Environmental Assessment of the Lower Cape Fear River System, 2018

By

Michael A. Mallin, Matthew R. McIver and James F. Merritt
August 2019

CMS Report No. 19-02
Center for Marine Science
University of North Carolina Wilmington
Wilmington, N.C. 28409

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 2018. 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 in the estuary is usually high (Ensign et al. 2004). During periods of low flow algal biomass as chlorophyll *a* increases in the cape Fear 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 (traditional agriculture and/or industrialized animal production), and some sites periodically show elevated pollutant loads or effects (Mallin et al. 2001). This region has been hit by hurricanes several times in the past three decades and such storms have a marked impact on water quality and organisms.

GenX Issues - During the past three years 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, aquatic organisms, 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 and provide financial compensation. 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 2018</u> – The major single impact of 2018 was the arrival of **Hurricane Florence**, which dumped approximately two feet of water on the region in September 2018 (Plate 1). Biochemical oxygen-demanding materials from industrial livestock production facilities, wastewater treatment plants, flooded septic systems and natural debris caused very low dissolved oxygen (DO) concentrations in all major rivers, but especially in the Northeast Cape Fear River, where DO dropped down to 0.2 mg/L for weeks at the two LCFRP sites. Massive fish kills occurred in that river as well as the mainstem Cape Fear River (Plate 1). We note, however, that even before the storm DO concentrations were very low in some areas, often falling below 4.0 mg/L at several blackwater and upper estuary stations.

Year after year 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 are highest at the upper river stations NC11 and ANC and in the low-to-middle estuary at stations M35 to M18. Lowest mainstem mean DO levels normally occur at the river and upper estuary stations NAV, HB, BRR and M61. 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.

Dissolved oxygen concentrations in the tributary streams were briefly impacted by the hurricane, but some are chronically bad year-after-year. In 2018 SC-CH and GS were below standard 27% of the time sampled, and NC403 and AC below standard 18% of the time. Considering all sites sampled in 2018, we rated 28% as poor for dissolved oxygen, 16% as fair, and 56% as good.

Annual mean turbidity levels for 2018 were lower than the long-term average in all estuary stations. Highest mean riverine turbidities were at NC11-DP (26-19 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 Northeast Cape Fear River and Black River than in the mainstem river. Turbidity levels were low in the freshwater streams, with all streams rated as good for 2018.

Average chlorophyll *a* concentrations across most sites were low in 2018. The standard of 40 µg/L was exceeded once at Station SR, and there were several smaller algal blooms as well. We note the highest chlorophyll *a* levels in the river and estuary typically occur late spring to late-summer.

High river discharge prevents riverine algal blooms from forming. For 2018, discharge at Lock and Dam #1 in the May-September growing season (8,590 CFS) was 4X the 2009-2012 low-flow period average of 1,698 CFS. Nuisance cyanobacterial blooms did not occur in the river and upper estuary in 2018, probably due to the elevated discharge washing out any algal bloom formation. For the 2018 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 elevated in 2018. Almost all of the stream stations in the Northeast Cape Fear and Black River basins were rated as poor for fecal coliform bacteria counts. However, the main river and estuary sites were generally in good condition in 2018. For bacterial water quality overall, 39% of the sites rated as poor, 22% as fair, and 39% as good in 2018.

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

Plate 1. Hurricane Florence high water marks along the Cape Fear River and Harrison's Creek, dead fish at Lock and Dam #1, flooded poultry and swine lagoons (CAFO photos W. Golder, Audubon), and dead fish at Northeast Cape Fear River boat ramp (photos M. Mallin unless noted otherwise).

Table of Contents

Executive Summary……………………………………………………………………………1

1.0 Introduction..………..............….......5

1.1 Site Description...………...6
1.2 Report Organization…………………………………………………………..………7

2.0 Physical, Chemical, and Biological Characteristics of the Lower Cape Fear River and Estuary…………………………………………..………………………..............11

Physical Parameters.…......................………...………...14
Chemical Parameters…...……..………...…..18
Biological Parameters.......………....……..….21

1.0 Introduction

Michael A. Mallin
Aquatic Ecology Laboratory
Center for Marine Science
University of North Carolina Wilmington

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 2018.

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 24-year (1995-2018) data base that is available to the public, and is used as a teaching tool. 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 5^{th} 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

Section 1 of this report provides a summary and introduction, and Section 2 of this report presents a detailed 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

Ensign, S.H., J.N. Halls and M.A. Mallin. 2004. Application of digital bathymetry data in an analysis of flushing times of two North Carolina estuaries. *Computers and Geosciences* 30:501-511.

Mallin, M.A., S.H. Ensign, M.R. McIver, G.C. Shank and P.K. Fowler. 2001. Demographic, landscape, and meteorological factors controlling the microbial pollution of coastal waters. *Hydrobiologia* 460:185-193.

Table 1.1 Description of sampling locations for the Lower Cape Fear River Program, 2018.

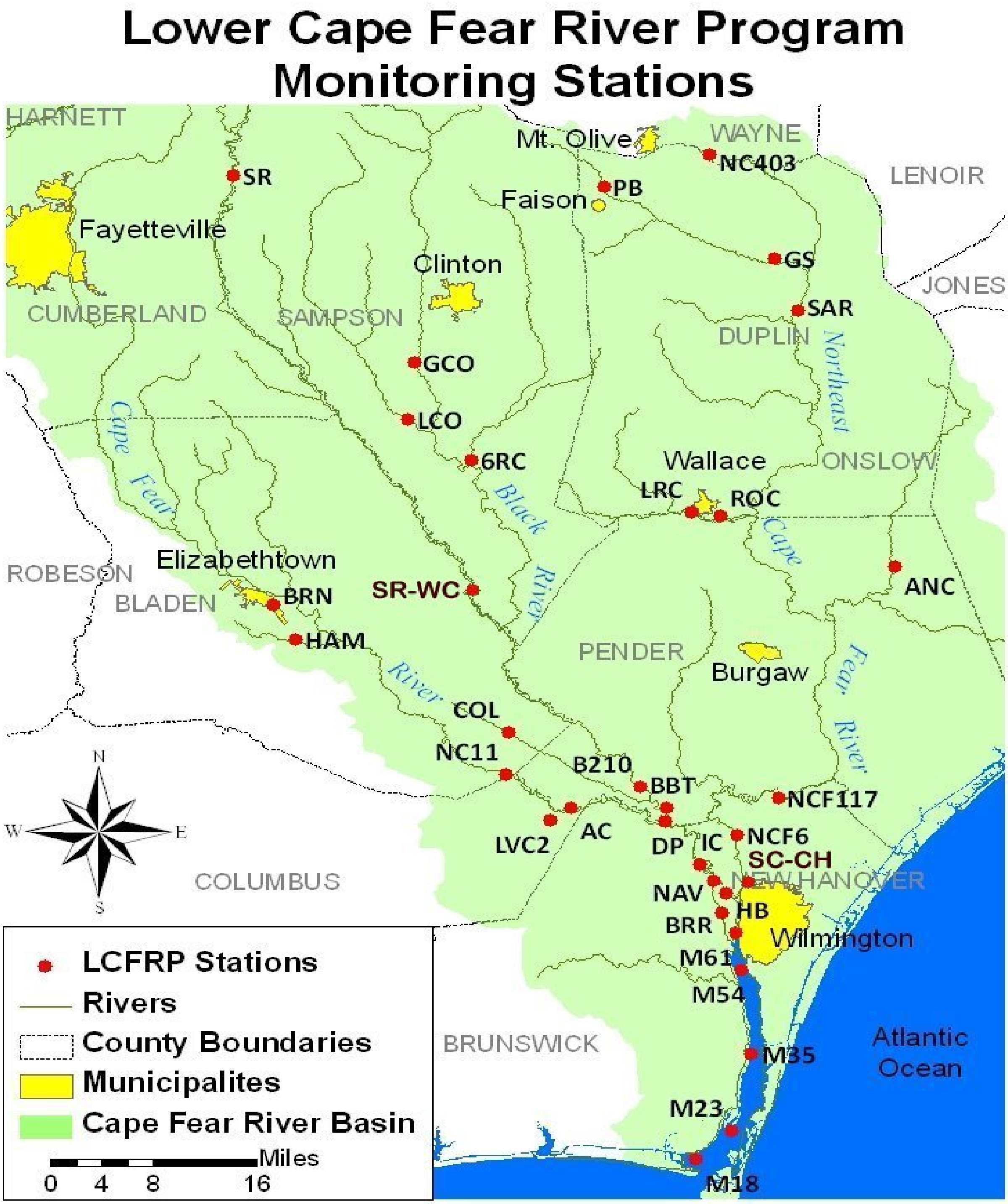
Collected by Boat

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

Michael A. Mallin and Matthew R. McIver
Aquatic Ecology Laboratory
Center for Marine Science
University of North Carolina Wilmington

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 2018 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, and metals as requested by NCDEQ. Selected biological parameters including fecal coliform bacteria or *Enterococcus* bacteria and chlorophyll *a* were examined.

2.2 - Materials and Methods

Samples and field parameters collected for the estuarine stations of the Cape Fear River (NAV down through M18) were gathered (when possible) 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). Special sampling for dissolved metals was initiated at selected stations by NCDEQ in 2015 and is ongoing.

<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 6920/650 MDS or YSI EXO3. 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 UNCW Aquatic Ecology Laboratory 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); the rest of the large amount of chlorophyll a data presented here were not State-certified.

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; previous BOD data are available from LCFRP.

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 2018. 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. As noted, the Cape Fear region experienced major impacts from Hurricane Florence in 2018; therefore this report reflects the impacts in fall; note that September sampling was missing from some stations due to lack of access.

Physical Parameters

Water temperature

Water temperatures at all stations ranged from 3.1 to 31.3^{o}C, and individual station annual averages ranged from 15.2 to 19.1^{o}C (Table 2.1). Highest temperatures occurred during July 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 31.4 practical salinity units (psu) and station annual means ranged from 0.1 to 22.3 psu (Table 2.2). Lowest salinities occurred in late spring and again in October following the heavy rains from the hurricane. As such, the annual mean salinities for 2018 were lower compared with the twenty-one year average for 1995-2017 (Figure 2.1). Two stream stations, NC403 and PB, had occasional oligohaline conditions due to discharges from pickle production facilities. SC-CH is a blackwater tidal creek that enters the Northeast Cape Fear River upstream of Wilmington and salinity there ranged from 0.1 to 2.4 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.09 to 48.16 mS/cm and from 0.05 to 4.56 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

System pH values ranged from 3.5 to 8.1 and station annual means ranged from 4.1 to 8.0 (Table 2.4). pH was typically lowest upstream due to acidic swamp water inputs and highest downstream as alkaline seawater mixes with the river water. Low pH values at COL predominate because of naturally acidic blackwater inputs in this wetland-rich rural watershed.

Dissolved Oxygen

Dissolved oxygen (DO) problems have long 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). There is an annual 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). 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. Surface concentrations for all sites in 2018 ranged from 0.2 to 13.6 mg/L and station annual means ranged from 5.8 to 8.3 mg/L (Table 2.5). Overall, average dissolved oxygen levels were mixed in 2018 compared with the long-term average (Fig. 2.2). River dissolved oxygen levels were low during the summer (Table 2.5), often falling below the state standard of 5.0 mg/L at several river and upper estuary stations.

While DO concentrations were already low in summer the September arrival of Hurricane Florence brought approximately two feet of rain to the area, caused a massive BOD load from animal waste, sewage and natural swamp organic matter to drop DO lower than usual in October. Hurricane Florence led to the release of many millions of gallons of untreated or partially treated sewage due to system flooding, power failures, generator damage and pump station failures. According to reported data, Fayetteville had > 7.6 million gallons reaching surface waters, Wilmington had to reroute 5.25 million gallons into the river, and Carolina Beach had to discharge 17.2 million gallons to the estuary. According to industry self-reporting, 49 swine waste lagoons serving concentrated animal feeding operations (CAFOs) either breached, overtopped or were inundated by floodwaters, and another 47 lagoons were possibly compromised by high freeboard in the lagoons. Many thousands of acres of swine sprayfields and poultry CAFO litterfields were inundated by floodwaters as well. The Northeast Cape Fear River stations (NCF117 and BCF6) were particularly hard hit by the BOD load, with DO dropping to 0.2 mg/L for several weeks. This caused massive fish kills in the system (see front cover) including endangered sturgeon

Overall for the year, stations M61 and M54 were below 5.0 mg/L on 45% or more of occasions sampled, NAV was below on 36% of occasions sampled, and HB and M35 below standard 27% of th etime. Based on number of occasions the river stations were below 5 mg/L UNCW rated NAV, HB, M61, M54, M35 and BRR as poor for 2018; the lower estuary stations were rated as good. On a year-to-year basis, 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 from 2009-2012), 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 due to the hurricane, DO conditions in the lower river and estuary in 2018 were worse than 2017.

The hurricane impacted the tributary stream stations in October, but DO levels recovered in November. Tributary Stations SC-CH and GS were below 4.0 mg/L on 27% of occasions sampled (rated poor), and NC403 and ANC 18% (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 87 Nephelometric turbidity units (NTU) and station annual means ranged from 3 to 26 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Highest mean turbidities were at NC11-DP (26-19 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 2018 sampling trips. As in the previous year, mean turbidity levels for 2018 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. 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 (TSS)

An altered 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 85.0 mg/L with station annual means from 2.3 to 27.3 mg/L (Table 2.7). The overall highest river values were at NC11 and AC. In the stream stations TSS was generally considerably lower than the river and estuary. 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 2018 data). The fine silt and clay in the upper to middle estuary sediments are most likely derived from the Piedmont and carried downstream to the estuary, while the sediments in the lowest portion of the estuary are marine-derived sands (Benedetti et al. 2006).

Light Attenuation

The attenuation of solar irradiance through the water column is measured by a logarithmic function (k) per meter. The higher this light attenuation coefficient is the more strongly light is attenuated (reduced through absorbance or reflection) in the water column. River and estuary light attenuation coefficients ranged from 0.74 to 7.10/m and station annual means ranged from 2.23 at M18 to 3.98 at NAV (Table 2.8). Elevated mean and median light attenuation occurred from NC11 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 6,480 μg/L (at ROC) and station annual means ranged from 657 to 2,804 μg/L (at NC403; 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 2,540 μg/L; other elevated TN values were seen at ANC, ROC, 6RC 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 4,430 μg/L (at PB) and station annual means ranged from 24 to 1,858 μg/L (at NC403; Table 2.10). The highest average riverine nitrate levels were at NC11, AC and DP (734-660 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 = 302 μg/L) and the Black River (B210 = 327 μg/L). Lowest river nitrate occurred during late spring and early summer. In general, average concentrations in 2018 for the mainstem river were lower than those of the average from 1995-2017 (Fig. 2.4); although nitrate concentrations post-hurricane (October and November were elevated in the rivers compared with pre-storm values (Table 2.10).

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. In general, the stream stations showed elevated nitrate in late fall and early winter following the massive runoff from the storm in September. 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 1,240 µg/L and station annual means ranged from 53 to 237 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 2018 continued to be 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, 2017 and 2018 (Fig. 2.6). 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 local sewage infrastructure in the densely-developed area immediately surrounding the lake). 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 2018 included ANC, LRC and PB (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 4,200 µg/L and station annual means ranged from 468 to 1,464 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 and COL. As with ammonium, upper groundwater in the White Lake drainage contained high TKN (NC DEQ 2017), some of which may have gone downstream.

Total Phosphorus

Total phosphorus (TP) concentrations ranged from 10 (detection limit) to 1,390 μg/L (at ROC) and station annual means ranged from 45 to 305 μg/L (ROC; Table 2.13). For the mainstem and upper estuary, average TP for 2018 was higher than the 1995-2017 average; at all sites downstream of AC (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; there was an increase at M61, however. 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 480 μg/L and station annual means ranged from 6 to 170 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 2.140. 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 orthophosphate 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 periodically upon request from NCDEQ. 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. There was one metals sample collected in December 2018 at IC and NAV, with no unusual or adversely high concentrations. Two more samples are scheduled for those locations for 2019.

Biological Parameters

Chlorophyll a

During this monitoring period, chlorophyll *a* was low in river and estuary locations (Table 2.15). The state standard was not exceeded in the river or estuary samples in 2018. 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 43 µg/L, and station annual means ranged from 1-13 µg/L, generally low because of high river discharge in 2018 (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 river 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. We note that there were a series of problematic cyanobacterial (blue-green algae) blooms of Microcyctis aeruginosa on the mainstem river in summers of 2009-2012 (Isaacs et al. 2014). For the growing season May-September, long-term (1995-2018) average monthly flow at Lock and Dam #1 was approximately 3,631 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 2018, discharge in May-September (due to the hurricane) was more than triple the 2009-2012 average at 8,590 CFS. Nuisance cyanobacterial blooms did not occur in the river and upper estuary in 2018.

The blooms in 2009-2012 all occurred when average river discharge for May-September was below 1,900 CFS. Algal bloom formation was 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 2018 (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). A stream station bloom exceeding the state standard of 40 µg/L occurred on one occasion at Station SR, and lesser blooms occurred on occasion at PB, N403, ROC, ANC and GS (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 12 to 340 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 2018 (Table 2.17). The Northeast Cape Fear River showed unusually high fecal coliform counts in 2018, with NCF6 and NCF117 both exceeding the standard on three occasions. During 2018 some stream stations showed very high fecal coliform pollution levels. HAM exceeded 200 CFU/100 mL 73% of the time sampled; ROC 64%, BRN 55%, PB and LCO 46%, NC403 and SCH 36% and ANC and LRC 27% of the time sampled. One notably excessive count of 60,000 CFU/100 mL occurred at PB in July, while most other counts stayed below 2,000 CFU/100 mL. 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; but counts were much lesser in 2018 (Fig. 2.5). Overall, 2018 was comparatively better than previous years, despite the hurricane. In fact, at most chronically polluted sites high counts were in spring and summer months before the hurricane, whereas the high counts immediately after the hurricane decreased rapidly after October (Table 2.16; Fig. 2.8). We speculate that the extreme rainfall and river discharge (25,600 CFS at Lock and Dam #1 in September) diluted fecal bacteria counts, despite the CAFO accidents and sewage discharges.

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 2018 this standard was not exceeded in the estuary samples. Geometric mean enterococcus counts for 2018 were lower than those of the 2012-2017 period for the lower Cape Fear Estuary (Fig. 2.8). Overall, elevated fecal coliform and *Enterococcus* counts are problematic in this system, with 61% of the stations rated as Fair or Poor in 2018 (although that was an improvement from 2017).

2.4 - References Cited

APHA. 1995. Standard Methods for the Examination of Water and Wastewater, 19th ed. American Public Health Association, Washington, D.C.

Benedetti, M.M., M.J. Raber, M.S. Smith and L.A. Leonard. 2006. Mineralogical indicators of alluvial sediment sources in the Cape Fear River basin, North Carolina. *Physical Geography* 27:258-281.

Dubbs, L. L. and S.C. Whalen. 2008. Light-nutrient influences on biomass, photosynthetic potential and composition of suspended algal assemblages in the middle Cape Fear River, USA. *International Review of Hydrobiology* 93:711-730.

Ensign, S.H., J.N. Halls and M.A. Mallin. 2004. Application of digital bathymetry data in an analysis of flushing times of two North Carolina estuaries. *Computers and Geosciences* 30:501-511.

Isaacs, J.D., W.K. Strangman, M.A. Mallin, M.R. McIver, and J.L.C. Wright. 2014. Microcystins and two new micropeptin cyanopeptides produced by unprecedented *Microcystis aeruginosa* blooms in North Carolina's Cape Fear River. *Harmful Algae* 31:82-86.

Lin, J. L. Xie, L.J. Pietrafesa, J. Shen, M.A. Mallin and M.J. Durako. 2006. Dissolved oxygen stratification in two microtidal partially-mixed estuaries. *Estuarine, Coastal and Shelf Science.* 70:423-437.

Mallin, M.A., L.B. Cahoon, M.R. McIver, D.C. Parsons and G.C. Shank. 1997. Nutrient limitation and eutrophication potential in the Cape Fear and New River Estuaries. Report No. 313. Water Resources Research Institute of the University of North Carolina, Raleigh, N.C.

Mallin, M.A., L.B. Cahoon, D.C. Parsons and S.H. Ensign. 1998. Effect of organic and inorganic nutrient loading on photosynthetic and heterotrophic plankton communities in blackwater rivers. Report No. 315. Water Resources Research Institute of the University of North Carolina, Raleigh, N.C.

Mallin, M.A., L.B. Cahoon, M.R. McIver, D.C. Parsons and G.C. Shank. 1999. Alternation of factors limiting phytoplankton production in the Cape Fear Estuary. *Estuaries* 22:985-996.

Mallin, M.A., M.H. Posey, M.R. McIver, S.H. Ensign, T.D. Alphin, M.S. Williams, M.L. Moser and J.F. Merritt. 2000. *Environmental Assessment of the Lower Cape Fear River System, 1999-2000.* CMS Report No. 00-01, Center for Marine Science, University of North Carolina at Wilmington, Wilmington, N.C.

Mallin, M.A., L.B. Cahoon, D.C. Parsons and S.H. Ensign. 2001. Effect of nitrogen and phosphorus loading on plankton in Coastal Plain blackwater streams. *Journal of Freshwater Ecology* 16:455-466.

Mallin, M.A., L.B. Cahoon, M.R. McIver and S.H. Ensign. 2002. Seeking science-based nutrient standards for coastal blackwater stream systems. Report No. 341. Water Resources Research Institute of the University of North Carolina, Raleigh, N.C.

Mallin, M.A., M.R. McIver, S.H. Ensign and L.B. Cahoon. 2004. Photosynthetic and heterotrophic impacts of nutrient loading to blackwater streams. *Ecological Applications* 14:823-838.

Mallin, M.A., L.B. Cahoon and M.J. Durako. 2005. Contrasting food-web support bases for adjoining river-influenced and non-river influenced continental shelf ecosystems. *Estuarine, Coastal and Shelf Science* 62:55-62.

Mallin, M.A., V.L. Johnson, S.H. Ensign and T.A. MacPherson. 2006. Factors contributing to hypoxia in rivers, lakes and streams. *Limnology and Oceanography* 51:690-701.

Mallin, M.A., M.R. McIver, A.R. Robuck and A.K. Dickens. 2015. Industrial swine and poultry production causes chronic nutrient and fecal microbial stream pollution. *Water, Air and Soil Pollution* 226:407, DOI 10.1007/s11270-015-2669-y.

NCDEQ 2017. 2017 White Lake Water Quality Investigation, White Lake, Bladen County (Cape Fear Basin). North Carolina Department of Environmental Quality, Division of Water Resources.

U.S. EPA 1997. Methods for the Determination of Chemical Substances in Marine and Estuarine Environmental Matrices, 2nd Ed. EPA/600/R-97/072. National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio.

Welschmeyer, N.A. 1994. Fluorometric analysis of chlorophyll *a* in the presence of chlorophyll *b* and phaeopigments. *Limnology and Oceanography* 39:1985-1993.

Table 2.1 Water temperature (^oC) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	3.0	3.7	4.0	4.0	3.9	4.1	4.2	4.7
FEB	7.9	8.5	8.5	8.8	9.4	9.9	9.3	9.4
MAR	12.4	13.0	12.1	12.8	13.0	13.6	13.1	12.8
APR	15.9	16.0	16.0	16.6	16.6	16.1	15.7	15.1
MAY	25.4	25.7	25.7	25.3	25.4	25.4	25.8	25.3
JUN	27.7	26.7	29.2	27.8	28.6	28.0	27.7	27.2
JUL	30.5	31.3	31.0	31.0	30.7	30.8	30.1	29.9
AUG	27.7	27.8	28.1	27.6	27.9	28.2	28.7	28.6
SEP								
OCT	22.4	22.5	22.6	23.6	23.7	24.4	25.3	25.5
NOV	15.9	16.5	16.2	17.1	17.1	17.3	17.2	19.2
DEC	8.5	8.7	8.3	9.0	9.0	9.9	9.9	12.5
mean	**17.9**	**18.2**	**18.3**	**18.5**	**18.7**	**18.9**	**18.8**	**19.1**
std dev	9.4	9.2	9.5	9.1	9.1	9.0	9.1	8.7
median	15.9	16.5	16.2	17.1	17.1	17.3	17.2	19.2
max	30.5	31.3	31.0	31.0	30.7	30.8	30.1	29.9
min	3.0	3.7	4.0	4.0	3.9	4.1	4.2	4.7

	NC11	AC	DP	BBT	IC	NCF6
JAN	4.4	5.1	4.4	2.4	3.2	4.3
FEB	8.4	8.1	8.0	8.0	8.2	8.5
MAR	11.8	11.9	11.8	13.1	12.3	13.3
APR	15.8	16.5	16.3	16.8	16.2	16.7
MAY	17.9	17.9	18.1	19.8	20.3	20.1
JUN	27.2	27.0	27.3	26.2	27.1	26.0
JUL	28.8	28.9	29.3	28.9	28.7	27.5
AUG	27.1	27.3	27.2	27.3	27.4	26.3
SEP	29.4	29.4	29.2	28.6	29.0	29.4
OCT	25.1	25.1	25.1	25.5	25.4	27.7
NOV	17.0	16.9	17.0	17.5	17.6	18.5
DEC	8.8	8.9	9.0	9.2	9.2	10.5
mean	**18.5**	**18.6**	**18.6**	**18.6**	**18.7**	**19.1**
std dev	8.9	8.8	8.9	9.0	9.0	8.5
median	17.5	17.4	17.6	18.7	19.0	19.3
max	29.4	29.4	29.3	28.9	29.0	29.4
min	4.4	5.1	4.4	2.4	3.2	4.3

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	5.7	3.1	4.5	3.6	3.2	5.2	4.2	8.1	7.5
FEB	11.2	12.0	11.6	11.2	10.3	11.7	12.1	9.1	11.1
MAR	9.2	6.2	8.6	7.3	7.0	9.1	8.3	11.2	11.5
APR	12.6	11.9	13.4	13.2	13.3	13.8	12.3	16.8	16.4
MAY	18.6	18.4	21.0	20.2	18.0	18.6	17.3	18.7	19.9
JUN	23.7	24.1	25.2	24.2	24.6	24.8	23.1	25.0	25.5
JUL	26.0	26.8	26.1	26.8	27.3	26.6	25.8	28.5	28.1
AUG	26.0	25.8	26.0	26.2	26.8	24.9	25.6	26.8	28.2
SEP									
OCT	21.2	24.9	26.6	25.3	24.3	25.3	24.1	25.2	25.8
NOV	8.6	5.3	6.6	7.3	6.1	7.9	6.8	9.6	10.7
DEC	9.5	8.3	9.2	9.6	7.7	10.2	9.7	10.7	10.9
mean	**15.7**	**15.2**	**16.3**	**15.9**	**15.3**	**16.2**	**15.4**	**17.2**	**17.8**
std dev	7.6	9.1	8.8	8.8	9.2	8.1	8.1	7.9	8.0
median	12.6	12.0	13.4	13.2	13.3	13.8	12.3	16.8	16.4
max	26.0	26.8	26.6	26.8	27.3	26.6	25.8	28.5	28.2
min	5.7	3.1	4.5	3.6	3.2	5.2	4.2	8.1	7.5

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	6.8	5.5	7.4	7.3	6.5	5.0	5.8	6.2	6.6
FEB	12.8	13.4	12.9	14.6	14.3	12.7	11.8	12.8	12.0
MAR	10.8	10.8	10.8	11.3	11.4	11.0	13.3	16.7	15.2
APR	18.1	17.2	16.1	16.4	16.5	17.0	17.4	17.8	17.1
MAY	20.0	18.3	19.9	19.0	19.9	20.3	20.5	20.0	19.4
JUN	24.7	23.7	24.0	24.1	24.2	25.0	25.6	24.5	24.1
JUL	27.0	24.8	25.3	25.2	25.4	26.4	27.7	25.2	24.5
AUG	27.0	27.6	25.6	25.5	25.4	25.8	26.9	26.3	26.1
SEP									
OCT	21.8	20.5	20.8	20.9	20.8	20.0	19.2	14.3	12.4
NOV	17.0	18.0	16.2	17.2	17.1	18.0	18.3	19.7	18.6
DEC	10.7	12.0	10.6	11.6	11.9	7.2	7.2	7.9	7.0
mean	**17.9**	**17.4**	**17.2**	**17.6**	**17.6**	**17.1**	**17.6**	**17.4**	**16.6**
std dev	7.0	6.6	6.4	6.1	6.2	7.4	7.5	6.7	6.7
median	18.1	18.0	16.2	17.2	17.1	18.0	18.3	17.8	17.1
max	27.0	27.6	25.6	25.5	25.4	26.4	27.7	26.3	26.1
min	6.8	5.5	7.4	7.3	6.5	5.0	5.8	6.2	6.6

Table 2.2 Salinity (psu) during 2018 at the Lower Cape Fear River Program estuarine stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NCF6	SC-CH
JAN	0.3	3.1	6.3	9.9	11.2	16.4	23.5	26.4	0.1	0.8
FEB	0.1	0.1	0.1	0.8	2.7	8.3	24.2	27.7	0.2	0.1
MAR	0.1	0.6	0.5	3.9	6.3	14.8	21.1	31.4	0.5	1.4
APR	0.1	0.1	2.0	6.0	9.4	14.3	20.0	23.4	0.1	1.0
MAY	0.1	0.1	0.1	0.2	1.8	5.5	13.0	18.6	0.0	0.1
JUN	0.1	0.0	0.1	0.2	1.0	3.1	9.1	16.4	0.0	0.1
JUL	0.3	0.7	2.5	5.9	8.0	13.7	22.4	26.1	0.1	2.4
AUG	0.0	0.0	0.0	0.0	0.1	1.3	7.0	8.2	0.0	0.1
SEP										
OCT	0.0	0.0	0.0	1.0	1.2	3.0	8.1	10.7	0.0	0.1
NOV	0.1	0.6	0.2	2.1	4.8	10.8	16.8	29.6	0.5	0.1
DEC	0.0	0.1	0.1	1.1	3.0	8.7	11.9	26.5	0.0	0.1
mean	**0.1**	**0.5**	**1.1**	**2.8**	**4.5**	**9.1**	**16.1**	**22.3**	**0.1**	**0.6**
std dev	0.1	0.9	1.9	3.2	3.7	5.3	6.5	7.7	0.2	0.8
median	0.1	0.1	0.1	1.1	3.0	8.7	16.8	26.1	0.1	0.1
max	0.3	3.1	6.3	9.9	11.2	16.4	24.2	31.4	0.5	2.4
min	0.0	0.0	0.0	0.0	0.1	1.3	7.0	8.2	0.0	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations 1995-2017 versus 2018.

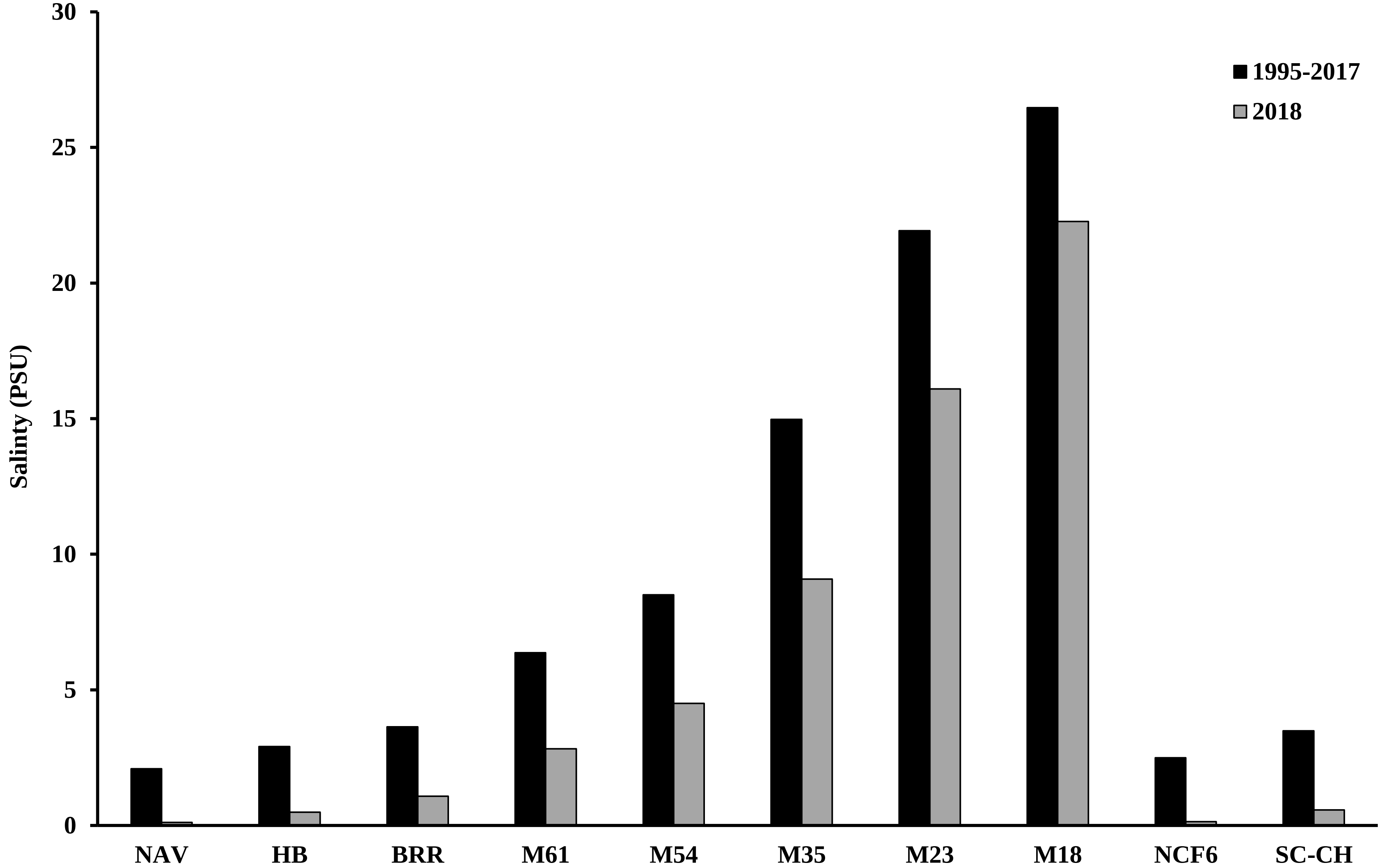


Table 2.3 Conductivity (mS/cm) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	0.67	5.83	11.29	17.09	19.19	27.15	37.85	42.01
FEB	0.15	0.18	0.22	1.51	4.99	14.29	38.25	43.12
MAR	0.16	1.23	0.92	7.08	11.06	24.24	33.72	48.16
APR	0.14	0.24	3.71	10.60	15.86	23.62	32.03	36.94
MAY	0.17	0.17	0.18	0.41	3.52	9.78	21.57	30.13
JUN	0.11	0.09	0.14	0.49	2.00	5.81	15.60	26.78
JUL	0.64	1.41	4.76	10.57	13.96	23.46	35.53	40.94
AUG	0.09	0.09	0.10	0.10	0.16	2.51	12.02	14.22
SEP								
OCT	0.09	0.09	0.09	2.02	2.26	5.61	13.95	18.19
NOV	0.10	1.20	0.43	3.90	8.64	18.19	27.07	45.52
DEC	0.09	0.21	0.12	2.10	5.86	15.04	19.95	41.44
mean	**0.22**	**0.98**	**2.00**	**5.08**	**7.95**	**15.43**	**26.14**	**35.22**
std dev	0.22	1.69	3.48	5.56	6.30	8.62	9.92	11.34
median	0.14	0.21	0.22	2.10	5.86	15.04	27.07	40.94
max	0.67	5.83	11.29	17.09	19.19	27.15	38.25	48.16
min	0.09	0.09	0.09	0.10	0.16	2.51	12.02	14.22

	NC11	AC	DP	BBT	IC	NCF6
JAN	0.15	0.33	0.27	0.15	0.22	0.18
FEB	0.15	0.18	0.18	0.17	0.17	0.31
MAR	0.12	0.13	0.14	0.13	0.14	0.95
APR	0.12	0.11	0.14	0.12	0.13	0.13
MAY	0.10	0.10	0.10	0.09	0.09	0.10
JUN	0.10	0.12	0.15	0.09	0.11	0.07
JUL	0.14	0.13	0.22	0.18	0.16	0.12
AUG	0.07	0.09	0.08	0.09	0.01	0.07
SEP	0.13	0.24	0.16	0.12	0.17	2.75
OCT	0.08	0.08	0.08	0.07	0.07	0.07
NOV	0.10	0.11	0.12	0.11	0.11	1.02
DEC	0.06	0.07	0.07	0.07	0.07	0.08
mean	**0.11**	**0.14**	**0.14**	**0.11**	**0.12**	**0.49**
std dev	0.03	0.08	0.06	0.04	0.06	0.79
median	0.11	0.12	0.14	0.11	0.12	0.12
max	0.15	0.33	0.27	0.18	0.22	2.75
min	0.06	0.07	0.07	0.07	0.01	0.07

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	0.09	0.16	0.15	0.56	0.46	0.12	0.15	0.09	1.61
FEB	0.08	0.16	0.20	0.40	0.85	0.12	0.14	0.11	0.26
MAR	0.08	0.18	0.16	0.57	0.50	0.12	0.14	0.14	2.62
APR	0.11	0.13	0.13	0.34	0.51	0.11	0.12	0.13	1.84
MAY	0.09	0.15	0.13	0.38	1.75	0.11	0.11	0.08	0.12
JUN	0.07	0.18	0.16	0.30	1.24	0.09	0.11	0.08	0.07
JUL	0.07	0.30	0.28	1.59	4.56	0.16	0.18	0.13	4.52
AUG	0.07	0.15	0.14	0.63	2.43	0.15	0.19	0.11	0.26
SEP									
OCT	0.06	0.16	0.15	0.45	0.87	0.13	0.12	0.09	0.17
NOV	0.07	0.16	0.14	0.39	0.47	0.12	0.14	0.10	0.15
DEC	0.08	0.14	0.13	0.33	0.44	0.12	0.13	0.11	0.11
mean	**0.08**	**0.17**	**0.16**	**0.54**	**1.28**	**0.12**	**0.14**	**0.11**	**1.06**
std dev	0.01	0.05	0.04	0.36	1.26	0.02	0.03	0.02	1.45
median	0.08	0.16	0.15	0.40	0.85	0.12	0.14	0.11	0.26
max	0.11	0.30	0.28	1.59	4.56	0.16	0.19	0.14	4.52
min	0.06	0.13	0.13	0.30	0.44	0.09	0.11	0.08	0.07

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.10	0.06	0.08	0.16	0.10	0.13	0.09	0.16	0.14
FEB	0.10	0.06	0.08	0.15	0.11	0.13	0.10	0.16	0.18
MAR	0.10	0.06	0.07	0.14	0.09	0.13	0.08	0.14	0.16
APR	0.09	0.06	0.07	0.11	0.08	0.15	0.08	0.11	0.10
MAY	0.09	0.06	0.08	0.15	0.10	0.17	0.09	0.14	0.17
JUN	0.08	0.06	0.07	0.13	0.10	0.13	0.08	0.12	0.13
JUL	0.09	0.06	0.09	0.16	0.12	0.36	0.11	0.13	0.16
AUG	0.08	0.06	0.06	0.09	0.08	0.10	0.06	0.14	0.11
SEP									
OCT	0.09	0.06	0.07	0.13	0.10	0.15	0.08	0.12	0.18
NOV	0.10	0.05	0.07	0.14	0.10	0.15	0.07	0.12	0.17
DEC	0.07	0.05	0.06	0.11	0.08	0.10	0.06	0.10	0.14
mean	**0.09**	**0.06**	**0.07**	**0.13**	**0.10**	**0.16**	**0.08**	**0.13**	**0.15**
std dev	0.01	0.00	0.01	0.02	0.01	0.07	0.02	0.02	0.03
median	0.09	0.06	0.07	0.14	0.10	0.13	0.08	0.13	0.16
max	0.10	0.06	0.09	0.16	0.12	0.36	0.11	0.16	0.18
min	0.07	0.05	0.06	0.09	0.08	0.10	0.06	0.10	0.10

Table 2.4 pH during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	7.5	7.4	7.5	7.6	7.8	8.0	8.1	8.1
FEB	6.4	6.5	7.0	6.8	7.3	7.7	8.1	8.1
MAR	7.0	7.1	7.1	7.1	7.5	7.9	8.0	7.7
APR	6.9	6.9	6.9	7.1	7.3	7.7	8.0	8.0
MAY	6.7	6.7	6.7	6.6	6.7	7.0	7.5	7.7
JUN	6.4	6.1	6.5	6.2	6.6	6.7	7.1	7.6
JUL	6.5	6.8	6.8	7.0	7.1	7.5	7.9	8.0
AUG	6.2	6.3	6.3	6.0	6.3	6.5	6.9	7.0
SEP								
OCT	6.4	6.5	6.7	6.6	6.8	7.0	7.1	7.4
NOV	6.9	7.3	7.2	7.5	7.4	7.8	8.0	8.0
DEC	7.1	7.1	7.6	7.0	7.6	7.8	7.9	8.0
mean	**6.7**	**6.8**	**6.9**	**6.9**	**7.1**	**7.4**	**7.7**	**7.8**
std dev	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.3
median	6.7	6.8	6.9	7.0	7.3	7.7	7.9	8.0
max	7.5	7.4	7.6	7.6	7.8	8.0	8.1	8.1
min	6.2	6.1	6.3	6.0	6.3	6.5	6.9	7.0

	NC11	AC	DP	BBT	IC	NCF6
JAN	6.4	6.9	6.9	6.4	6.8	6.7
FEB	6.2	6.6	6.7	6.7	6.7	6.4
MAR	6.8	6.9	6.9	6.8	6.9	6.8
APR	6.9	6.9	6.8	6.7	6.8	6.8
MAY	6.7	6.7	6.7	6.4	6.5	6.3
JUN	6.5	6.6	6.7	6	6.4	5.8
JUL	6.7	6.7	6.9	6.6	6.6	5.9
AUG	6.2	6.2	6.2	6.1	6.2	5.7
SEP	6.7	7.0	6.7	6.4	6.6	6.4
OCT	6.4	6.2	6.1	5.8	5.9	5.5
NOV	6.5	6.5	6.7	6.7	6.7	6.6
DEC	6.1	5.8	5.7	5.5	5.6	5.7
mean	**6.5**	**6.6**	**6.6**	**6.3**	**6.5**	**6.2**
std dev	0.3	0.4	0.4	0.4	0.4	0.5
median	6.5	6.7	6.7	6.4	6.6	6.4
max	6.9	7.0	6.9	6.8	6.9	6.8
min	6.1	5.8	5.7	5.5	5.6	5.5

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	4.9	6.4	6.7	6.6	6.6	6.5	6.1	5.9	6.3
FEB	5.2	6.5	6.4	6.7	6.6	6.7	6.5	5.6	6.2
MAR	5.3	6.4	6.9	6.5	6.7	6.9	6.5	6.6	6.5
APR	6.1	6.7	7.0	6.6	6.8	7.0	6.8	6.9	7.2
MAY	6.1	6.7	6.8	6.8	6.6	7.1	6.7	6.1	6.4
JUN	4.8	6.7	6.7	6.4	6.6	6.8	6.6	6.0	6.1
JUL	6	6.8	7.0	7.0	7.0	7.7	7.0	6.5	6.4
AUG	5.7	6.4	6.5	6.6	6.7	7.1	6.9	6.2	6.9
SEP									
OCT	4.3	6.4	6.7	6.6	6.6	6.9	6.4	6.0	6.3
NOV	4.8	6.4	6.8	6.6	6.6	6.3	6.4	5.6	6.3
DEC	5.0	6.5	6.8	6.6	6.7	6.7	6.5	5.9	6.3
mean	**5.3**	**6.5**	**6.8**	**6.6**	**6.7**	**6.9**	**6.6**	**6.1**	**6.4**
std dev	0.6	0.2	0.2	0.2	0.1	0.4	0.3	0.4	0.3
median	5.2	6.5	6.8	6.6	6.6	6.9	6.5	6.0	6.3
max	6.1	6.8	7.0	7.0	7.0	7.7	7.0	6.9	7.2
min	4.3	6.4	6.4	6.4	6.6	6.3	6.1	5.6	6.1

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	5.5	3.6	5.6	6.3	5.9	6.0	5.8	6.4	6.4
FEB	5.4	3.9	5.3	6.3	6.3	6.3	6.0	6.6	6.8
MAR	6.8	4.0	6.1	6.9	6.7	6.7	6.5	5.8	6.2
APR	6.3	4.1	5.9	6.6	6.2	6.6	6.3	6.7	6.5
MAY	6.3	4.0	6.3	7.1	6.9	6.9	6.3	7.1	7.1
JUN	6.1	4.0	5.9	6.8	6.7	6.6	6.2	6.9	6.8
JUL	6.1	4.0	6.3	7.0	6.9	7.0	6.7	6.7	7.0
AUG	6.0	3.9	5.7	6.3	5.7	6.2	5.9	6.9	6.6
SEP									
OCT	6.0	4.1	5.9	6.6	6.5	6.4	6.2	6.3	6.6
NOV	6.0	4.1	5.9	6.6	6.5	6.6	6.3	6.7	6.9
DEC	5.4	3.5	5.1	5.8	5.7	6.6	6.5	6.3	7.0
mean	**6.0**	**3.9**	**5.8**	**6.6**	**6.4**	**6.5**	**6.2**	**6.6**	**6.7**
std dev	0.4	0.2	0.4	0.4	0.4	0.3	0.3	0.4	0.3
median	6.0	4.0	5.9	6.6	6.5	6.6	6.3	6.7	6.8
max	6.8	4.1	6.3	7.1	6.9	7.0	6.7	7.1	7.1
min	5.4	3.5	5.1	5.8	5.7	6.0	5.8	5.8	6.2

Table 2.5 Dissolved Oxygen (mg/l) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	12.7	12.3	12.1	12.1	12.2	12.2	12.0	11.8
FEB	10.5	9.9	10.3	9.1	10.2	10.4	10.3	10.2
MAR	**9.1**	9.0	9.1	8.8	9.1	8.9	9.2	8.3
APR	7.5	7.4	7.3	7.3	7.3	7.6	8.2	8.3
MAY	5.1	4.9	4.9	4.6	4.8	5.6	6.5	6.4
JUN	4.4	3.5	5.0	3.7	4.7	4.5	5.2	5.5
JUL	3.8	4.3	5.2	4.5	4.5	5.5	6.1	6.1
AUG	4.8	5.1	5.1	4.1	4.0	4.0	4.6	4.7
SEP								
OCT	4.8	4.4	4.2	3.8	4.3	4.5	5.2	5.9
NOV	7.5	7.5	7.6	7.2	7.8	8.2	8.2	7.4
DEC	9.4	9.4	9.5	9.5	9.7	9.6	9.7	8.6
mean	**7.2**	**7.1**	**7.3**	**6.8**	**7.1**	**7.4**	**7.7**	**7.6**
std dev	2.9	2.8	2.6	2.8	2.9	2.7	2.4	2.1
median	7.5	7.4	7.3	7.2	7.3	7.6	8.2	7.4
max	12.7	12.3	12.1	12.1	12.2	12.2	12.0	11.8
min	3.8	3.5	4.2	3.7	4.0	4.0	4.6	4.7

	NC11	AC	DP	BBT	IC	NCF6
JAN	12.9	12.6	12.5	13.6	12.9	12.3
FEB	11.5	11.4	11.5	11.3	11.5	10.0
MAR	10.2	10.1	10.0	9.8	9.7	8.6
APR	9.2	8.9	8.3	7.9	8.4	6.6
MAY	7.5	7.2	7.1	5.7	6.2	5.0
JUN	5.9	5.5	5.2	3.7	4.4	2.8
JUL	6.1	5.8	5.9	5.4	5.3	4.2
AUG	6.2	6.0	5.8	4.8	5.1	3.4
SEP	5.4	4.9	4.2	3.5	3.6	3.6
OCT	4.9	4.5	2.6	0.2	0.2	0.2
NOV	8.8	8.8	8.6	8.3	8.0	6.8
DEC	10.1	9.9	9.6	8.8	9.1	8.3
mean	**8.2**	**8.0**	**7.6**	**6.9**	**7.0**	**6.0**
std dev	2.6	2.7	3.0	3.7	3.6	3.4
median	8.2	8.0	7.7	6.8	7.1	5.8
max	12.9	12.6	12.5	13.6	12.9	12.3
min	4.9	4.5	2.6	0.2	0.2	0.2

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	10.0	12.8	13.8	11.7	12.2	13.6	12.3	9.0	10.6
FEB	9.0	10.1	10.7	9.9	9.5	11.4	9.7	9.8	9.3
MAR	11.0	10.8	11.9	11.7	11.4	12.2	11.1	8.4	9.8
APR	8.6	8.4	10.1	8.5	8.8	10.1	8.7	6.6	7.5
MAY	7.0	6.5	7.7	6.4	3.9	8.8	7.5	4.9	5.2
JUN	4.9	5.9	5.4	4.6	4.4	7.4	6.4	3.0	3.5
JUL	3.4	7.1	1.7	3.1	6.6	8.8	4.6	3.2	3.5
AUG	4.1	4.9	2.0	2.6	4.7	6.7	5.1	3.3	4.0
SEP									
OCT	1.7	3.7	3.5	6.5	5.9	7.1	4.5	0.2	0.3
NOV	8.9	11.1	12.1	10.8	10.6	11.6	10.5	7.5	8.1
DEC	8.8	9.8	10.9	9.9	10.2	10.9	9.2	8.0	8.4
mean	**7.0**	**8.3**	**8.2**	**7.8**	**8.0**	**9.9**	**8.1**	**5.8**	**6.4**
std dev	3.0	2.9	4.3	3.3	3.0	2.3	2.7	3.1	3.3
median	8.6	8.4	10.1	8.5	8.8	10.1	8.7	6.6	7.5
max	11.0	12.8	13.8	11.7	12.2	13.6	12.3	9.8	10.6
min	1.7	3.7	1.7	2.6	3.9	6.7	4.5	0.2	0.3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	10.8	9.8	10.5	10.3	10.4	10.8	10.9	12.1	11.5
FEB	8.7	7.1	8.4	8.9	8.6	7.7	8.6	10.3	10.2
MAR	9.6	9.1	9.9	10.0	10.1	9.4	10.4	9.1	9.5
APR	6.5	6.3	7.6	7.6	7.4	6.3	5.1	8.0	7.7
MAY	5.7	6.3	6.9	7.8	7.7	6.9	2.3	7.9	6.4
JUN	4.7	5.1	5.9	6.6	6.8	5.7	4.6	7.2	6.5
JUL	4.4	5.2	4.7	6.4	5.6	5.6	5.4	7.2	5.9
AUG	4.1	4.6	5.6	5.0	5.4	4.8	3.7	6.9	6.1
SEP									
OCT	3.2	3.6	5.5	6.8	6.5	6.1	4.6	9.2	8.2
NOV	6.0	5.4	7.5	8.1	8.0	7.3	5.8	7.8	6.7
DEC	9.0	7.4	8.9	8.5	9.0	11.7	9.8	11.0	11.0
mean	**6.6**	**6.4**	**7.4**	**7.8**	**7.8**	**7.5**	**6.5**	**8.8**	**8.2**
std dev	2.5	1.9	1.9	1.6	1.7	2.2	2.9	1.7	2.1
median	6.0	6.3	7.5	7.8	7.7	6.9	5.4	8.0	7.7
max	10.8	9.8	10.5	10.3	10.4	11.7	10.9	12.1	11.5
min	3.2	3.6	4.7	5.0	5.4	4.8	2.3	6.9	5.9

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations 1995-2017 versus 2018.

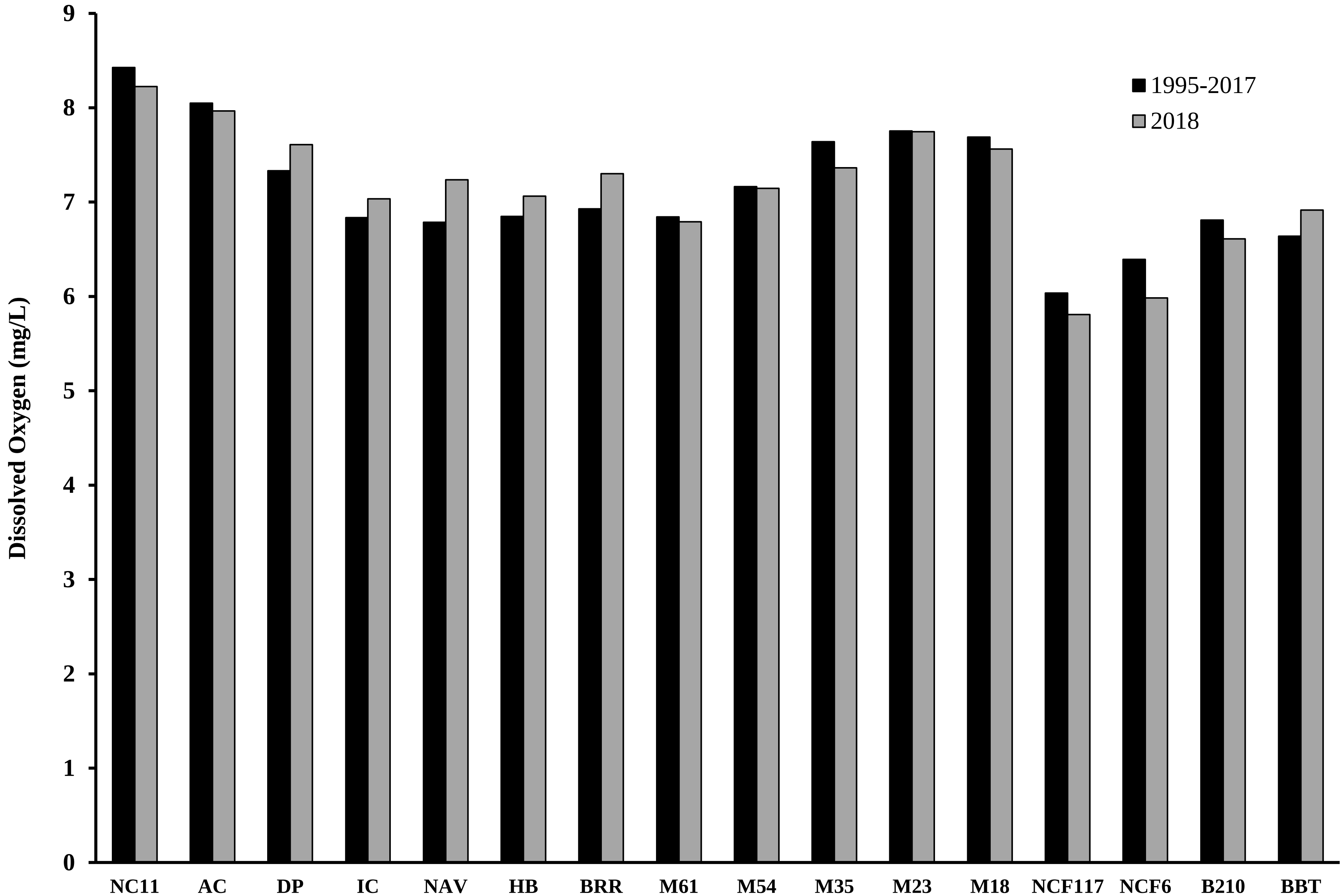


Table 2.6 Field Turbidity (NTU) during 2018 at the Lower Cape Fear River Program stations.

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

	NC11	AC	DP	BBT	IC	NCF6
JAN	5	7	8	5	8	12
FEB	87	85	40	30	22	10
MAR	20	18	18	10	14	6
APR	17	13	11	9	10	6
MAY	28	28	29	9	13	5
JUN	13	12	13	5	7	3
JUL	15	19	11	9	7	6
AUG	30	26	24	13	15	5
SEP	17	16	14	8	14	22
OCT	22	21	13	5	9	6
NOV	23	19	14	11	7	7
DEC	30	30	28	9	17	4
mean	**26**	**25**	**19**	**10**	**12**	**8**
std dev	21	20	10	7	5	5
median	21	19	14	9	12	6
max	87	85	40	30	22	22
min	5	7	8	5	7	3

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

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	5	6	5	13	10	3	8	8	20
FEB	3	3	2	7	3	2	3	6	6
MAR	2	4	1	5	3	2	5	8	7
APR	4	5	8	22	13	4	23	13	22
MAY	5	7	3	5	4	4	18	6	7
JUN	4	7	4	7	6	4	11	5	6
JUL	3	8	7	2	2	3	10	4	6
AUG	2	15	3	4	5	3	5	4	5
SEP									
OCT	2	2	2	7	3	3	3	6	4
NOV	1	2	0	3	1	1	1	4	3
DEC	1	0	0	1	0	0	0	4	3
mean	**3**	**5**	**3**	**7**	**5**	**3**	**8**	**6**	**8**
std dev	1	4	3	6	4	1	7	3	7
median	3	5	3	5	3	3	5	6	6
max	5	15	8	22	13	4	23	13	22
min	1	0	0	1	0	0	0	4	3

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2017 versus 2018.

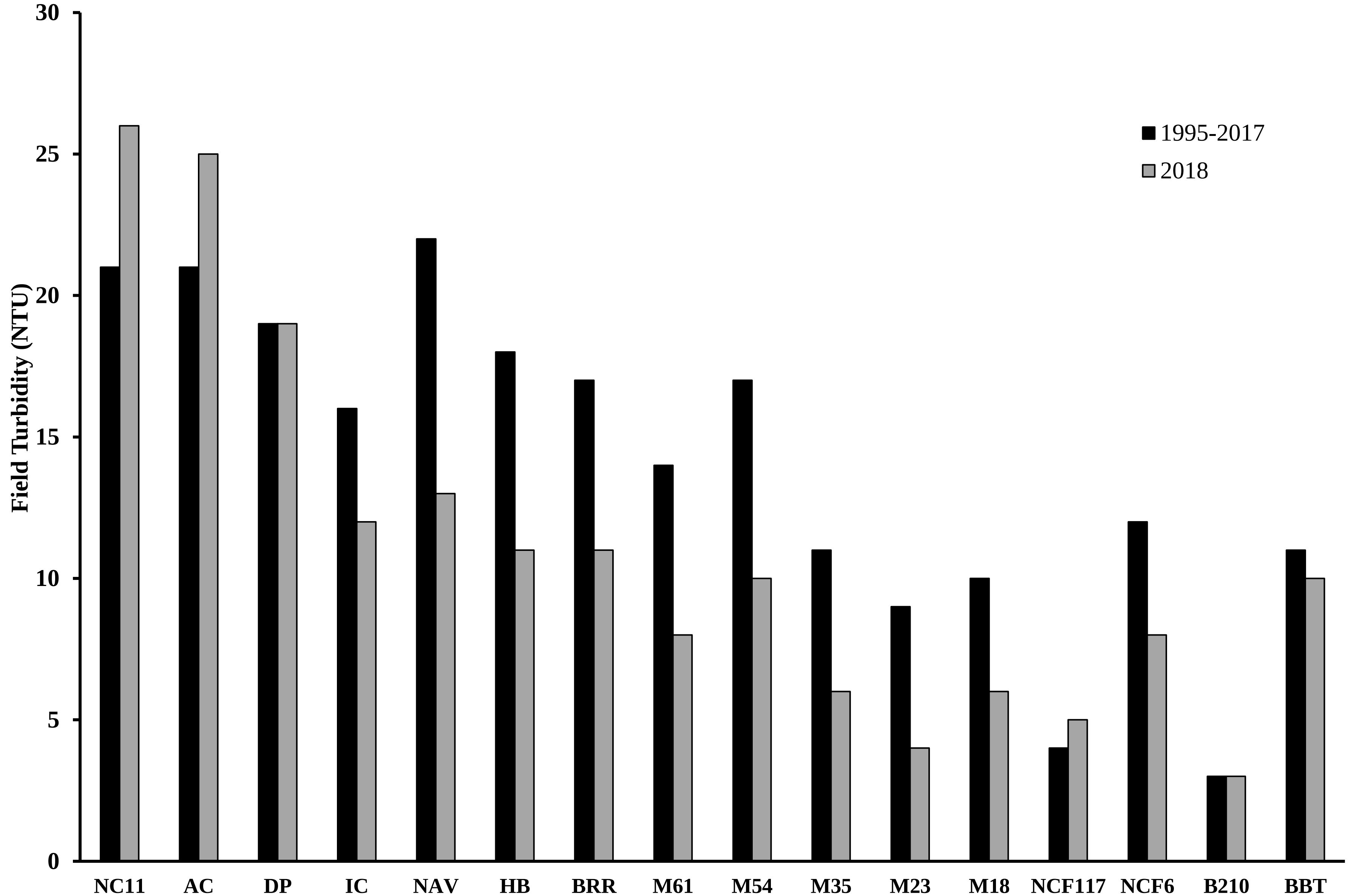


Table 2.7 Total Suspended Solids (mg/L) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	10.8	9.7	8.0	7.6	7.4	9.9	20.3	13.4
FEB	10.6	11.4	11.0	15.8	22.9	11.2	28.9	36.0
MAR	7.3	7.2	12.6	11.6	15.0	15.6	41.4	74.4
APR	10.5	11.6	12.1	9.0	8.5	9.9	11.0	17.4
MAY	6.5	5.4	5.0	9.3	12.1	12.4	10.6	12.7
JUN	4.6	4.3	5.4	4.4	9.0	6.6	6.9	7.9
JUL	5.8	4.1	8.9	7.4	6.8	8.0	9.5	9.0
AUG	27.0	9.1	9.9	9.9	13.3	8.7	7.7	9.4
SEP								
OCT	15.8	8.6	6.9	8.1	8.7	8.8	7.0	8.0
NOV	8.1	8.6	9.6	10.1	11.4	9.1	9.3	24.9
DEC	6.4	5.4	6.2	5.2	17.4	7.1	7.0	39.2
mean	**10.3**	**7.8**	**8.7**	**8.9**	**12.0**	**9.8**	**14.5**	**22.9**
std dev	6.4	2.7	2.6	3.1	4.9	2.6	11.2	20.3
median	8.1	8.6	8.9	9.0	11.4	9.1	9.5	13.4
max	27.0	11.6	12.6	15.8	22.9	15.6	41.4	74.4
min	4.6	4.1	5.0	4.4	6.8	6.6	6.9	7.9

	NC11	AC	DP	IC	NCF6
JAN	1.4	4.5	5.8	5.8	9.3
FEB	85.0	72.5	38.4	17.2	10.4
MAR	27.3	23.3	23.9	15.1	9.4
APR	13.0	8.7	5.6	6.5	7.7
MAY	29.9	30.5	29.9	5.8	4.8
JUN	9.0	8.6	10.7	3.9	3.7
JUL	16.6	16.0	14.3	10.5	10.2
AUG	53.2	36.4	46.2	28.6	6.0
SEP	13.5	8.8	10.9	9.7	41.1
OCT	23.6	27.4	13.3	13.0	14.3
NOV	27.0	21.0	14.8	4.1	7.2
DEC	28.4	28.7	25.0	15.0	1.4
mean	**27.3**	**23.9**	**19.9**	**11.3**	**11.3**
std dev	22.4	18.4	13.0	7.1	7.1
median	25.3	22.2	14.6	10.9	10.1
max	85.0	72.5	46.2	6.8	28.6
min	1.4	4.5	5.6	10.6	3.9

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN		1.4		3.0	6.6	6.6	5.1	7.7	9.3
FEB		3.4		3.5	5.7	9.5	6.2	3.5	10.2
MAR		1.4		5.1	6.7	1.4	5.6	3.1	12.7
APR		3.4		4.3	5.2	3.8	13.0	4.2	11.7
MAY		5.9		6.1	5.9	1.4	7.8	5.4	13.0
JUN		9.9		6.3	6.0	7.5	12.9	2.9	15.6
JUL		1.3		5.8	10.8	1.3	19.0	7.0	7.2
AUG		9.0		4.0	7.3	1.5	4.1	5.5	15.8
SEP									
OCT		6.2		8.3	6.3	4.0	6.6	16.1	13.3
NOV		1.3		1.3	2.9	1.3	1.3	1.4	5.6
DEC		1.5		1.3	1.4	1.4	1.3	1.3	7.8
mean		**4.1**		**4.5**	**5.9**	**3.6**	**7.5**	**5.3**	**11.1**
std dev		3.2		2.2	2.4	3.0	5.4	4.1	3.4
median		3.4		4.3	6.0	1.5	6.2	4.2	11.7
max		9.9		8.3	10.8	9.5	19.0	16.1	15.8
min		1.3		1.3	1.4	1.3	1.3	1.3	5.6

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1.8					1.4			
FEB	1.3					1.4			
MAR	1.4					1.5			
APR	3.5					5.8			
MAY	4.2					3.7			
JUN	3.9					5.4			
JUL	1.3					1.3			
AUG	4.2					4.1			
SEP									
OCT	1.4					4.3			
NOV	1.3					1.3			
DEC	1.3					1.8			
mean	**2.3**					**2.9**			
std dev	1.3					1.8			
median	1.4					1.8			
max	4.2					5.8			
min	1.3					1.3			

Table 2.8 Light Attenuation (k) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN								
FEB	3.55	4.54	4.37	3.62	4.01	2.20	2.19	2.44
MAR								
APR	3.75	3.37	3.06	2.49	2.55	1.96	1.41	1.11
MAY		3.01	2.75		3.65		2.25	1.96
JUN	4.06	4.09	3.20	3.95	3.96	3.54	2.53	2.74
JUL		3.33	3.12	3.66	3.09	2.52	1.73	1.90
AUG	4.56	4.02	3.48	2.71	4.62	3.72	3.31	3.24
SEP								
OCT								
NOV								
DEC								
mean	**3.98**	**3.73**	**3.33**	**3.29**	**3.65**	**2.79**	**2.24**	**2.23**
std dev	0.44	0.58	0.56	0.64	0.73	0.80	0.66	0.74
max	4.56	4.54	4.37	3.95	4.62	3.72	3.31	3.24
min	3.55	3.01	2.75	2.49	2.55	1.96	1.41	1.11

	NC11	AC	DP	BBT	IC	NCF6
JAN						
FEB	7.10	6.42	4.52	3.64	3.05	4.22
MAR	3.23	3.45	3.08	2.95	2.68	4.16
APR	2.83	2.67	2.90	2.79	2.91	3.46
MAY	4.02	4.23	3.63	3.74	3.58	3.90
JUN	2.60	2.99	3.31	4.20	3.30	3.86
JUL	2.67	2.65	2.87			
AUG	4.78	4.75	4.36	3.78	4.47	4.58
SEP	1.00	1.13	1.44	1.02	1.33	1.03
OCT	1.72	1.76	0.74	0.75	1.54	1.31
NOV						
DEC						
mean	**3.33**	**3.34**	**2.98**	**2.86**	**2.86**	**3.32**
std dev	1.80	1.61	1.24	1.30	1.03	1.36
max	7.10	6.42	4.52	4.20	4.47	4.58
min	1.00	1.13	0.74	0.75	1.33	1.03

Table 2.9 Total Nitrogen (µg/l) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	1,630	1,090	940	950	890	580	370	510
FEB	1,630	1,920	1,620	1,550	1,600	1,020	680	850
MAR	1,360	1,290	1,400	1,240	1,200	1,330	580	920
APR	1,200	1,190	1,290	1,050	830	730	480	630
MAY	760	1,540	1,530	1,120	1,100	900	650	680
JUN	1,050	1,230	1,190	1,080	1,140	1,070	760	780
JUL	890	740	440	350	420	210	50	50
AUG	970	930	1,030	950	970	920	770	650
SEP								
OCT	1,960	2,020	1,930	1,760	1,480	1,340	1,140	780
NOV	1,610	1,390	1,480	1,400	1,330	1,350	1,280	1,260
DEC	820	900	910	810	780	830	580	120
mean	**1,262**	**1,295**	**1,251**	**1,115**	**1,067**	**935**	**667**	**657**
std dev	401	405	409	380	338	350	337	344
median	1,200	1,230	1,290	1,080	1,100	920	650	680
max	1,960	2,020	1,930	1,760	1,600	1,350	1,280	1,260
min	760	740	440	350	420	210	50	50

	NC11	AC	DP	IC	NCF6
JAN	1,870	1,880	1,750	1,350	1,070
FEB	2,330	2,190	1,880	1,730	1,200
MAR	1,700	1,590	1,430	1,330	950
APR	1,510	1,480	1,620	1,330	1,110
MAY	1,370	1,330	1,630	1,890	1,790
JUN	1,160	1,040	1,150	970	670
JUL	1,470	1,640	1,480	1,480	840
AUG	1,580	1,080	1,130	980	1,000
SEP	1,860	1,980	1,460	1,530	1,320
OCT	1,110	910	1,010	1,010	1,700
NOV	1,390	1,640	1,640	1,670	1,470
DEC	1,060	880	940	1,070	970
mean	**1,534**	**1,470**	**1,427**	**1,362**	**1,174**
std dev	367	430	304	311	340
median	1,490	1,535	1,470	1,340	1,090
max	2,330	2,190	1,880	1,890	1,790
min	1,060	880	940	970	670

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	3,000	1,900	670	2,520	2,020	2,360	2,070	1,410	950
FEB	1,480	1,120	1,940	3,960	4,100	1,650	2,050	1,220	700
MAR	2,240	1,230	680	2,310	1,680	960	1,170	1,490	1,010
APR	2,130	1,430	930	2,950	2,270	1,350	1,630	1,440	820
MAY	720	1,230	930	2,540	1,360	2,200	1,510	1,600	1,880
JUN	1,120	1,290	630	1,600	960	1,370	1,280	870	910
JUL	1,630	910	1,300	1,270	800	350	6,480	1,140	800
AUG	1,690	1,140	1,100	1,280	2,490	1,210	2,890	1,160	1,010
SEP									
OCT	2,530	1,520	1,640	2,970	2,110	1,170	2,140	2,750	1,840
NOV	1,820	1,550	960	4,540	4,820	1,290	1,790	1,090	710
DEC	1,130	1,170	950	4,900	5,430	1,260	1,850	1,450	1,070
mean	**1,772**	**1,317**	**1,066**	**2,804**	**2,549**	**1,379**	**2,260**	**1,420**	**1,064**
std dev	670	269	413	1,237	1,555	551	1,476	490	412
median	1,690	1,230	950	2,540	2,110	1,290	1,850	1,410	950
max	3,000	1,900	1,940	4,900	5,430	2,360	6,480	2,750	1,880
min	720	910	630	1,270	800	350	1,170	870	700

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	950	1,040	1,140	2,150	1,630	1,030	820	1,570	2,030
FEB	870	820	480	1,550	1,320	850	550	1,280	1,260
MAR	820	1,000	590	1,370	1,280	820	850	920	840
APR	850	800	720	2,040	1,090	1,220	1,130	930	1,350
MAY	970	1,100	950	2,030	960	1,580	1,540	1,080	900
JUN	890	1,100	830	1,640	850	1,040	1,170	870	870
JUL	1,230	1,940	900	960	960	1,300	1,310	1,060	1,560
AUG	1,440	2,140	1,590	1,400	1,410	860	1,450	1,280	1,430
SEP									
OCT	1,530	2,020	1,560	2,310	1,350	1,480	1,110	1,750	910
NOV	1,280	1,900	1,250	1,790	1,400	1,360	1,050	1,740	970
DEC	1,470	750	950	2,560	1,840	1,420	660	1,630	1,820
mean	**1,118**	**1,328**	**996**	**1,800**	**1,281**	**1,178**	**1,058**	**1,283**	**1,267**
std dev	276	548	361	470	300	272	314	339	412
median	970	1,100	950	1,790	1,320	1,220	1,110	1,280	1,260
max	1,530	2,140	1,590	2,560	1,840	1,580	1,540	1,750	2,030
min	820	750	480	960	850	820	550	870	840

Table 2.10 Nitrate/Nitrite (μg/l) during 2018 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	630	490	440	350	390	280	170	110
FEB	630	620	620	550	500	420	180	50
MAR	660	590	600	540	500	330	80	20
APR	500	490	490	350	330	230	180	130
MAY	760	640	630	320	400	300	250	180
JUN	450	330	490	380	440	370	260	180
JUL	690	640	440	350	320	210	90	50
AUG	370	430	430	250	270	220	170	150
SEP								
OCT	760	720	630	560	580	440	240	180
NOV	610	490	580	500	430	350	280	60
DEC	420	400	410	410	380	330	380	120
mean	**589**	**531**	**524**	**415**	**413**	**316**	**207**	**112**
std dev	135	120	89	106	90	77	87	59
median	630	490	490	380	400	330	180	120
max	760	720	630	560	580	440	380	180
min	370	330	410	250	270	210	80	20

	NC11	AC	DP	IC	NCF6
JAN	1,170	980	850	650	270
FEB	930	1,090	980	930	400
MAR	700	690	730	630	250
APR	710	680	520	530	210
MAY	570	530	530	490	390
JUN	660	640	650	470	270
JUL	870	1,040	880	860	140
AUG	480	480	430	380	200
SEP	1,060	880	760	530	220
OCT	410	410	310	110	10
NOV	690	740	740	670	470
DEC	560	580	540	570	570
mean	**734**	**728**	**660**	**568**	**283**
std dev	231	224	199	213	152
median	695	685	690	550	260
max	1,170	1,090	980	930	570
min	410	410	310	110	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1,200	900	170	1,820	1,320	1,260	1,170	510	250
FEB	280	520	1,040	3,160	3,200	1,050	1,050	520	300
MAR	240	530	80	1,510	880	260	370	290	210
APR	630	330	30	1,650	970	250	430	240	120
MAY	120	330	30	1,340	160	500	610	300	380
JUN	220	690	30	1,000	360	670	580	270	210
JUL	130	210	10	270	10	350	2,280	240	200
AUG	90	140	10	380	990	410	1,690	160	110
SEP									
OCT	30	220	40	1,670	1,010	170	540	50	40
NOV	220	850	360	3,740	3,920	690	1,090	290	210
DEC	230	570	350	3,900	4,430	560	950	450	370
mean	**308**	**481**	**195**	**1,858**	**1,568**	**561**	**978**	**302**	**218**
std dev	334	259	309	1,238	1,543	342	584	143	105
median	220	520	40	1,650	990	500	950	290	210
max	1,200	900	1,040	3,900	4,430	1,260	2,280	520	380
min	30	140	10	270	10	170	370	50	40

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	250	40	440	1,050	730	330	120	770	930
FEB	370	20	80	850	720	250	50	680	560
MAR	220	10	90	670	480	220	50	320	240
APR	250	10	220	1,140	490	520	230	230	550
MAY	270	10	250	1,130	360	680	340	480	200
JUN	290	10	230	1,040	350	340	370	370	370
JUL	230	40	400	460	260	500	110	460	160
AUG	140	40	90	300	210	60	50	480	230
SEP									
OCT	330	20	460	1,210	450	480	110	950	310
NOV	380	10	250	590	400	360	50	840	170
DEC	870	50	350	1,860	1,340	920	160	830	1,120
mean	**327**	**24**	**260**	**936**	**526**	**424**	**149**	**583**	**440**
std dev	193	16	139	431	316	235	116	241	323
median	270	20	250	1,040	450	360	110	480	310
max	870	50	460	1,860	1,340	920	370	950	1,120
min	140	10	80	300	210	60	50	230	160

Figure 2.4 Nitrate + Nitrite at the Lower Cape Fear River Program mainstem stations, 1995-2017 versus 2018.

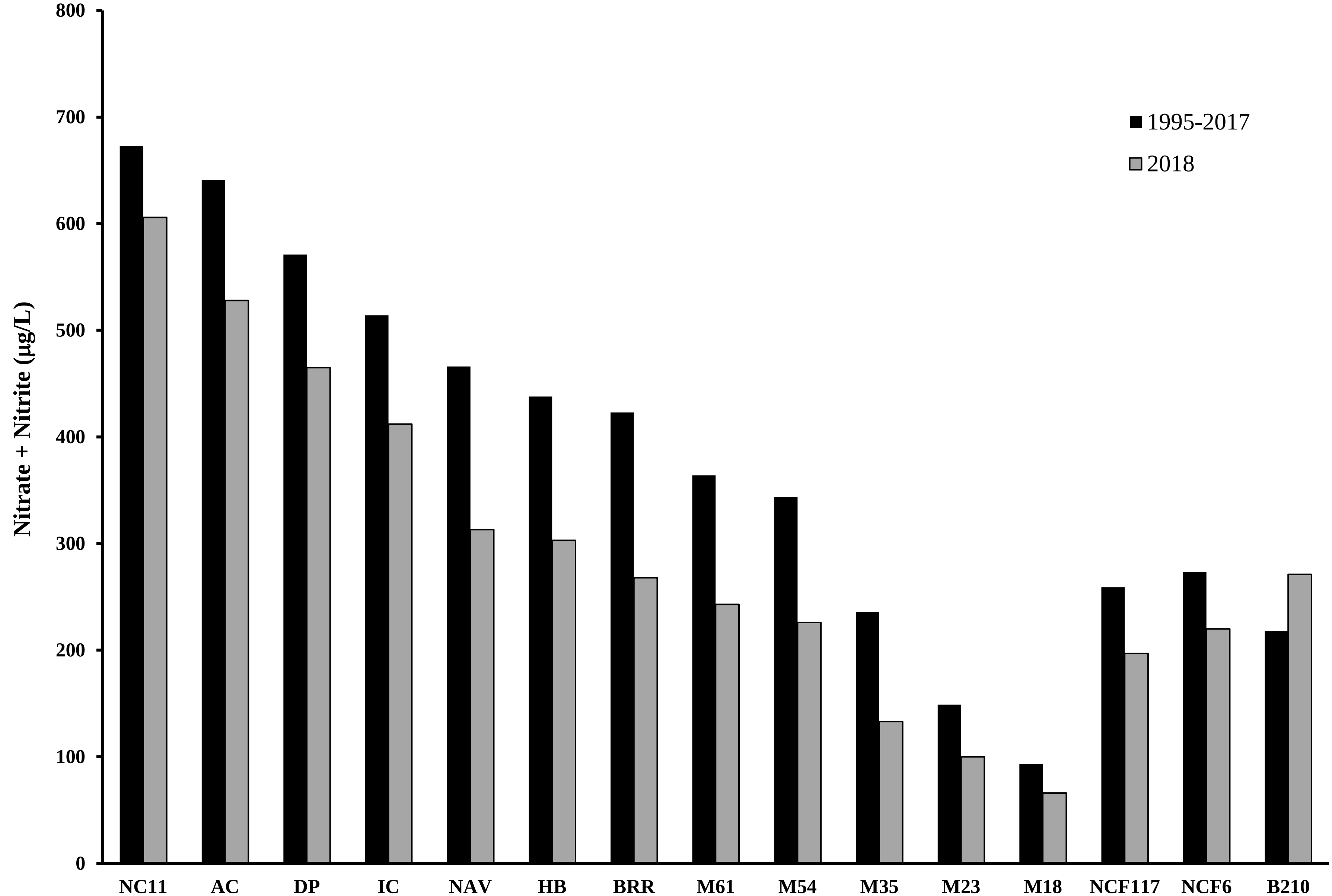


Table 2.11 Ammonia (µg/l) during 2018 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	100	150	170	170	200	160	80	50
FEB	110	100	130	110	200	110	10	10
MAR	30	60	60	70	100	40	10	10
APR	90	100	90	90	90	80	60	10
MAY	130	150	130	90	110	130	110	90
JUN	80	80	70	90	210	120	100	80
JUL	60	70	10	60	70	30	10	10
AUG	110	80	150	170	200	140	150	90
SEP								
OCT	140	140	160	230	200	210	190	200
NOV	90	90	130	110	120	60	10	170
DEC	80	60	150	90	120	60	10	120
mean	**93**	**98**	**114**	**116**	**147**	**104**	**67**	**76**
std dev	31	34	50	52	54	55	64	67
median	90	90	130	90	120	110	60	80
max	140	150	170	230	210	210	190	200
min	30	60	10	60	70	30	10	10

	NC11	AC	DP	IC	NCF6
JAN	80	160	150	110	80
FEB	50	70	50	50	50
MAR	90	110	100	110	80
APR	110	110	110	100	30
MAY	90	110	100	70	80
JUN	110	120	190	130	100
JUL	150	160	160	110	100
AUG	140	110	80	100	120
SEP	80	280	140	100	50
OCT	50	40	70	50	170
NOV	90	80	90	90	100
DEC	90	50	60	20	30
mean	**94**	**117**	**108**	**87**	**83**
std dev	30	64	43	32	40
median	90	110	100	100	80
max	150	280	190	130	170
min	50	40	50	20	30

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	70	60	40	90	160	90	270	80	110
FEB	180	20	10	70	130	80	320	40	130
MAR	40	30	10	70	60	70	120	50	50
APR	200	30	20	140	210	100	120	80	60
MAY	130	80	40	130	1,240	300	190	120	160
JUN	240	60	40	110	290	390	70	170	110
JUL	230	70	50	200	70	60	10	80	130
AUG	170	80	50	100	80	60	110	580	100
SEP									
OCT	540	260	310	170	180	200	380	320	380
NOV	330	10	10	120	50	50	30	30	30
DEC	450	100	30	130	140	240	240	100	130
mean	**235**	**73**	**55**	**121**	**237**	**149**	**169**	**150**	**126**
std dev	153	68	86	40	340	116	121	164	93
median	200	60	40	120	140	90	120	80	110
max	540	260	310	200	1,240	390	380	580	380
min	40	10	10	70	50	50	10	30	30

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	30	20	20	70	10	10	10	40	40
FEB	10	40	10	60	20	20	10	70	280
MAR	40	70	50	60	50	40	40	90	120
APR	20	40	10	170	50	60	240	40	120
MAY	180	400	70	100	80	100	620	100	260
JUN	60	280	40	60	40	100	90	50	60
JUL	80	340	70	30	50	70	320	70	50
AUG	130	170	90	90	90	80	90	130	120
SEP									
OCT	170	570	150	110	110	90	100	140	70
NOV	80	240	70	70	70	60	50	100	40
DEC	30	90	30	130	10	10	10	100	80
mean	**75**	**205**	**55**	**86**	**53**	**58**	**144**	**85**	**113**
std dev	60	178	41	39	33	34	187	34	84
median	60	170	50	70	50	60	90	90	80
max	180	570	150	170	110	100	620	140	280
min	10	20	10	30	10	10	10	40	40

Figure 2.5 Ammonia and Fecal Coliform Bacteria at COL 2010-2018.

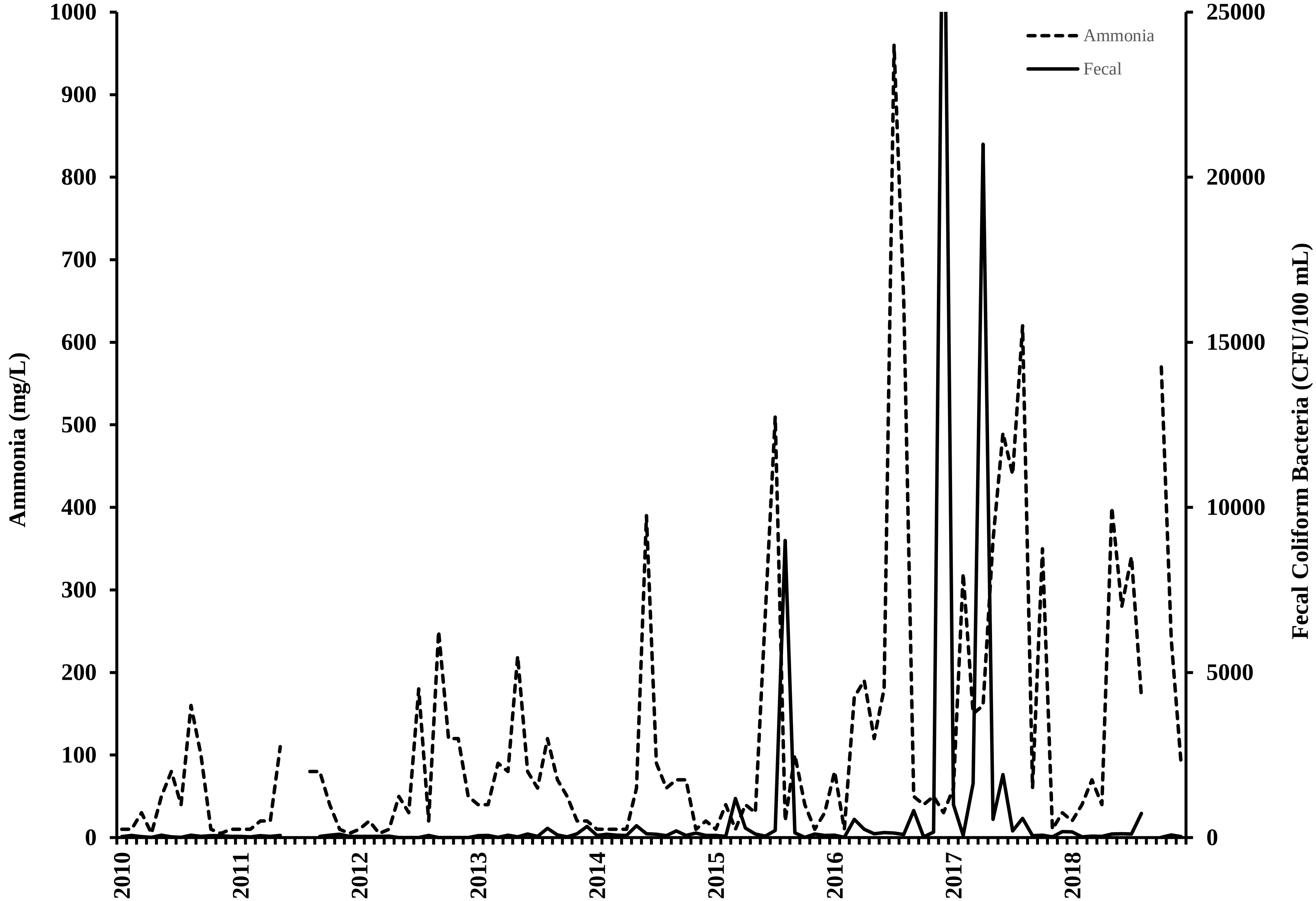


Table 2.12 Total Kjeldahl Nitrogen (µg/l) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	1,000	600	500	600	500	300	200	400
FEB	1,000	1,300	1,000	1,000	1,100	600	500	800
MAR	700	700	800	700	700	1,000	500	900
APR	700	700	800	700	500	500	300	500
MAY	50	900	900	800	700	600	400	500
JUN	600	900	700	700	700	700	500	600
JUL	200	100	50	50	100	50	50	50
AUG	600	500	600	700	700	700	600	500
SEP								
OCT	1,200	1,300	1,300	1,200	900	900	900	600
NOV	1,000	900	900	900	900	1,000	1,000	1,200
DEC	400	500	500	400	400	500	200	50
mean	**677**	**764**	**732**	**705**	**655**	**623**	**468**	**555**
std dev	360	353	324	302	273	289	290	338
median	700	700	800	700	700	600	500	500
max	1,200	1,300	1,300	1,200	1,100	1,000	1,000	1,200
min	50	100	50	50	100	50	50	50

	NC11	AC	DP	IC	NCF6
JAN	700	900	900	700	800
FEB	1,400	1,100	900	800	800
MAR	1,000	900	700	700	700
APR	800	800	1,100	800	900
MAY	800	800	1,100	1,400	1,400
JUN	500	400	500	500	400
JUL	600	600	600	600	700
AUG	1,100	600	700	600	800
SEP	800	1,100	700	1,000	1,100
OCT	700	500	700	900	1,700
NOV	700	900	900	1,000	1,000
DEC	500	300	400	500	400
mean	**800**	**742**	**767**	**792**	**892**
std dev	259	261	219	257	375
median	750	800	700	750	800
max	1,400	1,100	1,100	1,400	1,700
min	500	300	400	500	400

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1,800	1,000	500	700	700	1,100	900	900	700
FEB	1,200	600	900	800	900	600	1,000	700	400
MAR	2,000	700	600	800	800	700	800	1,200	800
APR	1,500	1,100	900	1,300	1,300	1,100	1,200	1,200	700
MAY	600	900	900	1,200	1,200	1,700	900	1,300	1,500
JUN	900	600	600	600	600	700	700	600	700
JUL	1,500	700	1,300	1,000	800	50	4,200	900	600
AUG	1,600	1,000	1,100	900	1,500	800	1,200	1,000	900
SEP									
OCT	2,500	1,300	1,600	1,300	1,100	1,000	1,600	2,700	1,800
NOV	1,600	700	600	800	900	600	700	800	500
DEC	900	600	600	1,000	1,000	700	900	1,000	700
mean	**1,464**	**836**	**873**	**945**	**982**	**823**	**1,282**	**1,118**	**845**
std dev	545	238	347	238	271	412	1,003	567	425
median	1,500	700	900	900	900	700	900	1,000	700
max	2,500	1,300	1,600	1,300	1,500	1,700	4,200	2,700	1,800
min	600	600	500	600	600	50	700	600	400

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	700	1,000	700	1,100	900	700	700	800	1,100
FEB	500	800	400	700	600	600	500	600	700
MAR	600	1,000	500	700	800	600	800	600	600
APR	600	800	500	900	600	700	900	700	800
MAY	700	1,100	700	900	600	900	1,200	600	700
JUN	600	1,100	600	600	500	700	800	500	500
JUL	1,000	1,900	500	500	700	800	1,200	600	1,400
AUG	1,300	2,100	1,500	1,100	1,200	800	1,400	800	1,200
SEP									
OCT	1,200	2,000	1,100	1,100	900	1,000	1,000	800	600
NOV	900	1,900	1,000	1,200	1,000	1,000	1,000	900	800
DEC	600	700	600	700	500	500	500	800	700
mean	**791**	**1,309**	**736**	**864**	**755**	**755**	**909**	**700**	**827**
std dev	270	545	332	238	225	163	288	126	283
median	700	1,100	600	900	700	700	900	700	700
max	1,300	2,100	1,500	1,200	1,200	1,000	1,400	900	1,400
min	500	700	400	500	500	500	500	500	500

Table 2.13 Total Phosphorus (µg/l) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	140	120	90	80	60	50	30	40
FEB	60	90	80	100	90	60	40	40
MAR	280	260	180	320	170	270	190	180
APR	100	120	130	50	40	40	40	80
MAY	130	100	90	90	80	70	30	30
JUN	100	140	270	270	160	120	110	80
JUL	210	150	130	130	110	270	90	90
AUG	210	160	230	250	330	180	180	210
SEP								
OCT	190	230	200	250	160	90	90	70
NOV	130	120	140	180	80	80	100	80
DEC	100	80	90	70	80	60	70	110
mean	**150**	**143**	**148**	**163**	**124**	**117**	**88**	**92**
std dev	62	54	61	91	77	81	53	54
median	130	120	130	130	90	80	90	80
max	280	260	270	320	330	270	190	210
min	60	80	80	50	40	40	30	30

	NC11	AC	DP	IC	NCF6
JAN	130	70	210	190	230
FEB	210	210	160	160	70
MAR	230	220	220	190	140
APR	100	120	80	120	70
MAY	140	180	170	200	210
JUN	140	130	160	150	130
JUL	230	220	270	170	150
AUG	170	170	220	130	130
SEP	210	260	160	170	250
OCT	150	150	200	220	390
NOV	80	110	90	80	100
DEC	140	110	90	80	80
mean	**161**	**163**	**169**	**155**	**155**
std dev	48	55	57	43	90
median	145	160	165	165	135
max	230	260	270	220	220
min	80	70	80	80	80

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	390	70	40	70	140	90	100	160	70
FEB	200	60	40	80	90	60	40	60	70
MAR	90	60	40	120	100	80	50	70	50
APR	280	170	60	150	190	160	150	60	30
MAY	120	170	170	210	230	130	210	140	140
JUN	400	180	160	250	240	150	220	240	190
JUL	270	300	310	220	240	10	1,390	120	70
AUG	240	200	220	190	380	110	460	200	120
SEP									
OCT	380	350	380	250	370	170	430	430	360
NOV	140	40	60	110	160	60	160	70	80
DEC	120	390	140	170	220	110	150	100	210
mean	**239**	**181**	**147**	**165**	**215**	**103**	**305**	**150**	**126**
std dev	110	116	111	62	91	47	367	105	92
median	240	170	140	170	220	110	160	120	80
max	400	390	380	250	380	170	1,390	430	360
min	90	40	40	70	90	10	40	60	30

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	50	70	10	140	50	100	40	50	70
FEB	30	40	10	90	30	110	30	30	80
MAR	50	70	10	50	10	150	10	40	80
APR	110	70	60	240	120	370	100	130	170
MAY	120	110	60	210	90	530	80	110	260
JUN	150	140	40	160	90	390	90	100	140
JUL	170	240	80	170	160	600	120	80	360
AUG	180	160	80	180	90	290	100	100	160
SEP									
OCT	160	230	80	180	90	280	90	100	180
NOV	80	180	10	110	10	210	10	60	110
DEC	80	140	60	90	50	20	20	70	20
mean	**107**	**132**	**45**	**147**	**72**	**277**	**63**	**79**	**148**
std dev	50	64	29	55	44	175	39	30	92
median	110	140	60	160	90	280	80	80	140
max	180	240	80	240	160	600	120	130	360
min	30	40	10	50	10	20	10	30	20

Figure 2.5 Total Phosphorus at the Lower Cape Fear River Program mainstem stations, 1995-2017 versus 2018.

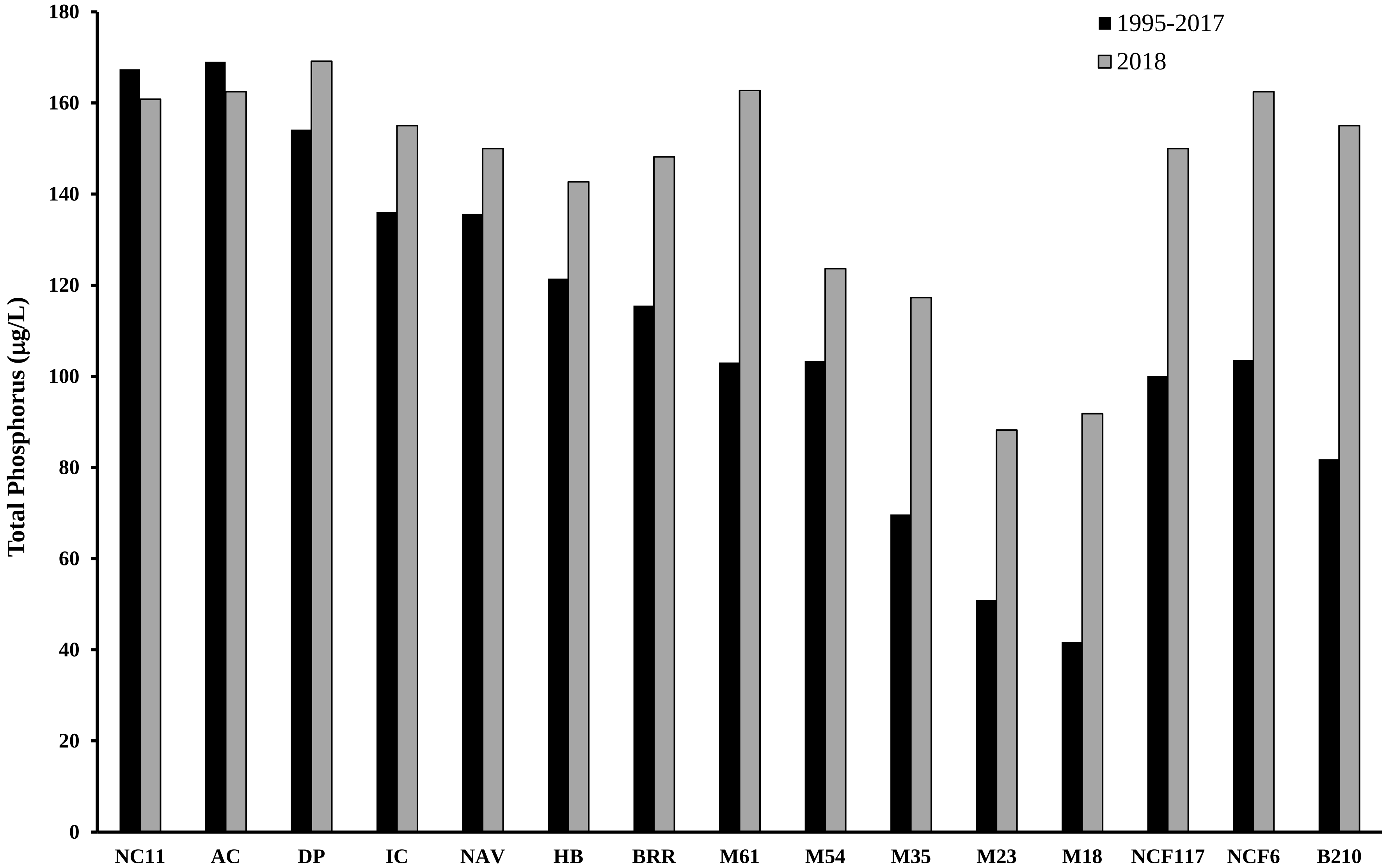


Table 2.14 Orthophosphate (μg/l) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	50	30	30	30	30	20	10	10
FEB	30	60	40	60	50	40	30	20
MAR	20	30	20	40	30	20	10	10
APR	40	40	30	30	20	20	10	10
MAY	40	30	40	20	40	20	20	10
JUN	30	60	40	60	50	40	30	20
JUL	60	60	40	40	40	30	20	10
AUG	30	30	40	50	50	30	30	30
SEP								
OCT	70	70	70	70	60	50	40	30
NOV	30	30	30	20	20	20	20	10
DEC	20	30	20	30	30	20	20	10
mean	**38**	**43**	**36**	**41**	**38**	**28**	**22**	**15**
std dev	16	16	14	17	13	11	10	8
median	30	30	40	40	40	20	20	10
max	70	70	70	70	60	50	40	30
min	20	30	20	20	20	20	10	10

	NC11	AC	DP	BBT	IC	NCF6
JAN	110	100	80	20	50	10
FEB	50	40	50	40	40	80
MAR	30	40	50	50	60	20
APR	40	30	30	20	40	20
MAY	30	30	30	30	30	50
JUN	50	40	50	40	40	80
JUL	70	90	100	80	80	30
AUG	30	40	40	50	40	50
SEP	70	110	60	50	50	50
OCT	30	30	20	70	40	90
NOV	20	30	30	30	30	30
DEC	30	40	30	20	20	30
mean	**47**	**52**	**48**	**42**	**43**	**45**
std dev	26	30	23	19	16	26
median	35	40	45	40	40	40
max	110	110	100	80	80	90
min	20	30	20	20	20	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	240	10	5	10	20	10	20	70	10
FEB	240	40	20	20	70	50	40	60	60
MAR	120	10	10	20	20	10	10	20	5
APR	220	10	10	30	30	10	40	20	10
MAY	130	30	30	30	20	10	40	40	50
JUN	240	40	20	20	70	50	40	60	60
JUL	130	30	10	20	5	20	480	40	20
AUG	120	50	40	40	20	20	150	60	10
SEP									
OCT	230	80	60	60	120	40	180	60	60
NOV	70	10	10	20	20	10	50	20	20
DEC	130	20	20	30	70	30	80	20	50
mean	**170**	**30**	**21**	**27**	**42**	**24**	**103**	**43**	**32**
std dev	64	22	16	13	35	16	136	20	23
median	130	30	20	20	20	20	40	40	20
max	240	80	60	60	120	50	480	70	60
min	70	10	5	10	5	10	10	20	5

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	20	30	5	50	10	50	5	10	10
FEB	50	70	10	40	20	150	5	30	40
MAR	10	20	20	20	5	50	5	10	20
APR	30	50	5	30	20	170	5	10	30
MAY	40	70	10	40	20	230	10	20	40
JUN	50	70	10	40	20	150	5	30	40
JUL	50	90	20	60	30	300	5	10	40
AUG	60	40	10	60	20	140	5	10	50
SEP									
OCT	70	170	40	70	30	130	10	10	50
NOV	20	70	10	30	20	80	10	10	20
DEC	20	50	10	30	10	20	5	20	20
mean	**38**	**66**	**14**	**43**	**19**	**134**	**6**	**15**	**33**
std dev	19	40	10	16	8	83	2	8	13
median	40	70	10	40	20	140	5	10	40
max	70	170	40	70	30	300	10	30	50
min	10	20	5	20	5	20	5	10	10

Table 2.15 Chlorophyll *a* (µg/l) during 2018 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	2	1	1	1	1	1	2	2
FEB	2	1	3	2	2	2	7	5
MAR	3	2	3	2	4	5	10	13
APR	1	1	1	1	1	2	3	3
MAY	2	3	2	1	2	5	6	5
JUN	1	1	4	1	4	6	4	5
JUL	3	7	21	11	4	9	11	12
AUG	1	1	1	1	1	1	1	1
SEP								
OCT	2	3	2	2	2	1	2	3
NOV	2	2	2	2	3	3	2	4
DEC	3	3	2	1	2	1	1	6
mean	**2**	**2**	**4**	**2**	**2**	**3**	**4**	**5**
std dev	1	2	6	3	1	3	4	4
median	2	2	2	1	2	2	3	5
max	3	7	21	11	4	9	11	13
min	1	1	1	1	1	1	1	1

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

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1	2	3	11	28	2	2	1	0
FEB	1	18	6	7	9	1	12	1	2
MAR	1	1	1	3	12	2	1	0	1
APR	4	2	3	5	11	5	3	1	12
MAY	4	1	2	13	2	2	1	1	2
JUN	3	1	2	11	5	4	1	1	1
JUL	4	4	13	17	22	2	38	1	13
AUG	25	1	3	9	13	2	0	0	6
SEP									
OCT	4	1	20	39	18	7	7	17	24
NOV	1	1	1	3	1	2	0	1	5
DEC	3	1	1	2	1	6	1	0	1
mean	**5**	**3**	**5**	**11**	**11**	**3**	**6**	**2**	**6**
std dev	7	5	6	10	9	2	11	5	7
median	3	1	3	9	11	2	1	1	2
max	25	18	20	39	28	7	38	17	24
min	1	1	1	2	1	1	0	0	0

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	3	2	2	4	1	2	11	2	4
FEB	2	3	2	3	2	3	16	2	5
MAR	1	2	2	1	1	1	9	0	3
APR	1	3	2	6	1	2	14	2	3
MAY	1	2	0	0	0	1	18	1	2
JUN	0	2	1	1	1	2	16	1	1
JUL	1	3	1	1	1	2	43	2	5
AUG	0	2	1	1	1	1	4	1	1
SEP									
OCT	0	0	0	1	1	2	4	6	0
NOV	0	1	0	1	0	2	5	2	0
DEC	1	1	1	2	4	2	2	1	1
mean	**1**	**2**	**1**	**2**	**1**	**2**	**13**	**2**	**2**
std dev	1	1	1	2	1	1	11	2	2
median	1	2	1	1	1	2	11	2	2
max	3	3	2	6	4	3	43	6	5
min	0	0	0	0	0	1	2	0	0

Figure 2.7 Chlorophyll *a* at the Lower Cape Fear River Program mainstem stations, 1995-2017 versus 2018.

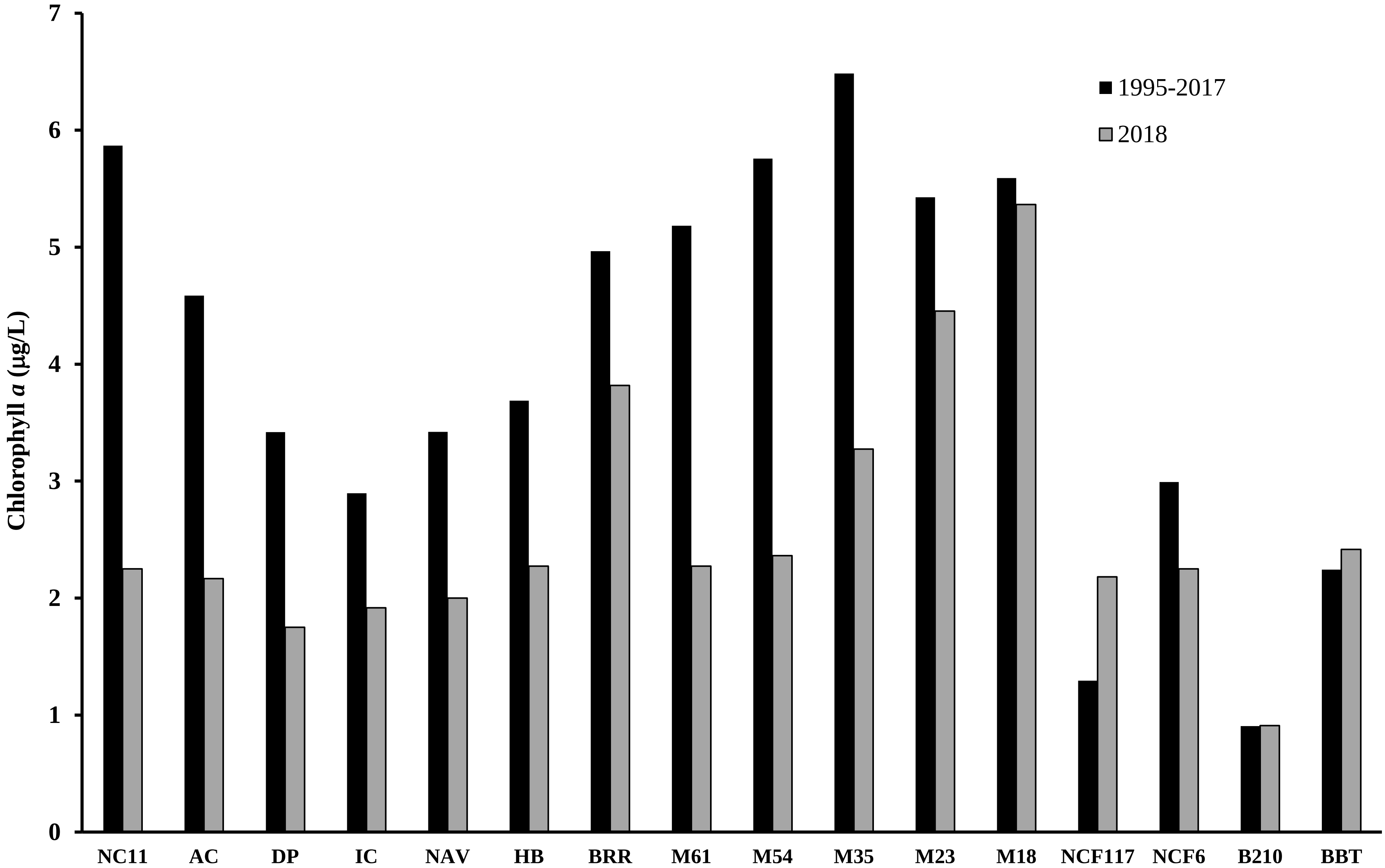


Table 2.16 Fecal Coliform (cfu/100 mL) and Enterococcus (MPN) during 2018 at the Lower Cape Fear River Program stations.

	NC11	AC	DP	IC	NCF6	NAV	HB
JAN	19	19	28	37	5	5	91
FEB	390	290	55	172	10	46	55
MAR	28	28	55	10	37	546	10
APR	46	5	28	28	55	46	46
MAY	19	73	73	19	73	10	82
JUN	14	23	41	32	43	37	37
JUL	46	181	5	19	230	19	46
AUG	127	181	46	100	5	127	91
SEP	19	28	46	91	280		
OCT	55	37	82	145	819	28	10
NOV	55	55	46	5	109	91	28
DEC	320	300	109	91	37	5	5
mean	**95**	**102**	**51**	**62**	**142**	**87**	**46**
std dev	121	103	26	54	221	149	30
max	390	300	109	172	819	546	91
min	14	5	5	5	5	5	5
Geomean	50	55	42	39	51	34	32

ENTEROCOCCUS

	BRR	M61	M54	M35	M23	M18
JAN	31	51	5	10	5	20
FEB	22	57	94	75	67	101
MAR	97	85	63	20	10	96
APR	5	5	10	5	5	5
MAY	20	41	41	62	20	20
JUN	30	31	20	26	89	5
JUL	10	31	5	5	5	5
AUG	20	10	10	5	10	10
SEP						
OCT	10	20	20	5	5	5
NOV	5	10	5	5	10	5
DEC	20	20	85	31	31	5
mean	**25**	**33**	**33**	**23**	**23**	**25**
std dev	24	23	32	24	27	35
max	97	85	94	75	89	101
min	5	5	5	5	5	5
Geomean	17	25	19	13	13	12

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	37	28	5	5	19	37	109	163	340
FEB	10	82	37	37	5	19	163	240	64
MAR	109	145	82	163	190	28	728	46	73
APR	530	210	46	163	73	136	340	28	154
MAY	37	145	163	1,270	340	163	410	37	200
JUN	91	145	28	260	235	73	340	260	136
JUL	240	37	127	200	60,000	320	910	10	217
AUG	250	270	370	250	1,730	355	340	37	270
SEP									
OCT	37	144	250	270	3000	480	172	1,180	480
NOV	28	73	19	82	24	37	240	46	145
DEC	19	28	5	5	5	5	64	10	5
mean	**126**	**119**	**103**	**246**	**5,966**	**150**	**347**	**187**	**189**
std dev	151	74	112	337	17,111	155	248	326	129
max	37	270	370	1,270	60,000	480	910	1,180	480
min	10	28	5	5	5	5	64	10	5
Geomean	65	93	49	99	172	73	267	66	127

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	37	172	190	530	340	145	210	91	728
FEB	28	19	55	55	37	37	28	73	1,180
MAR	19	46	37	64	28	73	73	136	199
APR	19	37	440	1,460	480	199	240	310	1,550
MAY	64	109	28	55	290	154	127	136	217
JUN	55	118	37	73	73	100	64	240	91
JUL	55	109	210	136	570	19	430	520	217
AUG	100	728	19	460	370	300	163	819	260
SEP									
OCT	28	10	100	200	91	127	172	270	1,000
NOV	82	82	136	91	73	230	118	320	430
DEC	37	28	28	19	19	28	37	37	55
mean	**48**	**133**	**116**	**286**	**216**	**128**	**151**	**268**	**539**
std dev	25	194	121	405	191	85	110	219	479
max	100	728	440	1,460	570	300	430	819	1,550
min	19	10	19	19	19	19	28	37	55
Geomea	41	67	72	133	123	95	114	191	340

Figure 2.8 Geometric Mean Fecal Coliform (NC11-B210) and Enterococcus (BRR-M18) at the LCFRP mainstem stations, 1996-2017 (Entero 2012-2017) vs. 2018.