

Environmental Assessment of the Lower Cape Fear River System, 2016

By

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Executive Summary

Multiparameter water sampling for the Lower Cape Fear River Program (LCFRP) <http://www.uncw.edu/cms/aelab/LCFRP/index.htm>, 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 32 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 2016. 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 2008-2012) 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 2016 were generally comparable to the average for 1995-2015. 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 2016 DO levels occurred at the lower river and upper estuary stations IC, NAV, HB, BRR and M61 (6.4-6.7 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 generally has lower

dissolved oxygen than the Black River; as such, in 2016 Stations NCF117 and B210, representing those rivers, had average DO concentrations of 5.3 and 6.7 mg/L, respectively. Several stream stations were stressed in terms of low dissolved oxygen during the year 2016, including NC403, GS, and SR. The Northeast Cape Fear River station NCF117 had DO below 4.0 mg/L on 5 of 12 occasions in 2016. Considering all sites sampled in 2016, we rated 9% as poor for dissolved oxygen, 34% as fair, and 56% as good.

Annual mean turbidity levels for 2016 were lower than the long-term average in all estuary stations. Highest mean riverine turbidities were at NC11-DP (18-21 NTU) with turbidities generally low in the middle to lower estuary. The estuarine stations did not exceed the estuarine turbidity standard on our sampling trips except in March 2016. 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 one excursion to 83 NTU in September at BRN and 59 NTU at HAM. 97% of the stations were rated as good for turbidity.

Average chlorophyll *a* concentrations across most sites were low in 2016. The standard of 40 µg/L was exceeded once at Station PB and once at SR, although those sites hosted several smaller algal blooms as well. We note the highest levels in the river and estuary typically occur late spring to late-summer. During the growing season May-September river flow as measured by USGS at Lock and Dam #1 was double the average for the blue-green algal bloom years 2009-2012 (3,427 CFS compared with 1,698 CFS) washing out any significant algal bloom formation. For the 2016 period UNCW rated all of the stations as good in terms of chlorophyll *a*.

Fecal coliform counts in the river and at many of the stream stations were very high in 2016. Three main river sites, DP, NAV and HB were rated as poor, while the estuarine stations were mostly rated as good to fair for *Enterococcus*. All of the stream stations in the Northeast Cape Fear basin were rated as poor for fecal coliforms, as were most stations in the Black River basin. For bacterial water quality overall, 61% of the sites rated as poor, 23% as fair, and only 16% as good in 2016.

In addition, by our UNCW standards excessive nitrate and phosphorus concentrations were problematic at a number of stations.

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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 2016.

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 21-year (1995-2016) 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 Resources, 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, then lowered to 33 in 2011; currently it stands at 32 water quality stations. 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 eight 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 32 individual stations, and provides tables of raw data as well as figures showing spatial or temporal trends.

LCFRP data are freely available to the public. 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/. Additionally, there is an on-line data base. <http://lcfpr.uncw.edu/riverdatabase/>

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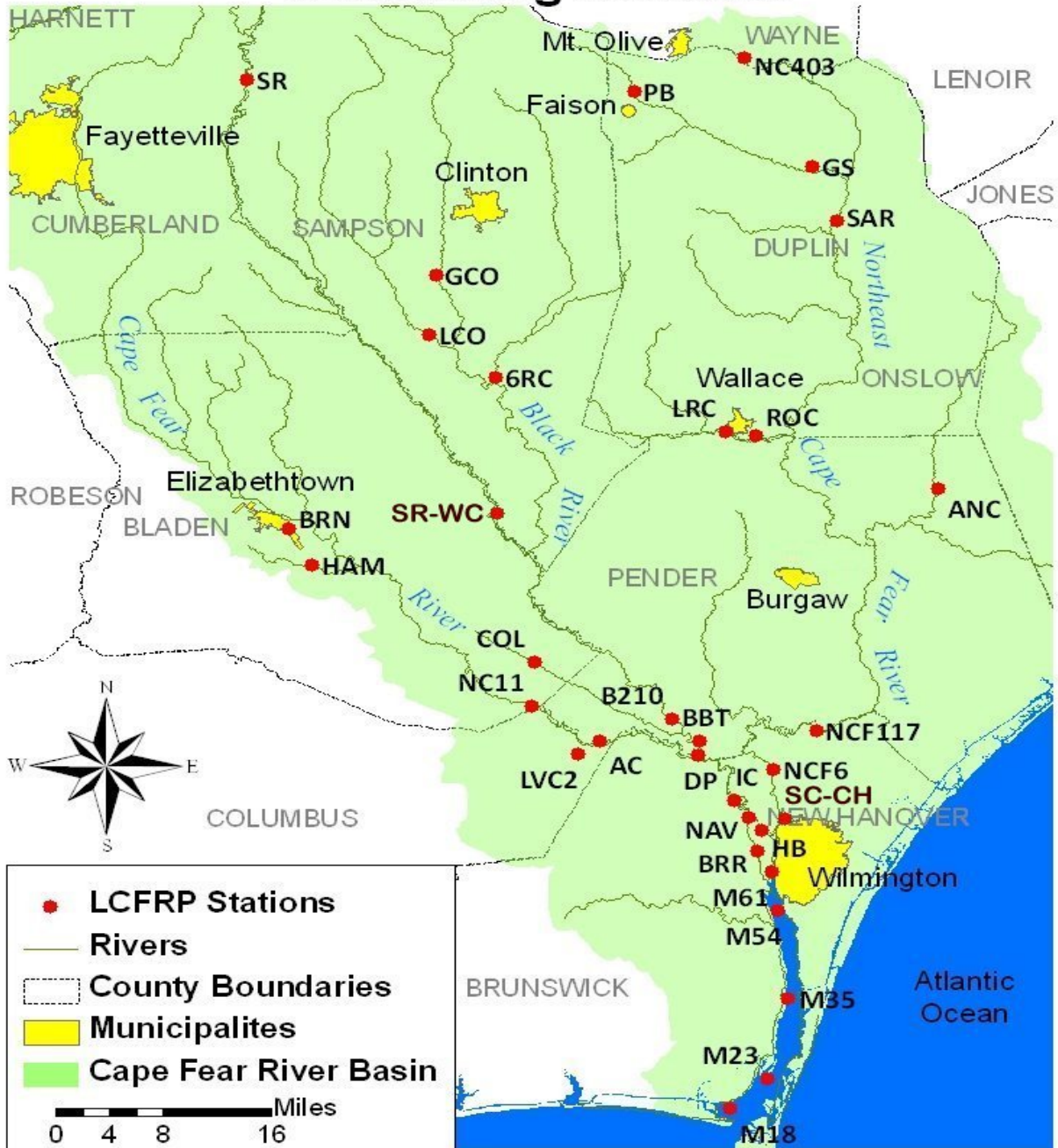
Table 1.1 Description of sampling locations in Lower Cape Fear River Watershed, 2016

<i>Collected by Boat</i>								
AEL Station	DWR Station #	Description	Comments	County	Lat	Lon	Stream Class	HUC
NC11	B8360000	Cape Fear River at NC 11 nr East Arcadia	Below Lock and Dam 1, Represents water entering lower basin	Bladen	34.3969	-78.2675	WS-IV Sw	03030005
LVC2	B8441000	Livingston Creek at Momentive Walkway nr Acme	DWR ambient station, Downstream of Momentive	Columbus	34.3353	-78.2011	C Sw	03030005
AC	B8450000	Cape Fear River at Neils Eddy Landing nr Acme	1 mile below IP, DWR ambient station	Columbus	34.3555	-78.1794	C Sw	03030005
DP	B8465000	Cape Fear River at Intake nr Hooper Hill	AT DAK intake, just above confluence with Black R.	Brunswick	34.3358	-78.0534	C Sw	03030005
BBT		Black River below Lyons Thorofare	UNCW AEL station	Pender	34.3513	-78.0490	C Sw ORW+	03030005
IC	B9030000	Cape Fear River ups Indian Creek nr Phoenix	Downstream of several point source discharges	Brunswick	34.3021	-78.0137	C Sw	03030005
NAV	B9050025	Cape Fear River dns of RR bridge at Navassa	Downstream of several point source discharges	Brunswick	34.2594	-77.9877	SC	03030005
HB	B9050100	Cape Fear River at S. end of Horseshoe Bend nr Wilmington	Upstream of confluence with NE Cape Fear River	Brunswick	34.2437	-77.9698	SC	03030005
BRR	B9790000	Brunswick River dns NC 17 at park nr Belville	Near Belville discharge	Brunswick	34.2214	-77.9787	SC	03030005
M61	B9800000	Cape Fear River at Channel Marker 61 at Wilmington	Downstream of several point source discharges	New Hanover	34.1938	-77.9573	SC	03030005
M54	B9795000	Cape Fear River at Channel Marker 54	Downstream of several point source discharges	New Hanover	34.1393	-77.946	SC	03030005
M35	B9850100	Cape Fear River at Channel Marker 35	Upstream of Carolina Beach discharge	Brunswick	34.0335	-77.937	SC	03030005
M23	B9910000	Cape Fear River at Channel Marker 23	Downstream of Carolina Beach discharge	Brunswick	33.9456	-77.9696	SA HQW	03030005
M18	B9921000	Cape Fear River at Channel Marker 18	Near mouth of Cape Fear River	Brunswick	33.913	-78.017	SC	03030005
NCF6	B9670000	NE Cape Fear nr Wrightsboro	Downstream of several point source discharges	New Hanover	34.3171	-77.9538	C Sw	03030007
<i>Collected by Land</i>								
6RC	B8740000	Six Runs Creek at SR 1003 nr Ingold	Upstream of Black River, CAFOs in watershed	Sampson	34.7933	-78.3113	C Sw ORW+	03030006
LCO	B8610001	Little Coharie Creek at SR 1207 nr Ingold	Upstream of Great Coharie, CAFOs in watershed	Sampson	34.8347	-78.3709	C Sw	03030006
GCO	B8604000	Great Coharie Creek at SR 1214 nr Butler Crossroads	Downstream of Clinton, CAFOs in watershed	Sampson	34.9186	-78.3887	C Sw	03030006
SR	B8470000	South River at US 13 nr Cooper	Downstream of Dunn	Sampson	35.156	-78.6401	C Sw	03030006
BRN	B8340050	Browns Creek at NC87 nr Elizabethtown	CAFOs in watershed	Bladen	34.6136	-78.5848	C	03030005
HAM	B8340200	Hammond Creek at SR 1704 nr Mt. Olive	CAFOs in watershed	Bladen	34.5685	-78.5515	C	03030005

<i>Collected by Land</i>							
6RC	Six Runs Creek at SR 1003 nr Ingold	B8740000	Sampson	34.7933	-78.3113	C Sw ORW+	03030006
LCO	Little Coharie Creek at SR 1207 nr Ingold	B8610001	Sampson	34.8347	-78.3709	C Sw	03030006
GCO	Great Coharie Creek at SR 1214 nr Butler Crossroads	B8604000	Sampson	34.9186	-78.3887	C Sw	03030006
SR	South River at US 13 nr Cooper	B8470000	Sampson	35.156	-78.6401	C Sw	03030006
BRN	Browns Creek at NC87 nr Elizabethtown	B8340050	Bladen	34.6136	-78.5848	C	03030005
HAM	Hammond Creek at SR 1704 nr Mt. Olive	B8340200	Bladen	34.5685	-78.5515	C	03030005
COL	Colly Creek at NC 53 at Colly	B8981000	Bladen	34.4641	-78.2569	C Sw	03030006
B210	Black River at NC 210 at Still Bluff	B9000000	Pender	34.4312	-78.1441	C Sw ORW+	03030006
NC403	NE Cape Fear River at NC 403 nr Williams	B9090000	Duplin	35.1784	-77.9807	C Sw	03030007
PB	Panther Branch (Creek) nr Faison	B9130000	Duplin	35.1345	-78.1363	C Sw	03030007
GS	Goshen Swamp at NC 11 and NC 903 nr Komegay	B9191000	Duplin	35.0281	-77.8516	C Sw	03030007
SAR	NE Cape Fear River SR 1700 nr Sarecta	B9191500	Duplin	34.9801	-77.8622	C Sw	03030007
ROC	Rockfish Creek at US 117 nr Wallace	B9430000	Duplin	34.7168	-77.9795	C Sw	03030007
LRC	Little Rockfish Creek at NC 11 nr Wallace	B9460000	Duplin	34.7224	-77.9814	C Sw	03030007
ANC	Angola Creek at NC 53 nr Maple Hill	B9490000	Pender	34.6562	-77.7351	C Sw	03030007
SR WC	South River at SR 1007 (Wildcat/Ennis Bridge Road)	B8920000	Sampson	34.6402	-78.3116	C Sw ORW+	03030006
NCF117	NE Cape Fear River at US 117 at Castle Hayne	B9580000	New Hanover	34.3637	-77.8965	B Sw	03030007
SC-CH	Smith Creek at US 117 and NC 133 at Wilmington	B9720000	New Hanover	34.2586	-77.9391	C Sw	03030007

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

Lower Cape Fear River Program Monitoring 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 2016 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. Selected biological parameters including fecal coliform bacteria or enterococcus bacteria and chlorophyll *a* were examined.

2.2 - Materials and Methods

All samples and field parameters collected for the estuarine stations of the Cape Fear River (NAV down through M18) were gathered on an ebb tide. This was done so that the data better represented the river water flowing downstream through the system rather than the tidal influx of coastal ocean water. Sample collection and analyses were conducted according to the procedures in the Lower Cape Fear River Program Quality Assurance/Quality Control (QA/QC) manual. Technical Representatives from the LCFRP Technical Committee and representatives from the NC Division of Water Quality inspect UNCW laboratory procedures and periodically accompany field teams to verify proper procedures are followed. By agreement with N.C. Division of Water Quality, after June 2011 sampling was discontinued at stations M42 and SPD, but full sampling was added at SC-CH and SR-WC in 2012. We note the Town of Burgaw left the program as of 2013 and Stations BCRR and BC117 are no longer being sampled.

Physical Parameters

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

Field parameters other than light attenuation 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 and at the bottom (up to 12 m); only surface data are reported within. 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. The light attenuation coefficient k was determined from data collected on-site using vertical profiles obtained by a Li-Cor LI-1000 integrator interfaced with a Li-Cor LI-193S spherical quantum sensor.

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 separate 1.0 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 antimony potassium tartrate in an acidic medium (sulfuric acid) to form an antimony-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 / Enterococcus

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 (chlorophyll at four LCFRP stations are required by NCDWR to be analyzed by state-certified methods).

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. BOD analysis was stopped in August 2015 due to insufficient program funding.

<i>Parameter</i>	<i>Method</i>	<i>NC DWR Certified</i>
Water Temperature	SM 2550B-2000	Yes
Dissolved Oxygen	SM 4500O G-2001	Yes
pH	SM 4500 H B-2000	Yes
Specific Conductivity	SM 2510 B-1997	Yes
Lab Turbidity	SM 2130 B-2001	Yes
Field Turbidity	SM 2130 B-2001	No
Chlorophyll a	EPA 445.0 Rev. 1.2	Yes
Biochemical Oxygen Demand	SM 5210 B-2001	No
<i>Parameter</i>	<i>Method</i>	<i>NC DWR Certified</i>
Total Nitrogen	By addition	

Nitrate + Nitrite	EPA 353.2 Rev 2.0 1993	Yes
Total Kjeldahl Nitrogen	EPA 351.2 Rev 2.0 1993	Yes
Ammonia Nitrogen	EPA 350.1 Rev 2.0 1993	Yes
Total Phosphorus	SM 4500 P E-1999	Yes
Orthophosphate	EPA 365.5	No
Fecal Coliform	SM 9222 D-1997	Yes
Enterococcus	Enterolert IDEXX	Yes

Lower Cape Fear River Program 2015/2016 Metals Sampling

The Lower Cape Fear River Program began voluntary metals sampling at two estuarine locations at Channel Markers 23 and 35 during 2015/2016. This sampling was suggested by the NC Division of Water Resources Coalition Monitoring Program Coordinator in order to assess the 303d listing (impaired) at these sites using the newly established protocols for dissolved metals analysis. The US EPA has determined that dissolved metals, rather than total metals, is more appropriate to assess toxicity to aquatic life.

In December 2015 the LCFRP began collecting a series of ten samples which was completed in October 2016. The methodology involved filtering ambient water in the field and preservation with nitric acid following the Standard Operating Procedure from an addendum to the NC Division of Water Resources –Intensive Survey Branch - Standard Operating Procedures Manual: Physical and Chemical Monitoring, version 2.1, December 2013; ISB-SOP.

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 2016. 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 experienced some impacts from Hurricane Matthew October 8-9, 2016, although not to the extent of the major hurricanes in 1996, 1998, and 1999. Therefore this report reflects low to medium growing season (May-September) flow conditions for the Cape Fear River and Estuary.

Physical Parameters

Water temperature

Water temperatures at all stations ranged from 4.1 to 31.4°C, and individual station annual averages ranged from 16.2 to 20.6°C (Table 2.1). Highest temperatures occurred during

July and August and lowest temperatures during January and February. Stream stations were generally cooler than river stations, most likely because of shading and lower nighttime air temperatures affecting the shallower waters.

Salinity

Salinity at the estuarine stations (NAV through M18; also NCF6 in the Northeast Cape Fear River) ranged from 0.0 to 34.2 practical salinity units (psu) and station annual means ranged from 0.6 to 26.4 psu (Table 2.2). Lowest salinities occurred in late spring and early-summer and in October from Hurricane Matthew, and highest salinities occurred in late fall and winter. The annual mean salinity for 2016 was slightly lower than that of the nineteen-year average for 1995-2015 for all of the estuarine stations (Figure 2.1). Two stream stations, NC403 and PB, had occasional oligohaline conditions due to discharges from pickle production facilities. SC-CH is a tidal creek that enters the Northeast Cape Fear River upstream of Wilmington and salinity there ranged from 0.0 to 4.5 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.05 to 52.25 mS/cm and from 0.05 to 3.55 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 3.4 to 8.5 and station annual means ranged from 3.9 to 8.0 (Table 2.4). pH was typically lowest upstream due to acidic swamp water inputs and highest downstream as alkaline seawater mixes with the river water. Low pH values at COL predominate because of naturally acidic blackwater inputs at this near-pristine stream station.

Dissolved Oxygen

Dissolved oxygen (DO) problems 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; 2001; 2002; 2004; 2005; 2006; 2015). Surface concentrations for all sites in 2016 ranged from 1.8 to 12.5 mg/L and station annual means ranged from 5.3 to 9.1 mg/L (Table 2.5). Average annual DO levels at the river channel and estuarine stations for 2016 were generally comparable to the average for 1995-2015, although 2016 DO values in the Northeast Cape Fear River were notably lower (Figure 2.2). Dissolved oxygen levels in the river and estuary, as well as some stream sites, were unseasonably low due to the influence of Hurricane Matthew. Otherwise, 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 2016 DO levels occurred at the river and upper estuary stations HB, BRR and M61 (6.4-6.6 mg/L). Stations M61 and IC were below 5.0 mg/L on 33% or more of occasions sampled, and NAV was on 25% of occasions sampled. Based on number of occasions the river stations were below 5 mg/L UNCW rated M61 and IC as poor for 2016; the mid to lower estuary stations were rated as fair to good. Discharge of 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. 2006); 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. We note that DO conditions in the lower river and estuary in 2016 were an improvement from 2015.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River (NCF117 2016 mean = 5.3, NCF6 = 5.9, B210 2016 mean = 6.7, all decreased from 2015). 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. 2006).

Several stream stations were stressed in terms of low dissolved oxygen during the year 2016. Station GS, SR and SC-CH were below 4.0 mg/L 25% of the occasions sampled, while the others were in the fair to good range (Table 2.5). Some hypoxia 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. 2001; 2002; 2004). Hypoxia is thus a continuing problem, with 43% of the sites impacted in 2016.

Field Turbidity

Field turbidity levels ranged from 1 to 83 Nephelometric turbidity units (NTU) and station annual means ranged from 2 to 21 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Highest mean turbidities were at NC11-AC (20-21 NTU), plus DP (18 NTU) with turbidities generally low in the middle to lower estuary (Figure 2.3). The estuarine stations did not exceed the estuarine turbidity standard on our 2016 sampling trips except during March. As in the previous year, mean turbidity levels for 2016 were well below the long-term average at all estuary sites (Fig. 2.3). Turbidity was considerably lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river. Average turbidity levels were low in the freshwater streams, with the exception of one excursion to 83 NTU at BRN and 59 NTU at HAM in September. The State standard for freshwater turbidity is 50 NTU.

Note: In addition to the laboratory-analyzed turbidity that are required by 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

A new monitoring plan was developed for the LCFRP in September 2011. These changes were suggested by the NC Division of Water Resources (then DWQ). NCDWR suggested the LCFRP stop monitoring TSS at Stations ANC, GS, 6RC, LCO, SR, BRN, HAM, COL, SR-WC and monitor turbidity instead. DWQ believed turbidity would be more useful than TSS in evaluating water quality at these stations because there are water quality standards for turbidity. TSS is used by the DWQ NPDES Unit to evaluate discharges. No LCFRP subscribers discharge in these areas.

Total suspended solid (TSS) values system wide ranged from 1.3 to 49.5 mg/L with station annual means from 2.5 to 17.2 mg/L (Table 2.7). The overall highest river values were at NC11, M54 and M18. In the stream stations TSS was generally considerably lower than the river and estuary, except for a peak incident of 49.5 mg/L at Station PB. Although total suspended solids (TSS) and turbidity both quantify suspended material in the water column, they do not always go hand in hand. High TSS does not mean high turbidity and vice versa. This anomaly may be explained by the fact that fine clay particles are effective at dispersing light and causing high turbidity readings, while not resulting in high TSS. On the other hand, large organic or inorganic particles may be less effective at dispersing

light, yet their greater mass results in high TSS levels. While there is no NC ambient standard for TSS, many years of data from the lower Cape Fear watershed indicates that 25 mg/L can be considered elevated (reached on a few occasions in the 2016 data). 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 (reduced through absorbance or reflection) in the water column. River and estuary light attenuation coefficients ranged from 0.73 to 6.25/m and station annual means ranged from 1.70 at M18 to 3.63 at HB (Table 2.8). Elevated mean and median light attenuation occurred from DP in the lower river downstream to M54 in the estuary (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 generally high light attenuation. The high average light attenuation is a major reason why phytoplankton production in the major rivers and the estuary of the LCFR is generally low. Whether caused by turbidity or water color this attenuation tends to limit light availability to the phytoplankton (Mallin et al. 1997; 1999; 2004; Dubbs and Whalen 2008).

Chemical Parameters – Nutrients

Total Nitrogen

Total nitrogen (TN) is calculated from TKN (see below) plus nitrate; it is not analyzed in the laboratory. TN ranged from 50 (detection limit) to 8,010 $\mu\text{g/L}$ and station annual means ranged from 443 to 3,157 $\mu\text{g/L}$ (Table 2.9). 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 and relatively similar between NC11 and M54, then declining 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 2,290 $\mu\text{g/L}$; other elevated TN values were seen at PB, NC403, 6RC and ANC.

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 6,810 $\mu\text{g/L}$ and station annual means ranged from 29 to 2,192 $\mu\text{g/L}$ (Table 2.10). The

highest average riverine nitrate levels were at NC11, AC and DP (455-491 $\mu\text{g/L}$) indicating that much of this nutrient is imported from upstream. Moving downstream, nitrate levels decrease most likely as a result of uptake by primary producers, microbial denitrification in riparian marshes and tidal dilution. Despite this, the rapid flushing of the estuary (Ensign et al. 2004) permits sufficient nitrate to enter the coastal ocean in the plume and contribute to offshore productivity (Mallin et al. 2005). 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 = 292 $\mu\text{g/L}$) and the Black River (B210 = 318 $\mu\text{g/L}$). Lowest river nitrate occurred during late spring and early summer. In general, average concentrations in 2016 for the mainstem river were lower than those of the average from 1995-2015, but nitrate in the blackwater rivers was slightly higher than the long-term average (Fig. 2.4).

Several stream stations showed high levels of nitrate on occasion including ROC, NC403, PB and GCO. ROC and GCO primarily receive non-point agricultural or animal waste drainage, while point sources contribute to NC403 and PB. 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 200 to 500 $\mu\text{g/L}$ as N (Mallin et al. 1998; Mallin et al. 2001; Mallin et al. 2002, Mallin et al. 2004). Thus, we conservatively consider nitrate concentrations exceeding 500 $\mu\text{g/L}$ as N in Cape Fear watershed streams to be potentially problematic to the stream's environmental health.

Ammonium/ammonia

Ammonium concentrations ranged from 10 (detection limit) to 960 $\mu\text{g/L}$ and station annual means ranged from 22 to 211 $\mu\text{g/L}$ (Table 2.11). River areas with the highest mean ammonium levels this monitoring period included NC11, which represent what comes into the system, and AC and DP, which are downstream of a pulp mill discharge, and M61 in the upper estuary. At the stream stations, areas with highest levels of ammonium were COL, NC403, and LRC. COL had two highly unusual peaks of 960 in July and 650 in August.

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 2,600 $\mu\text{g/L}$ and station annual means ranged from 425 to 1,267 $\mu\text{g/L}$ (Table 2.12). TKN concentration decreases oceanward through the estuary, likely due to ocean dilution and food chain uptake of nitrogen. Several individual peaks at or exceeding 2,000 $\mu\text{g/L}$ occurred in stations SR, NCF6 and M23. ANC, ROC, COL and SR also had the highest median concentrations.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from 10 (detection limit) to 970 $\mu\text{g/L}$ and station annual means ranged from 43 to 349 $\mu\text{g/L}$ (Table 2.13). For the mainstem and upper estuary, average TP for 2016 was lower than the 1995-2015 average; however, for the lower estuary and the Northeast Cape Fear River at Highway 117 TP was higher than the long-term average (Figure 2.5). In the river TP was highest at the upper riverine channel stations NC11, AC and DP and declined 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 500 $\mu\text{g/L}$ led to significant increases in bacterial counts, as well as significant increases in BOD over control. Thus, we consider concentrations of phosphorus above 500 $\mu\text{g/L}$ to be potentially problematic to blackwater streams (Mallin et al. 1998; 2004). Streams periodically exceeding this critical concentration included ROC and GCO; NC403 also yielded some high values. Station NC403 is downstream of an industrial wastewater discharge, while ROC and GCO are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from undetectable to 870 $\mu\text{g/L}$ and station annual means ranged from 14 to 204 $\mu\text{g/L}$ (Table 2.14). Much of the main river 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).

ROC, ANC and GCO had the highest stream station concentrations. All of those sites are in non-point source areas.

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. Revised metals sampling was re-initiated in late 2015 and continued through 2016.

Results showed that for both stations sampled (M35 and M23) concentrations of As, Cd, Cr, Cu, Pb, Ni and Zn were below detection limits on all sampling occasions. Iron (Fe) concentrations were measurable but not at harmful levels.

Biological Parameters

Chlorophyll a

During this monitoring period in most locations chlorophyll a was low, except for elevated concentrations in August in the upper and middle estuary (Table 2.15). The state standard was not exceeded in the river or estuary samples in 2016. 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. 2006). System wide, chlorophyll a ranged from undetectable to 100 µg/L and station annual means ranged from 1-20 µg/L, higher than in 2014. 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 (Dubbs and Whalen 2008) and high organic color and low inorganic nutrients in the blackwater tributary rivers.

Spatially, along the mainstem highest values are normally found in the mid-to-lower estuary stations because light becomes more available downstream of the estuarine turbidity maximum (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 (1995-2016) average monthly flow at Lock and Dam #1 was approximately 3,401 CFS; however, for cyanobacterial bloom years 2009-2012 the growing season average flow was 1,698 CFS (USGS data; (http://nc.water.usgs.gov/realtime/real_time_cape_fear.html)). For 2016, discharge in May-September was double the 2009-2012 average at 3,427 CFS. Nuisance cyanobacterial blooms did not occur in the river and upper estuary that year.

River discharge appears to be a major factor controlling formation and persistence of these blooms. The blooms in 2009-2012 all occurred when average river discharge for May-September was below 1,900 CFS. The cyanobacterial blooms were suppressed by elevated river flow in 2013-2014 and 2016, but flow in 2015 was well within the range when blooms can occur. Clearly other factors are at work in bloom formation.

Phytoplankton blooms occasionally occur at the stream stations, with a few occurring at various months in 2016 (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. 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. 2001; 2002; 2004; 2006; 2015). Stream station blooms exceeding the state standard of 40 µg/L occurred on two occasions at Stations PB and SR and lesser blooms occurred at these and a few other stream sites (Table 2.15).

Biochemical Oxygen Demand

Beginning in 2015 samples for BOD₅ and BOD₂₀ are no longer collected for the program due to insufficient funds.

Fecal Coliform Bacteria/ Enterococcus bacteria

Fecal coliform (FC) bacterial counts ranged from 5 to 60,000 CFU/100 mL (60,000 is the laboratory maximum) and station annual geometric means ranged from 30 to 1,653 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded in the mainstem numerous times at the riverine stations from AC through NAV in 2016 (Table 2.17). During 2016 the stream stations showed very high fecal coliform pollution levels. HAM exceeded 200 CFU/100 mL 92% of the time sampled; BRN 83%, ANC 75%, ROC, LRC and SC-CH 67%, SAR, GS, NC403, PB, 6RC and SR 50%, GCO and LCO 42%, and NCF117 and COL 33% of the time sampled. Notably excessive counts exceeding 37,000 CFU/100 mL occurred at SAR, NC403, PB, SC-CH, LCO, GCO and SAR occurred in 2016, mainly in summer and fall. NC403 and PB are located below point source discharges and the other sites are primarily influenced by non-point source pollution. Overall, 2016 was a very bad year for fecal coliform counts, with geometric mean counts in the mainstem river and the blackwater tributaries well exceeding the geometric mean for the 1995-2015 period (Fig. 2.6).

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 2016 stations M35, M23 and M18 all exceeded the standard on two to three occasions, and M54 and BRR exceeded the standard on one occasion. Geometric mean enterococcus counts for 2016 were higher than those of the 2012-2015 period for the lower Cape Fear Estuary (Fig. 2.6). Overall, elevated fecal coliform and enterococcus counts are problematic in this system, with 84% of the stations rated as Fair or Poor in 2016.

2.4 - References Cited

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Table 2.1 Water temperature (°C) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NC11	AC	DP	BBT	IC	NCF6
JAN	9.1	9.2	9.0	9.4	9.7	10.6	11.5	12.8	7.1	7.2	7.2	5.2	7.2	7.3
FEB	7.5	8.0	8.0	8.5	8.6	9.1	9.3	10.0	6.0	6.4	6.8	6.5	6.6	6.9
MAR	11.0	11.0	11.7	11.7	11.5	11.8	12.1	12.7	11.5	11.6	11.7	12.6	12.5	13.2
APR	18.1	18.2	18.3	18.3	18.1	17.9	17.7	17.6	20.0	20.0	20.7	20.3	20.3	20.2
MAY	21.7	21.9	22.8	22.8	22.4	22.6	22.4	22.1	22.0	22.1	22.3	21.7	22.4	22.4
JUN	24.4	24.4	25.3	25.2	25.2	25.8	25.6	25.2	26.4	26.9	26.8	25.8	26.4	26.6
JUL	29.8	29.9	30.0	30.0	29.8	30.0	29.9	29.9	29.9	29.7	30.2	29.8	30.1	30.5
AUG	30.3	30.9	30.8	30.5	30.5	30.4	29.9	29.7	31.2	29.0	29.7	29.9	31.1	31.4
SEP	29.6	29.8	29.1	30.1	29.8	29.4	28.9	28.7	25.7	25.7	26.7	26.2	27.4	25.2
OCT	20.1	20.0	20.8	21.9	21.3	21.0	21.5	23.3	21.6	21.7	21.7	21.7	21.9	22.8
NOV	15.8	16.0	16.0	16.1	16.1	16.6	17.0	17.6	18.6	19.0	18.8	18.7	18.9	19.6
DEC	11.4	11.7	11.7	12.1	12.4	13.4	13.4	14.3	12.6	12.4	12.3	12.0	12.4	
mean	19.1	19.3	19.5	19.7	19.6	19.9	19.9	20.3	19.4	19.3	19.6	19.1	19.8	20.6
std dev	8.3	8.3	8.3	8.2	8.1	7.8	7.5	7.1	8.5	8.2	8.3	8.9	8.5	8.4
median	19.1	19.1	19.6	20.1	19.7	19.5	19.6	19.9	20.8	20.9	21.2	21.7	21.1	22.4
max	30.3	30.9	30.8	30.5	30.5	30.4	29.9	29.9	31.2	29.7	30.2	29.9	31.1	31.4
min	7.5	8.0	8.0	8.5	8.6	9.1	9.3	10.0	6.0	6.4	6.8	5.2	6.6	6.9

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	9.0	5.8	6.3	7.3	5.1	7.6	7.0	8.6	9.3	9.8	5.4	7.7	6.2	5.2	4.1	4.8	6.2	6.3
FEB	8.0	7.0	7.1	8.0	8.0	8.2	6.5	9.0	8.8	6.4	7.5	6.5	9.0	8.0	8.1	8.5	8.5	8.8
MAR	11.5	10.2	12.6	11.3	10.7	11.2	10.9	11.3	11.3	18.3	16.8	17.7	18.0	17.8	17.8	17.2	17.9	17.7
APR	16.3	14.9	17.0	17.5	19.4	16.6	15.9	19.3	18.7	15.4	13.9	14.8	14.4	14.2	14.9	14.8	16.1	15.4
MAY	20.7	20.6	22.0	21.9	22.6	21.3	19.5	21.2	21.6	19.5	18.2	18.9	18.8	19.1	18.9	18.4	18.8	18.5
JUN	29.8	24.3	24.8	25.2	25.8	22.9	23.4	26.2	26.8	25.6	23.4	25.2	25.3	24.8	26.3	25.9	24.2	23.8
JUL	25.5	26.3	27.4	27.7	28.1	25.7	26.4	29.5	29.7	30.0	27.2	28.4	28.0	28.4	29.1	30.0	27.2	27.7
AUG	25.6	26.9	26.6	27.2	27.4	26.7	26.0	29.8	30.1	30.0	25.3	26.1	25.7	25.7	26.3	26.5	24.9	25.1
SEP	23.4	24.5	25.6	25.5	27.6	24.9	23.6	25.2	25.6	24.7	22.9	23.0	22.9	22.9	22.5	21.7	21.3	21.3
OCT	20.8	21.4	21.5			21.8	20.8	20.0	20.5	16.2	14.5	15.3	15.3	14.9	14.4	14.1	15.7	14.3
NOV	18.0	17.1	18.3		18.5	18.0	16.9	18.2	19.2	10.5	10.9	10.5	10.6	10.8	11.3	11.3	13.7	13.0
DEC	11.7	10.7	12.5	12.1	11.8	11.4	11.0	13.2	13.9	8.2	7.8	7.7	8.8	8.3	6.5	6.2	7.8	7.7
mean	18.4	17.5	18.5	18.4	18.6	18.0	17.3	19.3	19.6	17.7	16.2	16.8	16.9	16.7	16.7	16.6	16.9	16.6
std dev	7.1	7.6	7.4	8.1	8.5	6.9	7.1	7.5	7.6	8.0	7.4	7.7	7.4	7.7	8.3	8.2	6.9	7.0
median	19.4	18.9	19.9	19.7	19.4	19.7	18.2	19.7	19.9	17.3	15.7	16.5	16.7	16.4	16.4	16.0	17.0	16.6
max	29.8	26.9	27.4	27.7	28.1	26.7	26.4	29.8	30.1	30.0	27.2	28.4	28.0	28.4	29.1	30.0	27.2	27.7
min	8.0	5.8	6.3	7.3	5.1	7.6	6.5	8.6	8.8	6.4	5.4	6.5	6.2	5.2	4.1	4.8	6.2	6.3

Table 2.2 Salinity (psu) during 2016 at the Lower Cape Fear River Program estuarine stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NCF6	SC-CH
JAN	0.0	0.1	0.1	0.1	0.1	6.6	15.4	27.2	0.1	0.1
FEB	0.1	0.1	0.1	0.5	1.0	4.3	7.8	11.5	0.0	0.0
MAR	0.0	0.0	0.0	0.0	0.1	2.4	7.4	14.4	0.1	1.3
APR	0.1	1.8	3.1	7.9	10.7	17.8	24.9	29.1	1.4	0.9
MAY	0.1	0.9	0.4	1.6	4.8	13.4	26.2	28.4	0.1	3.7
JUN	0.1	0.1	1.2	5.9	6.9	12.5	21.6	24.3	0.1	1.8
JUL	0.1	0.1	0.4	7.1	7.9	11.6	20.2	22.5	0.1	2.2
AUG	3.5	4.1	3.5	6.5	12.6	20.3	27.6	34.2	3.1	4.3
SEP	10.9	10.6	13.1	15.3	18.7	27.0	31.6	33.6	0.0	0.6
OCT	0.0	0.0	0.0	0.0	0.0	0.2	1.9	26.0	0.0	0.0
NOV	4.8	5.0	9.0	10.4	16.2	25.3	30.7	32.8	2.1	0.5
DEC	2.0	3.0	3.0	6.0	9.0	22.0	23.0	33.0		4.5
mean	1.8	2.2	2.8	5.1	7.3	13.6	19.9	26.4	0.6	1.7
std dev	3.3	3.2	4.2	4.8	6.4	9.0	9.7	7.4	1.1	1.7
median	0.1	0.5	0.8	6.0	7.4	13.0	22.3	27.8	0.1	1.1
max	10.9	10.6	13.1	15.3	18.7	27.0	31.6	34.2	3.1	4.5
min	0.0	0.0	0.0	0.0	0.0	0.2	1.9	11.5	0.0	0.0

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations 1995-2015 versus 2016.

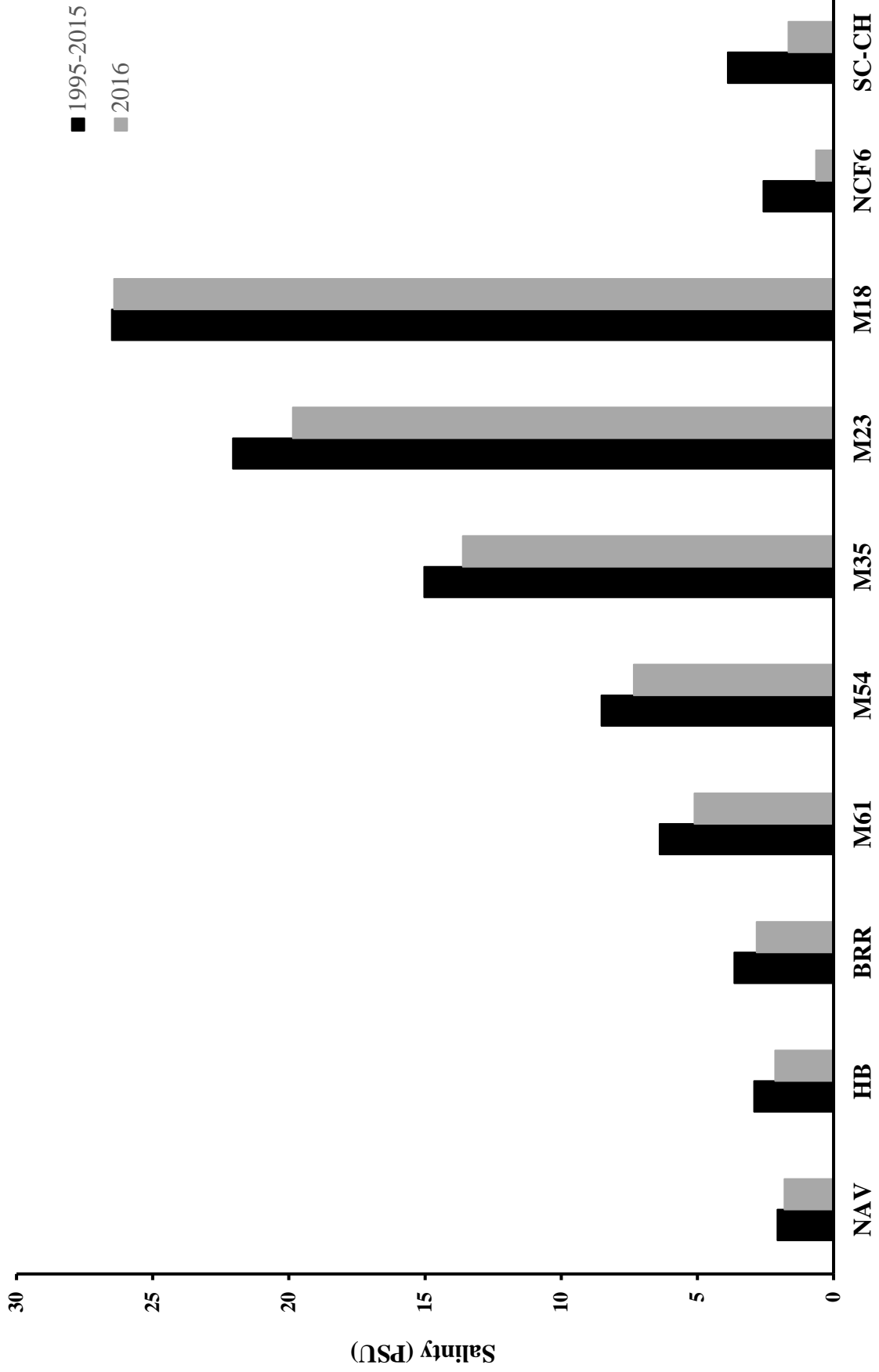


Table 2.3 Specific Conductivity (mS/cm) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	BBT	IC	NCF6
JAN	0.09	0.10	0.10	0.12	0.33	11.57	25.35	42.32		0.09	0.13	0.10	0.09	0.11	0.11
FEB	0.10	0.10	0.10	1.05	1.90	7.69	13.47	19.34		0.08	0.09	0.09	0.06	0.07	0.06
MAR	0.08	0.08	0.09	0.09	0.15	4.46	12.86	23.63		0.09	0.11	0.11	0.10	0.09	0.28
APR	0.15	3.43	5.70	13.65	18.01	28.75	38.93	44.98		0.12	0.13	0.15		0.13	2.64
MAY	0.11	1.69	0.89	3.07	8.61	22.30	40.94	44.02		0.12	0.14	0.13	0.10	0.13	0.11
JUN	0.15	0.27	2.26	10.45	12.06	20.93	34.42	38.28		0.12	0.27	0.18	0.09	0.12	0.12
JUL	0.14	0.16	0.85	1.24	13.76	19.70	32.51	36.43		0.13	0.17	0.19	0.14	0.16	0.20
AUG	6.39	7.54	6.39	11.44	21.18	32.64	43.05	52.25		0.14	0.12	0.18	0.17	0.19	5.71
SEP	18.44	18.17	21.90	25.23	30.25	42.22	48.53	51.28		0.10	0.09	0.14	0.10	0.12	0.07
OCT	0.05	0.05	0.05	0.06	0.06	0.33	3.62	40.03		0.05	0.06	0.06	0.06	0.06	0.09
NOV	8.51	9.40	15.35	17.38	26.35	39.65	47.09	49.98		0.10	0.10	0.11	0.10	0.12	3.92
DEC	4.37	6.25	5.75	10.78	15.70	34.97	36.84	49.92		0.11	0.12	0.15	0.12	0.14	
mean	3.21	3.94	4.95	7.88	12.36	22.10	31.47	41.04		0.10	0.13	0.13	0.10	0.12	1.21
std dev	5.63	5.59	6.97	8.25	10.48	13.96	14.58	10.53		0.02	0.05	0.04	0.03	0.03	1.98
median	0.14	0.98	1.57	6.76	12.91	21.61	35.63	43.17		0.11	0.12	0.14	0.10	0.12	0.12
max	18.44	18.17	21.90	25.23	30.25	42.22	48.53	52.25		0.14	0.27	0.19	0.17	0.19	5.71
min	0.05	0.05	0.05	0.06	0.06	0.33	3.62	19.34		0.05	0.06	0.06	0.06	0.06	0.06

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.09	0.14	0.14	0.38	0.79	0.11	0.11	0.09	0.10	0.07	0.06	0.06	0.11	0.08	0.10	0.07	0.09	0.11
FEB	0.06	0.09	0.09	0.15	0.26	0.05	0.05	0.05	0.06	0.07	0.05	0.05	0.09	0.08	0.10	0.07	0.07	0.08
MAR	0.07	0.13	0.12	0.26	0.87	0.10	0.10	0.10	2.51	0.08	0.05	0.07	0.12	0.09	0.13	0.08	0.11	0.15
APR	0.09	0.14	0.14	0.37	1.40	0.12	0.12	0.13	1.76	0.09	0.05	0.07	0.13	0.10	0.14	0.08	0.12	0.15
MAY	0.11	0.18	0.17	0.61	2.92	0.11	0.16	0.16	6.77	0.08	0.05	0.06	0.12	0.09	0.14	0.08	0.11	0.11
JUN	0.12	0.17	0.16	0.60	3.55	0.14	0.14	0.12	3.44	0.07	0.06	0.06	0.14	0.11	0.32	0.11	0.12	0.18
JUL	0.08	0.19	0.18	0.69	1.43	0.13	0.29	0.14	4.16	0.10	0.06	0.07	0.14	0.10	0.15	0.09	0.14	0.25
AUG	0.10	0.25	0.23	0.76	1.55	0.07	0.24	0.18	7.81	0.13	0.06	0.08	0.15	0.11	0.13	0.10	0.15	0.24
SEP	0.08	0.18	0.18	0.89	3.27	0.10	0.20	0.10	1.21	0.10	0.07	0.07	0.12	0.09	0.09	0.06	0.06	0.07
OCT	0.07	0.13	0.12			0.11	0.13	0.07	0.07	0.07	0.06	0.06	0.13	0.09	0.12	0.08	0.12	0.16
NOV	0.07	0.18	0.18			0.13	0.17	0.12	0.93	0.10	0.05	0.07	0.14	0.10	0.16	0.09	0.14	0.20
DEC	0.07	0.17	0.17	0.58	0.67	0.12	0.15	0.19	7.96	0.10	0.06	0.07	0.14	0.10	0.14	0.08	0.13	0.14
mean	0.08	0.16	0.16	0.53	1.62	0.11	0.15	0.12	3.06	0.09	0.06	0.07	0.13	0.09	0.14	0.08	0.11	0.15
std dev	0.02	0.04	0.03	0.23	1.12	0.02	0.06	0.04	2.99	0.02	0.00	0.01	0.02	0.01	0.06	0.01	0.03	0.06
median	0.08	0.17	0.16	0.59	1.40	0.11	0.14	0.12	2.13	0.09	0.06	0.07	0.13	0.10	0.13	0.08	0.12	0.15
max	0.12	0.25	0.23	0.89	3.55	0.14	0.29	0.19	7.96	0.13	0.07	0.08	0.15	0.11	0.32	0.11	0.15	0.25
min	0.06	0.09	0.09	0.15	0.26	0.05	0.05	0.05	0.06	0.07	0.05	0.05	0.09	0.08	0.09	0.06	0.06	0.07

Table 2.4 pH during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	BBT	IC	NCF6
JAN	6.8	6.9	7.6	7.2	8.5	8.1	8.1	8.0		5.8	6.2	6.4	6.0	6.5	6.3
FEB	6.7	6.9	7.1	7.5	7.8	8.0	7.7	8.1		6.4	6.5	6.5	5.9	6.2	6.0
MAR	6.7	6.8	6.7	6.7	7.0	7.2	7.6	8.0		6.7	6.8	6.8	6.7	6.5	6.5
APR	7.0	7.0	7.2	7.3	7.4	7.9	8.1	8.1		6.9	7.0	7.0	6.5	6.9	6.8
MAY	6.5	6.7	6.6	6.8	7.1	7.6	7.9	8.0		6.9	7.0	7.0	6.5	6.9	6.5
JUN	6.8	6.8	6.9	6.9	7.2	7.5	7.9	7.9		6.9	7.1	7.0	6.4	6.7	6.6
JUL	6.7	6.8	6.9	7.1	7.3	7.5	8.0	8.0		6.7	6.9	6.8	6.5	6.6	6.5
AUG	6.8	6.9	7.2	7.0	7.4	7.9	7.9	8.0		6.9	6.7	6.7	6.7	6.7	6.9
SEP	7.0	7.0	7.1	7.2	7.5	7.8	7.9	7.9		6.1	6.3	6.4	5.7	6.2	5.7
OCT	5.4	5.2	5.3	5.6	5.6	6.4	7.2	7.9		5.8	5.9	6.0	5.9	5.9	6.0
NOV	7.4	7.4	7.4	7.5	7.7	7.9	8.0	8.0		6.1	6.4	6.3	6.2	6.3	6.4
DEC	7.5	7.6	7.7	7.6	8.0	8.0	8.0	8.0		5.5	6.4	6.6	6.3	6.5	6.4
mean	6.8	6.8	7.0	7.0	7.4	7.7	7.9	8.0		6.4	6.6	6.6	6.3	6.5	6.4
std dev	0.5	0.6	0.6	0.5	0.7	0.5	0.3	0.1		0.5	0.4	0.3	0.3	0.3	0.4
median	6.8	6.9	7.1	7.2	7.4	7.9	7.9	8.0		6.6	6.6	6.7	6.3	6.5	6.5
max	7.5	7.6	7.7	7.6	8.5	8.1	8.1	8.1		6.9	7.1	7.0	6.7	6.9	6.9
min	5.4	5.2	5.3	5.6	5.6	6.4	7.2	7.9		5.5	5.9	6.0	5.7	5.9	5.7

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117 SC-CH		B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	5.9	7.0	7.1	7.0	6.8	6.8	6.6	6.6	6.8	4.7	3.4	5.0	5.6	5.6	5.8	5.9	5.9	6.1
FEB	3.9	6.1	6.1	6.4	6.2	6.0	5.5	5.6	5.9	5.8	4.2	5.5	6.3	6.2	6.6	6.4	6.2	6.4
MAR	5.6	6.8	7.2	6.7	6.9	7.2	6.8	6.5	6.7	6.0	4.0	6.1	6.7	6.6	6.8	6.3	6.8	7.1
APR	6.2	7.0	7.2	6.8	6.8	7.3	7.0	6.7	6.9	6.1	3.9	6.1	6.9	6.7	6.8	6.3	6.8	7.0
MAY	6.5	7.0	7.0	6.9	6.8	7.3	6.9	6.9	6.9	5.8	3.9	6.1	6.9	6.8	6.8	6.3	6.9	6.9
JUN	6.7	6.9	6.9	6.9	7.0	7.4	6.9	6.6	6.7	6.1	4.0	6.1	6.9	7.0	7.1	6.5	7.0	7.2
JUL	5.8	6.6	6.6	6.7	6.9	7.5	7.2	6.5	6.7	6.5	4.3	6.2	7.1	7.0	6.7	6.2	7.1	7.4
AUG	5.9	7.3	6.9	6.8	6.7	6.7	6.9	6.7	6.9	6.4	4.4	6.0	6.6	6.9	6.7	6.0	6.9	7.2
SEP	5.2	6.5	6.5	6.8	6.9	6.8	6.6	5.7	6.2	6.4	3.9	5.6	6.1	6.2	6.0	6.1	6.1	6.1
OCT	5.0	6.4	6.7		6.5	6.2	5.3	5.4		4.8	3.4	5.4	6.1	6.2	6.3	6.5	6.7	6.8
NOV	5.3	6.4	6.9		6.8	6.6	6.4	5.8	6.0	5.0	3.4	5.6	6.2	6.4	6.5	6.5	6.9	6.9
DEC	5.4	6.6	6.9	6.8	6.8	6.8	6.5	6.9	6.4	4.9	3.4	5.2	5.9	6.2	6.2	6.2	6.3	6.4
mean	5.6	6.7	6.8	6.8	6.8	6.9	6.6	6.3	6.5	5.7	3.9	5.7	6.4	6.5	6.5	6.3	6.6	6.8
std dev	0.7	0.3	0.3	0.2	0.2	0.4	0.5	0.6	0.5	0.7	0.4	0.4	0.5	0.4	0.4	0.2	0.4	0.4
median	5.7	6.7	6.9	6.8	6.8	6.8	6.7	6.6	6.7	5.9	3.9	5.8	6.5	6.5	6.7	6.3	6.8	6.9
max	6.7	7.3	7.2	7.0	7.0	7.5	7.2	6.9	6.9	6.5	4.4	6.2	7.1	7.0	7.1	6.5	7.1	7.4
min	3.9	6.1	6.1	6.4	6.2	6.0	5.5	5.3	5.4	4.7	3.4	5.0	5.6	5.6	5.8	5.9	5.9	6.1

Table 2.5 Dissolved Oxygen (mg/l) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	BBT	IC	NCF6
JAN	9.0	8.9	8.9	8.7	8.8	8.8	8.7	8.3		10.9	10.8	10.7	10.3	10.8	9.2
FEB	10.6	10.6	10.6	10.3	10.4	10.2	10.1	9.8		12.0	11.8	11.3	10.8	11.0	10.2
MAR	9.6	9.6	9.5	9.3	9.5	9.9	9.9	9.8		10.5	10.3	10.4	9.9	9.4	8.7
APR	7.6	7.6	7.5	7.7	7.9	8.5	8.6	8.5		8.7	8.4	8.2		7.6	7.2
MAY	6.0	5.6	5.9	6.1	6.2	7.0	7.2	7.3		7.5	7.3	7.0	5.5	6.9	4.7
JUN	5.7	5.6	5.1	5.2	5.4	6.1	6.4	6.4		6.6	6.4	6.1	4.2	5.1	4.1
JUL	5.1	5.1	5.1	4.6	4.9	5.4	6.3	6.4		6.0	5.6	5.5	4.0	4.9	4.0
AUG	4.1	4.3	6.1	4.4	5.3	6.5	5.7	5.8		6.3	5.6	4.5	4.5	4.4	5.0
SEP	3.5	3.9	3.8	4.3	5.1	5.5	5.4	5.6		6.2	6.0	5.6	3.8	5.1	3.7
OCT	3.1	3.1	3.2	2.7	3.0	3.3	4.0	5.8		4.7	5.0	4.9	3.7	4.1	4.2
NOV	7.0	7.0	7.0	7.2	7.4	7.6	7.5	7.4		7.9	7.7	5.7	5.0	4.9	4.1
DEC	8.5	8.4	4.5	8.5	8.5	8.3	8.4	7.9		9.5	9.1	9.0	7.5	8.4	
mean	6.7	6.6	6.4	6.6	6.9	7.3	7.4	7.4		8.1	7.8	7.4	6.3	6.9	5.9
std dev	2.5	2.4	2.3	2.4	2.2	2.0	1.9	1.5		2.3	2.3	2.4	2.8	2.5	2.4
median	6.5	6.3	6.0	6.7	6.8	7.3	7.4	7.4		7.7	7.5	6.6	5.0	6.0	4.7
max	10.6	10.6	10.6	10.3	10.4	10.2	10.1	9.8		12.0	11.8	11.3	10.8	11.0	10.2
min	3.1	3.1	3.2	2.7	3.0	3.3	4.0	5.6		4.7	5.0	4.5	3.7	4.1	3.7

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117 SC-CH		B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	10.3	10.9	11.1	10.3	9.4	11.4	10.7	7.7	8.3	8.3	9.8	9.3	9.9	10.8	11.4	9.7	11.3	11.4
FEB	7.9	10.9	11.2	10.5	11.0	10.9	10.7	8.5	9.0	11.3	9.4	10.9	10.2	10.9	11.1	11.1	11.2	11.5
MAR	10.6	10.5	12.5	11.2	11.4	12.0	10.6	8.7	9.4	6.4	6.1	7.5	7.7	7.8	6.8	4.3	8.8	8.9
APR	7.7	7.9	9.4	7.5	6.2	9.5	8.2	6.1	6.9	7.3	7.5	8.4	8.8	8.8	7.9	5.7	8.7	8.5
MAY	5.8	7.1	6.8	6.8	5.1	9.2	7.5	6.1	6.4	5.5	6.1	7.4	7.9	7.9	7.1	4.1	8.7	8.0
JUN	6.0	5.7	6.1	5.3	3.9	8.6	6.1	3.9	4.4	4.6	4.9	5.8	6.5	6.6	6.0	1.0	7.5	6.5
JUL	5.1	5.6	5.4	3.7	4.9	7.0	5.7	3.3	4.1	4.4	4.0	5.7	5.9	6.1	5.0	1.5	7.0	5.8
AUG	4.9	6.3	2.8	3.6	4.6	7.1	5.5	4.3	4.2	4.7	4.3	5.9	6.2	6.6	6.0	2.2	7.4	6.1
SEP	3.7	5.1	2.5	4.0	9.9	7.5	5.4	2.9	3.4	5.0	5.4	6.8	7.1	6.9	5.4	5.5	7.4	7.3
OCT	2.5	3.9	2.5			7.5	4.9	1.8	1.8	5.3	5.6	6.6	8.1	7.2	6.3	4.8	8.9	8.4
NOV	4.8	6.3	5.5		9.5	8.5	7.1	3.0	3.7	8.5	7.7	9.3	10.1	9.8	9.3	5.5	9.2	7.9
DEC	6.9	8.9	8.9	8.8	8.7	9.8	8.9	7.0	7.7	9.2	8.3	10.5	10.3	10.3	10.0	9.4	10.5	10.7
mean	6.4	7.4	7.1	7.2	7.7	9.1	7.6	5.3	5.8	6.7	6.6	7.8	8.2	8.3	7.7	5.4	8.9	8.4
std dev	2.5	2.4	3.5	2.9	2.8	1.7	2.2	2.4	2.5	2.2	1.9	1.8	1.6	1.8	2.2	3.2	1.5	1.9
median	5.9	6.7	6.5	7.2	8.7	8.9	7.3	5.2	5.4	6.0	6.1	7.5	8.0	7.9	7.0	5.2	8.8	8.2
max	10.6	10.9	12.5	11.2	11.4	12.0	10.7	8.7	9.4	11.3	9.8	10.9	10.3	10.9	11.4	11.1	11.3	11.5
min	2.5	3.9	2.5	3.6	3.9	7.0	4.9	1.8	1.8	4.4	4.0	5.7	5.9	6.1	5.0	1.0	7.0	5.8

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations 1995-2015 versus 2016.

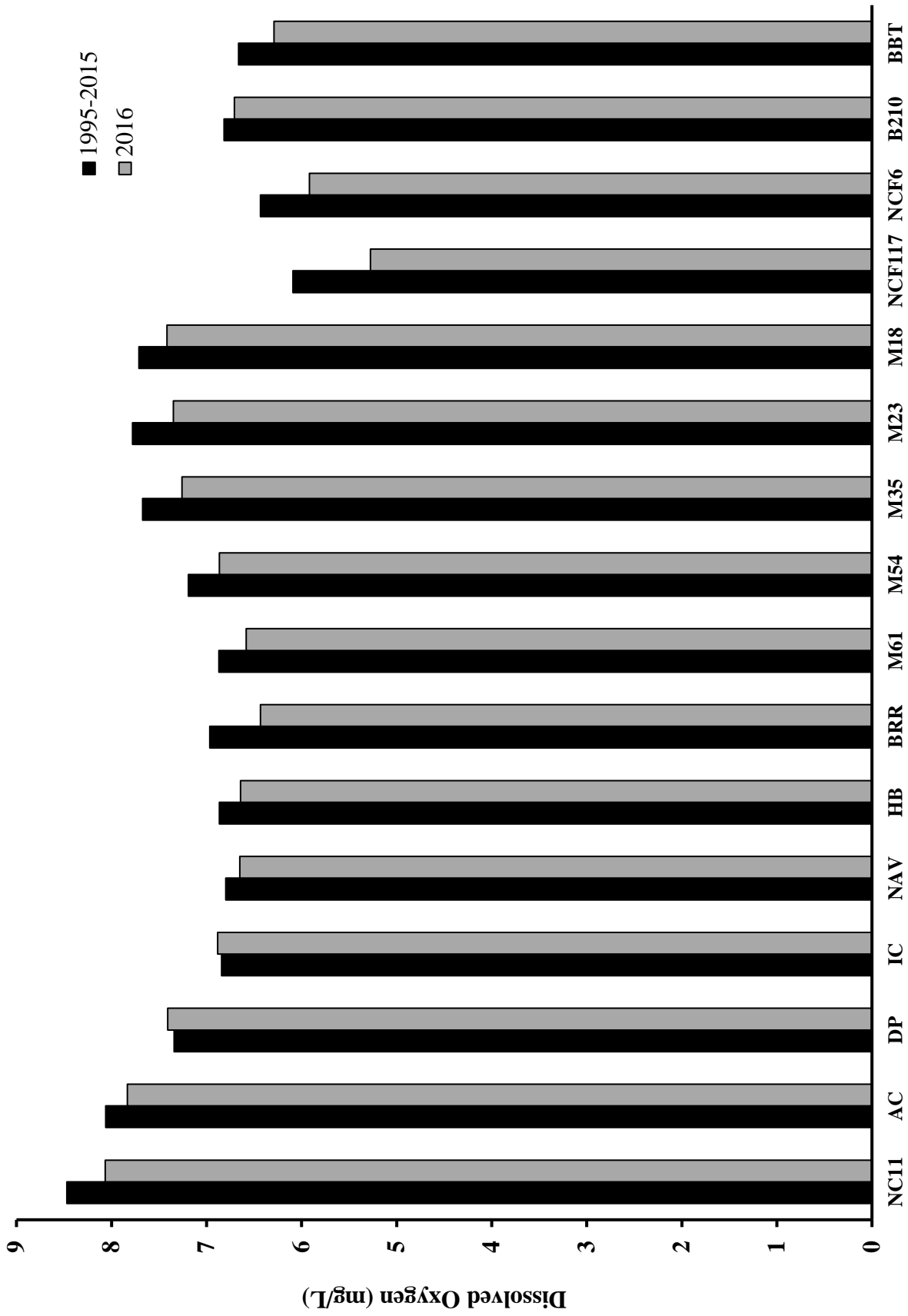


Table 2.6 Field Turbidity (NTU) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	BBT	IC	NCF6
JAN	14	13	16	18	29	9	7	16		20	20	20	7	20	4
FEB	10	10	9	7	8	7	5	3		41	34	30	11	18	8
MAR	57	53	46	42	56	33	18	13		40	38	32	26	21	14
APR	14	12	11	6	6	5	7	6		22	19	20		16	17
MAY	17	19	18	19	17	9	10	8		24	25	25	12	20	7
JUN	14	12	8	9	6	4	4	4		5	5	10	3	7	3
JUL	8	8	7	8	7	6	4	3		13	13	15	6	8	1
AUG	9	8	8	6	5	3	2	3		10	10	10	9	8	6
SEP	11	13	11	5	6	3	2	2		17	16	13	3	6	4
OCT	10	11	12	12	13	21	13	4		43	47	27	12	21	5
NOV	5	7	5	4	6	6	4	5		9	8	7	7	6	6
DEC	11	12	9	7	7	8	7	13		6	7	8	5	6	
mean	15	15	13	12	14	10	7	7		21	20	18	9	13	7
std dev	14	12	11	11	15	9	5	5		14	13	9	6	7	5
median	11	12	10	8	7	7	6	5		19	18	18	7	12	6
max	57	53	46	42	56	33	18	16		43	47	32	26	21	17
min	5	7	5	4	5	3	2	2		5	5	7	3	6	1

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117 SC-CH		B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	7	3	2	2	5	7	6	4		3	2	2	3	1	1	4	10	6
FEB	1	5	4	6	35	8	11	10		0	2	0	23	3	0	4	15	13
MAR	14	7	3	6	22	17	13	9		5	5	3	11	6	4	8	8	5
APR	10	4	2	4	11	5	7	5		5	6	3	5	4	3	9	45	7
MAY	23	19	3	6	25	5	14	7		6	5	2	9	8	4	9	6	20
JUN	9	5	1	2	16	2	4	4		4	14	3	3	2	3	11	4	5
JUL	42	3	2	2	19	1	4	4		3	3	2	4	3	5	4	4	5
AUG	17	3	4	2	10	8	7	2		3	2	1	3	5	3	6	3	5
SEP	3	6	2	1	6	3	6	2		2	3	3	11	9	2	18	83	59
OCT	3	2	2			4	3	2		2	2	2	3	2	2	4	7	2
NOV	7	3	2		3	5	4	2		3	2	1	4	2	2	3	5	2
DEC	6	3	2	4	8	25	22	4		2	2	1	5	4	2	2	12	7
mean	12	5	2	3	15	8	8	5		3	4	2	7	4	3	7	17	11
std dev	11	5	1	2	10	7	6	3		2	3	1	6	3	1	5	24	16
median	8	4	2	3	11	5	7	4		3	3	2	5	4	3	5	8	6
max	42	19	4	6	35	25	22	10		6	14	3	23	9	5	18	83	59
min	1	2	1	1	3	1	3	2		0	2	0	0	1	0	2	3	2

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2015 versus 2016.

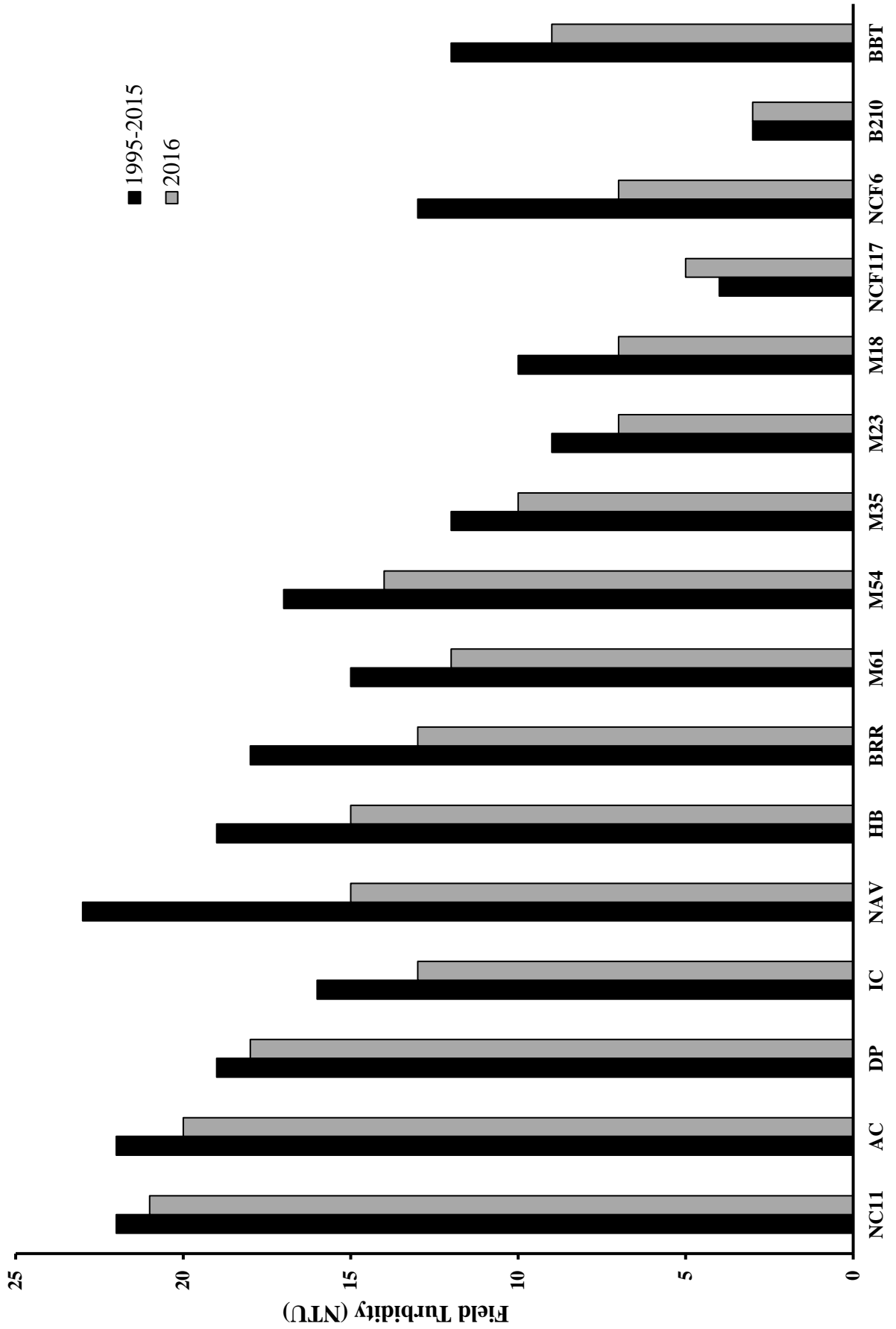


Table 2.7 Total Suspended Solids (mg/L) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	HR	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	IC	NCF6
JAN	7.7	6.2	8.4	8.4	10.6	25.4	10.8	11.2	31.1		22.0	19.5	18.0	20.4	4.5
FEB	7.3	5.1	4.5	4.5	5.4	5.5	7.8	10.2	8.2		24.0	18.4	15.2	7.9	1.4
MAR	21.5	19.4	17.3	17.3	16.5	26.8	16.2	11.3	13.3		16.7	13.7	12.5	8.2	9.0
APR	16.6	16.3	15.6	15.6	12.2	13.9	15.8	20.9	11.9		12.0	8.2	7.8	6.4	12.3
MAY	8.4	12.7	9.0	11.9	13.3	11.5	14.8	18.0			26.5	31.6	26.4	21.2	9.8
JUN	16.7	7.9	7.7	7.7	15.7	8.5	9.6	9.9	14.1		6.1	5.0	9.0	8.8	5.3
JUL	4.6	5.3	5.9	12.3	11.1	12.3	12.4	10.1			14.9	12.0	17.8	9.5	3.4
AUG	17.0	15.6	16.5	14.5	15.3	13.0	12.4	18.7			9.6	10.3	9.9	6.6	10.3
SEP	24.1	21.4	24.3	15.1	19.4	12.6	13.7	14.8			15.9	17.3	9.7	5.4	3.7
OCT	1.5	9.7	8.6	10.6	11.6	20.9	14.1	15.8			25.0	24.0	29.2	22.2	7.4
NOV	11.7	10.6	8.6	8.9	13.8	16.9	14.8	18.8			8.3	8.4	8.3	4.8	10.4
DEC	17.2	16.0	13.9	10.1	15.7	25.8	22.0	32.1			5.9	7.7	9.4	5.0	
mean	12.9	12.2	11.7	12.0	15.0	14.4	14.0	17.2			15.6	14.7	14.4	10.5	10.5
std dev	7.0	5.6	5.8	3.2	6.3	5.1	3.9	7.5			7.4	7.8	7.2	6.6	6.6
median	14.2	11.7	8.8	12.1	13.9	12.8	13.1	15.3			15.4	12.9	11.2	9.6	8.1
max	24.1	21.4	24.3	16.5	26.8	25.8	22.0	32.1			26.5	31.6	29.2	5.9	22.2
min	1.5	5.1	4.5	5.4	5.5	7.8	9.9	8.2			5.9	5.0	7.8	9.7	4.8

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117 SC-CH	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1.4			1.4	1.4	2.7	4.3	1.4	3.0					1.4			
FEB	12.3			2.8	8.0	4.7	4.6	6.3	1.5					1.4			
MAR	1.4			1.4	3.1	5.7	5.3	3.1	5.1					5.3			
APR	3.8			3.8	9.2	3.0	7.9	6.0	3.9					4.9			
MAY	9.9			3.3	8.5	1.4	5.8	3.3	5.8					4.6			
JUN	6.2			3.8	10.6	1.5	4.4	3.1	2.7					1.4			
JUL	4.3			3.3	7.2	2.8	3.6	4.6	1.5					4.2			
AUG	1.4			5.2	49.5	9.4	5.5	1.4	1.5					4.4			
SEP	10.8			3.9	9.7	3.3	4.4	1.4	1.3					1.3			
OCT	4.4					6.7	6.2	2.9	1.4					4.3			
NOV	2.9				9.6	2.8	1.3	1.3	1.3					1.4			
DEC	3.1			4.8	6.4	22.3	18.8	4.5	1.4					1.3			
mean	5.2	3.4	11.2	5.5	6.0	3.3	12.0		2.5					3.0			
std dev	3.8	1.3	13.0	5.8	4.3	1.8	5.6		1.6					1.7			
median	4.1	3.6	8.5	3.2	5.0	3.1	10.2		1.5					2.8			
max	12.3	5.2	49.5	22.3	18.8	6.3	23.6		5.8					5.3			
min	1.4	1.4	1.4	1.4	1.4	1.3	1.3		1.3					1.3			

Table 2.8 Light Attenuation (k) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	BBT	IC	NCF6
JAN	3.45	3.93	3.77	4.48	5.44	3.54	2.58	2.84		3.12	3.22	3.17	3.60	3.21	4.29
FEB	2.93	2.84	2.71	3.30	3.31	2.86	2.50	2.16		3.60	3.41	3.40	3.34	3.50	3.82
MAR	4.54	4.27	4.10	4.49	4.73	3.51	2.63	2.34		3.39	3.48	3.14	3.15	3.42	4.08
APR	3.21	3.25	3.50	2.74	2.18	2.06	1.34	1.33		2.53	2.35	2.59		2.68	4.66
MAY	4.14	4.28	3.86	3.64	3.04	2.06	1.35	1.04		3.61	3.59	4.05	4.05	3.36	3.95
JUN	3.29	3.58	2.92	2.63	2.27	1.83	1.41	1.59		2.12	2.74	2.58	3.57	2.57	3.94
JUL	2.35	2.56	2.73	2.87		2.08	1.57	1.66		2.30	2.58	3.04	2.76	3.00	4.40
AUG	2.80	2.99	4.07	2.67	1.96	1.79	0.74	0.80		2.30	2.84	3.65	3.26	2.98	3.36
SEP	2.69	2.83	2.52	2.18	1.90	1.44	0.79	0.73		3.28	3.17	2.74	3.47	2.73	3.66
OCT	4.80	4.64	4.71	5.96	5.83	6.25	4.46	2.59		3.97	4.72	4.61	4.86	4.65	6.12
NOV	3.39	4.01	2.99	2.67	2.49	1.88	1.29	1.23		2.41	2.43	2.89	3.39	2.77	
DEC	3.97	4.32	3.50	3.56	2.69	2.46	2.04	2.03		2.41	2.43	2.89	3.39	2.77	
mean	3.46	3.63	3.45	3.43	3.26	2.65	1.89	1.70		2.97	3.14	3.26	3.55	3.17	4.23
std dev	0.76	0.71	0.68	1.08	1.42	1.32	1.04	0.70		0.65	0.68	0.63	0.57	0.58	0.76
max	4.80	4.64	4.71	5.96	5.83	6.25	4.46	2.84		3.97	4.72	4.61	4.86	4.65	6.12
min	2.35	2.56	2.52	2.18	1.90	1.44	0.74	0.73		2.12	2.35	2.58	2.76	2.57	3.36

Table 2.9 Total Nitrogen (µg/l) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NCl1	AC	DP	IC	NCF6
JAN	1,380	1,850	1,540	1,540	1,520	1,190	1,000	1,010		960	1,180	1,480	1,540	1,610
FEB	1,830	1,780	1,890	2,770	1,720	1,500	2,760	860		1,560	1,690	1,070	1,700	2,070
MAR	600	530	600	600	740	630	400	300		440	470	480	580	560
APR	1,000	800	800	800	700	500	400	400		500	1,540	600	700	800
MAY	1,280	1,190	1,290	1,290	1,270	870	350	350		1,290	1,320	1,400	1,280	2,630
JUN	1,460	1,780	1,470	1,210	1,200	900	330	400		840	1,320	820	1,090	850
JUL	1,390	1,610	1,470	1,260	1,450	1,030	270	200		2,000	1,840	1,780	1,510	1,110
AUG	770	760	960	850	650	100	200	200		550	340	1,120	880	1,160
SEP	1,240	1,110	580	680	680	220	500	300		1,150	1,170	1,240	1,280	910
OCT	830	1,130	1,110	880	900	1,040	840	300		1,110	1,590	940	1,120	1,560
NOV	690	720	720	720	630	500	450	500		750	540	920	720	840
DEC	960	810	1,140	780	860	570	470	500		1,000	990	990	1,030	
mean	1,119	1,173	1,131	1,115	1,027	754	664	443		1,013	1,166	1,070	1,119	1,282
std dev	370	472	415	598	387	408	699	251		456	494	368	358	628
median	1,120	1,120	1,125	865	880	750	425	375		980	1,250	1,030	1,105	1,110
max	1,830	1,850	1,890	2,770	1,720	1,500	2,760	1,010		2,000	1,840	1,780	1,700	2,630
min	600	530	580	600	630	100	200	200		440	340	480	580	560

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,750	2,400	1,970	3,040	2,280	2,070	2,240	1,750	1,440	1,510	1,240	1,200	2,850	2,060	1,990	1,920	1,490	1,780
FEB	2,550	2,890	3,330	4,470	4,520	1,650	1,610	1,170	1,080	1,670	850	1,010	2,530	2,430	2,430	1,190	1,270	1,400
MAR	1,200	750	600	740	750	900	900	900	50	1,000	1,500	1,000	1,100	1,000	1,000	1,300	800	800
APR	800	800	900	1,100	1,000	1,000	1,100	1,000	1,000	1,000	1,500	900	750	1,030	920	1,300	870	600
MAY	1,620	1,310	780	1,950	970	810	2,820	1,320	930	1,040	1,320	1,020	1,510	1,330	900	1,430	900	720
JUN	1,530	470	530	2,100	1,300	840	2,340	1,500	1,140	990	1,760	1,170	1,350	1,060	3,820	2,060	1,100	650
JUL	2,280	720	700	780	640	550	7,640	930	950	630	1,050	610	1,040	780	1,040	1,020	1,220	230
AUG	1,630	1,220	1,100	1,000	1,300	970	8,010	1,130	1,090	1,550	1,860	540	1,670	1,240	880	1,300	1,490	870
SEP	1,650	1,150	2,600	1,180	2,000	740	3,980	1,010	1,020	930	1,520	1,050	1,590	1,260	900	1,330	1,030	1,530
OCT	420	640	720			960	1,900	1,060	860	860	1,000	800	1,490	920	1,020	700	1,040	270
NOV	1,130	720	500		600	980	1,860	840	950	930	700	790	1,380	1,390	980	460	1,020	200
DEC	1,130	1,030	400	1,140	650	1,320	3,480	770	700	880	900	510	1,650	1,380	930	520	870	710
mean	1,474	1,175	1,178	1,750	1,455	1,066	3,157	1,115	934	1,083	1,267	883	1,576	1,323	1,401	1,211	1,092	813
std dev	591	739	943	1,196	1,158	422	2,356	286	330	318	372	235	591	477	909	491	233	513
median	1,575	915	750	1,160	1,000	965	2,290	1,035	975	995	1,280	950	1,500	1,250	990	1,300	1,035	715
max	2,550	2,890	3,330	4,470	4,520	2,070	8,010	1,750	1,440	1,670	1,860	1,200	2,850	2,430	3,820	2,060	1,490	1,780
min	420	470	400	740	600	550	900	770	50	630	700	510	750	780	880	460	800	200

Table 2.10 Nitrate/Nitrite ($\mu\text{g/l}$) during 2016 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NC11	AC	DP	IC	NCF6
JAN	580	550	540	540	520	390	300	110	160	280	580	640	610
FEB	930	880	890	870	820	600	560	460	760	690	670	800	670
MAR	10	30	10	10	40	30	10	10	40	170	80	80	60
APR	10	10	10	10	10	10	10	10	10	740	10	10	10
MAY	580	490	490	490	470	370	150	50	790	820	800	780	430
JUN	460	580	470	410	400	200	30	10	540	520	520	390	350
JUL	690	710	670	460	450	330	70	10	900	840	780	610	310
AUG	270	260	260	250	150	10	10	10	450	340	320	380	360
SEP	340	310	280	280	280	20	10	10	650	570	640	580	310
OCT	130	130	110	80	100	140	140	10	310	290	240	220	60
NOV	390	420	420	320	230	100	50	10	250	40	320	120	40
DEC	360	310	440	280	260	170	170	10	600	590	590	530	
mean	396	390	383	333	311	198	126	59	455	491	463	428	292
std dev	275	267	264	246	234	188	163	130	300	263	264	272	229
median	375	365	430	300	270	155	60	10	495	545	550	460	310
max	930	880	890	870	820	600	560	460	900	840	800	800	670
min	10	10	10	10	10	10	10	10	10	40	10	10	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF17	SC-CH	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	150	1,500	1,270	2,140	1,580	1,170	1,240	650	440	410	40	300	1,850	1,260	1,090	220	590	980
FEB	750	2,190	2,530	3,570	3,420	850	910	470	380	1,170	50	610	1,830	1,930	2,030	690	670	700
MAR	10	50	10	140	50	10	10	10	10	10	10	10	10	10	10	10	10	10
APR	10	10	10	10	10	10	10	10	10	10	10	10	50	30	20	10	70	10
MAY	120	410	80	1,150	70	110	1,820	420	330	240	20	220	910	630	300	330	400	220
JUN	130	270	30	1,500	10	240	1,640	700	340	190	60	270	750	460	2,520	60	500	250
JUL	680	120	10	380	40	250	6,740	430	350	230	50	210	640	380	440	120	1,020	130
AUG	430	320	10	300	10	270	6,810	330	290	350	60	340	570	440	180	100	690	70
SEP	50	150	10	580	900	140	2,680	110	220	230	20	150	590	260	100	330	330	530
OCT	20	40	20			160	700	60	60	60	10	10	890	420	120	10	640	70
NOV	30	120	10		10	80	860	40	50	530	10	390	1,080	990	680	60	720	10
DEC	130	430	10	640	250	220	2,880	270	200	380	10	210	1,050	680	430	20	170	110
mean	209	468	333	1,041	577	293	2,192	292	223	318	29	228	852	624	660	163	484	258
std dev	263	675	780	1,109	1,068	353	2,321	247	155	313	21	176	572	545	821	203	299	314
median	125	210	10	610	50	190	1,440	300	255	235	20	215	820	450	365	80	545	120
max	750	2,190	2,530	3,570	3,420	1,170	6,810	700	440	1,170	60	610	1,850	1,930	2,520	690	1,020	980
min	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Figure 2.4 Nitrate + Nitrite at the Lower Cape Fear River Program mainstem stations, 1995-2015 versus 2016.

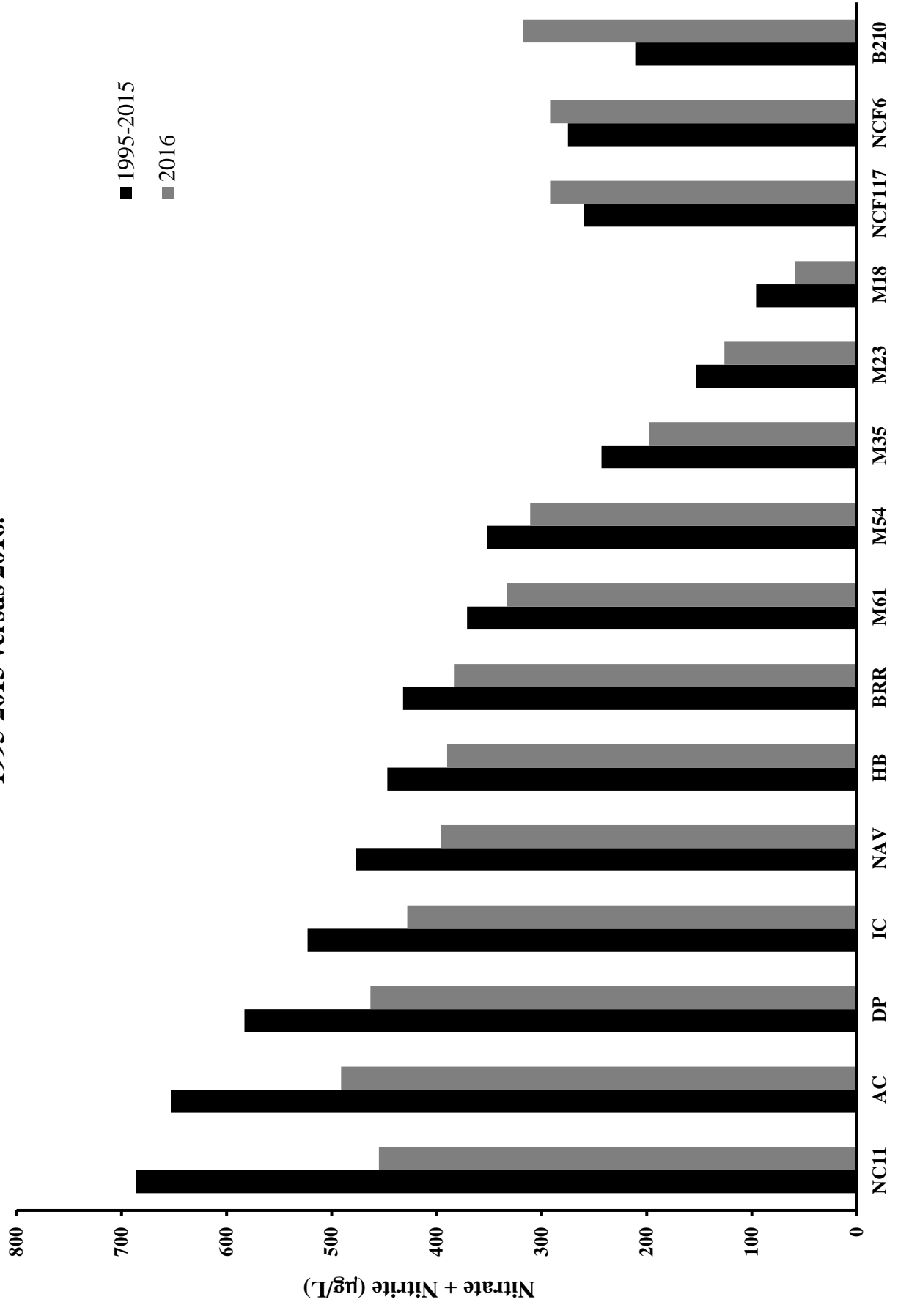


Table 2.11 Ammonia ($\mu\text{g/l}$) during 2016 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NC11	AC	DP	IC	NCF6
JAN	20	50	40	60	40	10	60	20	80	50	40	40	50
FEB	50	50	70	90	100	60	10	40	30	50	40	30	160
MAR	20	30	30	40	60	40	30	10	10	50	30	20	60
APR	60	30	40	50	50	10	10	10	120	10	70	60	40
MAY	130	110	80	90	90	10	10	10	100	110	100	100	90
JUN	60	60	60	80	80	60	30	10	20	240	90	60	40
JUL	110	70	60	90	80	40	10	10	400	50	40	30	10
AUG	120	180	50	120	50	20	20	10	100	70	110	70	60
SEP	10	10	10	10	20	10	10	10	70	70	100	90	60
OCT	10	10	10	10	10	10	40	40	10	50	40	30	10
NOV	30	60	80	120	20	10	10	80	40	170	70	50	60
DEC	50	80	80	110	170	70	50	10	50	70	70	70	60
mean	56	62	51	73	64	29	24	22	86	83	67	54	58
std dev	43	47	25	39	44	24	18	22	106	63	28	25	41
median	50	55	55	85	55	15	15	10	60	60	70	55	60
max	130	180	80	120	170	70	60	80	400	240	110	100	160
min	10	10	10	10	10	10	10	10	10	10	30	20	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	190	30	60	40	90	130	70	50	10	10	80	10	90	30	10	40	90	60
FEB	90	70	50	90	80	60	90	40	140	20	10	10	60	10	10	10	50	70
MAR	10	10	10	10	10	10	20	60	50	60	170	50	80	50	560	200	40	40
APR	90	30	480	860	270	70	60	80	70	40	190	40	50	50	40	160	60	30
MAY	260	70	50	120	390	90	100	80	80	20	120	20	40	20	20	140	20	40
JUN	10	30	10	70	10	90	80	70	40	60	180	10	10	10	10	600	20	20
JUL	90	30	10	60	100	10	10	20	60	90	960	60	70	80	130	390	80	80
AUG	110	90	60	230	130	240	140	50	70	40	650	10	30	10	10	160	10	10
SEP	90	80	40	100	50	130	130	60	60	30	50	30	70	50	40	50	40	90
OCT	50	10	60			220	110	90	50	10	40	10	10	50	10	10	40	10
NOV	170	20	10		10	220	50	50	50	20	50	30	20	20	30	40	30	10
DEC	190	30	30	130	110	770	70	80	90	10	30	10	40	20	20	10	10	140
mean	113	42	73	171	114	170	78	61	64	34	211	24	48	33	74	151	41	50
std dev	76	28	130	249	118	204	40	20	31	25	292	18	27	22	157	180	26	40
median	90	30	45	95	90	110	75	60	60	25	100	15	45	25	20	95	40	40
max	260	90	480	860	390	770	140	90	140	90	960	60	90	80	560	600	90	140
min	10	10	10	10	10	10	10	20	10	10	10	10	10	10	10	10	10	10

Table 2.12 Total Kjeldahl Nitrogen ($\mu\text{g/l}$) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	IC	NCF6		SR	BRN	HAM
JAN	800	1,300	1,000	1,000	1,000	800	700	900		800	900	900	900	1,000		900	900	800
FEB	900	900	1,000	1,900	900	900	2,200	400		800	1,000	400	900	1,400		500	600	700
MAR	600	500	600	600	700	600	400	300		400	300	400	500	500		800	800	800
APR	1,000	800	800	800	700	500	400	400		500	800	600	700	800		1,300	1,300	800
MAY	700	700	800	800	800	500	200	300		500	500	600	500	2,200		600	800	600
JUN	1,000	1,200	1,000	800	800	700	300	400		300	800	300	700	500		900	200	100
JUL	700	900	800	800	1,000	700	200	200		1,100	1,000	1,000	900	800		1,100	700	1,000
AUG	500	500	700	600	500	100	200	200		100	50	800	500	800		600	400	200
SEP	900	800	300	400	400	200	500	300		500	600	600	700	600		600	600	600
OCT	700	1,000	1,000	800	800	900	700	300		800	1,300	700	900	1,500		1,000	800	800
NOV	300	300	300	400	400	400	400	500		500	500	600	600	800		300	300	200
DEC	600	500	700	500	600	400	300	500		400	400	400	500	800		500	700	600
mean	725	783	750	783	717	558	542	392		558	679	608	692	991		608	608	558
std dev	209	301	250	397	208	257	550	188		271	351	215	173	517		284	219	284
median	700	800	800	800	750	550	400	350		500	700	600	700	800		600	650	600
max	1,000	1,300	1,000	1,900	1,000	900	2,200	900		1,100	1,300	1,000	900	2,200		2,000	2,000	1,000
min	300	300	300	400	400	100	200	200		100	50	300	500	500		400	400	100

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF17	SC-CH		B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,600	900	700	900	700	900	1,000	1,100	1,000		1,100	1,200	900	1,000	800	900	1,700	900	800
FEB	1,800	700	800	900	1,100	800	700	700	700		500	800	400	700	500	400	500	600	700
MAR	1,200	700	600	600	700	900	900	900	50		1,000	1,500	1,000	1,100	1,000	1,000	1,300	800	800
APR	800	800	900	1,100	1,000	1,000	1,100	1,000	1,000		1,000	1,500	900	700	1,000	900	1,300	800	600
MAY	1,500	900	700	800	900	700	1,000	900	600		800	1,300	800	600	700	600	1,100	500	500
JUN	1,400	200	500	600	1,300	600	700	800	800		800	1,700	900	600	600	1,300	2,000	600	400
JUL	1,600	600	700	400	600	300	900	500	600		400	1,000	400	400	400	600	900	200	100
AUG	1,200	900	1,100	700	1,300	700	1,200	800	800		1,200	1,800	200	1,100	800	700	1,200	800	800
SEP	1,600	1,000	2,600	600	1,100	600	1,300	900	800		700	1,500	900	1,000	1,000	800	1,000	700	1,000
OCT	400	600	700		800	800	1,200	1,000	800		800	1,000	800	600	500	900	700	400	200
NOV	1,100	600	500		600	900	1,000	800	900		400	700	400	300	400	300	400	300	200
DEC	1,000	600	400	500	400	1,100	600	500	500		500	900	300	600	700	500	500	700	600
mean	1,267	708	850	710	882	775	967	825	713		767	1,242	658	725	700	742	1,050	608	558
std dev	401	215	582	213	303	214	219	186	259		274	363	291	267	226	281	491	219	284
median	1,300	700	700	650	900	800	1,000	850	800		800	1,250	800	650	700	750	1,050	650	600
max	1,800	1,000	2,600	1,100	1,300	1,100	1,300	1,100	1,000		1,200	1,800	1,000	1,100	1,000	1,300	2,000	900	1,000
min	400	200	400	400	400	300	600	500	50		400	700	200	300	400	300	400	200	100

Table 2.13 Total Phosphorus ($\mu\text{g/l}$) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18		NC11	AC	DP	IC	NCF6
JAN	70	50	80	70	100	80	70	70		70	80	130	80	80
FEB	60	60	60	70	70	70	60	50		100	80	90	60	70
MAR	30	80	40	90	100	70	60	40		90	80	80	60	70
APR	120	120	110	90	80	60	40	30		110	100	110	100	100
MAY	130	110	110	110	100	70	50	30		100	70	100	90	60
JUN	130	110	100	90	80	60	40	40		80	130	110	100	130
JUL	130	130	140	110	90	110	120	120		90	80	60	30	10
AUG	110	100	100	90	60	40	30	20		90	70	100	110	90
SEP	100	170	90	80	100	40	30	30		130	100	120	100	140
OCT	70	80	80	120	100	110	90	40		80	90	90	100	90
NOV	80	70	60	40	30	10	10	10		70	80	80	80	100
DEC	130	100	100	90	80	60	50	40		190	130	140	120	
mean	97	98	89	89	83	67	54	43		100	91	101	86	86
std dev	32	32	26	17	18	24	28	27		32	20	22	24	33
median	105	100	95	90	85	65	50	40		90	80	100	95	90
max	130	170	140	120	100	110	120	120		190	130	140	120	120
min	30	50	40	40	40	30	10	10		70	70	60	30	30

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	170	80	70	60	190	80	160	80	110	70	60	10	80	50	90	50	70	70
FEB	210	120	120	110	120	100	150	120	110	40	60	20	90	40	60	30	70	60
MAR	130	60	40	90	130	60	110	60	150	80	190	50	120	60	240	70	90	130
APR	210	120	90	140	270	100	260	130	100	90	150	50	90	60	420	50	100	130
MAY	230	140	90	100	260	70	360	100	100	110	150	40	100	60	360	70	80	110
JUN	200	160	110	130	290	80	350	210	110	110	200	50	130	90	970	120	80	160
JUL	760	140	110	200	290	50	720	170	90	140	170	50	160	90	450	90	100	230
AUG	530	160	180	210	400	90	820	130	110	170	210	60	170	80	400	80	90	230
SEP	370	180	220	150	350	90	520	150	140	90	30	30	140	100	190	70	160	240
OCT	320	170	220			70	280	150	140	90	60	50	130	50	220	70	80	110
NOV	170	160	160		310	110	380	140	130	60	30	10	50	50	400	40	90	90
DEC	190	80	90	150	200	110	80	310	90	70	50	10	70	30	160	30	80	80
mean	291	131	125	134	255	84	349	146	115	93	113	36	111	63	330	64	91	137
std dev	177	38	55	45	84	18	225	62	19	34	68	18	35	21	231	25	23	62
median	210	140	110	135	270	85	315	135	110	90	105	45	110	60	300	70	85	120
max	760	180	220	210	400	110	820	310	150	170	210	60	170	100	970	120	160	240
min	130	60	40	60	120	50	80	60	90	40	30	10	50	30	60	30	70	60

Figure 2.5 Total Phosphorus at the Lower Cape Fear River Program mainstem stations, 1995-2015 versus 2016.

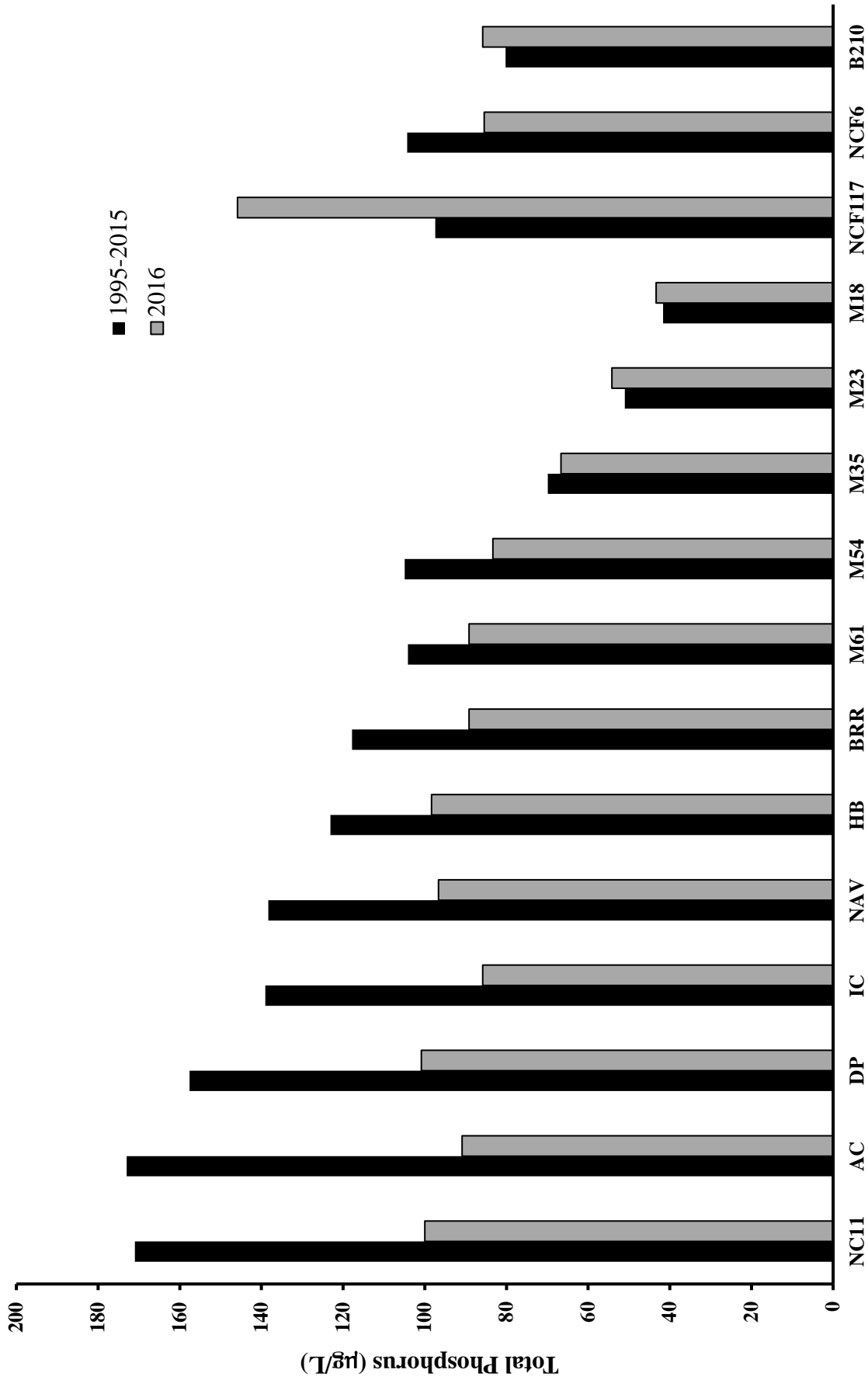


Table 2.14 Orthophosphate ($\mu\text{g/l}$) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NC11	AC	DP	BBT	IC	NCF6
JAN	20	30	30	30	30	30	20	20	20	20	23	20	20	30
FEB	20	20	20	20	20	20	10	10	30	30	20	20	20	30
MAR	30	30	30	30	30	20	20	10	20	20	30	20	20	30
APR	40	40	40	30	30	20	10	0	50	50	50	50	40	40
MAY	40	40	40	30	30	10			20	50	60	50	60	60
JUN	50	60	50	40	40	40	20	20	30	60	50	50	40	60
JUL	60	70	70	40	40	30	10	20	60	70	60	60	60	50
AUG	40	40	40	40	20	20	20	10	30	30	40	50	50	40
SEP	40	40	40	40	50	20	20	10	50	40	50	40	50	80
OCT	30	30	30	60	50	40	40	30	30	30	30	20	30	40
NOV	30	30	30	30	30	20	10	10	20	20	20	30	30	50
DEC	40	40	30	40	40	30	20	10	70	60	60	30	50	
mean	37	39	38	36	34	25	18	14	36	40	41	35	39	46
std dev	12	14	13	10	10	9	9	8	17	18	16	15	15	16
median	40	40	35	35	30	20	20	10	30	35	45	30	40	40
max	60	70	70	60	50	40	40	30	70	70	60	60	60	80
min	20	20	20	20	20	10	10	0	20	20	20	20	20	30

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF17	SC-CH	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	100	20	10	30	50	20	50	30	40	30	30	10	30	10	30	10	20	20
FEB	120	30	40	30	20	30	60	40	40	10	30	10	30	10	20	0	10	10
MAR	80	20	10	20	30	10	40	20	30	20	100	10	30	10	110	10	10	20
APR	100	40	30	40	60	20	110	50	40	30	80	10	20	10	230	10	10	30
MAY	130	40	30	50	40	30	180	40	40	40	90	20	40	20	220	10	20	40
JUN	110	50	40	60	20	20	160	100	60	40	140	20	50	30	870	10	20	60
JUL	590	60	50	100	80	20	510	90	60	60	120	20	60	40	220	20	30	90
AUG	350	60	50	120	80	30	560	70	50	70	120	20	70	30	220	50	30	10
SEP	260	60	60	60	60	30	240	80	70	50	20	20	60	20	110	20	30	10
OCT	30	70	90	60	40	20	50	30	90	30	90	90	50	20	60	30	100	40
NOV	110	50	40	40	80	20	160	60	60	30	30	10	20	30	270	0	10	40
DEC	140	20	20	40	20	20	160	30	30	20	30	10	30	10	90	0	10	20
mean	177	43	39	55	48	23	190	53	51	36	73	21	41	20	204	14	25	33
std dev	156	18	22	32	24	6	173	26	18	17	43	22	17	10	227	14	25	24
median	115	45	40	45	45	20	160	45	45	30	85	15	35	20	165	10	20	25
max	590	70	90	120	80	30	560	100	90	70	140	90	70	40	870	50	100	90
min	30	20	10	20	20	10	40	20	30	10	20	10	20	10	20	0	0	10

Table 2.15 Chlorophyll *a* ($\mu\text{g/l}$) during 2016 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NC11	AC	DP	BBT	IC	NCF6
JAN	1	1	1	1	2	1	1	5	2	2	2	1	2	0
FEB	2	2	2	2	2	2	2	3	2	1	1	1	1	1
MAR	3	3	3	3	3	2	3	6	8	7	7	5	5	1
APR	2	2	3	4	6	10	8	7	6	4	3	2	2	3
MAY	1	2	2	4	5	17	6	5	3	2	2	1	2	1
JUN	2	2	3	2	3	2	3	5	2	3	4	1	2	1
JUL	4	6	9	11	14	11	12	8	3	4	5	2	4	2
AUG	13	9	34	23	19	8	3	4	10	9	7	5	5	21
SEP	7	9	9	7	10	5	3	3	2	2	4	1	3	1
OCT	0	0	1	1	1	1	1	2	1	1	1	1	1	0
NOV	1	1	1	12	3	4	3	5	2	2	1	1	1	1
DEC	0	0	1	1	1	1	2	1	0	0	0	0	0	0
mean	3	3	6	6	6	5	4	5	3	3	3	2	2	3
std dev	4	3	9	7	6	5	3	2	3	3	2	2	2	6
median	2	2	3	4	3	3	3	5	2	2	3	1	2	1
max	13	9	34	23	19	17	12	8	10	9	7	5	5	21
min	0	0	1	1	1	1	1	1	0	0	0	0	0	0

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1	0	0	1	1	3	0	0	1
FEB	1	7	2	2	4	1	2	1	1
MAR	3	2	3	3	4	14	3	1	2
APR	2	2	3	4	13	10	1	0	1
MAY	7	2	3	3	4	4	1	1	4
JUN	26	1	4	7	20	1	0	1	2
JUL	5	4	8	3	12	5	1	1	7
AUG	2	2	29	6	100	16	1	1	14
SEP	9	2	4	23	26	1	0	0	1
OCT	7	0	1	3	32	2	0	0	0
NOV	2	1	3	1	32	3	0	0	1
DEC	1	3	1	2	2	5	0	0	1
mean	6	2	5	5	20	5	1	1	3
std dev	7	2	8	6	29	5	1	1	4
median	3	2	3	3	12	4	1	1	1
max	26	7	29	23	100	16	3	1	14
min	1	0	0	1	1	1	0	0	0

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	0	1	0	1	0	0	1	1	0
FEB	0	1	1	2	1	3	4	1	1
MAR	0	5	1	3	1	2	13	3	2
APR	0	2	1	1	1	1	12	2	2
MAY	0	5	0	1	1	2	10	2	2
JUN	0	7	1	1	0	1	83	2	1
JUL	0	35	0	0	0	1	5	6	1
AUG	2	13	0	0	1	1	34	0	1
SEP	0	1	1	1	2	1	5	2	5
OCT	0	1	0	1	1	1	5	4	1
NOV	3	3	0	21	2	3	8	29	1
DEC	1	1	0	1	2	6	7	2	2
mean	1	6	0	3	1	2	16	5	2
std dev	1	10	1	6	1	2	23	8	1
median	0	3	0	1	1	1	8	2	1
max	3	35	1	21	2	6	83	29	5
min	0	1	0	0	0	0	1	0	0

Table 2.16 Fecal Coliform (cfu/100 mL) and Enterococcus (MPN) during 2016 at the Lower Cape Fear River Program stations.

		ENTEROCOCCUS																
		BRR																
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	mean	std dev	max	min	Geomean
ANC	181	19,000	4,000	190	73	64	37											
JAN	181	19,000	4,000	190	73	64	37											
FEB	100	127	172	37	19	1,180	1,550											
MAR	10	55	10	546	28	154	118											
APR	109	19	5	64	100	667	570											
MAY	55	28	10	82	64	2,400	273											
JUN	28	19	10	37	109	91	73											
JUL	5	10	10	55	28	5	10											
AUG	163	1,270	364	91	190	82	118											
SEP	5	11,000	9,000	4,000	3,400	28,000	16,000											
OCT	340	181	244	154	109	10	28											
NOV	19	5	5	10	55	16,000	2,100											
DEC	82	127	118	8		64	109											
mean	91	2,653	1,162	440	380	4,060	1,749											
std dev	95	5,768	2,598	1,083	956	8,416	4,345											
max	340	19,000	9,000	4,000	3,400	28,000	16,000											
min	5	5	5	8	19	5	10											
Geomean	45	129	71	87	89	276	214											

		ENTEROCOCCUS																
		B210																
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	mean	std dev	max	min	Geomean
ANC	82	127	28	64	2,300	118	199	82	91									
JAN	82	127	28	64	2,300	118	199	82	91									
FEB	280	1,180	560	190	190	455	1,180	163	199									
MAR	5,300	163	28	37	109	118	127	5,400	1,910									
APR	109	118	28	199	145	260	136	10	82									
MAY	340	145	28	210	118	210	410	37	271									
JUN	340	163	127	270	46	127	570	28	73									
JUL	31,000	637	11,000	109	728	33,000	1,180	1,360	82									
AUG	1,460	637	2,300	819	60,000	2,400	1,910	190	2,700									
SEP	16,000	60,000	31,000	44,000	60,000	37,000	21,000	2,400	60,000									
OCT	37	64	109			100	145	37	19									
NOV	2,000	11,000	1,550			9,000	8,000	16,000	1,090									
DEC	7,000	60,000	728	1,820	4,900	5,800	5,900	118	181									
mean	5,329	11,186	3,957	4,772	12,503	7,299	4,063	910	5,709									
std dev	8,943	22,026	8,673	13,086	22,545	12,657	6,713	1,531	16,402									
max	280	60,000	31,000	44,000	60,000	37,000	21,000	5,400	60,000									
min	37	64	28	37	46	100	127	10	19									
Geomean	955	801	357	360	1,143	958	960	190	374									

		ENTEROCOCCUS																
		B210																
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	mean	std dev	max	min	Geomean
ANC	37	73	5	163	172	22,000	320	440	4,100	5,800	2,000							
JAN	37	73	5	163	172	22,000	320	440	4,100	5,800	2,000							
FEB	28	5	154	1,360	190	172	2,000	73	199	1,180	440							
MAR	199	550	172	2,000	320	440	4,100	5,800	2,000									
APR	100	250	73	118	2,000	73	199	1,180	440									
MAY	127	118	91	208	46	118	220	530	1,360									
JUN	637	154	82	55	46	100	91	1,460	240									
JUL	64	136	118	64	37	82	91	728	380									
AUG	154	91	11,000	270	8,000	230	12,000	728	60,000									
SEP	181	819	1,000	9,000	1,910	7,000	29,000	33,000										
OCT	91	19	46	163	73	109	127	270	380									
NOV	64	163	55	470	127	260	100	637	790									
DEC	9,400	32,000	20,000	58,000	66,000	66,000	54,000	38,000	120,000									
mean	924	2,865	2,734	7,085	6,811	5,799	6,610	6,556	18,256									
std dev	2,560	8,788	6,003	16,463	16,923	18,158	14,730	12,276	35,469									
max	9,400	32,000	20,000	58,000	62,000	66,000	54,000	38,000	120,000									
min	28	5	5	55	28	73	28	145	172									
Geomean	153	177	203	554	348	295	621	1,251	1,653									

Figure 2.6 Geometric Mean Fecal Coliform (NC11-B210) and Enterococcus (BRR-M18) at the Lower Cape Fear River Program mainstem stations, 1995-2015 (Entero 2012-2014) vs. 2016.

