Environmental Assessment of the Lower Cape Fear River System, 2017

By

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Executive Summary

Background – Multi-parameter water quality 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 2017. The opinions expressed are those of UNCW scientists and do not necessarily reflect viewpoints of individual contributors to the Lower Cape Fear River Program.

The mainstem lower Cape Fear River is a 6th order stream characterized by periodically turbid water containing moderate to high levels of inorganic nutrients. It is fed by two large 5th order blackwater rivers (the Black and Northeast Cape Fear Rivers) that have low levels of turbidity, but highly colored water with less inorganic nutrient content than the mainstem. While nutrients are reasonably high in the river channels, major algal blooms are normally 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).

GenX Issues - During the past year there has been considerable controversy in the lower Cape Fear River watershed regarding a family of manufactured chemical compounds collectively known as GenX. To briefly summarize, DuPont constructed a facility known as Fayetteville Works near the river downstream of Fayetteville, where it manufactured fluoropolymers since 1971. DuPont manufactured a chemical called PFOA at Fayetteville Works beginning in 2001, then later stopped its manufacture due to health concerns surrounding this chemical. They then developed a substitute chemical called GenX, which they began manufacturing there, along with GenX's parent compound, called HFPO-DA fluoride. Both compounds hydrolize in water to a third compound called HFPO-DA, CAS; the toxicity of this group of chemicals is unclear. Subsequently, DuPont spun-off a company called Chemours, which assumed plant operations in 2015. In the past few years researchers from US EPA, North Carolina State University, and the University of North Carolina Wilmington have found HFPO-DA and related fluoroethers (which tend to be lumped under the blanket term GenX) in river water, river sediments, well water near the plant, in air samples, and in finished drinking water at the Wilmington water treatment facility, which obtains its water near Lock and Dam #1. Fayetteville Works is currently trucking their wastewater out of state for treatment, and lawsuits have been filed against the company from NCDEQ and Cape Fear River Watch to cease releases. Sampling and analysis of GenX and related compounds is outside of the purview of the scientific staff of the Lower Cape Fear River Program and will not be discussed in this report.

<u>Summary of water quality data results from 2017</u> - Average annual dissolved oxygen (DO) levels at the river channel stations for 2017 were generally comparable to the average for 1995-2016, although somewhat lower for the Northeast Cape Fear River sites. 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 low-to-middle estuary at stations M35 to M18. Lowest mainstem mean 2017 DO levels occurred at the river and upper estuary stations BRR and M61 (6.6 mg/L). Stations NAV, HB, M61 and BRR were below 5.0 mg/L on 33% or more of occasions sampled, and M54 was on 17% of occasions sampled. Based on number of occasions the river stations were below 5 mg/L UNCW rated NAV, HB, M61 and BRR as poor for 2017; the mid to lower estuary stations were rated as fair to good. 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 are classified as blackwater systems because of their tea colored water. The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River (NCF117 2017 mean = 5.7, NCF6 = 6.0, B210 2017 mean = 6.8, all increased from 2016). As a comparison, average DO for 2017 at NC11 on the mainstream Cape Fear River was 7.9 mg/L. Two stream stations were stressed in terms of low dissolved oxygen during the year 2017, NC403 and SR. Considering all sites sampled in 2017, we rated 16% as poor for dissolved oxygen, 16% as fair, and 68% as good.

Annual mean turbidity levels for 2017 were lower than the long-term average in all estuary stations. Highest mean riverine turbidities were at NC11-DP (10-11 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. Turbidity was considerably lower in the blackwater tributaries (Northeast Cape Fear River and Black River) than in the mainstem river. Turbidity levels were low in the freshwater streams, with the exception of one excursion to 47 NTU in April at SR. 100% of the stations were rated as good for turbidity in 2017.

Average chlorophyll *a* concentrations across most sites were low in 2017. The standard of 40 µg/L was exceeded twice at Station GS and once each at stations PB, LRC and SR; there were several smaller algal blooms as well. We note the highest levels in the river and estuary typically occur late spring to late-summer.

For 2017, discharge at Lock and Dam #1 in the May-September growing season was more than double the 2009-2012 average at 3,724 CFS. Nuisance cyanobacterial blooms did not occur in the river and upper estuary in 2017, probably due to the elevated discharge washing out any algal bloom formation. For the 2017 period UNCW rated 97% of the stations as good in terms of chlorophyll *a*.

Fecal bacteria counts in the estuary and at many of the stream stations were very high in 2017. Almost all of the stream stations in the Northeast Cape Fear and Black River basins were rated as poor for fecal coliform bacteria counts. Three lower estuary sites, M35, M23 and M18 were rated as poor for high *Enterococcus* bacteria. For bacterial water quality overall, 64% of the sites rated as poor, 10% as fair, and only 26% as good in 2017.

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 2017.

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 22-year (1995-2017) 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 Environmental 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. The physical, chemical and biological data are state-certified and submitted to the US EPA.

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 various grant-funded 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.

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 estuarine 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 Dam #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://lcfrp.uncw.edu/riverdatabase/

References Cited

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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 Resources, Division of Water Quality/Planning, Raleigh, NC, 27699 Natural -1617.

Table 1.1 Description of sampling locations for the Lower Cape Fear River Program during 2017.

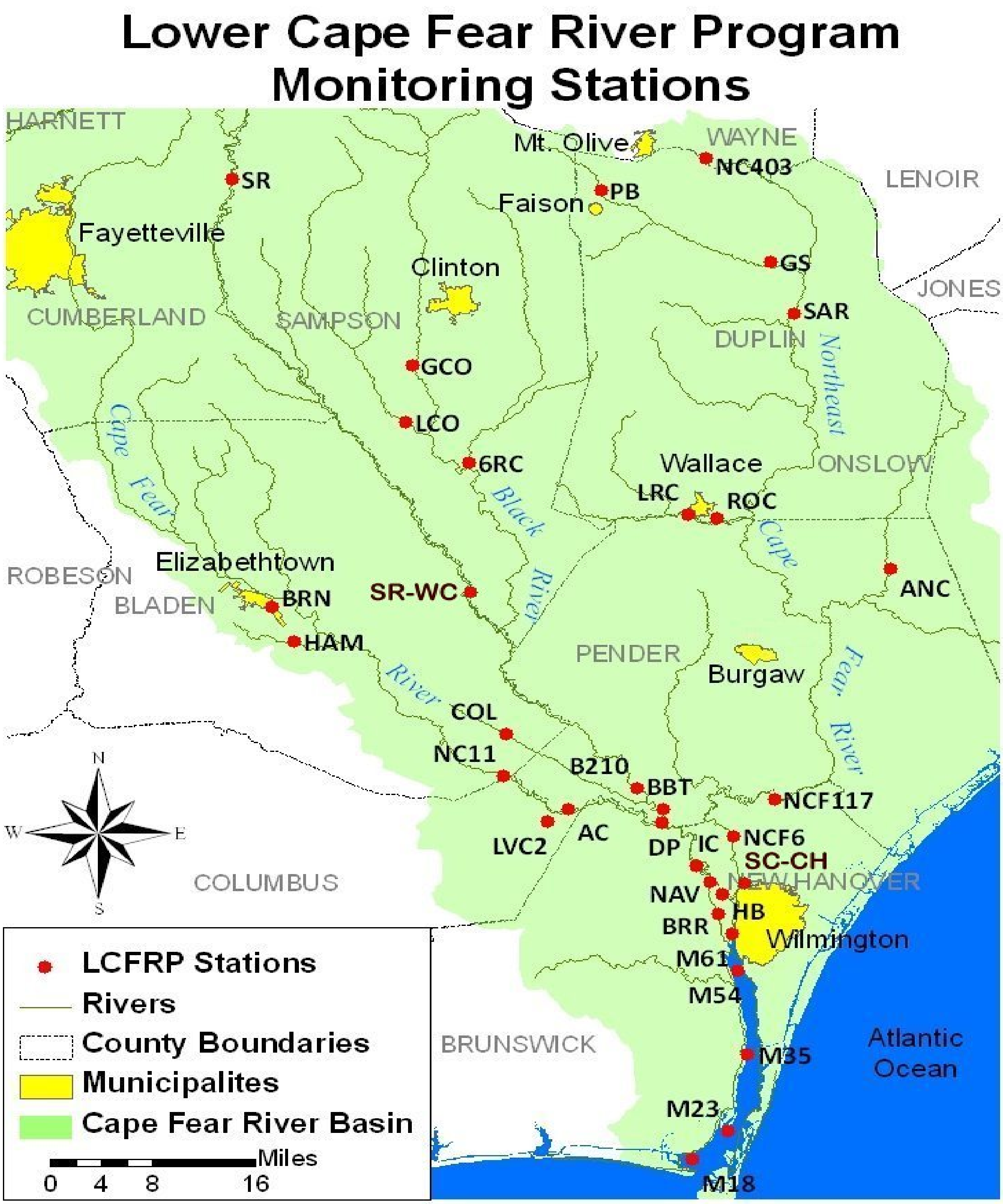
Collected by Boat

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
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+	0303005
IC	B9030000	Cape Fear River ups Indian Creek nr Phoenix	Downstream of several point source discharges	Brunswick	34.3021	-78.0137	C Sw	0303005
NAV	B9050025	Cape Fear River dns of RR bridge at Navassa	Downstream of several point source discharges	Brunswick	34.2594	-77.9877	SC	0303005
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	0303005
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	0303007

Collected by Land

AEL Station	DWR Station #	Description	Comments	County	Lat	Lon	Stream Class.	HUC
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
COL	B8981000	Colly Creek at NC 53 at Colly	Pristine area	Bladen	34.4641	-78.2569	C Sw	03030006
B210	B9000000	Black River at NC 210 at Still Bluff	1st bridge upstream of Cape Fear River	Pender	34.4312	-78.1441	C Sw ORW+	03030006
NC403	B9090000	NE Cape Fear River at NC 403 nr Williams	Downstream of Mt. Olive Pickle, CAFOs in watershed	Duplin	35.1784	-77.9807	C Sw	0303007
PB	B9130000	Panther Branch (Creek) nr Faison	Downstream of Bay Valley Foods	Duplin	35.1345	-78.1363	C Sw	0303007
GS	B9191000	Goshen Swamp at NC 11 and NC 903 nr Kornegay	CAFOs in watershed	Duplin	35.0281	-77.8516	C Sw	0303007
SAR	B9191500	NE Cape Fear River SR 1700 nr Sarecta	Downstream of several point source discharges	Duplin	34.9801	-77.8622	C Sw	0303007
ROC	B9430000	Rockfish Creek at US 117 nr Wallace	Upstream of Wallace discharge	Duplin	34.7168	-77.9795	C Sw	0303007
LRC	B9460000	Little Rockfish Creek at NC 11 nr Wallace	DWR Benthic station	Duplin	34.7224	-77.9814	C Sw	0303007
ANC	B9490000	Angola Creek at NC 53 nr Maple Hill	DWR Benthic station	Pender	34.6562	-77.7351	C Sw	0303007
SR WC	B8920000	South River at SR 1007 (Wildcat/Ennis Bridge Road)	Upstream of Black River	Sampson	34.6402	-78.3116	C Sw ORW+	03030006
NCF117	B9580000	NE Cape Fear River at US 117 at Castle Hayne	DWR ambient station, Downstream of point source discharges	New Hanover	34.3637	-77.8965	B Sw	0303007
SC-CH	B9720000	Smith Creek at US 117 and NC 133 at Wilmington	Urban runoff, Downstream of Wilmington Northside WWTP	New Hanover	34.2586	-77.9391	C Sw	0303007

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 2017 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 Environmental Quality inspect UNCW laboratory procedures and periodically accompany field teams to verify proper procedures are followed. By agreement with N.C. Division of Environmental Quality, changes have periodically occurred in the sampling regime. Station SCCH (lower Smith Creek) was added October 2004; sampling was discontinued at Stations M42 and SPD (June 2011); sampling at Stations BCRR and BC117 was discontinued (December 2012); sampling was added at Station SR-WC on the South River (March 2013); and sampling was discontinued at Station LVC2 (July 2015).

<u>Physical Parameters</u>

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 Environmental 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 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 / 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* bacteria 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 Environmental Quality for the analysis of chlorophyll *a* (chlorophyll at three LCFRP stations are required by NCDEQ 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.

Parameter	***Method***	***NC DEQ Certified***
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

Parameter	***Method***	***NC DEQ Certified***
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

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 2017. Discussion of the data focuses both on the river channel stations and stream stations, which sometimes reflect poorer water quality than the channel 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 impacts from hurricanes in 2017; therefore this report reflects low to medium growing season (May-September) flow conditions for the Cape Fear River and Estuary.

<u>Physical Parameters</u>

Water temperature

Water temperatures at all stations ranged from 4.0 to 29.5^{o}C, and individual station annual averages ranged from 16.8 to 20.7^{o}C (Table 2.1). Highest temperatures occurred during July-September 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 34.4 practical salinity units (psu) and station annual means ranged from 2.5 to 25.7 psu (Table 2.2). Lowest salinities occurred in late spring and early-summer, and highest salinities occurred in late fall and winter. The annual mean salinities for 2017 were mixed compared with the twenty-year average for 1995-2016 (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 0.1 to 12.9 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.10 to 52.24 mS/cm and from 0.05 to 6.00 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

Riverine pH values ranged from 3.8 to 8.1 and station annual means ranged from 4.1 to 7.9 (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). Surface concentrations for all sites in 2017 ranged from 1.8 to 13.2 mg/L and station annual means ranged from 5.1 to 9.3 mg/L (Table 2.5). Average annual DO levels at the river channel and estuarine stations for 2017 showed a comparable pattern to the average for 1995-2016, although 2017 DO values at some stations were somewhat lower, especially in the the Northeast Cape Fear River (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.

Overall, average dissolved oxygen levels were slightly lower in 2017 compared with the log-term average (Fig. 2.2). 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 2017

DO levels occurred at the river and upper estuary stations BRR and M61 (6.6 mg/L). Stations NAV, HB, M61 and BRR were below 5.0 mg/L on 33% or more of occasions sampled, and M54 was on 17% of occasions sampled. Based on number of occasions the river stations were below 5 mg/L UNCW rated NAV, HB, M61 and BRR as poor for 2017; 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 decrease 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 algal 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 2017 were an improvement from 2016.

The Northeast Cape Fear and Black Rivers generally have lower DO levels than the mainstem Cape Fear River (NCF117 2017 mean = 5.7, NCF6 = 6.0, B210 2017 mean = 6.8, all increased from 2016). 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; 2015; 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).

Tributary Station SR was below 4.0 mg/L 33% of the occasions sampled (rated poor), and NC403 17% (rated fair) most others were in the good category (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 32% of the sites impacted in 2017.

Field Turbidity

Field turbidity levels ranged from 0 to 47 Nephelometric turbidity units (NTU) and station annual means ranged from 3 to 21 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Highest mean turbidities were at NAV-HB (12 NTU), NC11-DP (10-11 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 2017 sampling trips. As in the previous year, mean turbidity levels for 2017 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 47 NTU at SR in April.   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 Environmental Quality (then DWQ). NCDEQ 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 76.7 mg/L with station annual means from 2.0 to 18.5 mg/L (Table 2.7). The overall highest river values were at M54 and M18. In the stream stations TSS was generally considerably lower than the river and estuary, except for a peak incident of 76.7 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 2017 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 1.14 to 5.40/m and station annual means ranged from 1.65 at M18 to 4.17 at NCF6 (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 5,190 μg/L and station annual means ranged from 499 to 1,993 μg/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 AC, 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 NC403 with 1,605 μg/L; other elevated TN values were seen at ANC, ROC, 6RC, COL and PB.

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 4,590 μg/L and station annual means ranged from 25 to 1,209 μg/L (Table 2.10). The highest average riverine nitrate levels were at NC11, AC and DP (606-465 μg/L) indicating that much of this nutrient is imported from upstream. Moving downstream, nitrate levels decrease most likely as a result of uptake by primary producers, microbial denitrification in riparian marshes and tidal dilution. Despite this, the rapid flushing of the estuary (Ensign et al. 2004) permits sufficient nitrate to enter the coastal ocean in the plume and contribute to offshore productivity (Mallin et al. 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 = 197 μg/L) and the Black River (B210 = 240 μg/L). Lowest river nitrate occurred during late spring and early summer. In general, average concentrations in 2017 for the mainstem river were lower than those of the average from 1995-2016, but nitrate in the blackwater rivers during 2017 was slightly higher than the long-term average (Fig. 2.4).

Several stream stations showed high levels of nitrate on occasion including NC403, PB, ROC and 6RC. ROC and 6RC 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 µg/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 µg/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 1,260 µg/L and station annual means ranged from 18 to 254 µg/L (Table 2.11). River areas with the highest mean ammonium levels this monitoring period included AC and DP, which are downstream of a pulp mill discharge, and M54 in the upper estuary near the Wilmington Southside Wastewater Treatment Plant. At the stream stations 2017 proved to be highly unusual in that Colly Creek (COL) showed multiple occasions of high ammonium. This station is in a wetland-rich watershed that has a low level of human development. Most previous years have showed generally low levels of ammonium; however, beginning in 2005 a few unusual peaks began to occur, which increased in magnitude and frequency after 2012, particularly in 2016 and 2017 (Fig. 2.5). We do not have a solid explanation for this increase in ammonium. We are aware that White Lake, located in the upper Colly Creek watershed has had increasing problems with eutrophication (NC DEQ 2017), with nearby upper groundwater and surface runoff showing elevated nutrient concentrations (especially ammonium; potentially from failing sewage infrastructure); general nutrient concentrations in the lake have been increasing over time as well (NCDEQ 2017). Thus, possibly ammonium-rich drainage from this area has made its way down to the COL station. Additional areas with periodic elevated ammonium in 2017 included NC403 and LRC (Table 2.11).

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of the total concentration of organic nitrogen plus ammonium. TKN ranged from 50 (detection limit) to 2,900 µg/L and station annual means ranged from 467 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. Stations with highest median concentrations included ANC, SR and COL. As with ammonium, upper groundwater in the White Lake drainage contained high TKN (NC DEQ 2917), some of which may have gone downstream.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from 10 (detection limit) to 970 μg/L and station annual means ranged from 41 to 387 μg/L (Table 2.13). For the mainstem and upper estuary, average TP for 2017 was lower than the 1995-2016 average; however, for the Northeast Cape Fear River at Highway 117 and the Black River at B210, TP in 2017 was higher than the long-term average (Figure 2.6). 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 μg/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 μg/L to be potentially problematic to blackwater streams (Mallin et al. 1998; 2004). Streams periodically exceeding this critical concentration included ROC, GCO and ANC; NC403 and PB also yielded some high values. Stations NC403 and PB are downstream of an industrial wastewater discharge, while ROC, GCO and ANC are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from 5 to 787 μg/L and station annual means ranged from 9 to 246 μg/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 (dissolved, not total metals) 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. Metals were not sampled in 2017.

Biological Parameters

Chlorophyll a

During this monitoring period, in river and estuary locations chlorophyll *a* was low (Table 2.15). The state standard was not exceeded in the river or estuary samples in 2017. 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 87 μg/L and station annual means ranged from 1-14 μg/L, lower than in 2016, potentially because of higher river discharge in 2017 (see below). 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. 2.7). 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 (1995-2017) average monthly flow at Lock and Dam #1 was approximately 3,415 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 2017, discharge in May-September was more than double the 2009-2012 average at 3,724 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, 2016 and 2018, 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 2017 (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 Station GS and on single occasions at PB, LRC 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 24 to 2,558 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded in the mainstem river on a few occasions in 2017 (Table 2.17). During 2017 the stream stations showed very high fecal coliform pollution levels. HAM and BRN exceeded 200 CFU/100 mL 100% of the time sampled; LRC 92%, PB and ROC 75%, ANC, SAR, and NC403 67%, GS, LCO, GCO and SR 58%, B210, 6RC, COL 50% and SRWC 33% of the time sampled. Notably excessive counts exceeding 37,000 CFU/100 mL occurred at NC403, PB, 6RC, GCO and HAM occurred in 2017, with no seasonal pattern evident. NC403 and PB are located below point source discharges and the other sites are primarily influenced by non-point source pollution. Beginning in 2015 but especially in 2017 COL had a number of unusually high fecal coliform counts; this is possibly related to the ammonium pollution increase noted above (Fig. 2.5). Overall, 2017 was a very bad year for fecal coliform counts, with geometric mean counts in the mainstem river and especially the blackwater tributaries well exceeding the geometric mean for the 1995-2016 period (Fig. 2.8).

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 2017 stations M35, M23 and M18 all exceeded the standard on four occasions, and M54 exceeded the standard on three occasions. Geometric mean enterococcus counts for 2017 were higher than those of the 2012-2016 period for the lower Cape Fear Estuary (Fig. 2.8). Overall, elevated fecal coliform and *Enterococcus* counts are problematic in this system, with 74% of the stations rated as Fair or Poor in 2017.

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Table 2.1 Water temperature (^{o}C) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	11.2	11.7	11.8	11.9	12.6	13.3	14.1	14.3
FEB	10.6	10.7	11.2	11.4	11.6	11.6	11.6	11.6
MAR	15.7	15.9	16.1	16.3	16.5	16.4	16.2	16.0
APR	18.7	19.0	18.9	19.2	19.3	19.3	19.2	18.4
MAY	21.6	21.8	22.3	23.3	23.6	22.7	23.3	23.5
JUN	25.1	26.0	25.7	26.4	26.8	26.8	26.9	26.5
JUL	28.6	28.8	28.8	29.1	29.2	29.4	29.4	29.0
AUG	29.4	29.5	29.2	28.8	28.4	27.6	27.1	26.8
SEP	27.1	27.9	27.2	27.3	27.5	27.8	27.8	27.7
OCT	24.3	24.5	24.0	24.2	23.8	23.4	23.4	23.8
NOV	14.7	14.5	14.3	14.9	14.1	14.4	15.1	15.7
DEC	13.9	14.0	13.9	14.2	14.1	14.6	14.8	15.0
mean	**20.1**	**20.4**	**20.3**	**20.6**	**20.6**	**20.6**	**20.7**	**20.7**
std dev	6.8	6.9	6.7	6.7	6.7	6.4	6.3	6.1
median	20.2	20.4	20.6	21.3	21.5	21.0	21.3	21.0
max	29.4	29.5	29.2	29.1	29.2	29.4	29.4	29.0
min	10.6	10.7	11.2	11.4	11.6	11.6	11.6	11.6

	NC11	AC	DP	BBT	IC	NCF6
JAN	5.3	5.6	5.7	5.9	5.9	7.9
FEB	10.0	10.0	11.0	10.5	10.5	12.2
MAR	16.0	16.9	16.1	16.2	16.4	17.1
APR	20.1	20.1	20.0	20.6	20.1	19.6
MAY	20.1	20.1	20.1	19.5	20.0	21.1
JUN	26.1	26.3	26.2	25.9	25.4	26.9
JUL	28.1	28.1	28.2	27.9	28.1	28.2
AUG	29.0	29.3	28.7	28.3	28.8	28.3
SEP	26.8	26.8	26.4	26.2	26.7	25.8
OCT	25.7	25.0	24.5	24.3	24.5	24.1
NOV	18.8	19.7	18.2	18.3	18.7	19.3
DEC	12.3	13.1	12.8	12.8	13.5	14.5
mean	**19.9**	**20.1**	**19.8**	**19.7**	**19.9**	**20.4**
std dev	7.7	7.6	7.4	7.3	7.3	6.6
median	20.1	20.1	20.1	20.1	20.1	20.4
max	29.0	29.3	28.7	28.3	28.8	28.3
min	5.3	5.6	5.7	5.9	5.9	7.9

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	9.4	4.4	6.5	6.4	5.8	6.7	4.5	5.4	7.8
FEB	11.9	11.4	13.7	12.9	10.0	11.9	12.3	12.6	12.6
MAR	10.0	9.4	9.6	9.2	8.6	10.7	9.5	14.0	13.8
APR	20.4	22.2	21.4	21.9	21.6	20.4	20.9	20.5	22.5
MAY	19.1	17.9	20.9	20.5	21.0	19.8	17.4	20.0	21.2
JUN	23.2	24.0	23.4	24.4	23.9	22.4	23.6	26.1	26.7
JUL	26.7	25.4	27.9	27.8	29.1	26.7	26.0	28.4	29.0
AUG	23.8	25.6	26.5	24.9	27.9	24.5	24.1	26.6	26.8
SEP	23.3	22.9	24.0	23.4	25.1	24.5	23.0	23.1	24.4
OCT	24.4	25.2	25.0	25.2	26.0	24.6	24.0	24.8	26.1
NOV	11.3	10.9	9.8	10.9	9.0	13.0	9.7	14.6	14.8
DEC	8.1	6.0	7.6	6.7	7.1	7.6	6.1	9.1	9.2
mean	**17.6**	**17.1**	**18.0**	**17.9**	**17.9**	**17.7**	**16.8**	**18.8**	**19.6**
std dev	6.9	8.1	8.0	8.0	9.0	7.3	7.9	7.5	7.5
median	19.8	20.1	21.2	21.2	21.3	20.1	19.2	20.3	21.9
max	26.7	25.6	27.9	27.8	29.1	26.7	26.0	28.4	29.0
min	8.1	4.4	6.5	6.4	5.8	6.7	4.5	5.4	7.8

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	13.2	14.2	13.0	14.2	14.2	14.5	14.0	14.8	14.4
FEB	13.6	11.5	14.0	12.9	13.2	13.0	11.8	13.9	12.9
MAR	11.4	11.6	11.0	11.7	11.9	13.3	14.3	15.6	15.1
APR	19.6	18.3	18.4	18.5	18.3	19.1	18.6	19.3	18.6
MAY	25.3	23.8	23.8	24.5	24.3	24.8	25.4	23.8	23.0
JUN	25.4	23.9	24.3	24.4	24.7	26.9	25.5	24.6	24.0
JUL	26.5	24.5	26.2	25.8	25.6	26.7	25.9	25.8	25.0
AUG	27.9	25.7	26.3	26.2	25.7	26.1	26.3	25.3	24.7
SEP	23.7	22.9	23.0	23.9	23.6	24.2	24.0	22.6	21.4
OCT	18.3	15.5	17.3	15.5	16.2	16.1	16.3	16.9	16.1
NOV	9.3	8.1	8.2	7.7	8.0	8.4	8.1	10.5	9.6
DEC	6.1	5.0	5.4	5.3	5.2	4.4	4.0	6.0	5.3
mean	**18.4**	**17.1**	**17.6**	**17.6**	**17.6**	**18.1**	**17.9**	**18.3**	**17.5**
std dev	7.5	7.1	7.2	7.4	7.2	7.7	7.6	6.4	6.4
median	19.0	16.9	17.9	17.0	17.3	17.6	17.5	18.1	17.4
max	27.9	25.7	26.3	26.2	25.7	26.9	26.3	25.8	25.0
min	6.1	5.0	5.4	5.3	5.2	4.4	4.0	6.0	5.3

Table 2.2 Salinity (psu) during 2017 at the Lower Cape Fear River Program estuarine stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NCF6	SC-CH
JAN	0.1	2.1	0.3	2.5	6.3	15.9	23.4	30.9	0.1	0.1
FEB	0.1	0.1	1.5	4.8	7.2	11.7	19.8	23.6	0.1	0.5
MAR	0.1	0.1	3.6	6.7	8.5	14.7	22.9	25.9	3.4	6.6
APR	0.1	0.1	0.1	1.4	3.7	8.4	16.2	23.2	0.1	0.2
MAY	0.0	0.0	0.1	0.1	0.1	0.1	3.6	5.9	0.0	0.1
JUN	0.1	0.2	0.1	0.8	1.8	7.1	15.7	21.9	0.2	0.5
JUL	0.1	0.1	0.1	2.6	3.6	7.0	14.1	21.7	0.0	0.6
AUG	0.4	4.2	6.9	12.9	14.4	18.0	24.8	26.3	2.6	3.7
SEP	1.3	0.8	3.4	7.3	8.7	16.1	23.1	29.4	0.1	0.2
OCT	11.9	12.0	14.0	16.6	20.3	27.3	30.6	34.4	4.8	2.8
NOV	7.5	6.4	10.0	11.4	16.3	25.9	31.3	32.8	3.5	12.9
DEC	12.2	15.0	9.3	17.9	21.8	28.2	31.1	32.9	14.7	2.7
mean	**2.8**	**3.4**	**4.1**	**7.1**	**9.4**	**15.0**	**21.4**	**25.7**	**2.5**	**2.6**
std dev	4.8	5.2	4.8	6.2	7.2	8.8	8.1	7.7	4.2	3.8
median	0.1	0.5	2.5	5.8	7.9	15.3	23.0	26.1	0.2	0.6
max	12.2	15.0	14.0	17.9	21.8	28.2	31.3	34.4	14.7	12.9
min	0.0	0.0	0.1	0.1	0.1	0.1	3.6	5.9	0.0	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations 1995-2016 versus 2017.

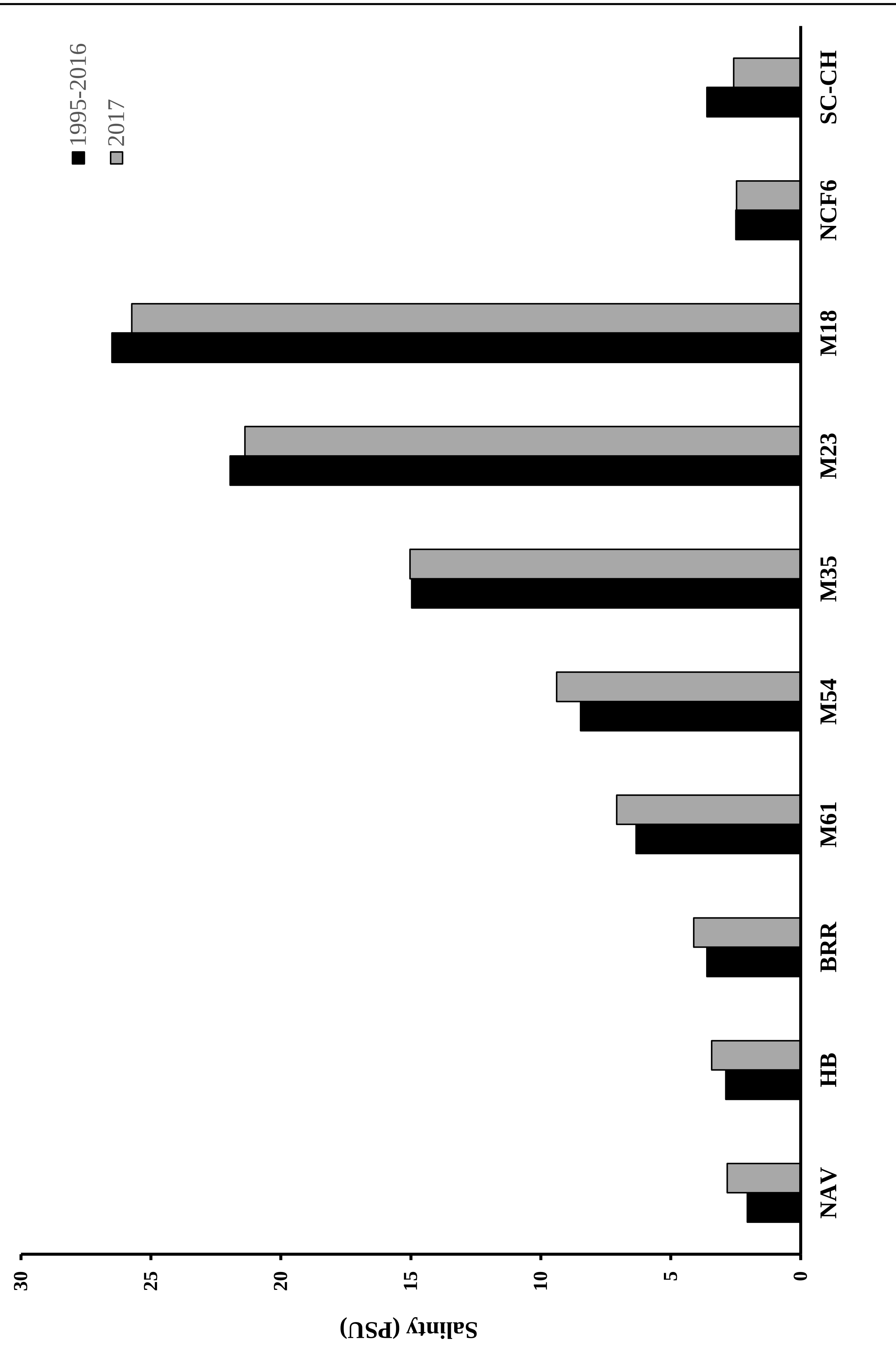

Table 2.3 Specific Conductivity (mS/cm) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	0.15	3.89	0.67	4.70	11.15	25.92	37.08	47.48
FEB	0.16	0.18	2.87	8.62	12.47	19.62	31.81	37.11
MAR	0.15	0.24	6.60	11.70	14.57	24.11	36.11	40.51
APR	0.11	0.13	0.13	2.74	6.77	14.37	26.38	36.60
MAY	0.10	0.10	0.10	0.11	0.11	0.17	6.59	10.57
JUN	0.13	0.46	0.15	1.68	3.45	12.41	25.85	34.98
JUL	0.13	0.14	0.24	4.28	6.59	12.24	23.41	34.90
AUG	0.88	7.68	12.17	21.55	23.83	29.21	39.08	41.22
SEP	2.62	1.63	6.30	12.73	15.04	26.42	36.74	45.47
OCT	20.02	20.48	23.14	27.11	32.47	42.45	47.00	52.24
NOV	12.82	11.19	16.91	19.06	26.53	40.45	47.98	49.98
DEC	20.90	24.51	15.65	28.87	34.49	44.47	47.36	50.07
mean	**4.85**	**5.89**	**7.08**	**11.93**	**15.62**	**24.32**	**33.78**	**40.09**
std dev	8.13	8.56	8.01	10.05	11.31	13.54	11.99	11.18
median	0.16	1.04	4.59	10.16	13.52	25.01	36.42	40.86
max	20.90	24.51	23.14	28.87	34.49	44.47	47.98	52.24
min	0.10	0.10	0.10	0.11	0.11	0.17	6.59	10.57

	NC11	AC	DP	BBT	IC	NCF6
JAN	0.11	0.13	0.12	0.11	0.12	0.11
FEB	0.13	0.14	0.15	0.11	0.15	0.13
MAR	0.11	0.17	0.14	0.14	0.15	6.87
APR	0.12	0.21	0.15	0.11	0.14	0.16
MAY	0.12	0.13	0.13	0.09	0.12	0.10
JUN	0.12	0.12	0.13	0.12	0.12	0.43
JUL	0.11	0.21	0.13	0.10	0.13	0.10
AUG	0.11	0.14	0.20	0.18	0.21	4.85
SEP	0.16	0.14	0.15	0.15	0.15	0.20
OCT	0.15	0.30	0.21	0.20	0.22	8.58
NOV	0.16	0.32	0.22	0.22	0.25	6.31
DEC	0.18	0.30	0.28	0.28	5.06	24.08
mean	**0.13**	**0.19**	**0.17**	**0.15**	**0.57**	**4.32**
std dev	0.02	0.08	0.05	0.06	1.41	7.00
median	0.12	0.16	0.15	0.13	0.15	0.31
max	0.18	0.32	0.28	0.28	5.06	24.08
min	0.11	0.12	0.12	0.09	0.12	0.10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	0.08	0.14	0.14	0.22	0.60	0.12	0.12	0.09	0.16
FEB	0.10	0.18	0.16	0.43	1.62	0.12	0.13	0.13	1.09
MAR	0.07	0.18	0.16	0.77	0.44	0.11	0.15	0.18	11.50
APR	0.12	0.18	0.17	1.06	1.22	0.13	0.12	0.11	0.39
MAY	0.08	0.15	0.13	0.66	0.81	0.11	0.12	0.10	0.12
JUN	0.09	0.17	0.15	0.34	0.78	0.10	0.11	0.11	0.99
JUL	0.11	0.18	0.15	1.71	1.45	0.20	0.15	0.12	1.24
AUG	0.08	0.24	0.18	1.33	6.00	0.10	0.13	0.12	6.73
SEP	0.08	0.18	0.14	0.32	0.92	0.08	0.09	0.10	0.47
OCT	0.08	0.30	0.21	1.31	1.52	0.13	0.20	0.17	5.15
NOV	0.10	0.31	0.23	1.33	2.04	0.14	0.16	0.16	21.60
DEC	0.12	0.22	0.19	0.72	0.68	0.13	0.14	0.15	5.05
mean	**0.09**	**0.20**	**0.17**	**0.85**	**1.51**	**0.12**	**0.13**	**0.13**	**4.54**
std dev	0.02	0.05	0.03	0.49	1.50	0.03	0.03	0.03	6.42
median	0.09	0.18	0.16	0.75	1.07	0.12	0.13	0.12	1.17
max	0.12	0.31	0.23	1.71	6.00	0.20	0.20	0.18	21.60
min	0.07	0.14	0.13	0.22	0.44	0.08	0.09	0.09	0.12

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.09	0.05	0.07	0.13	0.09	0.13	0.08	0.11	0.13
FEB	0.10	0.06	0.07	0.14	0.10	0.15	0.08	0.13	0.16
MAR	0.10	0.05	0.06	0.14	0.09	0.13	0.08	0.12	0.12
APR	0.10	0.05	0.06	0.14	0.09	0.13	0.08	0.12	0.12
MAY	0.10	0.05	0.06	0.13	0.08	0.10	0.06	0.13	0.17
JUN	0.08	0.05	0.07	0.11	0.09	0.18	0.09	0.13	0.18
JUL	0.08	0.05	0.07	0.13	0.08	0.18	0.08	0.13	0.09
AUG	0.11	0.05	0.08	0.15	0.10	0.34	0.10	0.13	0.22
SEP	0.09	0.06	0.08	0.15	0.10	0.15	0.11	0.12	0.17
OCT	0.12	0.06	0.08	0.16	0.11	0.18	0.12	0.15	0.23
NOV	0.14	0.05	0.09	0.17	0.11	0.21	0.11	0.16	0.23
DEC	0.13	0.06	0.09	0.17	0.10	0.13	0.11	0.14	0.17
mean	**0.10**	**0.05**	**0.07**	**0.14**	**0.09**	**0.17**	**0.09**	**0.13**	**0.17**
std dev	0.02	0.00	0.01	0.02	0.01	0.06	0.02	0.01	0.04
median	0.10	0.05	0.07	0.14	0.10	0.15	0.08	0.13	0.17
max	0.14	0.06	0.09	0.17	0.11	0.34	0.12	0.16	0.23
min	0.08	0.05	0.06	0.11	0.08	0.10	0.06	0.11	0.09

Table 2.4 pH (su) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	8.2	7.9	8.5	7.8	7.9	8.0	8.0	7.8
FEB	7.2	7.1	7.3	7.4	7.5	7.8	8.0	8.0
MAR	7.1	7.0	7.4	7.3	7.5	7.8	8.0	8.1
APR	6.7	6.7	7.0	6.9	7.2	7.7	8.0	8.0
MAY	6.4	6.4	6.6	6.3	6.6	6.9	7.1	7.3
JUN	6.7	6.7	6.8	6.9	7.0	7.4	7.8	8.0
JUL	6.7	6.7	6.7	6.9	7.2	7.4	7.8	7.9
AUG	7.2	7.2	7.1	7.3	7.5	7.7	7.9	8.0
SEP	6.7	7.0	7.0	7.1	7.4	7.6	7.9	7.9
OCT	7.0	7.0	7.1	7.3	7.6	7.9	7.9	8.0
NOV	7.3	7.3	7.4	7.5	7.7	7.9	8.0	8.0
DEC	7.3	7.4	7.5	7.6	7.8	8.0	8.0	8.0
mean	**7.0**	**7.0**	**7.2**	**7.2**	**7.4**	**7.7**	**7.9**	**7.9**
std dev	0.5	0.4	0.5	0.4	0.4	0.3	0.3	0.2
median	7.1	7.0	7.1	7.3	7.5	7.8	8.0	8.0
max	8.2	7.9	8.5	7.8	7.9	8.0	8.0	8.1
min	6.4	6.4	6.6	6.3	6.6	6.9	7.1	7.3

	NC11	AC	DP	BBT	IC	NCF6
JAN	6.5	6.7	6.7	6.6	6.5	6.4
FEB	6.1	6.7	6.9	6.6	6.8	6.7
MAR	6.8	7.0	6.8	6.8	6.8	7
APR	6.8	7.1	7	6.5	6.7	6.7
MAY	6.5	6.7	6.8	6.4	6.7	6.2
JUN	6.7	6.8	6.7	6.5	6.6	6.6
JUL	6.6	6.8	6.6	6.3	6.5	6.3
AUG	6.5	6.7	6.7	6.6	6.6	6.6
SEP	6.7	6.8	6.6	6.6	6.6	6.3
OCT	6.8	7.1	6.8	6.7	6.7	6.7
NOV	6.8	7.1	6.8	6.8	6.8	6.8
DEC	6.4	6.9	6.7	6.7	6.9	7.2
mean	**6.6**	**6.9**	**6.8**	**6.6**	**6.7**	**6.6**
std dev	0.2	0.2	0.1	0.2	0.1	0.3
median	6.7	6.8	6.8	6.6	6.7	6.7
max	6.8	7.1	7.0	6.8	6.9	7.2
min	6.1	6.7	6.6	6.3	6.5	6.2

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	5.2	6.5	6.5	6.5	6.3	6.3	5.7	5.8	5.3
FEB	6.1	6.9	7.3	7.1	6.9	7.6	7.0	6.6	6.7
MAR	5.9	6.9	7.1	6.9	7.0	7.2	7.1	7.0	7.0
APR	6.5	7	7.1	6.9	6.8	7.2	7.0	6.5	7.1
MAY	5.5	6.6	6.8	6.8	6.9	7.0	6.5	6.0	6.2
JUN	6.2	6.9	6.8	6.7	7.1	7.2	7.0	6.4	6.7
JUL	6.2	6.5	6.7	6.9	7.3	7.7	6.8	6.5	6.7
AUG	5.2	7.1	7.0	7.0	7.2	7.1	6.9	6.6	6.6
SEP	5.1	6.2	6.3	6.2	6.6	6.4	6.1	6.1	6.5
OCT	5.8	7.3	6.8	6.6	6.7	7.5	7.2	6.6	7.0
NOV	6	6.95	6.7	6.7	6.8	7.4	6.9	6.9	7.4
DEC	5.6	6.1	6.6	6.7	6.6	6.8	6.3	6.4	6.8
mean	**5.8**	**6.7**	**6.8**	**6.8**	**6.9**	**7.1**	**6.7**	**6.5**	**6.7**
std dev	0.5	0.4	0.3	0.2	0.3	0.4	0.5	0.3	0.5
median	5.9	6.9	6.8	6.8	6.9	7.2	6.9	6.5	6.7
max	6.5	7.3	7.3	7.1	7.3	7.7	7.2	7.0	7.4
min	5.1	6.1	6.3	6.2	6.3	6.3	5.7	5.8	5.3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	4.6	3.8	5.1	5.7	6.0	6.1	6.2	6.4	6.4
FEB	6.7	4.3	6.2	7.0	6.9	6.9	6.4	6.9	7.2
MAR	6.4	4.2	6.0	6.7	6.7	6.8	6.5	6.8	7.0
APR	5.9	4.0	5.7	6.0	5.9	6.3	6.0	6.3	6.4
MAY	6.3	4.1	6.0	6.7	6.1	6.4	6.2	6.8	7.0
JUN	6.3	4.1	6.0	6.5	6.5	6.9	6.4	6.8	6.8
JUL	6.2	4.1	6.1	6.8	6.4	6.7	6.2	6.8	6.4
AUG	6.6	4.3	6.2	6.8	6.8	6.8	6.6	7.0	7.3
SEP	6.2	4.3	6.4	7.2	6.9	6.9	6.3	7.0	7.1
OCT	6.6	4.6	6.5	7.0	7.1	6.9	6.4	7.1	7.4
NOV	6.2	3.8	5.9	6.7	6.7	6.6	5.8	6.9	7.2
DEC	5.7	3.8	5.6	6.3	6.0	6.2	6.0	6.6	6.7
mean	**6.1**	**4.1**	**6.0**	**6.6**	**6.5**	**6.6**	**6.3**	**6.8**	**6.9**
std dev	0.6	0.2	0.4	0.4	0.4	0.3	0.2	0.2	0.4
median	6.3	4.1	6.0	6.7	6.6	6.8	6.3	6.8	7.0
max	6.7	4.6	6.5	7.2	7.1	6.9	6.6	7.1	7.4
min	4.6	3.8	5.1	5.7	5.9	6.1	5.8	6.3	6.4

Table 2.5 Dissolved Oxygen (mg/l) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	9.3	8.9	9.2	9.0	9.1	8.7	8.6	8.3
FEB	10.2	10.3	9.9	9.6	9.7	9.8	9.8	9.6
MAR	**8.1**	8.1	8.2	7.9	8.1	8.4	8.7	8.5
APR	6.8	7.2	6.9	6.9	7.3	8.4	8.9	8.5
MAY	4.8	4.9	4.8	4.4	4.7	5.1	6.3	6.7
JUN	5.5	5.0	5.3	5.2	5.3	6.1	6.6	6.6
JUL	4.8	4.8	4.8	4.7	5.4	6.1	6.4	6.1
AUG	4.9	4.6	4.6	4.5	5.2	6.3	6.6	6.6
SEP	4.2	4.7	4.3	4.3	4.9	5.4	6.3	6.0
OCT	5.0	5.3	5.2	5.6	6.2	6.8	6.8	6.8
NOV	8.1	8.2	8.3	8.4	8.7	8.7	8.5	8.3
DEC	8.2	8.2	8.0	8.3	8.3	8.2	8.4	8.0
mean	**6.7**	**6.7**	**6.6**	**6.6**	**6.9**	**7.3**	**7.7**	**7.5**
std dev	2.0	2.0	2.0	2.0	1.8	1.5	1.3	1.2
median	6.2	6.3	6.1	6.3	6.8	7.5	7.6	7.4
max	10.2	10.3	9.9	9.6	9.7	9.8	9.8	9.6
min	4.2	4.6	4.3	4.3	4.7	5.1	6.3	6.0

	NC11	AC	DP	BBT	IC	NCF6
JAN	11.8	11.7	11.6	11.3	11.1	8.8
FEB	10.5	10.3	10.3	9.3	9.9	8.5
MAR	9.2	9.0	8.1	8.0	8.0	8.0
APR	7.9	7.9	7.9	5.8	6.8	6.8
MAY	6.8	6.6	6.6	4.8	6.0	4.1
JUN	7.1	6.8	6.1	5.5	5.7	5.0
JUL	6.3	5.9	5.6	3.9	4.9	3.7
AUG	5.5	6.4	4.2	4.2	4.1	4.2
SEP	6.5	6.5	5.2	5.1	5.2	4.3
OCT	6.0	7.3	4.6	4.5	4.3	4.5
NOV	7.7	8.9	6.7	6.7	6.2	6.1
DEC	9.6	9.0	8.0	8.0	7.8	7.9
mean	**7.9**	**8.0**	**7.1**	**6.4**	**6.7**	**6.0**
std dev	2.0	1.8	2.2	2.3	2.2	1.9
median	7.4	7.6	6.7	5.7	6.1	5.6
max	11.8	11.7	11.6	11.3	11.1	8.8
min	5.5	5.9	4.2	3.9	4.1	3.7

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	9.0	12.1	13.2	11.1	11.4	11.6	11.6	9.5	8.8
FEB	8.6	9.0	11.4	10.1	8.5	11.8	9.3	8.3	8.8
MAR	9.1	9.5	10.6	9.8	10.2	10.7	10.0	7.9	8.3
APR	5.7	6.0	4.7	5.9	4.8	7.5	6.6	5.4	6.0
MAY	6.3	7.3	7.2	7.4	8.0	8.5	7.5	3.6	4.6
JUN	4.7	5.9	4.1	5.0	6.5	7.4	6.1	3.4	4.6
JUL	4.4	5.7	6.1	5.0	9.4	9.4	4.9	4.0	4.4
AUG	5.1	7.3	6.6	4.4	9.7	7.4	4.9	4.3	4.5
SEP	4.7	5.6	4.7	3.7	5.8	7.2	4.5	4.2	4.8
OCT	3.0	6.4	2.3	2.7	3.9	7.6	5.5	3.1	4.3
NOV	6.2	9.8	7.4	6.6	7.2	10.4	9.2	6.4	7.5
DEC	9.1	10.7	10.7	9.0	10.1	12.3	10.8	8.1	9.1
mean	**6.3**	**7.9**	**7.4**	**6.7**	**8.0**	**9.3**	**7.6**	**5.7**	**6.3**
std dev	2.1	2.2	3.4	2.7	2.3	2.0	2.5	2.3	2.0
median	6.0	7.3	6.9	6.3	8.3	9.0	7.1	4.9	5.4
max	9.1	12.1	13.2	11.1	11.4	12.3	11.6	9.5	9.1
min	3.0	5.6	2.3	2.7	3.9	7.2	4.5	3.1	4.3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	8.2	6.3	8.7	8.6	8.2	7.5	6.9	8.6	8.5
FEB	7.7	8.6	8.4	9.3	9.3	8.8	6.5	9.6	10.8
MAR	9.4	8.6	9.7	9.9	9.8	8.7	7.4	9.2	10.6
APR	4.9	5.7	7.0	5.6	6.1	6.4	5.7	7.3	7.6
MAY	4.8	4.9	6.6	6.3	5.4	5.7	4.8	7.3	5.9
JUN	5.0	5.0	5.9	6.1	6.3	6.1	2.1	6.9	6.0
JUL	4.7	5.3	6.0	6.3	6.5	5.6	3.5	7.0	6.5
AUG	5.0	4.3	5.3	5.5	6.3	4.0	1.8	6.8	5.6
SEP	4.6	5.2	6.3	6.9	7.2	6.5	2.6	7.3	6.1
OCT	6.3	6.6	7.6	8.4	8.6	7.8	4.3	8.4	7.6
NOV	9.7	8.4	10.3	11.4	11.1	11.0	5.6	10.2	9.3
DEC	10.8	10.3	11.5	10.8	10.6	10.9	10.4	11.7	11.0
mean	**6.8**	**6.6**	**7.8**	**7.9**	**8.0**	**7.4**	**5.1**	**8.4**	**8.0**
std dev	2.3	1.9	2.0	2.1	1.9	2.1	2.5	1.6	2.0
median	5.7	6.0	7.3	7.7	7.7	7.0	5.2	7.9	7.6
max	10.8	10.3	11.5	11.4	11.1	11.0	10.4	11.7	11.0
min	4.6	4.3	5.3	5.5	5.4	4.0	1.8	6.8	5.6

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations 1995-2016 versus 2017.

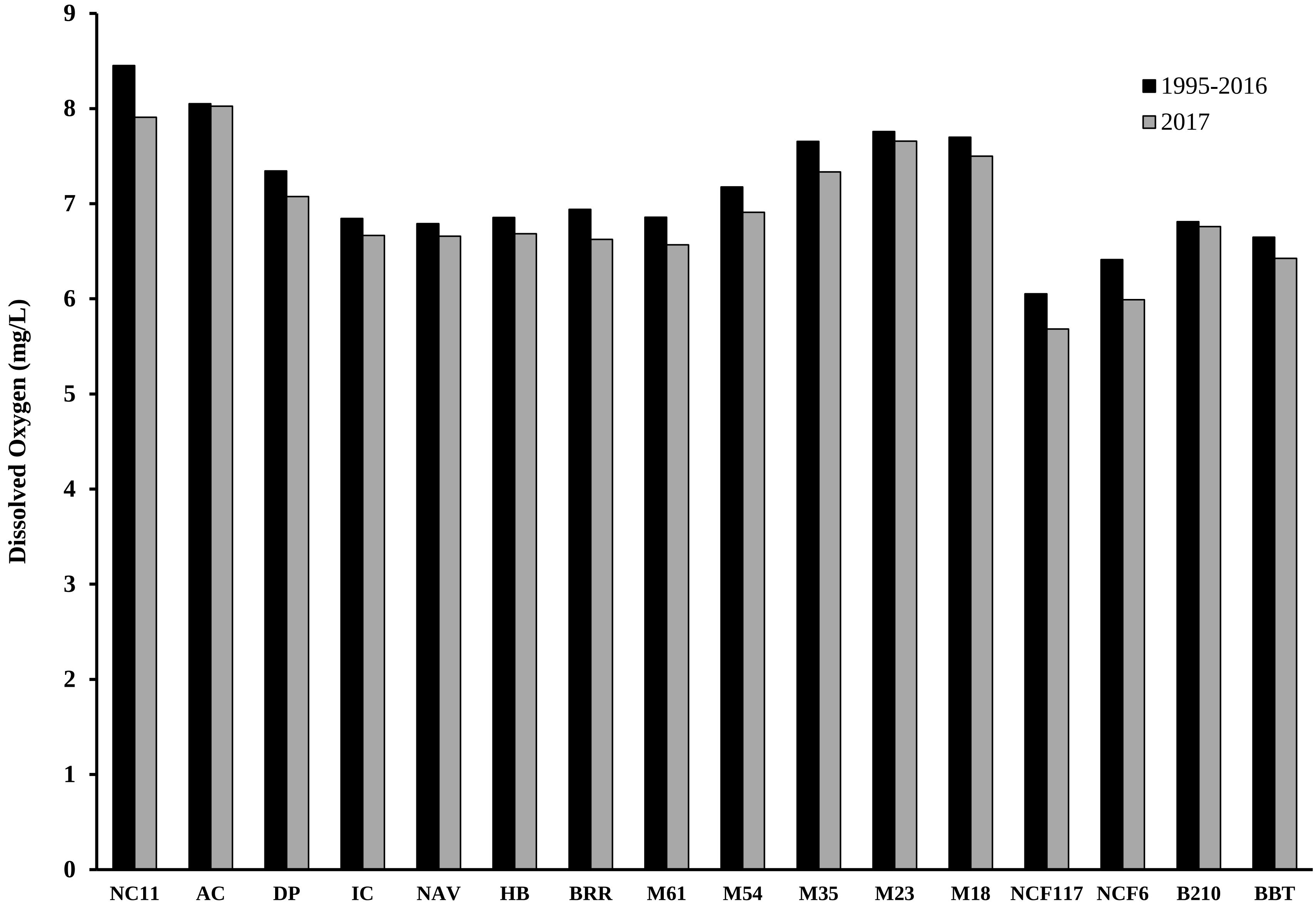

Table 2.6 Field Turbidity (NTU) during 2017 at the Lower Cape Fear River Program stations.

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

	NC11	AC	DP	BBT	IC	NCF6
JAN	16	15	16	11	11	8
FEB	15	20	15	6	12	7
MAR	10	11	10	9	10	9
APR	9	10	9	7	9	9
MAY	20	22	23	6	15	5
JUN	7	6	7	6	7	3
JUL	8	10	12	9	9	13
AUG	9	8	7	7	10	9
SEP	9	7	6	6	5	4
OCT	7	7	8	6	7	15
NOV	6	5	9	8	14	10
DEC	5	6	9	8	20	7
mean	**10**	**11**	**11**	**7**	**11**	**8**
std dev	5	6	5	2	4	3
median	9	9	9	7	10	9
max	20	22	23	11	20	15
min	5	5	6	6	5	3

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	6	1	1	2	7	21	4	5	11
FEB	7	2	0	2	6	4	3	3	24
MAR	7	4	1	8	9	13	11	4	9
APR	10	10	2	5	12	7	6	5	5
MAY	12	5	3	2	8	5	7	3	5
JUN	11	6	2	5	5	23	11	3	4
JUL	8	14	1	9	6	3	6	4	15
AUG	8	2	6	12	4	5	6	3	11
SEP	7	1	1	3	4	7	7	2	8
OCT	5	2	10	5	11	2	5	2	3
NOV	7	2	2	2	7	4	3	6	14
DEC	9	3	2	3	10	13	8	4	9
mean	**8**	**4**	**3**	**5**	**7**	**9**	**6**	**4**	**10**
std dev	2	4	3	3	3	7	3	1	6
median	8	3	2	4	7	6	6	4	9
max	12	14	10	12	12	23	11	6	24
min	5	1	0	2	4	2	3	2	3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	2	4	1	7	7	4	10	15	37
FEB	4	9	2	3	3	1	11	6	3
MAR	4	7	3	3	4	2	8	9	6
APR	8	10	6	14	8	5	47	22	16
MAY	5	10	3	4	2	3	8	7	5
JUN	6	12	2	12	7	2	8	7	6
JUL	4	7	3	4	13	3	7	7	18
AUG	3	3	2	3	3	6	10	5	5
SEP	2	2	2	4	2	3	6	9	4
OCT	2	3	2	3	2	3	3	2	3
NOV	3	2	2	2	2	1	2	2	4
DEC	6	6	4	6	4	2	4	6	13
mean	**4**	**6**	**3**	**5**	**5**	**3**	**10**	**8**	**10**
std dev	2	3	1	4	3	1	12	6	10
median	4	7	2	4	3	3	8	7	6
max	8	12	6	14	13	6	47	22	37
min	2	2	1	2	2	1	2	2	3

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2016 versus 2017.

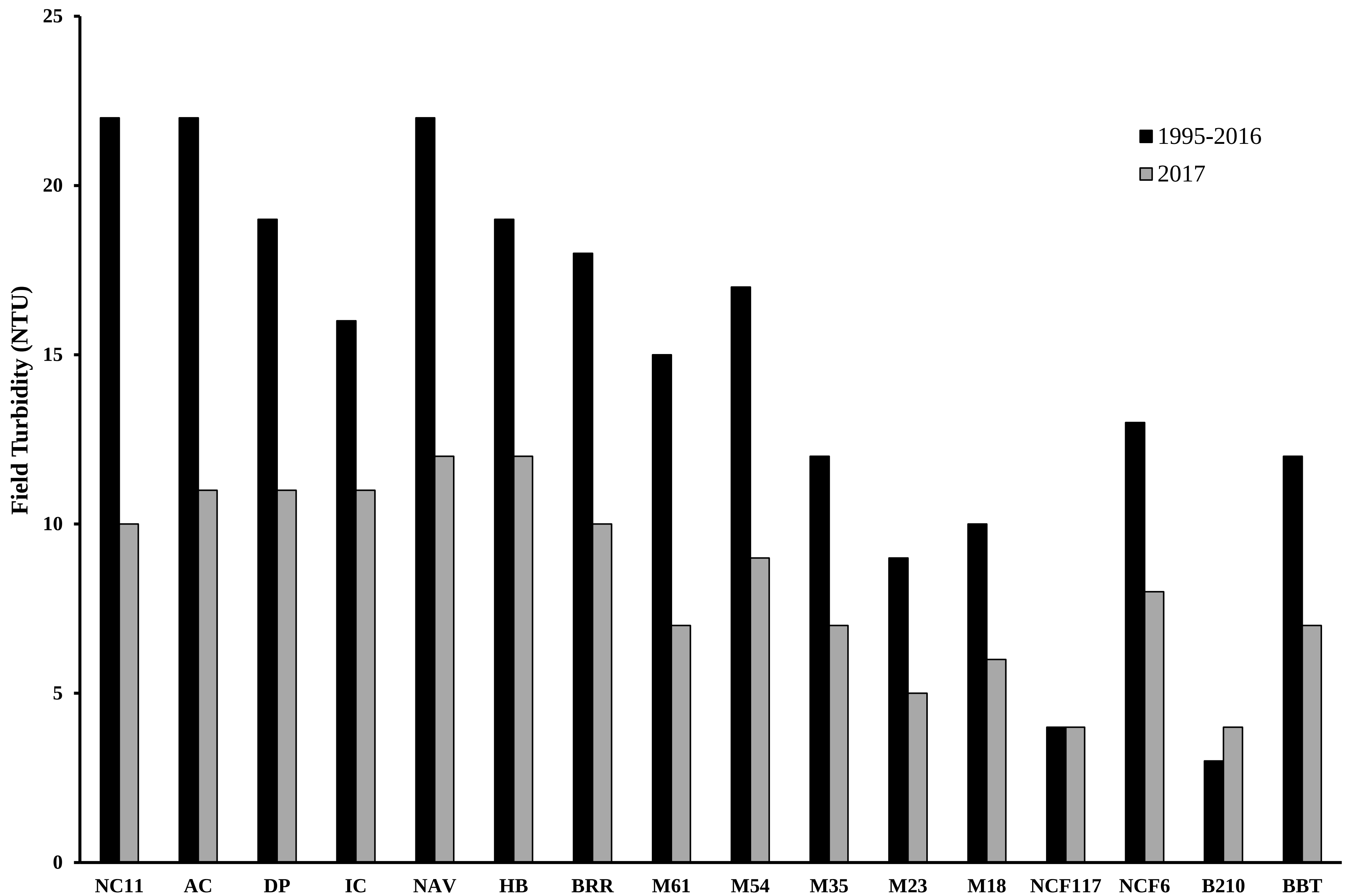

Table 2.7 Total Suspended Solids (mg/L) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	7.5	10.2	9.6	9.2	9.9	12.3	17.2	31.0
FEB	8.9	9.0	10.3	11.8	13.8	12.0	17.5	11.9
MAR	15.2	19.2	13.1	14.2	16.0	16.3	15.7	21.1
APR	17.8	18.4	17.9	11.0	19.0	12.8	12.4	13.2
MAY	19.7	10.8	9.0	9.4	11.6	13.1	12.1	12.5
JUN	7.7	6.2	8.1	7.1	9.4	9.7	11.2	11.8
JUL	13.1	8.3	4.9	6.4	9.3	10.1	9.9	12.9
AUG	8.1	8.7	8.0	11.4	12.8	14.3	1.5	14.1
SEP	18.8	11.5	11.2	7.1	11.1	22.3	12.8	16.3
OCT	18.8	27.8	22.3	13.1	36.0	23.0	21.0	26.0
NOV	19.0	17.1	16.8	11.4	18.8	15.2	20.0	28.6
DEC	23.0	27.5	27.1	23.9	37.0	19.1	20.4	22.9
mean	**14.8**	**14.6**	**13.2**	**11.3**	**17.1**	**15.0**	**14.3**	**18.5**
std dev	5.5	7.4	6.6	4.7	9.7	4.4	5.5	7.1
median	16.5	11.2	10.8	11.2	13.3	13.7	14.3	15.2
max	23.0	27.8	27.1	23.9	37.0	23.0	21.0	31.0
min	7.5	6.2	4.9	6.4	9.3	9.7	1.5	11.8

	NC11	AC	DP	IC	NCF6
JAN	13.0	11.7	12.7	8.3	7.5
FEB	13.0	17.7	11.9	7.6	9.1
MAR	12.2	15.4	8.7	11.6	12.5
APR	13.3	10.0	14.2	11.5	14.1
MAY	24.1	25.3	24	15.4	7.3
JUN	9.1	4.6	5.2	3.6	3.3
JUL	6.2	7.7	12.1	7.7	18
AUG	7.1	5.6	6.8	8.3	14.9
SEP	7.9	5.8	4.9	4.3	8.2
OCT	4.2	4.1	7.1	5.2	12.8
NOV	5.1	4.2	7.3	15.8	10.5
DEC	1.4	3.1	6.7	11.2	18
mean	**9.7**	**9.6**	**10.1**	**9.2**	**9.2**
std dev	6.0	6.8	5.4	4.0	4.0
median	8.5	6.8	8.0	9.0	8.3
max	24.1	25.3	24.0	4.2	15.8
min	1.4	3.1	4.9	8.2	3.6

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN		1.3		1.3	1.5	25.9	3.3	3.9	10.1
FEB		2.8		3.2	4.5	8.3	4.4	4.4	34.8
MAR		4.4		12.0	6.6	7.5	10.6	4.6	19.5
APR		10.7		5.7	11.8	1.4	4.9	4.8	8.0
MAY		4.5		1.3	10.7	1.4	6.6	2.9	7.7
JUN		6.2		1.4	11.9	11.9	11.2	4.0	6.5
JUL		15.2		12.7	8.7	1.3	3.6	7.6	17.0
AUG		1.3		10.7	8.6	11.2	3.7	4.9	21.4
SEP		1.6		4.0	3.8	8.2	5.0	1.3	12.2
OCT		1.3		5.4	76.7	1.3	2.8	3.4	6.2
NOV		1.4		1.3	2.5	1.4	1.3	2.5	26.0
DEC		1.4		1.3	5.9	6.1	5.0	2.6	10.0
mean		**4.3**		**5.0**	**12.8**	**7.2**	**5.2**	**3.9**	**15.0**
std dev		4.4		4.4	20.4	7.1	3.0	1.6	9.0
median		2.2		3.6	7.6	6.8	4.7	4.0	11.2
max		15.2		12.7	76.7	25.9	11.2	7.6	34.8
min		1.3		1.3	1.5	1.3	1.3	1.3	6.2

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1.4					3.9			
FEB	3.6					1.4			
MAR	1.4					1.3			
APR	7.3					3.9			
MAY	3.6					2.9			
JUN	5.1					1.4			
JUL	1.3					1.3			
AUG	1.3					3.4			
SEP	1.4					4.6			
OCT	1.5					2.8			
NOV	1.3					1.3			
DEC	3.1					1.4			
mean	**3**					**2**			
std dev	2					1			
median	1					2			
max	7					5			
min	1					1			

Table 2.8 Light Attenuation (k) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	3.06	3.76	3.50	3.56	3.12	2.43	2.06	2.10
FEB								
MAR	3.58	3.91	2.69	3.04	2.68	2.17	1.52	1.38
APR	3.62	3.47	3.61	3.03	3.21	2.23	1.73	1.40
MAY	3.67	3.72	3.26	3.99	4.22	3.97	3.19	2.64
JUN	3.58	3.49	3.03	3.14	2.71	2.11	1.68	1.48
JUL	2.23	3.65	2.35	2.45	3.10	2.54	1.68	1.37
AUG	3.01	2.56	2.37	2.28	2.07	2.02	1.35	1.24
SEP	4.94		3.60	2.70	3.06			
OCT								1.77
NOV								
DEC	3.44	3.78	2.57	2.69	2.90	1.69	1.14	1.43
mean	**3.46**	**3.54**	**3.00**	**2.99**	**3.01**	**2.40**	**1.79**	**1.65**
std dev	0.72	0.42	0.52	0.54	0.57	0.69	0.63	0.45
max	4.94	3.91	3.61	3.99	4.22	3.97	3.19	2.64
min	2.23	2.56	2.35	2.28	2.07	1.69	1.14	1.24

	NC11	AC	DP	BBT	IC	NCF6
JAN	3.06	3.11	3.13	3.15	3.34	3.94
FEB						
MAR	2.80	2.67	3.42	3.52	3.31	3.33
APR	2.55	3.09	2.91	3.61	3.11	3.83
MAY	3.35	3.43	3.44	3.75	2.74	5.40
JUN	1.82	1.95	2.47	2.84	2.43	3.66
JUL	2.03	2.65	2.35	3.24	1.77	5.19
AUG	2.23	2.44	2.84	2.84	2.68	4.39
SEP	2.23	2.12	2.82	3.23	2.64	4.61
OCT	2.41	3.18	3.75	3.44	3.82	4.98
NOV						
DEC	1.96	2.73	3.02	3.19	3.77	2.32
mean	**2.44**	**2.74**	**3.02**	**3.28**	**2.96**	**4.17**
std dev	0.50	0.48	0.44	0.30	0.63	0.94
max	3.35	3.43	3.75	3.75	3.82	5.40
min	1.82	1.95	2.35	2.84	1.77	2.32

Table 2.9 Total Nitrogen (µg/l) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	870	700	490	730	930	400	390	400
FEB	860	820	1,550	970	900	920	430	460
MAR	1,260	1,360	1,260	1,280	1,130	1,000	1,100	720
APR	1,660	1,700	1,780	1,380	1,630	1,420	1,480	580
MAY	700	700	600	800	1,100	800	700	600
JUN	1,340	800	740	1,020	740	1,000	700	900
JUL	50	500	500	500	500	440	300	300
AUG	400	500	400	400	500	300	300	300
SEP	770	600	600	500	630	400	600	400
OCT	830	910	1,100	1,380	850	760	430	500
NOV	1,210	1,330	1,190	920	860	540	740	530
DEC	1,770	820	890	1,020	840	360	200	300
mean	**977**	**895**	**925**	**908**	**884**	**695**	**614**	**499**
std dev	497	375	450	337	309	345	370	183
median	865	810	815	945	855	650	515	480
max	1,770	1,700	1,780	1,380	1,630	1,420	1,480	900
min	50	500	400	400	500	300	200	300

	NC11	AC	DP	IC	NCF6
JAN	1,600	1,590	1,510	1,430	1,480
FEB	1,540	1,410	1,440	1,410	1,220
MAR	1,340	1,410	1,390	1,410	1,190
APR	1,210	1,680	1,300	1,080	890
MAY	900	800	900	800	1,000
JUN	50	220	50	50	50
JUL	500	500	500	500	700
AUG	600	800	900	800	900
SEP	1,750	1,310	960	1,240	1,130
OCT	1,580	1,170	1,570	1,060	870
NOV	980	1,210	870	770	700
DEC	2,600	2,360	1,730	1,310	630
mean	**1,221**	**1,205**	**1,093**	**988**	**897**
std dev	675	572	490	423	365
median	1,275	1,260	1,130	1,070	895
max	2,600	2,360	1,730	1,430	1,480
min	50	220	50	50	50

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1,550	2,370	1,620	5,190	5,000	3,280	2,300	1,380	1,580
FEB	1,310	1,520	560	3,170	1,020	1,060	1,420	1,130	1,350
MAR	1,330	1,470	500	2,390	970	1,460	2,130	1,160	1,220
APR	1,440	2,050	970	2,170	1,260	880	1,050	960	730
MAY	1,500	800	700	800	1,200	900	900	1,000	1,200
JUN	1,160	700	600	1,100	600	620	2,500	930	140
JUL	1,100	660	300	700	500	200	400	500	400
AUG	1,400	1,100	1,300	1,500	900	1,800	600	600	600
SEP	1,660	1,030	800	1,710	1,030	1,310	1,410	1,160	790
OCT	1,540	890	1,000	1,050	1,100	870	2,450	900	600
NOV	1,340	820	700	880	700	400	680	840	860
DEC	3,190	1,240	500	3,250	1,950	1,360	1,830	670	700
mean	**1,543**	**1,221**	**796**	**1,993**	**1,353**	**1,178**	**1,473**	**936**	**848**
std dev	543	543	374	1,339	1,208	802	757	257	417
median	1,420	1,065	700	1,605	1,025	980	1,415	945	760
max	3,190	2,370	1,620	5,190	5,000	3,280	2,500	1,380	1,580
min	1,100	660	300	700	500	200	400	500	140

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	990	900	680	2,130	1,800	1,360	900	1,320	1,950
FEB	1,110	1,600	1,120	2,040	1,620	1,120	1,410	1,630	820
MAR	1,170	1,040	580	1,540	1,280	800	910	1,840	760
APR	1,030	1,070	1,050	2,540	850	1,030	2,180	2,300	1,700
MAY	900	1,700	900	1,100	1,000	900	400	600	600
JUN	700	1,800	700	700	700	800	1,100	300	400
JUL	900	1,800	1,200	600	800	930	1,200	620	1,150
AUG	700	1,400	600	500	600	800	1,200	400	300
SEP	1,040	1,240	970	1,140	790	1,290	2,900	1,140	910
OCT	950	1,550	1,100	1,400	1,010	1,420	1,080	1,330	440
NOV	550	700	700	1,160	580	1,060	600	1,010	200
DEC	1,230	1,020	1,070	1,720	1,750	780	740	700	1,690
mean	**939**	**1,318**	**889**	**1,381**	**1,065**	**1,024**	**1,218**	**1,099**	**910**
std dev	204	374	224	641	442	231	694	614	592
median	970	1,320	935	1,280	925	980	1,090	1,075	790
max	1,230	1,800	1,200	2,540	1,800	1,420	2,900	2,300	1,950
min	550	700	580	500	580	780	400	300	200

Table 2.10 Nitrate/Nitrite (µg/l) during 2017 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	370	300	190	130	330	100	90	10
FEB	360	320	350	370	200	320	230	160
MAR	760	760	660	580	530	400	200	120
APR	460	500	480	380	330	320	180	80
MAY	360	380	380	490	480	130	380	330
JUN	40	100	40	20	40	10	10	10
JUL	10	10	10	10	10	40	10	10
AUG	10	10	10	10	10	10	10	10
SEP	170	100	10	10	30	10	10	10
OCT	230	210	200	180	150	60	30	10
NOV	510	530	490	420	360	140	40	30
DEC	470	420	390	320	240	60	10	10
mean	**313**	**303**	**268**	**243**	**226**	**133**	**100**	**66**
std dev	229	230	222	208	183	137	121	98
median	360	310	275	250	220	80	35	10
max	760	760	660	580	530	400	380	330
min	10	10	10	10	10	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	1,000	990	910	830	580
FEB	840	810	840	810	520
MAR	840	710	590	610	490
APR	710	780	700	480	190
MAY	360	360	410	340	270
JUN	90	220	80	70	30
JUL	10	10	10	10	10
AUG	10	10	10	10	10
SEP	1,050	610	560	640	130
OCT	680	370	470	360	70
NOV	180	110	70	70	10
DEC	1,500	1,360	930	710	330
mean	**606**	**528**	**465**	**412**	**220**
std dev	476	421	351	314	215
median	695	490	515	420	160
max	1,500	1,360	930	830	580
min	10	10	10	10	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	450	1,770	1,320	4,590	4,100	1,880	1,600	680	680
FEB	210	720	60	2,370	320	160	820	430	350
MAR	330	570	10	1,490	270	160	630	360	420
APR	140	650	70	1,070	60	180	250	160	130
MAY	310	290	1,510	1,180	1,150	340	290	310	530
JUN	60	10	10	100	10	20	100	30	40
JUL	10	60	10	10	10	10	10	10	10
AUG	10	10	10	10	10	400	10	10	10
SEP	160	30	10	710	230	210	410	160	90
OCT	40	190	10	250	10	170	1,850	100	100
NOV	40	120	10	380	10	10	80	40	160
DEC	1,890	440	10	2,350	1,250	560	930	70	100
mean	**304**	**405**	**253**	**1,209**	**619**	**342**	**582**	**197**	**218**
std dev	519	501	545	1,353	1,180	512	617	208	222
median	150	240	10	890	145	175	350	130	115
max	1,890	1,770	1,510	4,590	4,100	1,880	1,850	680	680
min	10	10	10	10	10	10	10	10	10

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	490	10	180	1,330	1,100	660	200	620	750
FEB	410	10	220	1,140	720	420	210	930	120
MAR	470	40	180	1,040	680	200	110	840	160
APR	230	70	350	1,340	850	430	480	600	800
MAY	180	20	20	200	60	60	60	200	100
JUN	10	10	10	10	10	10	10	10	10
JUL	10	10	10	10	10	130	10	20	50
AUG	10	10	10	10	10	10	10	10	10
SEP	140	40	270	440	90	290	10	140	110
OCT	150	50	200	500	210	420	80	730	40
NOV	150	10	200	560	180	560	10	610	10
DEC	630	20	470	920	850	280	140	300	1,090
mean	**240**	**25**	**177**	**625**	**398**	**289**	**111**	**418**	**271**
std dev	210	20	146	514	408	215	138	341	379
median	165	15	190	530	195	285	70	450	105
max	630	70	470	1,340	1,100	660	480	930	1,090
min	10	10	10	10	10	10	10	10	10

Figure 2.4 Nitrate + Nitrite at the Lower Cape Fear River Program mainstem stations, 1995-2016 versus 2017.

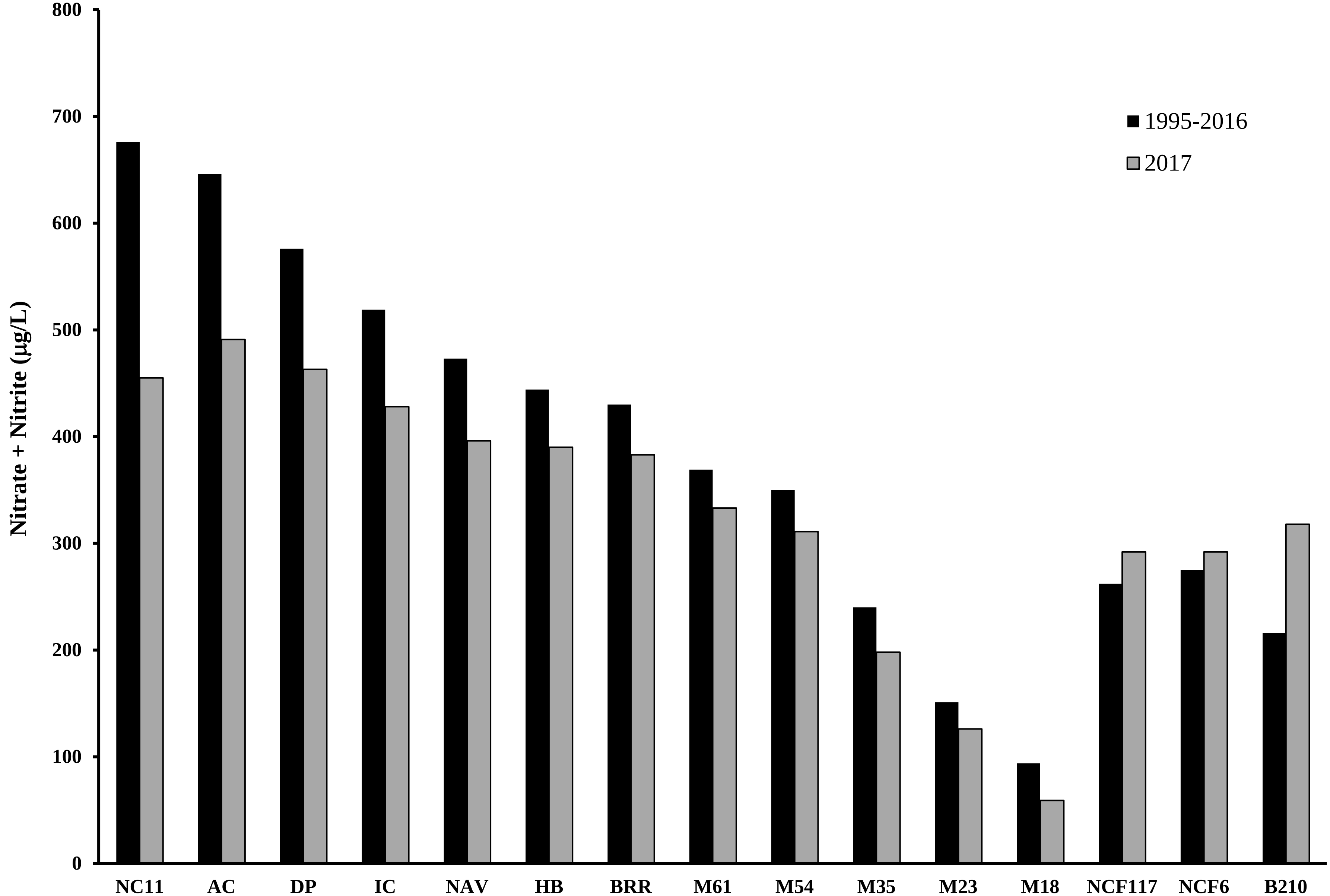

Table 2.11 Ammonia (µg/l) during 2017 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	40	80	60	170	120	90	10	10
FEB	100	80	100	110	160	100	70	50
MAR	50	80	90	110	100	90	30	10
APR	80	100	100	100	150	60	10	10
MAY	60	10	10	10	10	10	10	10
JUN	10	10	10	10	10	10	10	10
JUL	110	90	70	100	120	90	80	40
AUG	50	60	60	60	50	20	10	10
SEP	70	60	50	40	90	30	30	30
OCT	10	10	10	10	10	10	10	10
NOV	80	80	90	70	120	30	10	10
DEC	100	110	110	100	100	30	10	10
mean	**63**	**64**	**63**	**74**	**87**	**48**	**24**	**18**
std dev	33	36	37	50	54	36	25	14
median	65	80	65	85	100	30	10	10
max	110	110	110	170	160	100	80	50
min	10	10	10	10	10	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	70	60	60	40	30
FEB	100	120	130	130	80
MAR	20	20	50	40	80
APR	90	240	100	80	40
MAY	10	10	10	10	10
JUN	10	10	10	10	10
JUL	10	10	10	10	10
AUG	70	140	60	100	60
SEP	70	70	90	70	30
OCT	10	230	110	80	10
NOV	30	180	70	60	20
DEC	30	150	40	50	70
mean	**43**	**103**	**62**	**57**	**38**
std dev	34	86	40	38	28
median	30	95	60	55	30
max	100	240	130	130	80
min	10	10	10	10	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	40	20	10	190	90	410	100	40	50
FEB	100	50	40	80	80	50	40	70	80
MAR	10	50	10	140	40	420	340	70	80
APR	160	110	100	170	150	100	90	60	50
MAY	30	10	10	10	150	10	10	10	10
JUN	10	10	10	10	10	290	10	10	10
JUL	100	40	20	90	10	30	80	40	30
AUG	100	120	70	160	50	430	130	50	60
SEP	30	20	20	60	130	110	110	40	50
OCT	100	70	100	170	100	70	80	60	70
NOV	110	50	40	190	60	40	40	30	100
DEC	40	20	20	120	70	90	40	40	70
mean	**69**	**48**	**38**	**116**	**78**	**171**	**89**	**43**	**55**
std dev	48	37	34	65	48	166	88	20	28
median	70	45	20	130	75	95	80	40	55
max	160	120	100	190	150	430	340	70	100
min	10	10	10	10	10	10	10	10	10

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	50	60	20	60	50	60	90	90	150
FEB	50	320	40	50	50	50	170	70	50
MAR	10	150	20	10	10	10	70	60	10
APR	70	160	80	230	110	50	150	1,260	150
MAY	10	360	10	10	10	10	10	10	10
JUN	10	490	10	10	10	10	170	10	10
JUL	60	440	40	50	40	80	150	80	90
AUG	60	620	40	30	30	120	200	40	50
SEP	10	60	10	10	10	10	90	10	10
OCT	30	350	40	40	40	40	80	50	40
NOV	10	10	10	10	10	10	10	10	10
DEC	20	30	20	60	20	20	20	70	70
mean	**33**	**254**	**28**	**48**	**33**	**39**	**101**	**147**	**54**
std dev	24	203	21	61	29	35	67	352	52
median	25	240	20	35	25	30	90	55	45
max	70	620	80	230	110	120	200	1,260	150
min	10	10	10	10	10	10	10	10	10

Figure 2.5 Ammonia and Fecal Coliform Bacteria at COL 2010-2017.

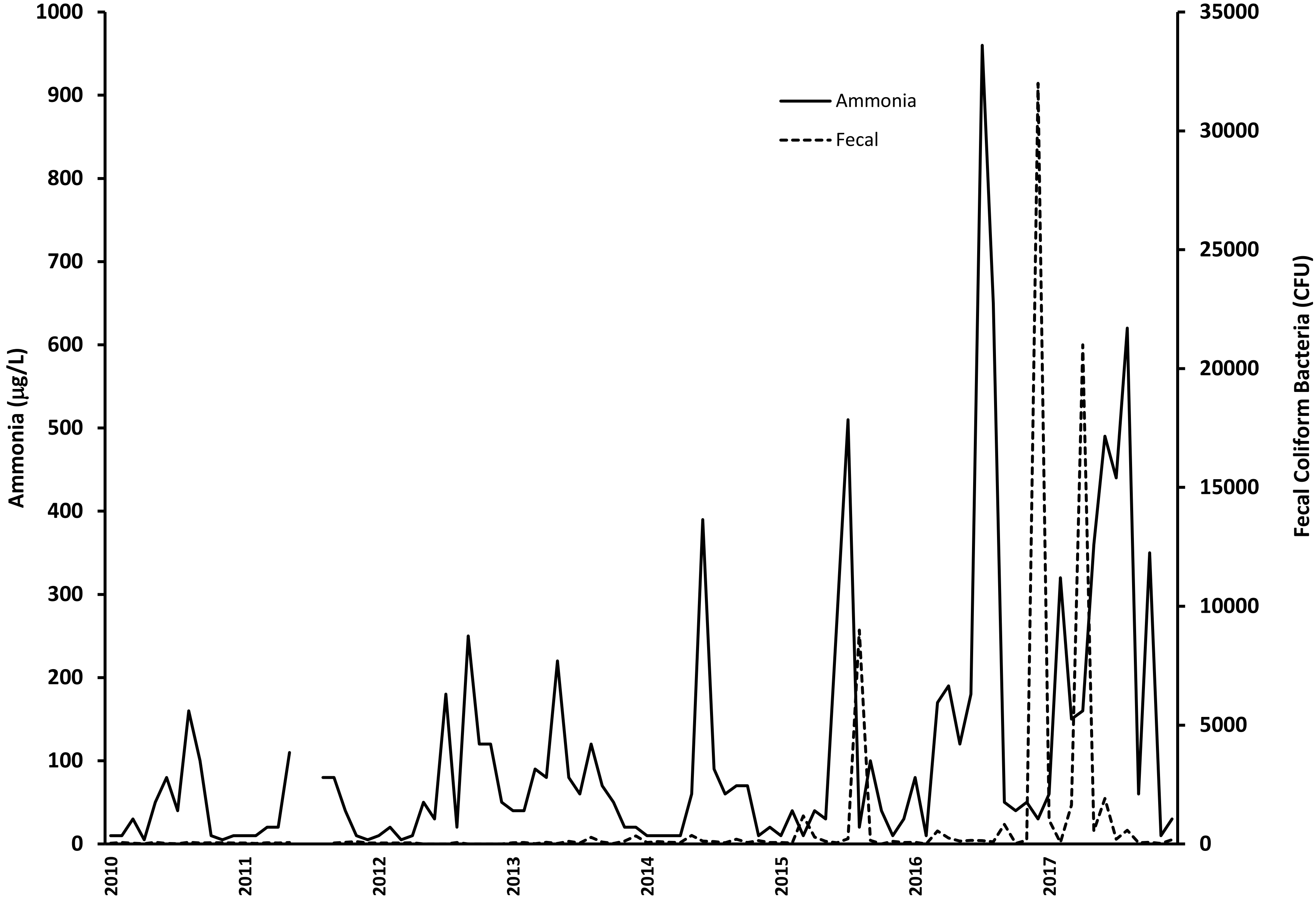

Table 2.12 Total Kjeldahl Nitrogen (μg/l) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	500	400	300	600	600	300	300	400
FEB	500	500	1,200	600	700	600	200	300
MAR	500	600	600	700	600	600	900	600
APR	1,200	1,200	1,300	1,000	1,300	1,100	1,300	500
MAY	700	700	600	800	1,100	800	700	600
JUN	1,300	700	700	1,000	700	1,000	700	900
JUL	50	500	500	500	500	400	300	300
AUG	400	500	400	400	500	300	300	300
SEP	600	500	600	500	600	400	600	400
OCT	600	700	900	1,200	700	700	400	500
NOV	700	800	700	500	500	400	700	500
DEC	1,300	400	500	700	600	300	200	300
mean	**696**	**625**	**692**	**708**	**700**	**575**	**550**	**467**
std dev	384	222	303	247	249	277	332	178
median	600	550	600	650	600	500	500	450
max	1,300	1,200	1,300	1,200	1,300	1,100	1,300	900
min	50	400	300	400	500	300	200	300

	NC11	AC	DP	IC	NCF6
JAN	600	600	600	600	900
FEB	700	600	600	600	700
MAR	500	700	800	800	700
APR	500	900	600	600	700
MAY	900	800	900	800	1,000
JUN	50	50	50	50	50
JUL	500	500	500	500	700
AUG	600	800	900	800	900
SEP	700	700	400	600	1,000
OCT	900	800	1,100	700	800
NOV	800	1,100	800	700	700
DEC	1,100	1,000	800	600	300
mean	**654**	**713**	**671**	**613**	**704**
std dev	268	270	277	202	278
median	650	750	700	600	700
max	1,100	1,100	1,100	800	1,000
min	50	50	50	50	50

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1,100	600	300	600	900	1,400	700	700	900
FEB	1,100	800	500	800	700	900	600	700	1,000
MAR	1,000	900	500	900	700	1,300	1,500	800	800
APR	1,300	1,400	900	1,100	1,200	700	800	800	600
MAY	1,500	800	700	800	1,200	900	900	1,000	1,200
JUN	1,100	700	600	1,000	600	600	2,400	900	100
JUL	1,100	600	300	700	500	200	400	500	400
AUG	1,400	1,100	1,300	1,500	900	1,400	600	600	600
SEP	1,500	1,000	800	1,000	800	1,100	1,000	1,000	700
OCT	1,500	700	1,000	800	1,100	700	600	800	500
NOV	1,300	700	700	500	700	400	600	800	700
DEC	1,300	800	500	900	700	800	900	600	600
mean	**1,267**	**842**	**675**	**883**	**833**	**867**	**917**	**767**	**675**
std dev	183	231	293	259	231	382	546	156	286
median	1,300	800	650	850	750	850	750	800	650
max	1,500	1,400	1,300	1,500	1,200	1,400	2,400	1,000	1,200
min	1,000	600	300	500	500	200	400	500	100

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	500	900	500	800	700	700	700	700	1,200
FEB	700	1,600	900	900	900	700	1,200	700	700
MAR	700	1,000	400	500	600	600	800	1,000	600
APR	800	1,000	700	1,200	50	600	1,700	1,700	900
MAY	900	1,700	900	1,100	1,000	900	400	600	600
JUN	700	1,800	700	700	700	800	1,100	300	400
JUL	900	1,800	1,200	600	800	800	1,200	600	1,100
AUG	700	1,400	600	500	600	800	1,200	400	300
SEP	900	1,200	700	700	700	1,000	2,900	1,000	800
OCT	800	1,500	900	900	800	1,000	1,000	600	400
NOV	400	700	500	600	400	500	600	400	200
DEC	600	1,000	600	800	900	500	600	400	600
mean	**717**	**1,300**	**717**	**775**	**679**	**742**	**1,117**	**700**	**650**
std dev	159	381	225	222	255	173	666	386	309
median	700	1,300	700	750	700	750	1,050	600	600
max	900	1,800	1,200	1,200	1,000	1,000	2,900	1,700	1,200
min	400	700	400	500	50	500	400	300	200

Table 2.3 Total Phosphorus (µg/l) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	80	70	90	80	70	50	30	40
FEB	90	80	80	80	80	60	50	40
MAR	130	130	100	80	80	60	30	10
APR	120	110	30	90	90	50	30	10
MAY	110	100	100	140	120	150	100	170
JUN	130	130	130	120	110	90	60	30
JUL	110	110	100	100	90	70	60	30
AUG	150	120	100	90	90	70	50	40
SEP	160	120	110	100	100	60	50	40
OCT	110	120	100	70	90	60	40	30
NOV	130	120	110	100	90	60	30	30
DEC	120	110	100	90	100	50	30	20
mean	**120**	**110**	**96**	**95**	**93**	**69**	**47**	**41**
std dev	22	18	23	18	13	27	20	40
median	120	115	100	90	90	60	45	30
max	160	130	130	140	120	150	100	170
min	80	70	30	70	70	50	30	10

	NC11	AC	DP	IC	NCF6
JAN	80	90	90	80	100
FEB	90	90	90	80	70
MAR	140	140	120	90	80
APR	150	160	150	130	80
MAY	110	90	110	100	140
JUN	120	120	130	110	160
JUL	100	100	100	110	100
AUG	160	180	170	160	100
SEP	250	210	170	140	120
OCT	200	240	170	140	120
NOV	270	310	210	200	90
DEC	260	260	210	160	90
mean	**161**	**166**	**143**	**125**	**125**
std dev	65	72	41	35	26
median	145	150	140	120	100
max	270	310	210	200	200
min	80	90	90	80	80

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	150	40	40	70	100	90	70	80	100
FEB	150	80	50	100	130	50	130	50	90
MAR	110	90	60	180	130	130	360	90	90
APR	250	180	150	220	360	120	260	110	90
MAY	210	150	140	90	200	80	200	150	140
JUN	170	180	160	240	240	100	250	110	110
JUL	230	190	120	210	350	70	970	110	100
AUG	310	260	280	120	150	150	400	120	110
SEP	520	110	90	200	260	10	220	110	70
OCT	360	230	260	170	390	110	330	120	60
NOV	190	110	50	120	50	220	60	180	90
DEC	300	90	60	60	170	120	120	70	60
mean	**246**	**143**	**122**	**148**	**211**	**104**	**281**	**108**	**93**
std dev	109	64	78	60	106	50	233	33	22
median	220	130	105	145	185	105	235	110	90
max	520	260	280	240	390	220	970	180	140
min	110	40	40	60	50	10	60	50	60

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	50	50	10	70	40	150	40	100	170
FEB	80	140	40	90	30	280	60	100	10
MAR	80	110	30	70	40	240	50	70	70
APR	110	210	60	160	100	210	150	140	120
MAY	120	170	10	130	60	230	50	80	180
JUN	130	180	60	270	70	580	90	70	210
JUL	110	170	60	150	90	640	80	80	130
AUG	140	150	10	140	80	950	20	70	100
SEP	110	50	40	190	70	430	90	110	190
OCT	120	100	50	160	60	390	70	70	170
NOV	90	60	20	60	20	430	40	40	100
DEC	80	50	30	100	30	110	40	60	90
mean	**102**	**120**	**35**	**133**	**58**	**387**	**65**	**83**	**128**
std dev	25	55	19	58	25	232	33	25	56
median	110	125	35	135	60	335	55	75	125
max	140	210	60	270	100	950	150	140	210
min	50	50	10	60	20	110	20	40	10

Figure 2.6 Total Phosphorus at the Lower Cape Fear River Program mainstem stations, 1995-2016 versus 2017.

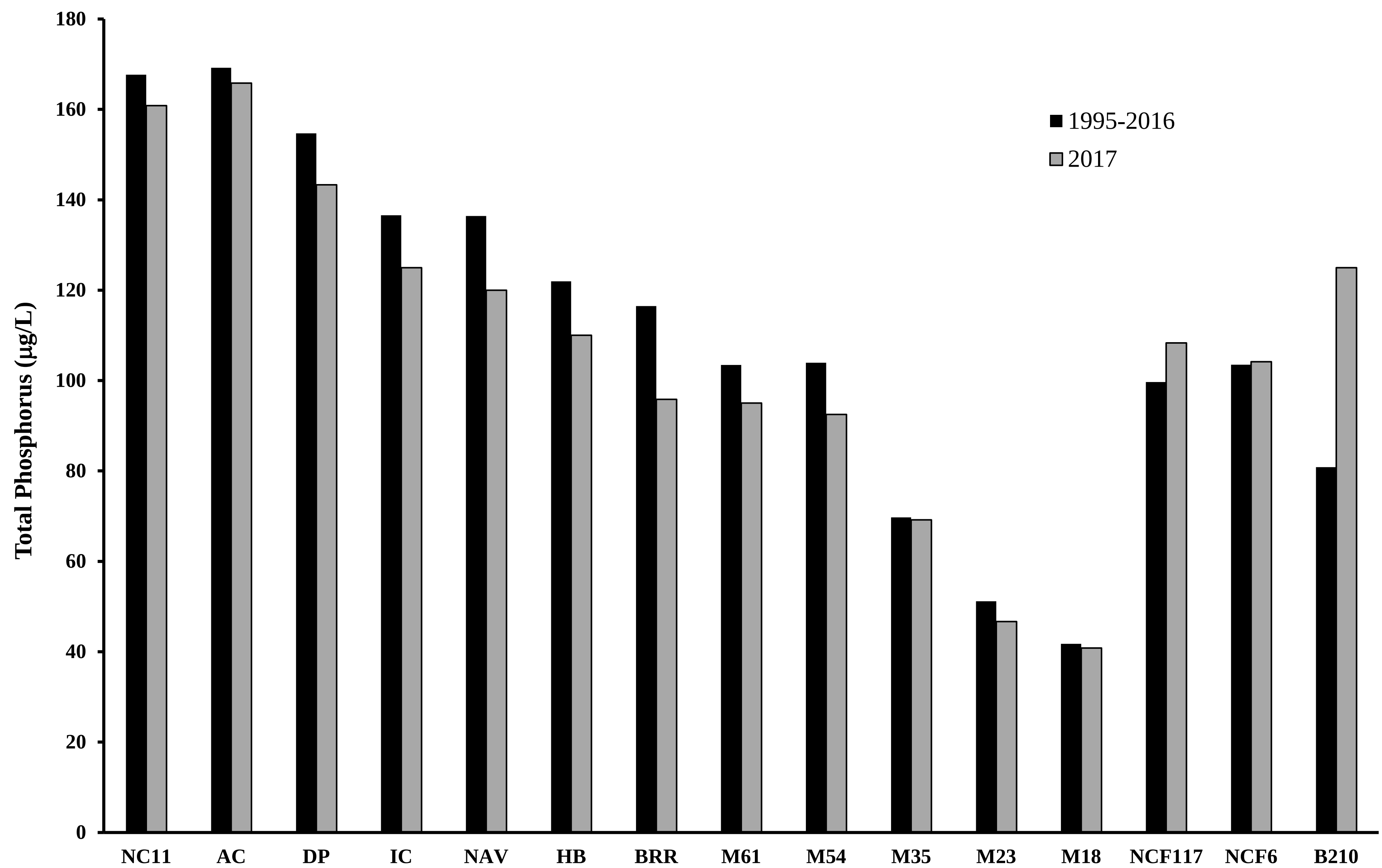

Table 2.14 Orthophosphate (µg/l) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	35	35	39	38	33	26	34	12
FEB	29	31	33	36	34	28	21	18
MAR	61	60	51	42	36	31	17	12
APR	43	37	38	35	37	23	14	8
MAY	29	30	32	59	53	48	43	37
JUN	56	51	56	53	51	39	24	17
JUL	40	43	43	40	50	35	34	15
AUG	63	59	51	45	42	33	19	16
SEP	62	57	53	49	50	26	27	18
OCT	34	35	34	36	36	23	15	9
NOV	56	62	56	51	49	25	14	9
DEC	45	43	41	40	38	19	12	7
mean	**46**	**45**	**44**	**44**	**42**	**30**	**23**	**15**
std dev	13	12	9	8	8	8	10	8
median	44	43	42	41	40	27	20	14
max	63	62	56	59	53	48	43	37
min	29	30	32	35	33	19	12	7

	NC11	AC	DP	BBT	IC	NCF6
JAN	37	40	40	35	33	66
FEB	38	35	35	28	35	30
MAR	55	58	47	44	44	37
APR	55	74	60	36	45	21
MAY	28	28	31	34	27	71
JUN	59	57	55	50	48	49
JUL	56	61	43	45	46	42
AUG	73	89	85	75	78	41
SEP	147	109	81	71	69	54
OCT	94	112	66	65	61	43
NOV	153	193	101	94	81	36
DEC	163	152	110	107	77	41
mean	**80**	**84**	**63**	**57**	**54**	**44**
std dev	48	50	26	25	19	14
median	57	67	58	48	47	42
max	163	193	110	107	81	71
min	28	28	31	28	27	21

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	123	20	17	31	41	18	41	43	59
FEB	86	23	19	43	38	8	61	22	31
MAR	65	25	21	60	30	19	146	33	33
APR	99	40	42	48	59	21	79	35	23
MAY	127	41	35	38	48	15	69	74	67
JUN	86	53	50	77	60	28	89	46	51
JUL	133	61	42	37	91	22	502	44	51
AUG	202	49	32	12	10	30	178	38	40
SEP	342	31	34	89	90	38	107	50	28
OCT	209	52	29	37	60	27	92	44	25
NOV	116		20	12	50	18	62	31	41
DEC	204	24	24	19	38	25	52	23	23
mean	**149**	**38**	**31**	**42**	**51**	**23**	**123**	**40**	**39**
std dev	78	14	11	24	23	8	126	14	15
median	125	40	31	37	49	22	84	41	36
max	342	61	50	89	91	38	502	74	67
min	65	20	17	12	10	8	41	22	23

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	20	42	8	25	20	96	9	24	56
FEB	25	83	10	32	15	190	10	17	32
MAR	32	64	8	25	10	147	6	13	25
APR	39	99	24	53	35	93	12	36	33
MAY	44	111	16	48	23	119	8	19	61
JUN	42	106	16	56	22	339	9	12	72
JUL	53	111	21	57	28	418	13	15	56
AUG	48	115	27	60	32	787	8	18	73
SEP	46	28	16	56	23	220	9	22	75
OCT	56	57	15	52	21	198	8	18	70
NOV	45	31	8	26	10	317	6	13	45
DEC	37	25	6	39	8	33	5	19	38
mean	**41**	**73**	**14**	**44**	**21**	**246**	**9**	**19**	**53**
std dev	11	36	7	14	9	204	2	6	18
median	43	73	15	50	22	194	9	18	56
max	56	115	27	60	35	787	13	36	75
min	20	25	6	25	8	33	5	12	25

Table 2.15 Chlorophyll *a* (µg/l) during 2017 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	1	1	1	2	3	3	4	4
FEB	5	5	3	3	3	3	4	4
MAR								
APR	2	2	1	3	4	6	5	4
MAY	2	2	2	2	2	2	3	4
JUN	2	2	4	6	3	6	8	8
JUL	2	3	3	5	11	12	10	11
AUG	6	4	5	5	8	9	11	10
SEP	2	3	2	2	2	3	8	3
OCT	10	4	3	3	5	5	5	7
NOV	4	3	3	5	4	4	7	8
DEC	4	3	2	4	5	3	5	5
mean	**4**	**3**	**3**	**4**	**5**	**5**	**6**	**6**
std dev	3	1	1	1	3	3	3	3
median	2	3	3	3	4	4	5	5
max	10	5	5	6	11	12	11	11
min	1	1	1	2	2	2	3	3

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

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	2	1	0	1	1	2	0	0	0
FEB	3	1	2	4	4	43	17	0	2
MAR	3	2	3	7	8	8	3	0	6
APR	2	1	4	7	13	1	0	1	18
MAY	5	1	2	7	10	3	1	1	1
JUN	25	2	3	19	24	1	1	1	1
JUL	11	7	11	29	33	1	1	1	7
AUG	2	4	87	29	26	2	1	1	3
SEP	1	1	3	4	6	16	3	0	4
OCT	2	2	41	10	42	3	1	0	6
NOV	1	1	3	1	2	1	0	0	3
DEC	1	1	1	3	2	8	1	0	1
mean	**5**	**2**	**13**	**10**	**14**	**7**	**2**	**0**	**4**
std dev	7	2	26	10	14	12	5	1	5
median	2	1	3	7	9	3	1	0	3
max	25	7	87	29	42	43	17	1	18
min	1	1	0	1	1	1	0	0	0

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1	2	1	1	2	3	11	2	6
FEB	1	4	1	1	1	1	9	1	1
MAR		6	1	1	1	2	18	6	2
APR	1	3	0	1	1	2	8	4	1
MAY	1	4	1	1	1	2	16	1	1
JUN	1	10	0	2	1	1	12	1	1
JUL	1	8	0	1	1	2	14	4	4
AUG	1	13	0	1	1	1	51	1	1
SEP	0	2	0	0	0	0	11	1	0
OCT	1	1	0	1	0	1	5	0	0
NOV	0	0	0	1	0	1	1	0	0
DEC	0	1	1	1	1	1	3	1	1
mean	**1**	**5**	**0**	**1**	**1**	**1**	**13**	**2**	**2**
std dev	0	4	1	0	1	1	13	2	2
median	1	4	0	1	1	1	11	1	1
max	1	13	1	2	2	3	51	6	6
min	0	0	0	0	0	0	1	0	0

Figure 2.7 Chlorophyll *a* at the Lower Cape Fear River Program mainstem stations, 1995-2016 versus 2017.

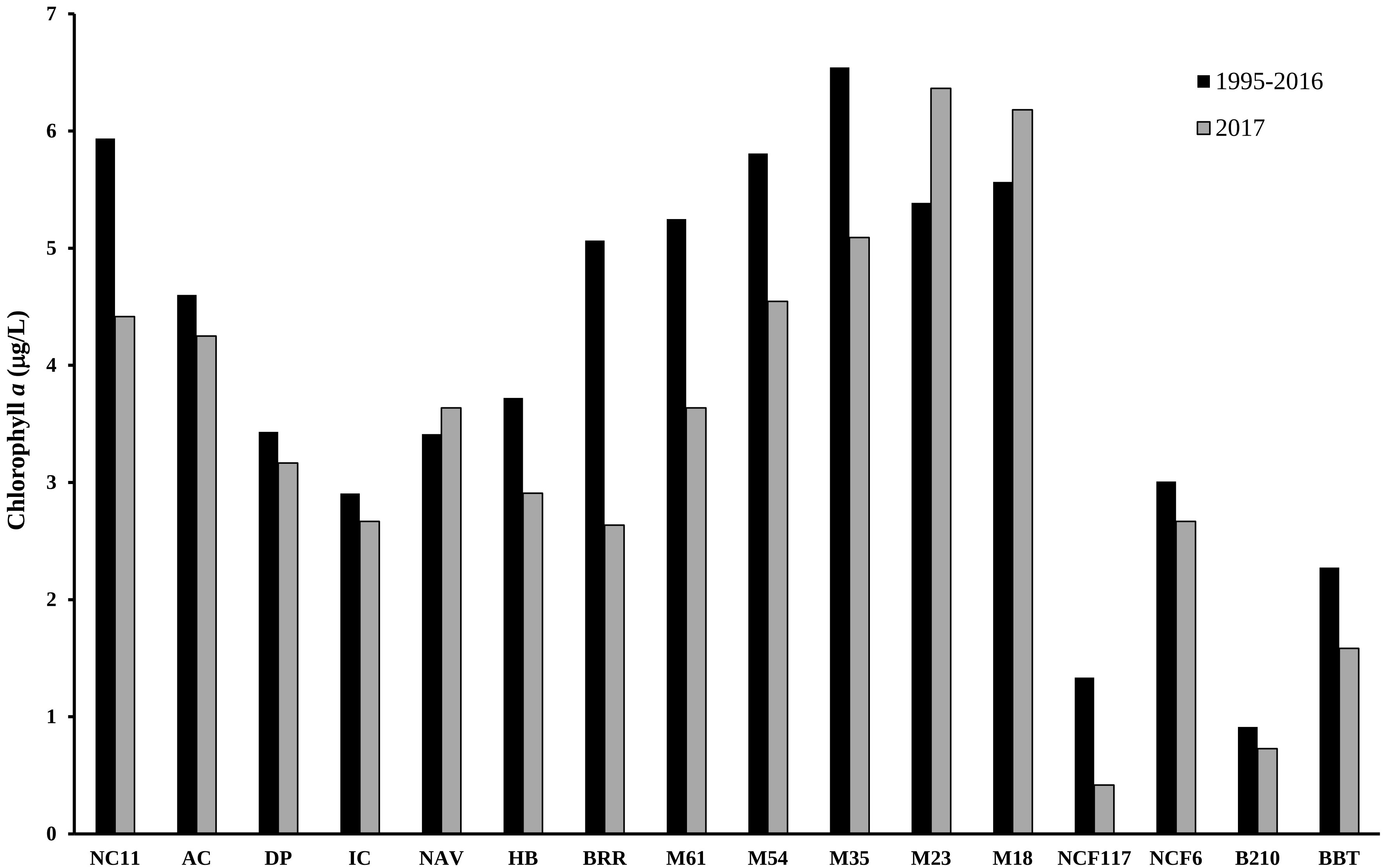

Table 2.16 Fecal Coliform (cfu/100 mL) and Enterococcus (MPN) during 2017 at the Lower Cape Fear River Program stations.

	NC11	AC	DP	IC	NCF6	NAV	HB
JAN	64	172	154	91	117	82	37
FEB	37	28	546	10	1,640	10	10
MAR	163	546	118	136	546	5	5
APR	46	28	10	28	172	37	37
MAY	127	73	28	28	55	55	5
JUN	5	19	10	19	28	19	19
JUL	5	5	46	64	91	2,000	2,100
AUG	5	10	19	10	19	19	28
SEP	145	55	46	55	37	55	118
OCT	19	46	19	82	73	109	100
NOV	10	46	19	64	172	82	64
DEC	28	5	82	91	220	127	91
mean	**55**	**86**	**91**	**57**	**264**	**217**	**218**
std dev	56	145	144	37	437	539	569
max	163	546	546	136	1,640	2,000	2,100
min	5	5	10	10	19	5	5
Geomean	28	35	42	42	114	52	42

ENTEROCOCCUS

	BRR	M61	M54	M35	M23	M18
JAN	5	5	20	10	5	5
FEB	5	5	5	30	5	10
MAR	17	5	31	5	5	5
APR	5	5	5	10	5	5
MAY	85	20	41	51	52	74
JUN	5	10	30	5	5	5
JUL	145	134	146	122	776	2,014
AUG	15	106	489	981	489	411
SEP	207	68	326	687	580	921
OCT	345	345	727	305	649	1,990
NOV	38	24	54	9	178	196
DEC	52	46	74	345	131	11
mean	**77**	**64**	**162**	**213**	**240**	**471**
std dev	102	94	222	305	283	731
max	345	345	727	981	776	2,014
min	5	5	5	5	5	5
Geomean	28	24	57	51	53	58

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	19	118	91	37	100	118	200	109	55
FEB	1640	2090	199	1730	637	11000	11000	208	208
MAR	1,000	470	5,300	550	24,000	37,000	910	64	9,000
APR	109	100	217	38,000	60,000	1,910	91	109	800
MAY	8,000	7,000	7,000	9,000	728	350	910	19	19
JUN	172	181	172	190	580	2,100	1,730	46	46
JUL	82	819	82	390	181	728	199	145	546
AUG	490	100	390	550	637	1,180	470	100	350
SEP	1,000	270	154	460	260	1,550	3,600	82	1,180
OCT	154	240	310	181	1090	230	210	19	819
NOV	390	2,800	430	380	1,730	2,400	2,180	210	300
DEC	380	637	210	189	140	270	490	91	136
mean	**1,120**	**1,235**	**1,213**	**4,305**	**7,507**	**4,903**	**1,833**	**100**	**1,122**
std dev	2,126	1,923	2,237	10,436	17,092	10,083	2,939	60	2,401
max	1,640	7,000	7,000	38,000	60,000	37,000	11,000	210	9,000
min	19	100	82	37	100	118	91	19	19
Geomean	357	477	351	615	906	1,241	727	79	301

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,550	1,000	819	4,900	31,000	44,000	5,500	8,000	60,000
FEB	819	64	28	28	910	1,270	22,000	10,000	330
MAR	1,910	1,640	2,000	580	550	1,820	3,700	5,900	19,000
APR	910	21,000	181	60,000	819	48,000	1,640	16,000	1,460
MAY	73	550	240	46	172	240	163	819	290
JUN	490	1,910	55	2,900	1,360	55	1,090	2,000	1,730
JUL	172	199	46	181	100	100	1,550	819	8,000
AUG	100	580	118	127	390	540	154	1,360	1,180
SEP	28	55	127	310	109	172	91	1,730	2,900
OCT	100	73	240	190	73	118	118	580	2,800
NOV	10	19	55	82	118	46	5	310	2,270
DEC	1,000	181	73	1,820	390	210	728	290	1,640
mean	**597**	**2,273**	**332**	**5,930**	**2,999**	**8,048**	**3,062**	**3,984**	**8,467**
std dev	617	5,680	543	16,366	8,451	17,001	5,933	4,788	16,319
max	1,910	21,000	2,000	60,000	31,000	48,000	22,000	16,000	60,000
min	10	19	28	28	73	46	5	290	290
Geomea	241	353	143	474	432	545	572	1,811	2,558

Figure 2.8 Geometric Mean Fecal Coliform (NC11-B210) and Enterococcus (BRR-M18) at the LCFRP mainstem stations, 1996-2016 (Entero 2012-2016) vs. 2017.