20 values showed similar patterns to BOD5 in 2012.

Fecal Coliform Bacteria/ Enterococcus bacteria

Fecal coliform (FC) bacterial counts ranged from 1 to 60,000 CFU/100 mL and station annual geometric means ranged from 17 to 602 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded at the mainstem sites only once in 2012, at HB in September. During 2012 the stream stations showed high fecal coliform pollution levels. BC117 and HAM exceeded 200 CFU/100 mL 67% of the time;

BCRR and BRN 58%, PB and SAR 50%, GS, NC403, ROC, LROC SR and SC-CH 42%, ANC, GCO and LVC2 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.

Enterococcus counts were initiated in the estuary in mid-2011, as this test is now the standard used by North Carolina regulators for swimming in salt waters. Sites covered by this test include BRR, M61, M54, M35, M23 and M18. The State has a single-sample level for Tier II swimming areas in which the enterococci level in a Tier II swimming area shall not exceed a single sample of 276 enterococci per 100 milliliter of water (15A NCAC 18A .3402); the LCFRP is using this standard for the Cape Fear estuary samples in our rating system. As such, in 2012 most estuary sites exceeded the standard on two occasions, yielding a Fair rating by our standards. Overall, elevated fecal coliform and enterococcus counts are problematic in this system, with 66% of the stations rated as Fair or Poor in 2012, higher than the previous year 2011.

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Table 2.0 Lower Cape Fear River Program Parameter Analysis Methods List

Lab	Parameter	Method
UNCW Aquatic Ecology Lab	Temperature	SM 2550 B-2000
	Dissolved Oxygen	SM 4500 O G-2001
	pH	SM 45500 H B-2000
	Specific Conductivity	SM 2510 B-1997
	Chlorophyll *a*	Welschmeyer 1985, EPA 445.0
	Orthophosphate	EPA 365.5
Commercial Contract Lab	Total Suspended Solids	SM 2540 D-1997
	Lab Turbidity	SM 2130 B-2001
	Total Nitrogen	*by addition, TKN + Nitrate/Nitrite*
	Nitrate-Nitrite	EPA 353.2, Rev. 2.0-1993
	Ammonia-N	SM 4500 NH3 D-1997
	Total Kjeldahl Nitrogen	EPA 351.2, Rev. 2.0-1993
	Total Phosphorus	SM 4500 P E-1999
	Fecal Coliform Bacteria	SM 9222 D-1997
	Enterococcus	EPA 1600, Enterolert IDEXX

Table 2.1 Water temperature (^oC) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	11.6	12.5	12.4	12.0	12.0	12.7	12.7	12.4
FEB	12.3	12.2	11.9	12.7	12.3	12.5	12.4	13.0
MAR	13.8	14.9	14.1	14.4	15.1	14.9	14.6	14.0
APR	19.4	19.7	19.5	20.0	20.2	20.1	19.5	19.5
MAY	21.7	22.0	22.1	22.0	22.1	22.2	22.4	22.2
JUN	24.7	24.3	24.6	25.9	25.1	25.1	25.0	25.3
JUL	30.9	31.0	31.3	30.9	30.6	30.0	29.5	29.6
AUG	29.6	29.7	29.5	29.4	29.7	29.5	29.7	29.9
SEP	26.9	27.1	28.3	27.3	27.9	28.4	28.4	28.6
OCT	25.2	26.0	26.5	25.5	25.7	25.9	26.1	26.5
NOV	14.5	15.1	14.8	15.0	15.4	15.1	15.2	15.5
DEC	12.6	12.9	15.0	13.2	12.9	13.2	13.8	13.9
mean	**20.3**	**20.6**	**20.8**	**20.7**	**20.8**	**20.8**	**20.8**	**20.9**
std dev	7.2	7.0	7.1	7.0	7.0	6.9	6.9	6.9
median	20.6	20.9	20.8	21.0	21.2	21.2	21.0	20.9
max	30.9	31.0	31.3	30.9	30.6	30.0	29.7	29.9
min	11.6	12.2	11.9	12.0	12.0	12.5	12.4	12.4

	NC11	AC	DP	BBT	IC	NCF6
JAN	9.3	9.5	9.8	9.8	9.9	11.5
FEB	10.5	10.8	11.1	11.1	11.2	12.7
MAR	13.4	13.4	13.7	14.0	13.7	14.5
APR	20.0	19.9	19.8	19.9	20.2	19.7
MAY	21.9	22.1	22.3	22.3	22.3	22.6
JUN	25.3	25.1	23.5	22.9	23.9	23.8
JUL	30.3	30.5	30.5	30.6	32.0	31.4
AUG	29.2	29.1	29.0	28.3	28.8	28.1
SEP	28.2	28.1	28.4	27.1	27.6	26.9
OCT	22.0	22.1	22.1	21.6	22.4	22.6
NOV	13.8	13.9	14.2	13.0	14.1	14.3
DEC	11.6	11.7	11.6	11.5	11.6	12.5
mean	**19.6**	**19.7**	**19.7**	**19.3**	**19.8**	**20.1**
std dev	7.7	7.6	7.4	7.3	7.6	6.8
median	21.0	21.0	21.0	20.8	21.3	21.2
max	30.3	30.5	30.5	30.6	32.0	31.4
min	9.3	9.5	9.8	9.8	9.9	11.5

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	9.6	8.3	9.3	8.7	6.6	10.1	9.0	10.1	9.4
FEB	9.4	8.4	9.4	8.0	8.0	10.6	8.9	8.8	9.2
MAR	16.3	15.7	17.3	16.4	16.7	17.5	16.4	13.5	14.3
APR	17.9	19.0	21.0	18.1	21.3	20.2	17.0	16.0	14.4
MAY	24.6	22.5	25.0	23.0	24.2	25.1	22.1	21.4	20.6
JUN	23.9	24.3	26.2	25.2	27.3	25.6	23.1	22.3	21.8
JUL	26.1	25.1	28.6	27.7	32.1	28.7	25.8	23.9	24.8
AUG	23.7	24.2	24.6	25.7	25.5	24.8	23.9	23.8	24.1
SEP	21.3	21.7	21.2	22.4	23.8	23.3	21.5	20.2	20.3
OCT	18.0	17.9	17.1	17.0	17.6	17.2	16.1	16.8	16.4
NOV	9.9	10.0	9.1	9.9	9.4	9.3	10.5	10.3	10.7
DEC	15.5	16.1	16.4	15.1	16.5	16.4	14.8	15.1	13.5
mean	**18.0**	**17.8**	**18.8**	**18.1**	**19.1**	**19.1**	**17.4**	**16.9**	**16.6**
std dev	6.1	6.2	6.9	6.8	8.1	6.6	5.9	5.5	5.6
median	18.0	18.5	19.2	17.6	19.5	18.9	16.7	16.4	15.4
max	26.1	25.1	28.6	27.7	32.1	28.7	25.8	23.9	24.8
min	9.4	8.3	9.1	8.0	6.6	9.3	8.9	8.8	9.2

	6RC	LCO	GCO	SR	BRN	HAM
JAN	3.9	4.2	3.3	4.0	4.8	4.8
FEB	8.5	8.7	9.5	9.2	10.2	10.3
MAR	13.5	13.5	15.4	14.7	15.2	15.0
APR	14.9	14.9	15.2	16.1	16.3	15.3
MAY	21.7	21.5	21.9	21.5	20.1	20.7
JUN	24.5	23.7	24.4	23.6	23.0	22.5
JUL	26.8	26.9	27.3	26.5	26.3	27.0
AUG	25.9	26.0	25.9	26.0	25.5	25.1
SEP	19.9	19.6	20.8	20.9	19.4	19.6
OCT	15.7	15.9	15.8	15.3	16.1	15.9
NOV	10.6	10.4	10.8	12.4	10.8	10.9
DEC	10.7	10.6	9.9	9.9	10.3	10.3
mean	**16.4**	**16.3**	**16.7**	**16.7**	**16.5**	**16.5**
std dev	7.4	7.3	7.5	7.1	6.7	6.7
median	15.3	15.4	15.6	15.7	16.2	15.6
max	26.8	26.9	27.3	26.5	26.3	27.0
min	3.9	4.2	3.3	4.0	4.8	4.8

	NCF117	B210	COL	LVC2	SC-CH
JAN	10.1	5.6	4.3	7.4	9.9
FEB	12.2	12.0	11.5	11.6	13.6
MAR	14.1	14.9	14.5	13.9	15.4
APR	17.8	15.6	13.3	16.4	18.5
MAY	24.0	23.3	18.9	21.4	24.9
JUN	22.3	20.9	18.4	23.3	23.4
JUL	29.3	29.5	25.1	27.9	30.1
AUG	27.1	26.4	23.9	26.4	29.0
SEP	26.2	26.0	23.9	25.8	27.6
OCT	22.3	19.0	16.5	19.4	22.5
NOV	16.0	13.1	10.6	14.0	16.6
DEC	12.4	12.5	10.4	12.2	13.2
mean	**19.5**	**18.2**	**15.9**	**18.3**	**20.4**
std dev	6.5	7.2	6.4	6.7	6.8
median	20.1	17.3	15.5	17.9	20.5
max	29.3	29.5	25.1	27.9	30.1
min	10.1	5.6	4.3	7.4	9.9

Table 2.2 Salinity (psu) during 2012 at the Lower Cape Fear River Program estuarine stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NCF6	SC-CH
JAN	3.9	3.3	3.8	7.3	15.5	24.4	30.3	35.1	11.9	4.9
FEB	3.9	5.3	7.6	10.8	15.5	24.9	31.2	35.1	0.1	2.5
MAR	0.1	0.2	0.2	3.2	4.3	13.4	20.6	26.7	0.1	2.1
APR	0.1	0.1	0.1	2.7	3.2	7.0	17.5	18.6	7.7	0.9
MAY	0.2	2.9	5.9	11.2	12.5	18.1	24.9	28.2	0.3	8.1
JUN	1.5	2.3	2.4	3.3	9.6	18.6	28.5	32.4	0.6	0.4
JUL	5.1	8.4	12.2	15.3	18.3	25.3	32.4	34.0	2.9	6.3
AUG	3.2	7.2	4.2	6.9	11.1	19.0	28.2	33.5	0.1	1.2
SEP	0.8	1.2	1.2	1.4	4.9	11.8	23.5	28.6	0.1	0.1
OCT	5.4	6.2	4.3	10.1	14.8	21.8	30.1	33.4	0.6	1.2
NOV	7.2	11.3	13.9	17.2	20.8	25.3	30.3	31.9	5.3	10.2
DEC	10.9	13.0	7.4	14.5	18.8	25.8	32.7	34.4	7.2	10.1
mean	**3.5**	**5.1**	**5.3**	**8.7**	**12.4**	**19.6**	**27.5**	**31.0**	**3.1**	**4.0**
std dev	3.3	4.2	4.4	5.4	5.9	6.2	4.9	4.8	4.0	3.8
median	3.6	4.3	4.3	8.7	13.7	20.4	29.3	32.9	0.6	2.3
max	10.9	13.0	13.9	17.2	20.8	25.8	32.7	35.1	11.9	10.2
min	0.1	0.1	0.1	1.4	3.2	7.0	17.5	18.6	0.1	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations, 1995-2011 versus 2012.

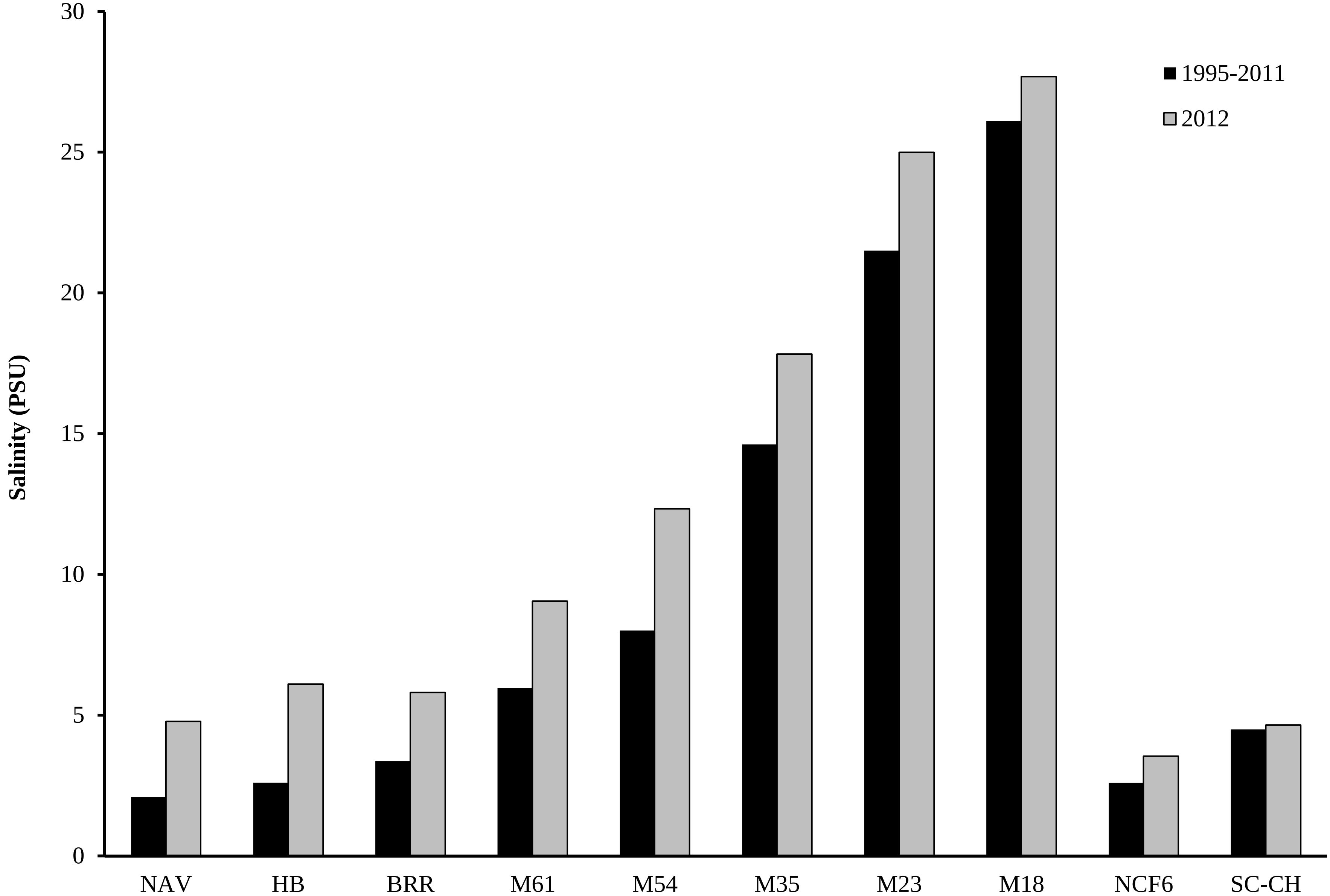

Table 2.3 Conductivity (mS/cm) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	7.00	5.77	6.93	12.60	25.51	38.40	46.68	53.27
FEB	7.21	9.43	13.21	18.17	25.41	39.09	47.93	53.26
MAR	0.18	0.36	0.33	5.92	7.71	22.19	32.85	41.75
APR	0.14	0.14	0.29	5.07	5.81	12.15	28.33	29.97
MAY	0.36	5.38	10.50	18.81	20.87	29.21	39.13	43.67
JUN	2.91	4.31	4.40	6.07	16.32	30.09	44.17	49.66
JUL	9.62	14.10	20.53	25.23	29.68	39.95	49.71	51.84
AUG	5.91	12.64	7.57	12.12	18.81	30.68	43.50	51.24
SEP	1.55	2.60	2.33	2.72	8.80	19.91	37.26	44.40
OCT	9.49	10.69	7.71	17.17	24.32	34.72	46.36	50.87
NOV	12.64	18.97	22.91	27.85	33.19	39.76	46.62	48.85
DEC	18.25	21.59	12.81	23.84	30.36	40.33	49.87	52.21
mean	**6.27**	**8.83**	**9.13**	**14.63**	**20.56**	**31.37**	**42.70**	**47.58**
std dev	5.64	7.00	7.29	8.53	9.26	9.23	6.88	6.77
median	6.45	7.60	7.64	14.89	22.59	32.70	45.27	50.26
max	18.25	21.59	22.91	27.85	33.19	40.33	49.87	53.27
min	0.14	0.14	0.29	2.72	5.81	12.15	28.33	29.97

	NC11	AC	DP	BBT	IC	NCF6
JAN	0.15	0.19	0.24	0.23	0.27	19.93
FEB	0.13	0.19	0.19	0.13	0.16	0.29
MAR	0.13	0.13	0.20	0.12	0.14	0.18
APR	0.14	0.15	0.25	0.22	0.24	13.34
MAY	0.13	0.26	0.24	0.16	0.21	0.69
JUN	0.15	0.19	0.15	0.12	0.16	0.70
JUL	0.17	0.28	0.42	0.24	0.33	5.40
AUG	0.14	0.36	0.20	0.14	0.20	0.16
SEP	0.16	0.16	0.24	0.11	0.15	0.12
OCT	0.16	0.24	0.26	0.16	0.21	1.13
NOV	0.19	0.24	0.37	0.23	0.30	9.35
DEC	0.20	0.27	0.31	0.30	0.35	12.54
mean	**0.16**	**0.22**	**0.26**	**0.18**	**0.23**	**5.32**
std dev	0.02	0.07	0.08	0.06	0.07	6.82
median	0.15	0.21	0.24	0.16	0.21	0.91
max	0.20	0.36	0.42	0.30	0.35	19.93
min	0.13	0.13	0.15	0.11	0.14	0.12

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	0.14	0.19	0.18	0.74	1.08	0.12	0.14	0.71	0.31
FEB	0.14	0.18	0.17	0.73	1.59	0.13	0.13	0.27	0.16
MAR	0.13	0.12	0.10	0.25	0.78	0.10	0.10	0.20	0.17
APR	0.10	0.16	0.16	0.33	1.72	0.16	0.15	0.25	0.27
MAY	0.12	0.18	0.16	0.61	2.16	0.15	0.10	0.25	0.23
JUN	0.09	0.17	0.17	0.54	2.32	0.10	0.11	0.28	0.22
JUL	0.18	0.18	0.18	0.61	0.73	0.08	0.11	0.22	0.24
AUG	0.10	0.14	0.16	0.64	3.99	0.09	0.09	0.11	0.10
SEP	0.09	0.18	0.21	0.69	5.50	0.10	0.13	0.13	0.07
OCT	0.11	0.21	0.18	0.72	2.48	0.13	0.16	0.36	0.24
NOV	0.14	0.22	0.21	1.01	4.64	0.16	0.29	0.26	0.27
DEC	0.12	0.26	0.24	1.01	4.67	0.16	0.25	0.34	0.33
mean	**0.12**	**0.18**	**0.18**	**0.66**	**2.64**	**0.12**	**0.14**	**0.28**	**0.22**
std dev	0.03	0.04	0.03	0.23	1.65	0.03	0.06	0.15	0.08
median	0.12	0.18	0.17	0.67	2.24	0.12	0.13	0.26	0.24
max	0.18	0.26	0.24	1.01	5.50	0.16	0.29	0.71	0.33
min	0.09	0.12	0.10	0.25	0.73	0.08	0.09	0.11	0.07

	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.15	0.10	0.20	0.15	0.16	0.23
FEB	0.14	0.10	0.17	0.13	0.16	0.21
MAR	0.13	0.09	0.14	0.10	0.15	0.17
APR	0.12	0.08	0.12	0.09	0.12	0.15
MAY	0.13	0.09	0.33	0.11	0.14	0.19
JUN	0.13	0.08	0.26	0.12	0.12	0.15
JUL	0.13	0.09	0.23	0.13	0.12	0.14
AUG	0.14	0.17	0.17	0.12	0.11	0.11
SEP	0.15	0.10	0.37	0.12	0.13	0.16
OCT	0.15	0.10	0.56	0.10	0.13	0.17
NOV	0.16	0.11	0.37	0.13	0.14	0.20
DEC	0.15	0.11	0.27	0.12	0.13	0.19
mean	**0.14**	**0.10**	**0.27**	**0.12**	**0.13**	**0.17**
std dev	0.01	0.02	0.12	0.02	0.02	0.03
median	0.14	0.10	0.25	0.12	0.13	0.17
max	0.16	0.17	0.56	0.15	0.16	0.23
min	0.12	0.08	0.12	0.09	0.11	0.11

	NCF117	B210	COL	LVC2	SC-CH
JAN	0.24	0.14	0.10	0.19	8.68
FEB	0.19	0.12	0.10	0.17	4.70
MAR	0.17	0.11	0.10	0.17	3.89
APR	0.14	0.09	0.09	0.14	1.70
MAY	0.24	0.12	0.08	0.18	13.95
JUN	0.10	0.09	0.08	0.13	0.84
JUL	0.20	0.13	0.09	0.16	11.16
AUG	0.14	0.10	0.08	0.16	2.30
SEP	0.10	0.08	0.08	0.11	0.27
OCT	0.16	0.09	0.08	0.13	2.32
NOV	0.20	0.13	0.07	0.15	17.18
DEC	0.18	0.14	0.07	0.17	17.06
mean	**0.17**	**0.11**	**0.08**	**0.15**	**7.00**
std dev	0.05	0.02	0.01	0.02	6.35
median	0.17	0.11	0.08	0.16	4.29
max	0.24	0.14	0.10	0.19	17.18
min	0.10	0.08	0.07	0.11	0.27

Table 2.4 pH during 2012 at the Lower Cape Fear River Program stations.

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

	NC11	AC	DP	BBT	IC	NCF6
JAN	7.1	7.3	7.2	7.2	7.2	7.5
FEB	7.0	7.3	7.2	6.6	6.9	7.0
MAR	6.9	6.9	7.1	6.4	6.7	6.6
APR	6.7	6.8	6.7	6.8	6.8	7.0
MAY	6.7	6.9	6.7	6.1	6.4	6.5
JUN	6.7	6.9	6.5	6.3	6.6	6.7
JUL	6.9	7.6	7.3	6.9	7.0	6.8
AUG	6.6	7.0	6.7	6.4	6.7	6.5
SEP	6.3	6.6	6.6	5.7	6.2	5.8
OCT	6.5	6.9	6.9	6.3	6.7	6.7
NOV	6.0	6.6	6.8	6.5	6.7	6.7
DEC	6.8	6.6	6.6	6.8	6.9	6.8
mean	**6.7**	**7.0**	**6.9**	**6.5**	**6.7**	**6.7**
std dev	0.3	0.3	0.3	0.4	0.3	0.4
median	6.7	6.9	6.8	6.5	6.7	6.7
max	7.1	7.6	7.3	7.2	7.2	7.5
min	6.0	6.6	6.5	5.7	6.2	5.8

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	6.4	6.6	6.8	6.5	6.7	7.2	6.8	7.5	6.8
FEB	6.4	6.7	6.9	6.7	6.8	7.5	7.0	7.2	6.9
MAR	5.9	6.0	6.4	6.0	6.5	6.7	6.3	6.6	6.4
APR	5.2	6.4	6.4	5.9	6.8	7.3	6.8	6.7	6.4
MAY	5.9	6.1	6.4	6.3	6.8	7.8	6.5	6.9	6.7
JUN	4.6	6.5	6.7	6.4	6.9	6.8	6.6	6.9	6.6
JUL	6.2	6.1	6.6	6.5	6.8	6.8	6.8	6.8	6.6
AUG	5.6	6.6	6.5	6.5	6.4	6.1	6.0	6.1	6.2
SEP	5.2	6.5	6.7	6.6	6.8	6.7	6.5	6.0	5.2
OCT	5.9	6.8	6.6	6.6	6.8	7.1	6.5	6.5	6.0
NOV	6.5	6.9	7.0	7.0	6.2	6.7	6.6	6.1	5.6
DEC	6.2	6.8	6.8	6.8	6.6	7.0	6.0	6.1	5.7
mean	**5.8**	**6.5**	**6.7**	**6.5**	**6.7**	**7.0**	**6.5**	**6.6**	**6.3**
std dev	0.6	0.3	0.2	0.3	0.2	0.4	0.3	0.5	0.5
median	5.9	6.6	6.7	6.5	6.8	6.9	6.6	6.7	6.4
max	6.5	6.9	7.0	7.0	6.9	7.8	7.0	7.5	6.9
min	4.6	6.0	6.4	5.9	6.2	6.1	6.0	6.0	5.2

	6RC	LCO	GCO	SR	BRN	HAM
JAN	6.4	6.5	6.5	6.0	6.5	6.7
FEB	6.9	6.5	6.5	5.8	6.8	7.2
MAR	6.7	6.3	6.4	5.8	6.8	6.9
APR	6.3	6.0	6.0	5.8	6.3	6.6
MAY	6.8	6.6	6.9	6.0	6.5	7.0
JUN	6.7	6.3	6.8	6.3	7.0	7.1
JUL	6.3	6.4	6.6	6.1	6.7	6.7
AUG	6.5	6.5	6.2	5.8	6.3	6.4
SEP	6.1	6.7	7.0	6.4	7.1	6.9
OCT	5.6	5.8	6.6	5.3	5.8	6.5
NOV	5.6	6.1	6.2	6.3	6.4	6.6
DEC	5.6	5.8	6.0	5.7	6.2	6.5
mean	**6.3**	**6.3**	**6.5**	**5.9**	**6.5**	**6.8**
std dev	0.5	0.3	0.3	0.3	0.4	0.3
median	6.4	6.4	6.5	5.9	6.5	6.7
max	6.9	6.7	7.0	6.4	7.1	7.2
min	5.6	5.8	6.0	5.3	5.8	6.4

	NCF117	B210	COL	LVC2	SC-CH
JAN	6.9	6.6	3.9	6.5	7.3
FEB	6.7	6.2	3.9	7.2	7.1
MAR	6.7	6.3	3.9	7.2	7.1
APR	6.4	5.9	3.5	6.5	6.8
MAY	6.7	6.2	4.0	6.6	6.8
JUN	6.0	5.8	3.7	6.3	6.4
JUL	6.6	6.4	4.2	6.8	6.5
AUG	6.2	5.9	3.8	6.5	6.6
SEP	5.8	5.5	3.7	6.4	6.3
OCT	6.3	5.7	3.4	7.0	6.9
NOV	6.1	5.7	3.3	6.7	6.3
DEC	6.5	6.2	3.3	6.6	7.1
mean	**6.4**	**6.0**	**3.7**	**6.7**	**6.8**
std dev	0.3	0.3	0.3	0.3	0.3
median	6.5	6.1	3.8	6.6	6.8
max	6.9	6.6	4.2	7.2	7.3
min	5.8	5.5	3.3	6.3	6.3

Table 2.5 Dissolved Oxygen (mg/l) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	10.0	10.4	9.8	9.7	9.4	9.5	9.2	8.7
FEB	8.2	7.9	7.5	7.7	7.9	8.3	8.6	8.2
MAR	9.5	9.7	9.5	9.3	9.3	9.8	9.8	9.7
APR	7.2	6.7	7.7	6.9	7.3	8.0	8.2	8.2
MAY	6.2	6.2	6.2	6.5	6.7	7.0	7.5	7.5
JUN	4.2	4.0	4.5	4.5	5.1	5.9	6.1	6.0
JUL	4.3	4.0	4.8	4.6	5.3	5.4	5.5	5.7
AUG	3.3	3.5	4.4	4.3	5.1	6.0	6.1	6.0
SEP	3.1	3.2	3.8	3.4	4.4	5.1	5.9	6.4
OCT	4.7	5.1	5.4	5.0	5.5	5.8	6.1	6.1
NOV	7.1	7.5	7.4	7.6	8.0	8.4	8.6	8.5
DEC	8.1	8.2	8.2	8.3	8.5	8.7	8.7	8.6
mean	**6.3**	**6.4**	**6.6**	**6.5**	**6.9**	**7.3**	**7.5**	**7.5**
std dev	2.4	2.4	2.0	2.1	1.8	1.7	1.5	1.4
median	6.7	6.5	6.8	6.7	7.0	7.5	7.9	7.9
max	10.0	10.4	9.8	9.7	9.4	9.8	9.8	9.7
min	3.1	3.2	3.8	3.4	4.4	5.1	5.5	5.7

	NC11	AC	DP	BBT	IC	NCF6
JAN	10.3	10.1	9.4	9.3	9.2	8.1
FEB	10.7	10.8	10.7	9.8	10.3	9.8
MAR	10.6	10.4	10.0	8.8	9.1	8.2
APR	7.1	6.7	5.7	5.6	5.4	6.2
MAY	7.5	7.0	6.5	5.5	6.1	5.9
JUN	6.1	5.7	4.4	4.3	4.3	4.1
JUL	4.5	7.0	4.5	3.8	4.0	5.4
AUG	5.7	6.2	4.8	3.9	4.2	3.7
SEP	5.9	5.6	4.8	3.2	3.6	3.0
OCT	7.0	6.3	5.6	5.0	5.0	5.1
NOV	8.1	8.4	7.7	6.7	6.6	7.4
DEC	9.3	9.1	8.4	8.4	8.1	8.5
mean	**7.7**	**7.8**	**6.9**	**6.2**	**6.3**	**6.3**
std dev	2.1	1.9	2.3	2.3	2.3	2.1
median	7.3	7.0	6.1	5.6	5.8	6.1
max	10.7	10.8	10.7	9.8	10.3	9.8
min	4.5	5.6	4.4	3.2	3.6	3.0

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	9.4	9.9	10.2	7.9	9.8	11.5	10.1	4.8	2.1
FEB	9.8	10.2	10.6	8.3	10.7	12.0	10.3	10.1	7.9
MAR	7.9	6.3	7.3	5.2	4.8	8.9	5.6	7.1	5.1
APR	4.2	6.4	4.9	3.6	6.5	10.2	7.5	3.3	0.9
MAY	3.4	5.2	4.4	0.3	6.5	9.6	6.1	2.8	0.3
JUN	4.3	5.2	3.6	1.2	8.9	7.3	5.5	2.0	1.2
JUL	4.8	4.7	2.7	0.4	8.6	6.9	5.7	3.4	1.0
AUG	4.0	4.5	3.6	1.2	4.4	7.2	4.9	5.4	4.9
SEP	4.1	5.1	3.6	0.8	6.4	7.9	6.4	6.6	5.9
OCT	4.2	7.3	6.1	4.1	8.8	9.8	8.4	2.7	0.8
NOV	5.0	8.9	6.7	4.8	8.7	10.8	8.9	4.2	1.4
DEC	3.9	7.9	4.9	2.9	4.6	10.3	7.9	1.6	1.6
mean	**5.4**	**6.8**	**5.7**	**3.4**	**7.4**	**9.4**	**7.3**	**4.5**	**2.8**
std dev	2.3	2.0	2.6	2.8	2.1	1.7	1.9	2.5	2.5
median	4.3	6.4	4.9	3.3	7.6	9.7	7.0	3.8	1.5
max	9.8	10.2	10.6	8.3	10.7	12.0	10.3	10.1	7.9
min	3.4	4.5	2.7	0.3	4.4	6.9	4.9	1.6	0.3

	6RC	LCO	GCO	SR	BRN	HAM
JAN	12.6	12.4	11.6	6.1	12.6	11.7
FEB	10.9	10.9	9.0	6.3	11.1	10.8
MAR	9.4	9.6	7.2	4.7	9.4	9.0
APR	8.8	8.7	6.4	3.2	8.6	8.3
MAY	7.1	7.0	6.3	1.0	7.6	7.3
JUN	6.5	6.5	5.1	0.4	7.0	6.1
JUL	5.7	6.2	4.4	0.4	6.5	5.5
AUG	6.7	6.0	3.8	0.6	7.0	7.5
SEP	7.7	7.6	6.4	3.7	8.2	6.6
OCT	9.2	8.9	8.3	4.4	9.2	9.3
NOV	9.6	9.3	9.3	1.5	9.9	8.1
DEC	9.6	9.4	7.5	3.8	10.1	8.7
mean	**8.7**	**8.5**	**7.1**	**3.0**	**8.9**	**8.2**
std dev	2.0	2.0	2.2	2.2	1.8	1.8
median	9.0	8.8	6.8	3.5	8.9	8.2
max	12.6	12.4	11.6	6.3	12.6	11.7
min	5.7	6.0	3.8	0.4	6.5	5.5

	NCF117	B210	COL	LVC2	SC-CH
JAN	9.4	11.2	10.5	7.0	9.4
FEB	9.0	9.9	8.4	7.5	9.3
MAR	8.8	8.7	7.5	7.8	9.4
APR	5.5	6.5	6.6	4.1	6.9
MAY	4.8	4.8	6.0	3.3	5.6
JUN	3.6	4.8	5.0	3.0	4.1
JUL	4.0	4.2	3.6	2.6	3.7
AUG	3.8	4.4	4.1	2.6	3.7
SEP	2.2	3.7	3.2	3.4	3.8
OCT	4.0	5.7	5.1	4.7	4.8
NOV	6.0	6.3	6.8	4.7	7.2
DEC	8.0	8.1	7.0	8.0	8.0
mean	**5.8**	**6.5**	**6.2**	**4.9**	**6.3**
std dev	2.5	2.4	2.1	2.1	2.3
median	5.2	6.0	6.3	4.4	6.3
max	9.4	11.2	10.5	8.0	9.4
min	2.2	3.7	3.2	2.6	3.7

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations, 1995-2011 versus 2012.

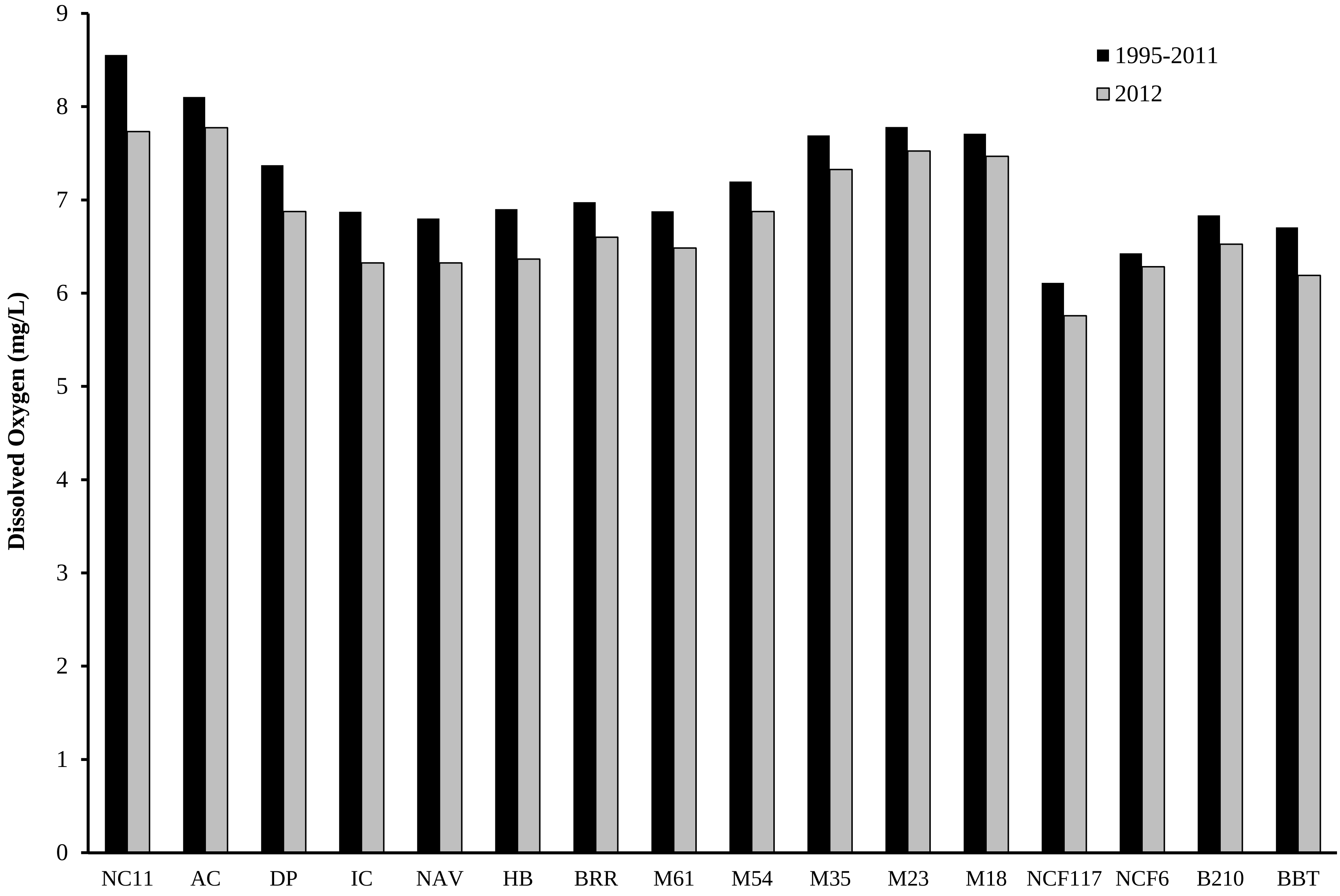

Table 2.6 Field Turbidity (NTU) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	16	11	9	8	8	4	4	7
FEB	17	16	13	8	10	6	6	11
MAR	29	42	29	13	14	6	7	10
APR	32	29	25	14	14	7	13	7
MAY	46	15	10	7	8	10	7	10
JUN	13	17	38	10	12	8	7	7
JUL	13	12	11	9	10	8	11	8
AUG	21	7	15	6	4	2	1	1
SEP	11	9	7	5	3	0	2	2
OCT	8	5	6	4	6	3	2	5
NOV	30	34	34	19	19	16	10	12
DEC	7	6	4	4	4	2	3	4
mean	**20**	**17**	**17**	**9**	**9**	**6**	**6**	**7**
std dev	12	12	12	5	5	4	4	3
median	17	14	12	8	9	6	7	7
max	46	42	38	19	19	16	13	12
min	7	5	4	4	3	0	1	1

	NC11	AC	DP	BBT	IC	NCF6
JAN	14	11	13	11	16	19
FEB	16	16	18	8	12	12
MAR	18	20	22	9	14	16
APR	20	14	12	9	8	13
MAY	16	15	15	9	12	32
JUN	14	12	9	7	12	12
JUL	23	31	28	8	12	7
AUG	24	25	18	5	12	9
SEP	37	27	19	10	11	9
OCT	35	32	23	12	14	14
NOV	10	5	8	2	3	2
DEC	6	6	5	4	10	6
mean	**19**	**18**	**16**	**8**	**11**	**13**
std dev	9	9	7	3	3	8
median	17	16	17	9	12	12
max	37	32	28	12	16	32
min	6	5	5	2	3	2

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	4	2	6	1	5	5	4	8	8
FEB	11	3	2	1	7	6	7	14	16
MAR	4	4	3	2	17	9	6	12	9
APR	5	5	6	2	10	3	5	22	7
MAY	11	3	3	10	6	2	10	11	13
JUN	9	5	3	7	11	12	39	9	6
JUL	10	10							
AUG	6	6	4	13	15	20	22	38	20
SEP	6	10	9	15	18	7	14	10	9
OCT	6	7	4	5	12	5	5	10	14
NOV	1	0	1	0	15	1	1	7	7
DEC	4	3	2	7	36	3	7	16	14
mean	**6**	**5**	**4**	**6**	**14**	**7**	**11**	**14**	**11**
std dev	3	3	2	5	9	5	11	9	4
median	6	5	3	5	12	5	7	11	9
max	11	10	9	15	36	20	39	38	20
min	1	0	1	0	5	1	1	7	6

	6RC	LCO	GCO	SR	BRN	HAM
JAN	3	3	2	2	3	3
FEB	7	5	3	2	7	5
MAR	7	7	4	2	6	8
APR	7	5	3	2	7	5
MAY	5	6	3	6	7	5
JUN	5	36	19	47	15	8
JUL	12	1	11	44	12	4
AUG	15	50	32	49	16	21
SEP	5	1	6	30	2	3
OCT	9	4	4	27	6	8
NOV	0	0	0	4	0	3
DEC	3	1	2	0	0	3
mean	**7**	**10**	**7**	**18**	**7**	**6**
std dev	4	16	9	20	5	5
median	6	5	4	5	7	5
max	15	50	32	49	16	21
min	0	0	0	0	0	3

	NCF117	B210	COL	LVC2	SC-CH
JAN	8	4	2	5	8
FEB	3	2	1	2	9
MAR	3	3	1	2	7
APR	4	3	1	5	22
MAY	6	3	0	5	10
JUN	4	3	2	4	31
JUL	6	2	2	5	11
AUG	3	2	0	1	14
SEP	1	1	0	1	4
OCT	2	0	0	1	6
NOV	5	2	1	3	18
DEC	3	0	0	1	34
mean	**4**	**2**	**1**	**3**	**15**
std dev	2	1	1	2	10
median	4	2	1	3	11
max	8	4	2	5	34
min	1	0	0	1	4

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2011 versus 2012.

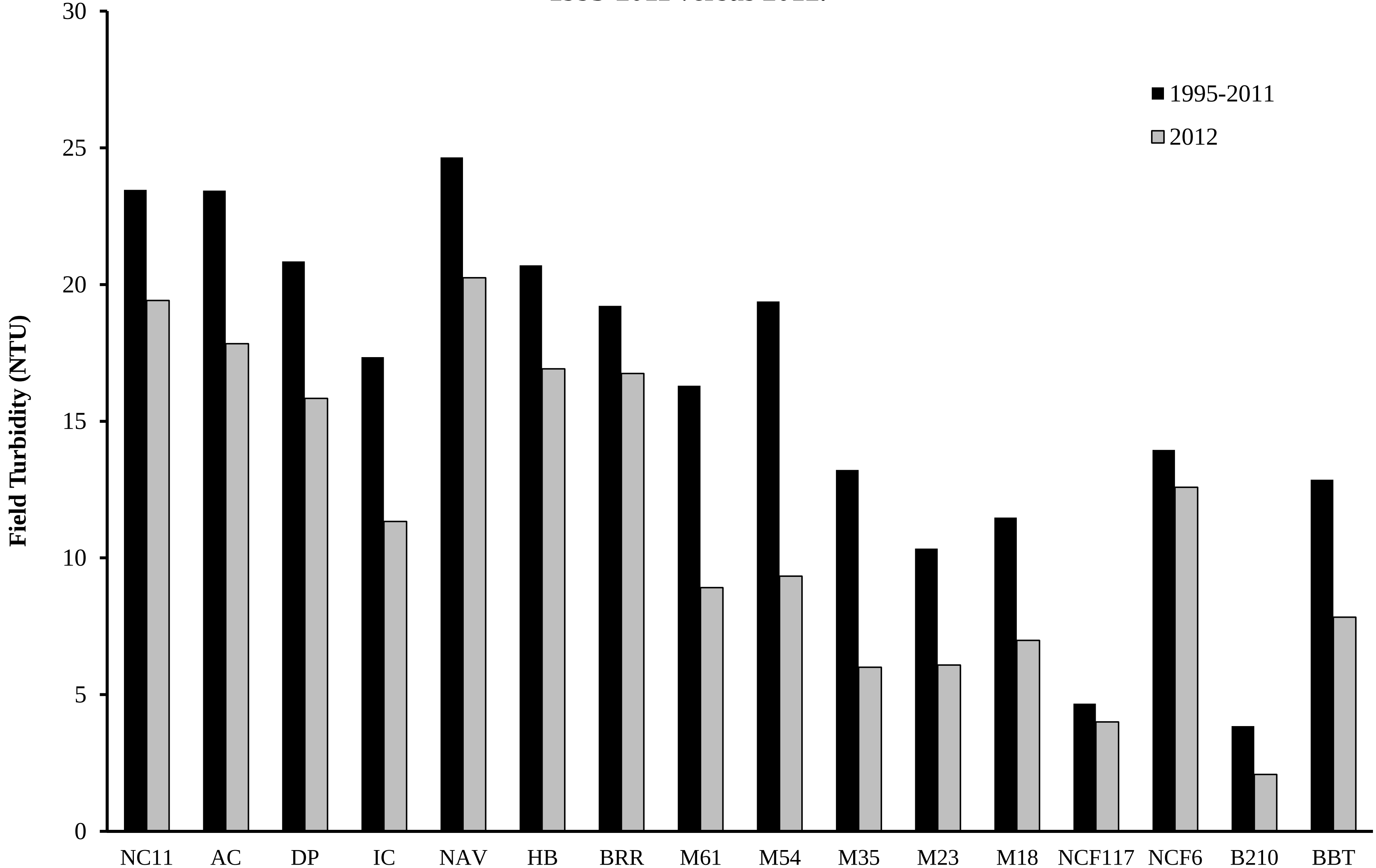

Table 2.7 Total Suspended Solids (mg/L) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	17	18	9	9	15	12	11	16
FEB	14	13	13	9	16	13	16	17
MAR	26	28	24	12	16	10	15	18
APR	27	20	14	10	11	8	22	7
MAY	29	13	10	11	8	15	14	22
JUN	10	10	10	7	16	16	15	10
JUL	13	12	13	16	17	15	22	36
AUG	19	16	20	12	13	13	18	15
SEP	12	14	11	9	9	8	13	16
OCT	16	12	12	12	14	13	18	18
NOV	29	27	24	26	25	20	19	24
DEC	13	18	11	11	13	13	17	24
mean	**19**	**17**	**14**	**12**	**14**	**13**	**17**	**19**
std dev	7	6	5	5	4	3	3	7
median	16	15	12	11	14	13	17	17
max	29	28	24	26	25	20	22	36
min	10	10	9	7	8	8	11	7

	NC11	AC	DP	IC	NCF6
JAN	5	4	6	12	26
FEB	5	6	10	5	10
MAR	9	10	12	7	9
APR	13	7	6	5	12
MAY	9	6	10	7	33
JUN	8	8	6	6	8
JUL	7	14	22	15	8
AUG	18	15	14	11	15
SEP	20	9	7	5	6
OCT	14	10	10	9	8
NOV	7	5	7	5	9
DEC	4	6	5	11	10
mean	**10**	**8**	**10**	**8**	**13**
std dev	5	3	5	3	8
median	8	7	9	7	9
max	20	15	22	15	33
min	4	4	5	5	6

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN		1		1	4	5	3	8	6
FEB		1		1	4	8	5	7	8
MAR		1		1	10	8	4	6	4
APR		5		1	8	2	1	19	4
MAY		1		12	11	2	9	6	7
JUN		7		7	8	12	40	6	7
JUL		9		10	31	7	23	8	6
AUG		3		9	6	14	12	22	10
SEP		7		22	9	3	4	5	4
OCT		3		1	4	2	1	3	14
NOV		1		2	51	1	1	3	8
DEC		1		3	17	2	1	4	6
mean		**3**		**6**	**14**	**5**	**9**	**8**	**7**
std dev		3		6	14	4	12	6	3
median		2		2	9	4	4	6	6
max		9		22	51	14	40	22	14
min		1		1	4	1	1	3	4

	6RC	LCO	GCO	SR	BRN	HAM
JAN			1			
FEB			1			
MAR			4			
APR			3			
MAY			1			
JUN			11			
JUL			6			
AUG			14			
SEP			1			
OCT			1			
NOV			1			
DEC			6			
mean			**4**			
std dev			4			
median			2			
max			14			
min			1			

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

Table 2.8 Light Attenuation (k) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	2.95	2.59	2.33	2.33	1.82	1.14	0.88	0.98
FEB	2.58	2.74	2.48	1.87	1.87	1.00	0.77	0.93
MAR	3.24	4.41	3.40	2.37	2.55	1.59	1.60	1.26
APR	3.72	3.85	3.62	3.04	3.10	2.48	1.88	1.53
MAY		3.00	2.58	2.55	2.09	1.95	1.31	1.88
JUN	4.18	4.31	3.47	3.68	2.82	1.88	1.33	1.07
JUL	2.65	2.31	2.38	2.18	2.28	1.56	1.46	1.08
AUG								
SEP	5.12	4.64	4.16	3.82	3.22	2.21	1.90	1.54
OCT	3.25	2.70	2.93	2.66	2.42	1.81	1.29	1.20
NOV	4.91	4.05	4.60	3.26	2.70	2.31	1.50	1.39
DEC	3.05	2.80	2.85	2.40	2.33	1.45	1.24	1.36
mean	**3.57**	**3.40**	**3.16**	**2.74**	**2.47**	**1.76**	**1.38**	**1.29**
std dev	0.90	0.85	0.75	0.63	0.46	0.47	0.35	0.28
max	5.12	4.64	4.60	3.82	3.22	2.48	1.90	1.88
min	2.58	2.31	2.33	1.87	1.82	1.00	0.77	0.93

	NC11	AC	DP	BBT	IC	NCF6
JAN						
FEB	2.30	2.30	2.28	2.19	2.36	3.91
MAR	2.48	2.81	3.11	3.04	3.02	3.50
APR	2.70	2.35	3.15	3.31	3.20	3.60
MAY	2.28	2.32	2.17	3.20	2.50	6.08
JUN	2.69	2.51	3.65	3.92	3.54	3.79
JUL	1.99	3.41	3.84	3.22	2.81	3.58
AUG	3.29	4.02	2.92	3.04	2.70	4.29
SEP	3.65	2.68	3.61	4.18	4.27	4.68
OCT	2.84	3.02	3.09	3.72	3.28	4.33
NOV	2.16	2.04	2.95	3.64	3.22	4.00
DEC	1.71	1.89	3.11	2.78	3.55	4.07
mean	**2.55**	**2.67**	**3.08**	**3.29**	**3.13**	**4.17**
std dev	0.57	0.62	0.52	0.56	0.54	0.73
max	3.65	4.02	3.84	4.18	4.27	6.08
min	1.71	1.89	2.17	2.19	2.36	3.50

Table 2.9 Total Nitrogen (μg/l) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	1,290	1,690	1,320	1,190	1,010	690	430	330
FEB	1,030	1,070	1,030	910	690	200	170	50
MAR	1,440	1,480	1,330	1,140	1,240	870	760	540
APR	1,150	1,110	1,170	1,240	1,290	1,090	770	730
MAY	1,640	1,360	1,200	860	840	670	430	340
JUN	940	920	850	890	890	700	450	400
JUL	580	560	560	300	400	200	300	300
AUG	980	900	950	790	790	340	300	50
SEP	960	810	680	690	700	260	200	50
OCT	800	600	960	760	690	460	100	140
NOV	1,070	780	640	1,050	500	810	3,110	470
DEC	430	340	460	550	620	160	50	50
mean	**1,026**	**968**	**929**	**864**	**805**	**538**	**589**	**288**
std dev	338	397	296	274	270	309	826	225
median	1,005	910	955	875	745	565	365	315
max	1,640	1,690	1,330	1,240	1,290	1,090	3,110	730
min	430	340	460	300	400	160	50	50

	NC11	AC	DP	IC	NCF6
JAN	1,140	1,230	770	1,170	960
FEB	1,030	1,080	1,080	770	490
MAR	1,490	1,570	1,300	1,270	1,370
APR	810	800	610	490	280
MAY	1,080	1,270	1,390	1,280	930
JUN	1,380	1,340	1,040	1,020	720
JUL	630	720	840	780	600
AUG	1,420	1,370	1,320	990	900
SEP	980	950	750	740	570
OCT	1,860	1,800	1,330	1,060	680
NOV	1,730	1,820	1,590	1,520	660
DEC	1,450	1,230	930	870	350
mean	**1,250**	**1,265**	**1,079**	**997**	**709**
std dev	368	351	306	286	299
median	1,260	1,250	1,060	1,005	670
max	1,860	1,820	1,590	1,520	1,370
min	630	720	610	490	280

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	760	480	100	560	150	260	990	11,100	1,030
FEB	2,180	850	420	710	460	550	1,160	2,870	1,110
MAR	1,530	970	710	550	620	890	1,010	1,680	610
APR	670	120	50	260	50	130	980	340	50
MAY	1,130	580	500	720	700	530	1,160	1,830	850
JUN	1,450	1,060	730	1,130	1,180	740	2,480	620	1,030
JUL	6,530	970	830	1,050	890	1,050	1,450	1,210	780
AUG	1,220	990	560	630	830	940	1,150	1,360	860
SEP	1,230	790	540	630	790	580	1,810	710	480
OCT	920	690	600	370	530	480	2,420	500	400
NOV	640	640	300	450	530	440	8,550	710	300
DEC	480	340	50	530	640	250	4,590	470	120
mean	**1,562**	**707**	**449**	**633**	**614**	**570**	**2,313**	**1,950**	**635**
std dev	1,634	290	270	252	309	289	2,223	2,974	364
median	1,175	740	520	595	630	540	1,305	960	695
max	6,530	1,060	830	1,130	1,180	1,050	8,550	11,100	1,110
min	480	120	50	260	50	130	980	340	50

	6RC	LCO	GCO	SR	BRN	HAM
JAN	940	510	820	330	530	200
FEB	590	370	360	1,210	560	50
MAR	1,440	960	640	850	770	1,080
APR	1,410	850	860	1,060	700	990
MAY	1,110	890	1,890	840	710	330
JUN	1,380	1,150	1,120	1,430	680	800
JUL	1,080	810	1,310	1,470	940	700
AUG	970	1,120	980	1,140	550	940
SEP	970	780	1,340	860	510	500
OCT	1,670	580	690	700	380	860
NOV	1,090	420	850	880	830	1,800
DEC	1,130	670	730	320	430	230
mean	**1,148**	**759**	**966**	**924**	**633**	**707**
std dev	287	256	403	368	167	486
median	1,100	795	855	870	620	750
max	1,670	1,150	1,890	1,470	940	1,800
min	590	370	360	320	380	50

	NCF117	B210	COL	LVC2
JAN	610	630	400	650
FEB	570	370	300	250
MAR	700	550	480	360
APR	1,150	880	1,000	680
MAY	800	620	730	790
JUN	1,250	890	940	1,030
JUL	600	500	1,100	690
AUG	750	590	940	640
SEP	640	660	750	340
OCT	690	730	720	560
NOV	1,180	640	900	420
DEC	790	460	700	400
mean	**811**	**627**	**747**	**568**
std dev	243	154	249	223
median	725	625	740	600
max	1,250	890	1,100	1,030
min	570	370	300	250

Figure 2.4 Total Nitrogen at the Lower Cape Fear River Program mainstem stations, 1995-2011 versus 2012.

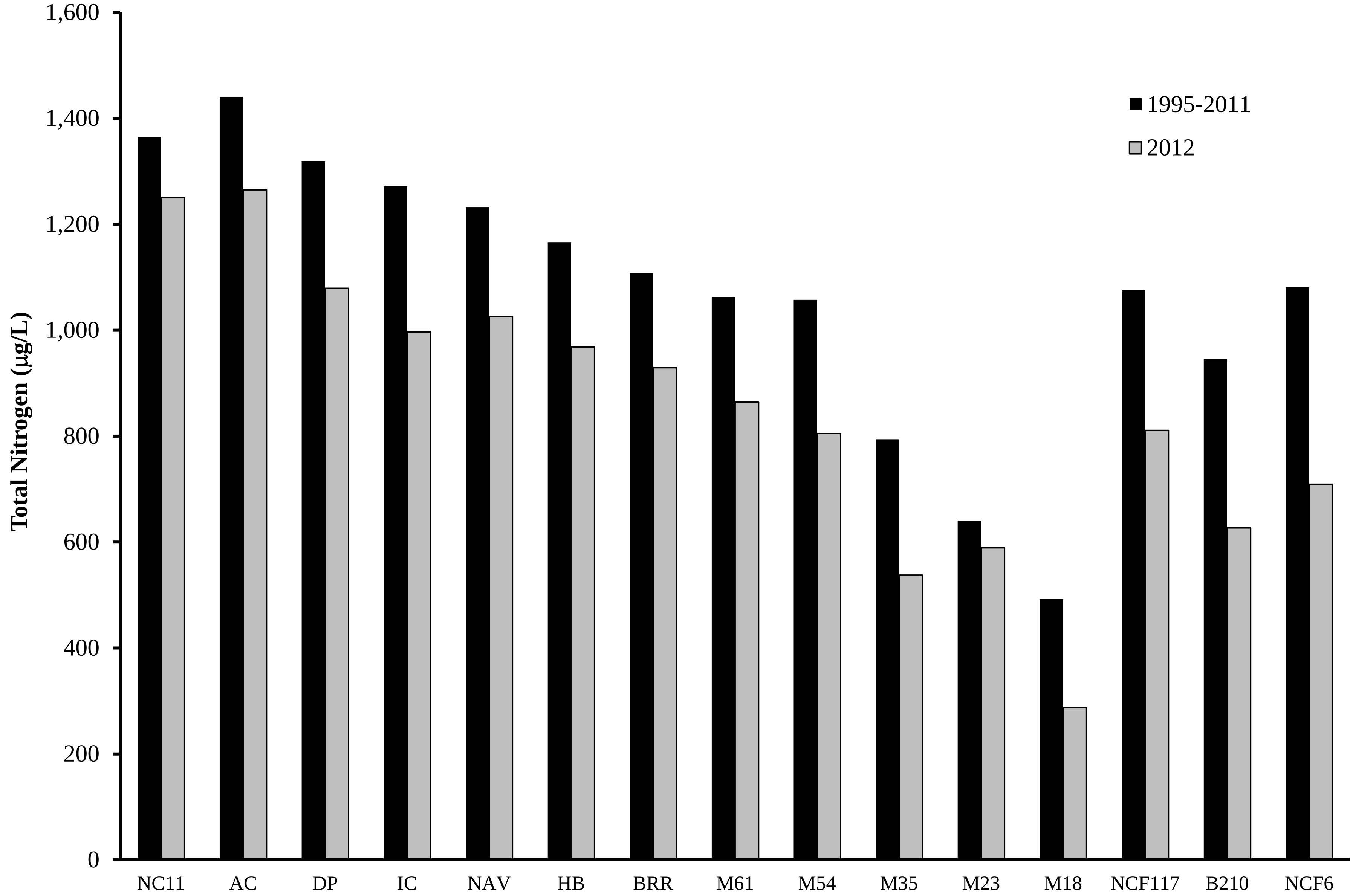

Table 2.10 Nitrate/Nitrite (μg/l) during 2012 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	790	1290	820	690	510	390	130	30
FEB	530	570	530	410	390	200	70	10
MAR	640	780	730	540	540	370	260	140
APR	450	410	470	440	390	390	270	230
MAY	1140	960	800	560	540	370	230	140
JUN	340	320	350	290	290	200	50	10
JUL	80	60	60	10	10	10	10	10
AUG	580	400	450	390	290	140	10	10
SEP	560	310	280	290	300	260	200	50
OCT	500	200	560	460	390	260	100	40
NOV	670	480	440	350	300	210	110	70
DEC	430	340	460	350	320	160	50	10
mean	**559**	**510**	**496**	**398**	**356**	**247**	**124**	**63**
std dev	256	346	218	169	145	118	94	71
median	545	405	465	400	355	235	105	35
max	1,140	1,290	820	690	540	390	270	230
min	80	60	60	10	10	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	840	1030	470	870	560
FEB	1030	980	980	770	290
MAR	690	670	600	470	470
APR	810	800	610	490	280
MAY	880	870	1090	980	330
JUN	980	840	440	420	220
JUL	30	20	40	80	10
AUG	1020	870	1020	690	300
SEP	780	650	550	340	107
OCT	1460	1400	1030	660	280
NOV	1330	1320	1290	920	160
DEC	1450	1230	530	870	250
mean	**942**	**890**	**721**	**630**	**271**
std dev	387	365	358	273	147
median	930	870	605	675	280
max	1,460	1,400	1,290	980	560
min	30	20	40	80	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	260	180	10	360	50	60	690	11100	330
FEB	980	350	20	410	60	50	560	1770	510
MAR	430	270	210	150	20	290	410	680	310
APR	70	120	10	260	30	130	980	140	50
MAY	130	80	10	20	10	30	560	1030	250
JUN	150	260	30	130	80	40	1380	120	30
JUL	530	270	30	50	90	50	650	410	80
AUG	120	190	60	30	130	340	450	460	260
SEP	130	190	40	30	90	80	1110	210	80
OCT	120	290	10	170	30	180	1920	100	10
NOV	140	340	10	250	30	140	7450	310	10
DEC	80	240	10	230	40	50	3890	270	20
mean	**262**	**232**	**38**	**174**	**55**	**120**	**1,671**	**1,383**	**162**
std dev	268	82	57	131	36	103	2,063	3,098	165
median	135	250	15	160	45	70	835	360	80
max	980	350	210	410	130	340	7,450	11,100	510
min	70	80	10	20	10	30	410	100	10

	6RC	LCO	GCO	SR	BRN	HAM
JAN	740	210	520	130	330	10
FEB	490	270	260	1010	560	10
MAR	840	360	40	50	170	280
APR	610	150	60	60	100	190
MAY	810	490	1290	40	310	130
JUN	880	550	220	130	180	200
JUL	380	310	210	70	240	200
AUG	570	220	80	40	150	240
SEP	670	380	740	60	310	100
OCT	1070	280	290	100	180	360
NOV	890	220	250	80	430	10
DEC	730	370	230	120	130	30
mean	**723**	**318**	**349**	**158**	**258**	**147**
std dev	192	119	356	270	136	117
median	735	295	240	75	210	160
max	1,070	550	1,290	1,010	560	360
min	380	150	40	40	100	10

	NCF117	B210	COL	LVC2
JAN	210	330	10	350
FEB	370	270	10	250
MAR	400	350	80	160
APR	250	180	10	180
MAY	300	220	30	390
JUN	450	190	40	330
JUL	10	10	10	90
AUG	250	190	40	340
SEP	140	160	50	140
OCT	190	230	20	160
NOV	480	140	10	220
DEC	290	160	10	200
mean	**278**	**203**	**27**	**234**
std dev	135	90	22	97
median	270	190	15	210
max	480	350	80	390
min	10	10	10	90

Table 2.11 Ammonia (μg/l) during 2012 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	60	60	40	110	80	30	5	5
FEB	50	70	70	80	100	20	5	5
MAR	20	40	40	60	150	50	20	10
APR	90	70	70	70	60	70	30	10
MAY	90	90	100	90	90	50	10	5
JUN	80	70	70	70	100	70	20	5
JUL	50	90	110	130	90	20	5	5
AUG	30	20	10	20	10	5	5	5
SEP	120	100	220	140	70	70	140	500
OCT	170	20	100	290	70	140	20	290
NOV	20	120	100	120	20	20	70	20
DEC	150	100	150	120	70	50	15	15
mean	**78**	**71**	**90**	**108**	**76**	**50**	**29**	**73**
std dev	49	32	55	67	37	36	39	157
median	70	70	85	100	75	50	18	8
max	170	120	220	290	150	140	140	500
min	20	20	10	20	10	5	5	5

	NC11	AC	DP	IC	NCF6
JAN	40	60	90	80	110
FEB	40	80	70	60	70
MAR	50	60	150	80	60
APR	100	90	130	100	80
MAY	80	160	100	80	5
JUN	50	70	80	60	10
JUL	130	90	230	70	40
AUG	50	130	40	30	20
SEP	110	180	110	70	70
OCT	170	50	140	120	50
NOV	50	120	100	70	50
DEC	20	100	70	120	50
mean	**74**	**99**	**109**	**78**	**51**
std dev	45	41	49	26	30
median	50	90	100	75	50
max	170	180	230	120	110
min	20	50	40	30	5

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	10	20	20	40	50	50	50	30	810
FEB	60	10	10	20	10	10	40	380	130
MAR	110	40	70	40	120	130	80	330	80
APR	80	20	10	30	100	50	50	140	120
MAY	120	30	5	110	40	30	40	300	560
JUN	170	50	20	200	90	30	130	140	110
JUL	3,380	40	10	420	120	100	110	170	160
AUG	140	120	90	310	510	190	190	230	140
SEP	140	90	70	260	210	90	140	140	90
OCT	20	20	70	50	70	100	100	20	170
NOV	60	30	30	80	100	30	40	170	30
DEC	170	50	20	50	270	50	20	100	50
mean	**372**	**43**	**35**	**134**	**141**	**72**	**83**	**179**	**204**
std dev	949	32	30	132	137	52	52	112	234
median	115	35	20	65	100	50	65	155	125
max	3380	120	90	420	510	190	190	380	810
min	10	10	5	20	10	10	20	20	30

	6RC	LCO	GCO	SR	BRN	HAM
JAN	10	10	10	20	10	5
FEB	30	40	20	30	20	20
MAR	40	20	20	10	30	50
APR	30	30	20	50	20	80
MAY	30	30	40	130	60	80
JUN	40	100	130	260	40	50
JUL	80	30	110	310	60	60
AUG	30	50	60	170	30	60
SEP	50	50	120	280	20	70
OCT	70	100	120	100	20	70
NOV	20	20	100	120	50	70
DEC	20	70	50	20	50	20
mean	**38**	**46**	**67**	**125**	**34**	**53**
std dev	21	30	46	108	17	25
median	30	35	55	110	30	60
max	80	100	130	310	60	80
min	10	10	10	10	10	5

	NCF117	B210	COL	LVC2
JAN	10	10	10	130
FEB	30	20	20	110
MAR	10	10	5	110
APR	40	30	10	110
MAY	30	40	50	130
JUN	50	10	30	130
JUL	10	30	180	100
AUG	30	20	20	100
SEP	40	180	250	180
OCT	170	100	120	170
NOV	150	50	120	150
DEC	20	50	50	270
mean	**49**	**46**	**72**	**141**
std dev	54	49	79	48
median	30	30	40	130
max	170	180	250	270
min	10	10	5	100

Table 2.12 Total Kjeldahl Nitrogen (μg/l) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	500	400	500	500	500	300	300	300
FEB	500	500	500	500	300	50	100	50
MAR	800	700	600	600	700	500	500	400
APR	700	700	700	800	900	700	500	500
MAY	500	400	400	300	300	300	200	200
JUN	600	600	500	600	600	500	400	400
JUL	500	500	500	300	400	200	300	300
AUG	400	500	500	400	500	200	300	50
SEP	400	500	400	400	400	50	50	50
OCT	300	400	400	300	300	200	50	100
NOV	400	300	200	700	200	600	3000	400
DEC	50	50	50	200	300	50	50	50
mean	**471**	**463**	**438**	**467**	**450**	**304**	**479**	**233**
std dev	191	177	172	183	202	223	811	170
median	500	500	500	450	400	250	300	250
max	800	700	700	800	900	700	3,000	500
min	50	50	50	200	200	50	50	50

	NC11	AC	DP	IC	NCF6
JAN	300	200	300	300	400
FEB	50	100	100	50	200
MAR	800	900	700	800	900
APR	50	50	50	50	50
MAY	200	400	300	300	600
JUN	400	500	600	600	500
JUL	600	700	800	700	600
AUG	400	500	300	300	600
SEP	2000	300	200	400	400
OCT	400	400	300	400	400
NOV	400	500	300	600	500
DEC	50	50	400	50	50
mean	**471**	**383**	**363**	**379**	**433**
std dev	532	261	229	256	245
median	400	400	300	350	450
max	2,000	900	800	800	900
min	50	50	50	50	50

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	500	300	100	200	100	200	300	50	700
FEB	1200	500	400	300	400	500	600	1100	600
MAR	1100	700	500	400	600	600	600	1000	300
APR	600	50	50	50	50	50	50	200	50
MAY	1000	500	500	700	700	500	600	800	600
JUN	1300	800	700	1000	1100	700	1100	500	1000
JUL	6000	700	800	1000	800	1000	800	800	700
AUG	1100	800	500	600	700	600	700	900	600
SEP	1100	600	500	600	700	500	700	500	400
OCT	800	400	600	200	500	300	500	400	400
NOV	500	300	300	200	500	300	1100	400	300
DEC	400	100	50	300	600	200	700	200	100
mean	**1,300**	**479**	**417**	**463**	**563**	**454**	**646**	**571**	**479**
std dev	1,512	255	247	317	289	261	293	343	273
median	1,050	500	500	350	600	500	650	500	500
max	6,000	800	800	1,000	1,100	1,000	1,100	1,100	1,000
min	400	50	50	50	50	50	50	50	50

	6RC	LCO	GCO	SR	BRN	HAM
JAN	200	300	300	200	200	200
FEB	100	100	100	200	50	50
MAR	600	600	600	800	600	800
APR	800	700	800	1000	600	800
MAY	300	400	600	800	400	200
JUN	500	600	900	1300	500	600
JUL	700	500	1100	1400	700	500
AUG	400	900	900	1100	400	700
SEP	300	400	600	800	200	400
OCT	600	300	400	600	200	500
NOV	200	200	600	800	400	1800
DEC	400	300	500	200	300	200
mean	**425**	**442**	**617**	**767**	**379**	**563**
std dev	218	227	279	410	197	463
median	400	400	600	800	400	500
max	800	900	1,100	1,400	700	1,800
min	100	100	100	200	50	50

	NCF117	B210	COL	LVC2
JAN	400	300	400	300
FEB	200	100	300	50
MAR	300	200	400	200
APR	900	700	1000	500
MAY	500	400	700	400
JUN	800	700	900	700
JUL	600	500	1100	600
AUG	500	400	900	300
SEP	500	500	700	200
OCT	500	500	700	400
NOV	700	500	900	200
DEC	500	300	700	200
mean	**533**	**425**	**725**	**338**
std dev	197	182	253	190
median	500	450	700	300
max	900	700	1,100	700
min	200	100	300	50

Table 2.13 Total Phosphorus (µg/l) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	80	110	90	80	70	10	10	10
FEB	140	110	140	80	160	100	10	70
MAR	180	170	180	160	110	60	50	80
APR	140	120	160	90	100	80	50	50
MAY	310	210	160	90	110	120	110	80
JUN	120	110	120	110	110	80	50	40
JUL	150	130	100	130	100	60	50	60
AUG	150	150	190	150	130	80	40	30
SEP	140	140	150	110	120	80	70	30
OCT	110	110	110	80	90		50	30
NOV	170	130	100	100	70	60	30	30
DEC	100	90	90	120	70	40	30	30
mean	**149**	**132**	**133**	**108**	**103**	**70**	**46**	**45**
std dev	56	31	34	26	26	28	26	22
median	140	125	130	105	105	80	50	35
max	310	210	190	160	160	120	110	80
min	80	90	90	80	70	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	120	150	140	130	60
FEB	180	180	140	120	80
MAR	110	160	130	90	140
APR	240	190	160	150	110
MAY	230	250	260	220	230
JUN	180	170	140	140	120
JUL	180	190	250	180	70
AUG	260	320	240	190	180
SEP	220	160	160	110	140
OCT	280	300	280	200	140
NOV	260	240	290	170	80
DEC	280	260	220	220	70
mean	**212**	**214**	**201**	**160**	**160**
std dev	56	55	59	41	50
median	225	190	190	160	115
max	280	320	290	220	220
min	110	150	130	90	90

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	60	40	40	10	110	40	120	1,400	520
FEB	150	120	170	130	170	120	140	330	110
MAR	130	40	110	90	380	120	150	620	100
APR	120	110	80	70	210	110	300	470	340
MAY	140	120	120	840	290	50	250	340	350
JUN	180	180	200	380	220	110	550	270	160
JUL	710	140	220	630	260	80	310	350	210
AUG	360	140	140	380	180	130	320	400	170
SEP	320	210	150	300	160	100	370	230	60
OCT	180	100	80	160	150	90	280	230	210
NOV	220	40	40	90	70	40	800	180	120
DEC	150	80	40	130	270	30	500	300	200
mean	**227**	**110**	**116**	**268**	**206**	**85**	**341**	**427**	**213**
std dev	166	52	60	242	81	35	187	315	126
median	165	115	115	145	195	95	305	335	185
max	710	210	220	840	380	130	800	1,400	520
min	60	40	40	10	70	30	120	180	60

	6RC	LCO	GCO	SR	BRN	HAM
JAN	30	10	140	10	30	60
FEB	60	40	220	10	60	50
MAR	60	40	290	70	60	50
APR	80	40	280	60	80	130
MAY	160	170	740	120	190	270
JUN	100	170	680	120	110	200
JUL	150	60	650	120	190	140
AUG	150	750	680	130	120	180
SEP	140	100	420	130	120	200
OCT	140	50	340	70	70	150
NOV	70	50	440	70	70	120
DEC	70	30	300	20	50	80
mean	**101**	**126**	**432**	**78**	**96**	**136**
std dev	43	195	197	45	50	66
median	90	50	380	70	75	135
max	160	750	740	130	190	270
min	30	10	140	10	30	50

	NCF117	B210	COL	LVC2
JAN	50	60	10	10
FEB	80	60	10	30
MAR	40	50	40	70
APR	100	90	70	40
MAY	110	130	40	60
JUN	120	90	10	50
JUL	110	140	60	70
AUG	170	140	60	40
SEP	160	110	30	30
OCT	120	80	30	30
NOV	80	60	10	20
DEC	50	40	10	10
mean	**99**	**88**	**32**	**38**
std dev	40	34	22	20
median	105	85	30	35
max	170	140	70	70
min	40	40	10	10

Figure 2.5 Total Phosphorus at the Lower Cape Fear River Program mainstem stations, 1995-2011 versus 2012.

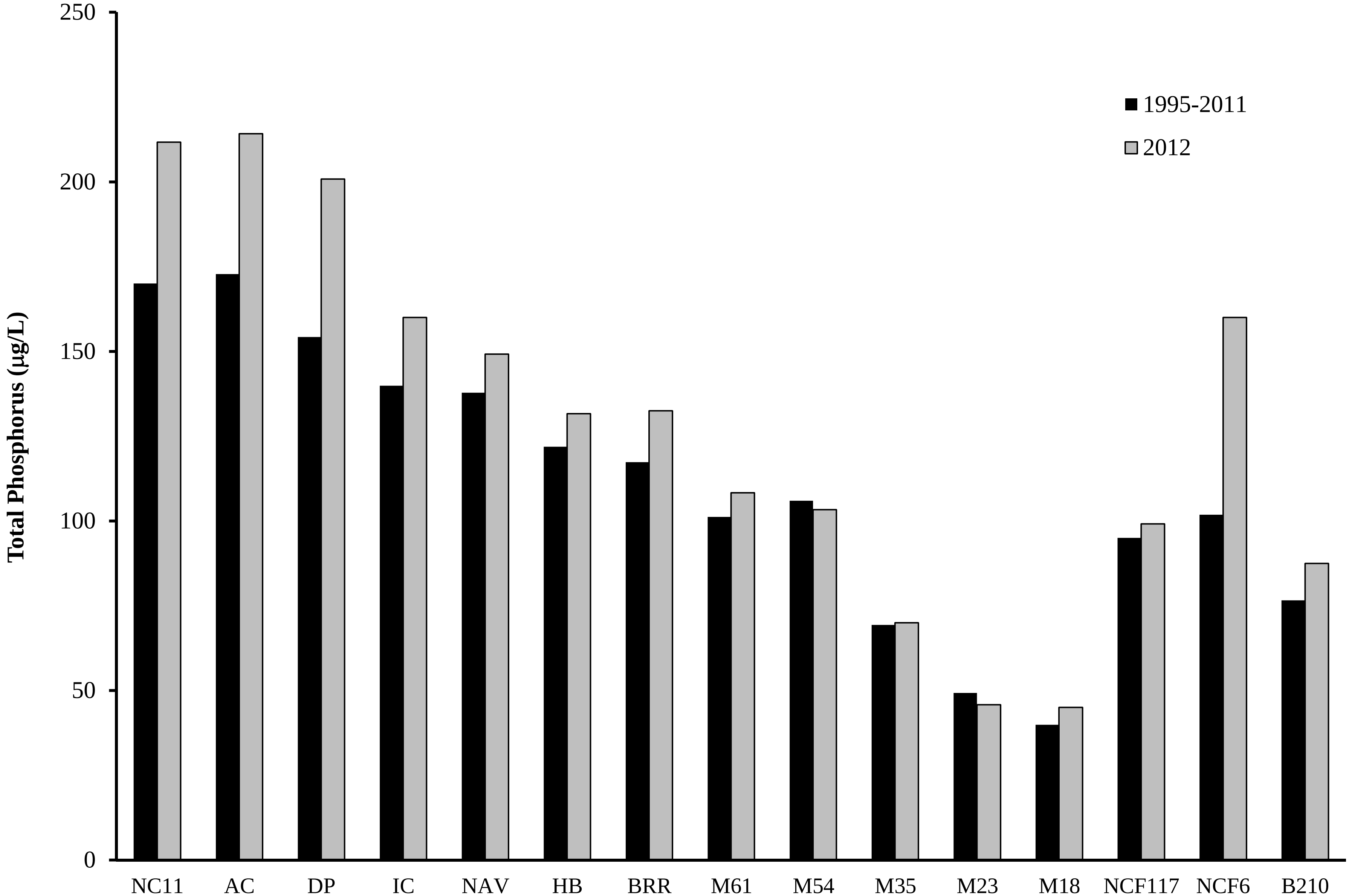

Table 2.14 Orthophosphate (µg/l) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	60	50	50	50	40	20	10	10
FEB	50	50	50	50	40	20	10	10
MAR	50	60	60	40	50	30	20	10
APR	40	40	50	50	50	40	30	20
MAY	90	90	70	60	50	40	20	20
JUN	50	50	60	50	50	30	10	20
JUL	70	60	50	50	40	30	20	10
AUG	70	60	50	70	60	40	10	10
SEP	50	60	60	60	60	50	30	20
OCT	40	50	50	50	50	30	20	10
NOV	70	50	40	50	50	30	20	10
DEC	50	40	60	50	30	30	10	10
mean	**58**	**55**	**54**	**53**	**48**	**33**	**18**	**13**
std dev	15	13	8	8	9	9	8	5
median	50	50	50	50	50	30	20	10
max	90	90	70	70	60	50	30	20
min	40	40	40	40	30	20	10	10

	NC11	AC	DP	BBT	IC	NCF6
JAN	100	100	80	60	70	30
FEB	110	100	80	30	60	20
MAR	50	50	60	20	40	50
APR	80	70	60	50	70	40
MAY	90	110	120	70	110	50
JUN	80	80	50	50	50	50
JUL	100	110	150	70	110	30
AUG	90	130	120	60	90	70
SEP	80	80	80	30	50	60
OCT	150	170	130	50	80	60
NOV	180	170	170	70	110	40
DEC	200	160	130	100	130	30
mean	**109**	**111**	**103**	**55**	**81**	**44**
std dev	45	40	39	22	29	15
median	95	105	100	55	75	45
max	200	170	170	100	130	70
min	50	50	50	20	40	20

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	40	10	10	30	40	0	60	990	250
FEB	110	10	10	30	20	0	60	240	40
MAR	90	30	30	50	70	10	60	410	40
APR	50	30	20	50	40	10	90	170	50
MAY	80	50	50	120	70	20	120	190	80
JUN	110	50	40	120	50	10	190	120	40
JUL	300	60	40	190	70	20	120	160	90
AUG	250	60	50	180	20	30	150	270	80
SEP	240	60	30	110	10	10	120	120	20
OCT	110	30	30	80	50	10	160	10	40
NOV	180	30	20	50	20	20	520	70	40
DEC	90	20	30	40	40	20	370	1180	40
mean	**138**	**37**	**30**	**88**	**42**	**13**	**168**	**328**	**68**
std dev	85	19	13	56	21	9	139	370	61
median	110	30	30	65	40	10	120	180	40
max	300	60	50	190	70	30	520	1180	250
min	40	10	10	30	10	0	60	10	20

	6RC	LCO	GCO	SR	BRN	HAM
JAN	10	10	180	10	10	30
FEB	10	10	180	10	10	30
MAR	20	10	190	0	10	30
APR	20	10	150	10	20	40
MAY	40	40	490	20	30	70
JUN	40	60	250	10	30	70
JUL	50	40	410	10	50	80
AUG	50	200	270	10	30	60
SEP	50	40	210	20	30	70
OCT	60	30	220	20	20	60
NOV	30	30	280	20	30	50
DEC	30	10	190	10	20	20
mean	**34**	**41**	**252**	**13**	**24**	**51**
std dev	17	53	102	6	12	20
median	35	30	215	10	25	55
max	60	200	490	20	50	80
min	10	10	150	0	10	20

	NCF117	B210	COL	LVC2
JAN	20	20	0	0
FEB	20	20	0	0
MAR	20	20	0	0
APR	40	40	0	0
MAY	40	50	0	10
JUN	70	50	10	10
JUL	50	60	30	20
AUG	60	60	20	10
SEP	70	50	10	10
OCT	50	30	10	10
NOV	30	20	10	0
DEC	20	20	10	0
mean	**41**	**37**	**8**	**6**
std dev	19	17	9	7
median	40	35	10	5
max	70	60	30	20
min	20	20	0	0

Table 2.15 Chlorophyll *a* (µg/l) during 2012 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	2	2	2	2	2	3	4	7
FEB	2	2	2	2	2	3	3	4
MAR	1	2	1	1	2	4	5	3
APR	1	1	1	1	3	4	5	7
MAY	5	3	4	4	6	7	8	5
JUN	3	3	4	3	8	7	7	8
JUL	17	14	13	9	14	9	8	7
AUG	4	7	21	54	25	19	7	7
SEP	2	2	3	5	7	4	8	9
OCT	3	7	9	4	8	3	5	5
NOV	2	2	3	2	3	3	4	5
DEC	2	2	4	3	4	4	7	7
mean	**4**	**4**	**6**	**8**	**7**	**6**	**6**	**6**
std dev	4	4	6	15	7	5	2	2
median	2	2	4	3	5	4	6	7
max	17	14	21	54	25	19	8	9
min	1	1	1	1	2	3	3	3

	NC11	AC	DP	BBT	IC	NCF6
JAN	1	0	0	1	1	3
FEB	1	1	1	1	1	8
MAR	2	3	3	1	2	6
APR	3	3	1	1	1	3
MAY	2	2	3	1	2	4
JUN	9	5	2	1	2	1
JUL	12	40	22	4	9	24
AUG	3	3	4	1	3	2
SEP	6	4	6	1	1	1
OCT	2	2	1	1	1	2
NOV	1	1	1	0	0	2
DEC	2	1	1	1	1	2
mean	**4**	**5**	**4**	**1**	**2**	**5**
std dev	4	11	6	1	2	6
median	2	3	2	1	1	3
max	12	40	22	4	9	24
min	1	0	0	0	0	1

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	2	2	2	3	2	32	2	2	1
FEB	3	1	2	2	3	30	2	2	1
MAR	2	3	2	1	4	3	2	3	1
APR	2	2	2	1	4	1	0	1	1
MAY	20	3	6	8	20	1	2	4	4
JUN	1	1	4	19	4	7	4	3	1
JUL	4	4	7	9	6	6	6	1	1
AUG	6	2	2	8	8	10	2	3	1
SEP	4	2	3	28	12	8	1	1	0
OCT	2	2	4	3	2	1	0	1	1
NOV	1	1	2	2	4	0	0	2	1
DEC	1	9	2	8	32	1	2	1	2
mean	**4**	**3**	**3**	**8**	**8**	**8**	**2**	**2**	**1**
std dev	5	2	2	8	9	11	2	1	1
median	2	2	2	6	4	5	2	2	1
max	20	9	7	28	32	32	6	4	4
min	1	1	2	1	2	0	0	1	0

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

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

Figure 2.6 Chlorophyll a at the Lower Cape Fear River Program mainstem stations, 1995-2011 versus 2012.

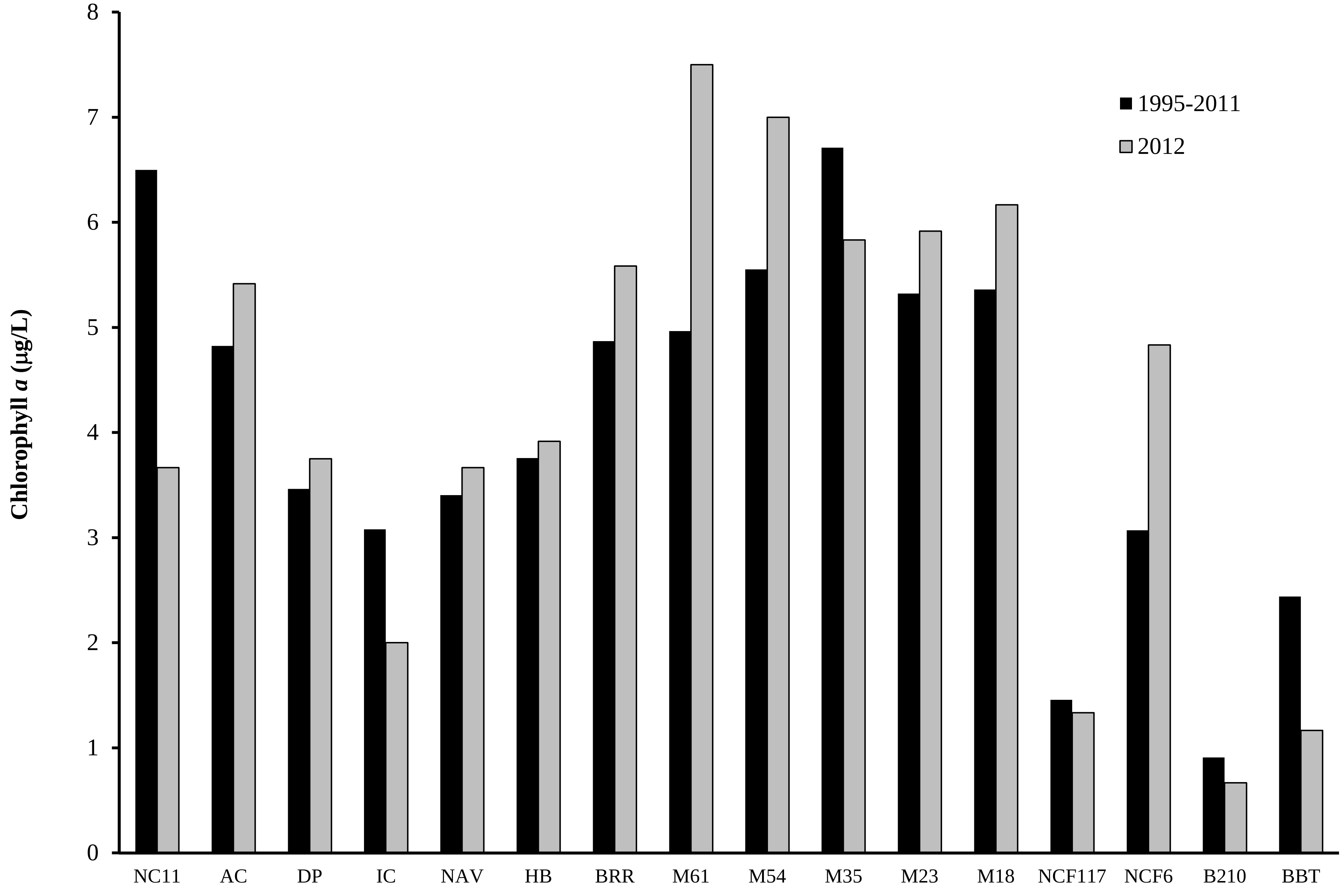

Table 2.16 Biochemical Oxygen Demand (mg/l) during 2012 at the Lower Cape Fear River Program stations.

5-Day Biochemical Oxygen Demand

	NC11	AC	NCF117	B210	LVC2	BBT
JAN	0.3	0.4	0.8	0.8	0.8	0.7
FEB	0.4	0.8	0.7	3.7	0.8	0.5
MAR	1.6	1.6	1.1	1.0	0.8	1.7
APR	1.9	0.9	1.6	1.2	1.2	1.4
MAY	0.8	0.9	1.0	0.9	2.0	0.8
JUN	1.3	0.9	1.6	1.7		1.0
JUL	2.3	4.2	0.9	1.5	1.4	
AUG	0.9	2.4				1.3
SEP	1.2	0.8	2.2	1.4	1.5	1.1
OCT	1.0	1.6	0.9	1.1	1.5	1.5
NOV	2.3	2.9	0.9	1.0	1.4	1.6
DEC			0.9	0.9	1.2	
mean	1.3	1.6	1.1	1.4	1.3	1.2
stdev	0.7	1.2	0.5	0.8	0.4	0.4
median	1.2	0.9	0.9	1.1	1.3	1.2
max	2.3	4.2	2.2	3.7	2.0	1.7
min	0.3	0.4	0.7	0.8	0.8	0.5

20-Day Biochemical Oxygen Demand

	NC11	AC	NCF117	B210	LVC2	BBT
JAN	2.5	2.5	2.6	2.1	2.6	3.5
FEB	1.9	3.0	2.4	6.3	2.6	2.0
MAR	4.8	3.7	3.6	2.7	2.6	3.8
APR	4.4	2.7	4.3	3.2	3.2	4.0
MAY	2.7	3.8	3.3	2.6	6.0	2.7
JUN	3.5	3.2	4.9	4.3		3.4
JUL	5.2	9.3	2.8	3.1	4.4	
AUG	3.0	6.3	3.8	3.3	2.9	3.6
SEP	2.6	1.8	5.2	3.1	3.6	3.3
OCT	3.1	4.0	4.0	3.4	4.9	3.8
NOV	4.6	6.3	2.9	2.4	3.4	4.2
DEC			3.6	2.1	4.5	
mean	3.5	4.2	3.6	3.2	3.7	3.4
stdev	1.1	2.2	0.9	1.2	1.1	0.7
median	3.1	3.7	3.6	3.1	3.4	3.6
max	5.2	9.3	5.2	6.3	6.0	4.2
min	1.9	1.8	2.4	2.1	2.6	2.0

Table 2.17 Fecal Coliform (cfu/100 mL) and Enterococcus (MPN) during 2012 at the Lower Cape Fear River Program stations.

	NC11	AC	DP	IC	NCF6	NAV	HB
JAN	19	28	82	100	64	37	37
FEB	10	10	145	10	5	73	91
MAR	28	10	91	210	73	136	55
APR	10	5	5	37	19	82	154
MAY	10	10	5	19	55	46	19
JUN	37	28	46	199	37	28	64
JUL	37	136	10	5	10	28	46
AUG	10	55	46	28	82	19	91
SEP	109	46	73	37	73	109	380
OCT	28	46	73	37	73	46	46
NOV	10	28	19	19	37	28	109
DEC	28	37	28	28	28	10	19
mean	**28**	**37**	**52**	**61**	**46**	**54**	**93**
std dev	26	34	41	68	26	37	94
max	109	136	145	210	82	136	380
min	10	5	5	5	5	10	19
Geomean	21	25	33	35	36	42	65

ENTEROCOCCUS

	BRR	M61	M54	M35	M23	M18
JAN	27	36	39	3	1	1
FEB	91	37	10	5	5	5
MAR	136	127	46	5	5	5
APR	118	91	109	19	5	10
MAY	90	110	5	100	5	5
JUN	220	50	10	10	5	10
JUL	687	921	1,047	817	1,120	1,120
AUG	187	62	20	31	5	5
SEP	256	109	20	20	20	5
OCT	215	326	649	291	1,204	2,420
NOV	109	52	20	5	5	5
DEC	20	20	10	10	5	109
mean	**180**	**162**	**165**	**110**	**199**	**308**
std dev	169	242	317	227	431	706
max	687	921	1,047	817	1,204	2,420
min	20	20	5	3	1	1
Geomean	123	87	36	22	12	17

	ANC	SAR	GS	NC403	PB	LRC	ROC	BC117	BCRR
JAN	46	91	28	5	10	118	181	109	46
FEB	1,182	82	19	19	46	37	163	200	580
MAR	55	230	37	64	190	109	190	109	28
APR	91	64	19	340	240	46	73	819	55
MAY	55	390	200	163	91	136	240	340	320
JUN	127	350	210	637	728	182	29,000	82	550
JUL	2,000	13,000	1,455	172	1,091	210	3,500	728	60,000
AUG	370	217	1,637	5,100	370	6,000	1,728	3,100	1,637
SEP	64	181	181	455	10	1,819	190	546	8,000
OCT	550	5600	260	546	540	100	728	380	190
NOV	37	82	118	64	181	1640	109	455	55
DEC	64	136	230	109	1090	546	118	380	230
mean	**491**	**1,803**	**451**	**904**	**346**	**1,056**	**4,384**	**680**	**7,913**
std dev	675	4,234	638	1,726	354	1,952	9,372	1,016	18,571
max	2,000	13,000	1,637	5,100	1,091	6,000	29,000	3,100	60,000
min	46	64	19	5	10	37	73	82	28
Geomean	186	284	118	141	165	222	602	289	563

	6RC	LCO	GCO	SR	BRN	HAM
JAN	91	19	19	28	37	910
FEB	100	2,273	490	19	118	13,000
MAR	82	28	28	19	200	154
APR	73	73	73	109	100	154
MAY	55	28	19	64	118	82
JUN	250	7,000	637	910	637	100
JUL	172	37	10	600	370	208
AUG	163	118	109	819	2,400	350
SEP	280	55	181	210	290	280
OCT	82	73	290	230	728	380
NOV	154	5	200	109	540	290
DEC	280	163	280	82	290	1000
mean	**116**	**1,193**	**196**	**281**	**516**	**2,107**
std dev	63	2,313	237	371	791	4,455
max	250	7,000	637	910	2,400	13,000
min	55	5	19	19	37	82
Geomean	103	100	82	91	206	361

	NCF117	B210	COL	LVC2	SC-CH
JAN	46	5	37	19	200
FEB	19	10	37	5	46
MAR	19	46	37	19	55
APR	28	64	46	19	546
MAY	1,455	546	46	262	210
JUN	28	46	91	91	91
JUL	82	82	136	5,100	60,000
AUG	82	82	64	73	181
SEP	37	73	10	127	240
OCT	55	28	100	390	510
NOV	46	64	19	91	73
DEC	82	163	220	530	163
mean	**240**	**114**	**44**	**873**	**10,171**
std dev	497	178	10	1,891	22,285
max	1,455	546	64	5,100	60,000
min	19	5	37	5	46
Geomean	55	44	43	48	380