Environmental Assessment of the Lower Cape Fear River System, 2019

By

Michael A. Mallin, Matthew R. McIver and James F. Merritt
November 2020

CMS Report No. 20-02
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 (Table 1.1; Fig. 1.1). 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 2019. 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 – Fig. 1.1) 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 four years there has been considerable controversy in the lower Cape Fear River watershed regarding a family of manufactured chemical compounds popularly 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, than later stopped its manufacture due to health concerns surrounding this chemical. They then developed a substitute chemical called GenX, which they began manufacturing there, along with GenX's parent compound, called HFPO-DA fluoride. Both compounds hydrolize in water to a third compound called HFPO-DA, CAS; the toxicity of this group of chemicals is unclear. Subsequently, DuPont spun-off a company called Chemours, which assumed plant operations in 2015. In the past few years researchers from US EPA, North Carolina State University, and the University of North Carolina Wilmington have found HFPO-DA

and related fluoroethers (which tend to be lumped under the blanket term GenX) in river water, river sediments, well water near the plant, in air samples, aquatic organism tissue, bird tissue, and in finished drinking water at the Wilmington water treatment facility, which obtains its water near Lock and Dam #1. Fayetteville Works says they have stopped the GenX discharge, and in 2019 built a thermal oxidizer to heat waste gases and reduce >99% of the chemicals from escaping. Legal actions were initiated against the company from NC Attorney General, NCDEQ and Cape Fear River Watch to provide financial compensation for the pollution and for installation of pollution-reduction equipment. 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.

Summary of water quality data results from 2019 – **Hurricane Dorian** impacted southeastern North Carolina September 5th with rain and tornadoes, and made landfall at Cape Hatteras September 6th. The hurricane had some impact on system dissolved oxygen (DO) but it was relatively short-lived and relegated to selected sites only, i.e. the impacts were far more mild than those of Hurricane Florence in 2018.

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 (Fig. 1.1). 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.

As noted, DO concentrations in the tributary streams were briefly impacted by the hurricane, but some are chronically bad year-after-year. In 2019 ANC was below standard 27% of the time sampled, but all of the other stream stations were below standard less than 25% of the time. Considering all sites sampled in 2019, we rated 16% as poor for dissolved oxygen, 34% as fair, and 50% as good.

Annual mean turbidity levels for 2019 were lower than the long-term average at all stations. Highest mean riverine turbidities (11-12 NTU) were at NC11-DP (Fig. 1.1) with turbidities generally low in the middle to lower estuary. The estuarine stations exceeded the estuarine turbidity standard only in April 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 2019.

Average chlorophyll *a* concentrations across most sites were low in 2019. The standard of 40 µg/L was exceeded once each at Station M54, SR, GS and PB, 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. Nuisance cyanobacterial

blooms did not occur in the river and upper estuary in 2019. For the 2019 period UNCW rated 100% 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 2019. Sites with the highest counts in general were BRN, PB, HAM, SAR and LRC. However, the main river and estuary sites were generally in good condition in 2019. For bacterial water quality overall, 10% of the sites rated as poor, 32% as fair, and 58% as good, an improvement from 2018.

In addition, according to our experimentally-derived key concentrations, excessive nitrate and phosphorus concentrations were problematic at a number of stations. Sites with high nutrient concentrations included point-source locations NC403 and PB, and non-point locations ROC, 6RC, and GCO.

Table of Contents

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 2019.

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 25-year (1995-2019) 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 5th order blackwater streams drain extensive riverine swamp forests and add organic color to the mainstem. The watershed (about 9,164 square miles) is the most heavily industrialized in North Carolina with 203 permitted wastewater discharges with a permitted flow of approximately 429 million gallons per day, and (as of 2010) over 2.07 million people residing in the basin (NCDENR Basinwide Information Management System (BIMS) & 2010 Census). Approximately 23% of the land use in the watershed is devoted to agriculture and livestock production (2006 National Land Cover Dataset), with livestock production dominated by swine and poultry operations. Thus, the watershed receives considerable point and non-point source loading of pollutants. However, the estuary is a well-flushed system, with flushing time ranging from 1 to 22 days with a median flushing time of about seven days, much shorter than the other large N.C. estuaries to the north (Ensign et al. 2004).

Water quality is monitored by boat at eight stations in the Cape Fear Estuary (from Navassa to Southport) and one station in the Northeast Cape Fear Estuary (Table 1.1; Fig. 1.1). We note that after July 2011 sampling was discontinued at estuarine stations M42 and SPD, per agreement with the North Carolina Division of Water Quality; and in 2012 sampling was expanded at Smith Creek at the Castle Hayne Road bridge (Table 1.1) and initiated at a new site along the South River (SR-WC). Riverine stations sampled by boat include NC11, AC, DP, IC, and BBT (Table 1.1; Fig. 1.1). NC11 is located upstream of any major point source discharges in the lower river and estuary system, and is considered to be representative of water quality entering the lower system (we note that the City of Wilmington and portions of Brunswick County get their drinking water from the river just upstream of Lock and Dam #1). Station BBT is located on the Black River between Thoroughfare (a stream connecting the Cape Fear and Black Rivers) and the mainstem Cape Fear, and is influenced by both rivers. We consider B210 and NCF117 to represent water quality entering the lower Black and Northeast Cape Fear Rivers, respectively. Data has also been collected at stream and

river stations throughout the Cape Fear, Northeast Cape Fear, and Black River watersheds (Table 1.1; Fig. 1.1; Mallin et al. 2001).

1.2. Report Organization

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, 2019.

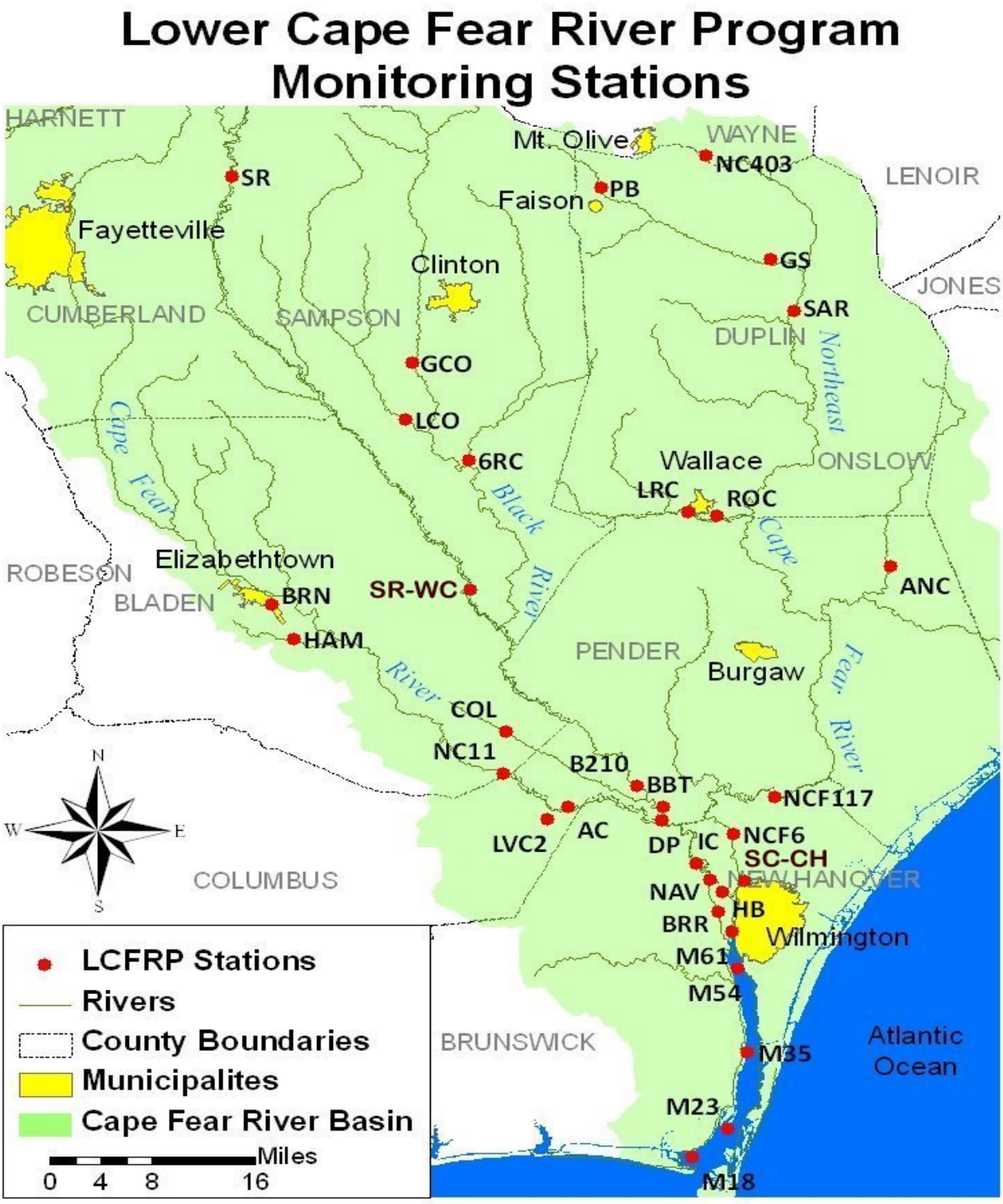
Collected by Boat

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

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 2019 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 (in freshwater) or *Enterococcus* bacteria (in the estuary) 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 SC-CH (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.

Physical Parameters

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

Field parameters other than light attenuation were measured at each site using a YSI EXO3 or YSI Pro D55. 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 eight 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 funding; previous BOD results are published (Mallin et al. 2006).

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 PF-2012	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 2019. 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 some impacts from Hurricane Dorian in 2019; therefore this report reflects its impacts in fall.

Physical Parameters

Water temperature

Water temperatures at all stations ranged from 2.9 to 32.1^{o}C, and individual station annual averages ranged from 16.7 to 20.5^{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 34.7 practical salinity units (psu) and station annual means ranged from 1.5 to 24.4 psu (Table 2.2). Lowest salinities occurred in late winter and spring of 2019 and again in September following the heavy rains from Hurricane Dorian. The annual mean salinities for 2019 were approximately the same compared with the twenty-two year average for 1995-2018 (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 just upstream of Wilmington and salinity there ranged from 0.1 to 2.4 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.07 to 52.83 mS/cm and from 0.05 to 4.85 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 3.3 to 8.4 and station annual means ranged from 3.9 (at COL) to 8.4 (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. 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 2019 ranged from 0.8 to 13.4 mg/L and station annual means ranged from 5.9 to 10.1 mg/L (Table 2.5). Overall, average dissolved oxygen levels for 2019 were slightly lower compared with the long-term average (Fig. 2.2). River dissolved oxygen levels were low during the summer and early fall (Table 2.5), often falling below the state standard of 5.0 mg/L at several river and upper estuary stations.

While DO concentrations were already low in summer the September arrival of Hurricane Dorian in September brought additional rainfall to the area. This caused increased BOD loading from animal waste, sewage and natural swamp organic matter which decreased DO lower than usual in September and October. However, the decrease in DO was relatively minor and short lived – with DO recovered by November, and relegated to

selected stations only (Table 2.5); i.e. very minor compared with 2018's Hurricane Florence.

NAV, HB and BRR were below 5.0 mg/L on 33% or more of occasions sampled, and IC was below 5.0 mg/L on 42% of occasions. Based on number of occasions the river stations were below 5 mg/L dissolved oxygen UNCW rated NAV, HB, IC and BRR as poor for 2019; 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, 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. DO conditions in the lower river and estuary in 2019 were better than 2018.

Most tributary Stations were rated Fair or good in 2019, except ANC, rated Poor (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 50% of the sites impacted in 2019.

Field Turbidity

Field turbidity levels ranged from 0 to 36 Nephelometric turbidity units (NTU) and station annual means ranged from 2 to 12 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Highest mean turbidities were at NC11-DP (11-12 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 2019 sampling trips. As in the previous year, mean turbidity levels for 2019 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 (APHA 1995) 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 NCDEQ NPDES Unit to evaluate discharges. No LCFRP subscribers discharge near these sites.

Total suspended solid (TSS) values system wide ranged from 1.3 to 33.3 mg/L with station annual means from 1.7 to 16.7 mg/L (Table 2.7). The overall highest river values were at DP 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 only two occasions in the 2019 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. Due to persistent instrumentation issues light attenuation data were not collected in the latter half of 2019. Based on limited data, river and estuary light attenuation coefficients ranged from 2.00 to 5.43/m and station annual means ranged from 2.42 at DP to 4.38 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 does 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. 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 9,890 μg/L (at ROC) and station annual means ranged from 660 to 3,758 μg/L (at ROC; 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 ROC with 3,225 μg/L; other sites with elevated TN were NC403, PB, COL, 6RC and GCO.

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 8,090 μg/L (at PB) and station annual means ranged from 33 to 2,350 μg/L (at ROC; Table 2.10). The highest average riverine nitrate levels were at NC11 through IC (583-496 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 = 290 μg/L) and the Black River (B210 = 396 μg/L). Lowest river nitrate occurred during September and October. In general, average concentrations in 2019 for the mainstem river were lower than those of the average from 1995-2018 (Fig. 2.4).

Several stream stations showed high levels of nitrate on occasion including NC403, PB, ROC and 6RC. ROC and 6RC primarily receive non-point agricultural or animal waste drainage, while point sources contribute to NC403 and PB. In general, the stream stations showed elevated nitrate in late winter and early spring. 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 dissolved nutrients were in the range of 200 to 500 μg-N/L (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-N/L 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 2,390 µg/L and station annual means ranged from 45 to 543 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 M23 in the lower estuary just upstream of Southport. At the stream stations 2019 continued to be unusual in that Colly Creek (COL) showed multiple occasions of high ammonium, with particularly high concentrations in May and June (Table 2.11). 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 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 increased 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 2019 included 6RC, ANC, ROC 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 4,800 µg/L (at COL) and station annual means ranged from 529 to 1,875 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 COL, ANC and ROC. 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 3,020 µg/L (at ROC) and station annual means ranged from 139 to 958 µg/L (ROC; Table 2.13). For the mainstem and upper estuary, average TP for 2019 was considerably higher than the 1995-2018 average (Figure 2.6).

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 wastewater discharges, while ROC, GCO and ANC are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from 5 to 1,570 μg/L (at ROC) and station annual means ranged from 12 to 492 μg/L (Table 2.14). Much of the main river orthophosphate load is imported into the Lower Cape Fear system from upstream areas, as NC11 or AC typically have high levels; there are also inputs of orthophosphate from the paper mill above AC (Table 2.14. 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. 1999). In spring, productivity in the estuary is usually limited by phosphorus (Mallin et al. 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 regularly collected by the LCFRP. Revised metals sampling (dissolved, not total metals) was re-initiated in late 2015 and has continued periodically upon request from NCDEQ. Results showed that for stations 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. M35 and M23 were on the 303 D list being impaired for Copper Arsenic and Nickel. The DWR determined that these sites could be de-listed using the new dissolved metals criteria.

There were two metals samples collected in December 2018 at IC and NAV, with no unusual or adversely high concentrations. Samples were also collected at those two sites in June and December 2019. Most metals were below detection limits. Mercury at IC was 3.39 ng/L in June and 2.39 ng/L in December, and Hg at NAV was 2.79 in December 2019. Zinc was 0.012 µg/L at IC in December 2019. LCFRP has voluntarily collected samples on 10 occasions using EPA Method 1669.

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 2019 except at M54 in July. We note that at the upper site NC11 it has been demonstrated that chlorophyll ***a*** biomass is significantly correlated with biochemical oxygen demand (BOD5 – Mallin et al. 2006). Multiple statistical approached demonstrated that chlorophyll ***a*** near Lock and Dam #1 is strongly associated with nitrate generated upstream about 100 km, in an area of point source dischargers downstream of Fayetteville (Saul et al. 2019). System wide, chlorophyll ***a*** ranged from undetectable to 175 µg/L, and station annual means ranged from 1-21 µg/L, generally low because of high river discharge in 2019 (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. 2.6). On average, flushing time of the Cape Fear estuary is rapid, ranging from 1-22 days with a median of 6.7 days (Ensign et al. 2004). This does not allow for much settling of suspended materials, leading to light limitation of phytoplankton production. However, under lower-than-average flows there is generally clearer water because of 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 (1995-2019) average monthly flow at Lock and Dam #1 was approximately 3,523 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 2019, discharge in May-September was 2,964 CFS, much higher than the 2009-2012 average, and nuisance cyanobacterial blooms did not occur in the river and upper estuary in 2019.

As noted, the blooms in 2009-2012 all occurred when average river discharge for May-September was below 1,900 CFS. Algal bloom formation was probably suppressed by elevated river flow in 2013-2014 and 2016-2019. Flow in 2015 was well within the range when blooms can occur, yet blooms did not occur in 2015. 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 2019 (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 GS (175 µg/L), SR (58 µg/L) and PB (52 µg/L), 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 10,500 CFU/100 mL and station annual geometric means ranged from 9 to 235 CFU/100 mL (Table 2.17). The state human contact standard (200 CFU/100 mL) was exceeded in the mainstem river on only one occasion in 2019 (Table 2.17). During 2019 some stream stations showed elevated fecal coliform pollution levels. HAM and BRN exceeded 200 CFU/100 mL 50% of the time sampled and LRC 33% of the time sampled. Other stations had periodic elevated counts particularly August-October – September and October would have been influenced by Hurricane Dorian. 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 lower in 2019 (Fig. 2.5). Overall, 2019 was comparatively better than previous years, despite Hurricane Dorian.

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 2019 this standard was exceeded in the estuary samples once each at BRR, M23 and M54, and twice at M18. Geometric mean enterococcus counts for 2019 were lower than those of the 2012-2018 period for the lower Cape Fear Estuary (Fig. 2.8). Overall, elevated fecal coliform and *Enterococcus* counts are problematic in this system, with 42% of the stations rated as Fair or Poor in 2018 (although that was an improvement from 2018).

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, 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., 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.

Saul, B., M.G. Hudgens and M.A. Mallin. 2019. Upstream causes of downstream effects. *Journal of the American Statistical Association.* https://doi.org/10.1080/01621459.2019.1574226.

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 (°C) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	7.8	7.8	7.9	8.7	8.5	9.1	10.0	10.0
FEB	9.5	10.9	10.7	11.1	10.4	12.1	12.5	12.9
MAR	6.7	6.7	7.0	6.8	7.1	7.5	8.0	7.9
APR	19.3	19.9	19.6	20.2	20.2	20.2	20.4	19.6
MAY	22.3	22.2	22.1	22.6	22.7	22.8	22.9	23.4
JUN	27.9	27.9	27.8	27.6	27.5	27.4	27.2	27.3
JUL	31.2	32.1	31.4	31.1	31.0	30.9	30.4	30.6
AUG	29.0	29.4	30.7	29.4	29.3	29.4	29.0	29.1
SEP	26.8	27.2	26.8	27.1	27.4	27.1	26.7	26.4
OCT	24.5	24.2	23.8	24.3	23.7	22.8	23.2	22.7
NOV	19.5	20.3	19.7	20.4	20.4	19.9	19.6	19.6
DEC	11.4	11.7	12.1	12.8	12.4	12.6	12.7	13.2
mean	**19.7**	**20.0**	**20.0**	**20.2**	**20.1**	**20.2**	**20.2**	**20.2**
std dev	8.8	8.8	8.7	8.4	8.5	8.1	7.7	7.7
median	20.9	21.3	20.9	21.5	21.6	21.5	21.7	21.2
max	31.2	32.1	31.4	31.1	31.0	30.9	30.4	30.6
min	6.7	6.7	7.0	6.8	7.1	7.5	8.0	7.9

	NC11	AC	DP	BBT	IC	NCF6
JAN	11.7	11.8	12.0	12.9	12.4	13.6
FEB	12.3	12.3	12.5	12.6	12.3	12.6
MAR	6.3	6.5	6.7	6.5	6.8	6.6
APR	14.4	14.5	14.5	16.7	15.3	16.0
MAY	22.8	22.9	23.2	24.2	24.4	25.0
JUN	28.4	28.6	28.2	27.9	27.9	27.8
JUL	30.3	30.2	29.7	29.2	29.7	29.5
AUG	29.5	29.6	29.6	29.2	29.8	28.9
SEP	27.6	27.0	26.1	24.8	25.4	26.3
OCT	27.6	27.9	27.8	27.1	27.5	27.7
NOV	18.4	18.8	19.0	18.1	19.0	20.2
DEC	10.3	10.7	10.9	10.4	10.6	11.9
mean	**20.0**	**20.1**	**20.0**	**20.0**	**20.1**	**20.5**
std dev	8.7	8.6	8.4	8.1	8.3	8.0
median	20.6	20.9	21.1	21.2	21.7	22.6
max	30.3	30.2	29.7	29.2	29.8	29.5
min	6.3	6.5	6.7	6.5	6.8	6.6

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	8.4	8.0	7.8	8.6	7.7	10.4	10.9	12.6	13.3
FEB	13.2	9.7	12.5	10.8	11.0	11.3	9.6	12.0	11.4
MAR	6.0	6.7	7.2	6.5	6.5	6.5	6.3	6.3	6.3
APR	21.9	21.3	23.6	22.8	24.0	21.5	20.8	20.4	22.0
MAY	22.5	21.6	20.2	21.4	22.7	19.8	20.0	24.4	23.5
JUN	23.1	22.7	22.7	22.7	22.5	23.5	23.6	27.0	26.4
JUL	26.5	28.4		28.9	29.8	29.4	28.5	29.5	29.6
AUG	24.9	27.5	26.9	27.1	27.7	26.7	26.6	29.5	30.2
SEP	22.3	21.6	22.1	23.0	22.6	22.6	22.3	24.9	25.6
OCT	27.4	25.6	24.3	26.2	27.4	26.7	24.8	26.3	27.3
NOV		7.0	7.2	7.6	6.9	8.6	8.4	14.5	15.1
DEC	10.2	9.0	8.9	9.9	8.7	9.0	11.2	11.1	11.7
mean	**18.8**	**17.4**	**16.7**	**18.0**	**18.1**	**18.0**	**17.8**	**19.9**	**20.2**
std dev	7.8	8.6	7.9	8.5	9.1	8.3	7.9	8.1	8.2
median	22.3	21.5	20.2	22.1	22.6	20.7	20.4	22.4	22.8
max	27.4	28.4	26.9	28.9	29.8	29.4	28.5	29.5	30.2
min	6.0	6.7	7.2	6.5	6.5	6.5	6.3	6.3	6.3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	7.7	7.1	7.0	5.7	4.6	3.6	2.9	8.0	7.0
FEB	11.6	11.3	10.7	11.3	11.2	11.8	12.0	13.6	12.5
MAR	6.1	3.8	5.7	6.4	6.2	6.4	6.3	6.5	6.8
APR	19.0	19.8	19.0	20.0	19.7	19.9	20.5	20.7	19.9
MAY	28.8	25.5	26.3	26.2	25.5	26.7	26.6	26.2	25.1
JUN	26.9	25.4	25.5	26.1	25.9	26.4	25.9	26.5	24.1
JUL	27.1	23.4	24.9	24.6	24.0	25.6	25.4	26.8	24.1
AUG	28.0	26.2	26.0	25.5	25.9	26.1	26.1	26.5	25.1
SEP	23.3	22.1	22.4	22.4	22.4	23.2	23.0	23.8	22.3
OCT	18.6	16.8	17.2	18.6	18.5	18.4	17.9	16.7	15.0
NOV	10.4	9.7	10.5	11.3	11.1	10.7	9.8	11.1	10.6
DEC	11.9	12.5	10.9	12.4	12.5	13.0	12.2	13.2	12.3
mean	**18.3**	**17.0**	**17.2**	**17.5**	**17.3**	**17.7**	**17.4**	**18.3**	**17.1**
std dev	8.5	7.9	7.9	7.8	7.8	8.3	8.4	7.7	7.1
median	18.8	18.3	18.1	19.3	19.1	19.2	19.2	18.7	17.5
max	28.8	26.2	26.3	26.2	25.9	26.7	26.6	26.8	25.1
min	6.1	3.8	5.7	5.7	4.6	3.6	2.9	6.5	6.8

Table 2.2 Salinity (psu) 2019 at the Lower Cape Fear River Program estuarine stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NCF6	SC-CH
JAN	0.0	0.0	0.0	1.4	1.6	3.6	10.7	11.6	0.0	0.1
FEB	0.1	0.6	0.1	1.5	4.0	10.0	15.1	28.9	0.1	1.1
MAR	0.0	0.0	0.1	2.8	3.9	6.6	13.7	16.4	0.1	0.1
APR	0.0	0.0	0.0	0.0	0.5	3.1	9.8	12.9	0.1	0.1
MAY	0.0	0.1	0.1	2.0	2.3	6.0	14.0	14.0	0.9	4.3
JUN	0.1	0.2	2.1	8.8	13.5	20.1	28.2	30.0	11.9	10.1
JUL	4.5	4.6	6.8	10.5	13.2	23.2	31.0	34.7	4.5	6.8
AUG	0.2	1.8	4.9	12.5	15.8	24.4	31.1	31.6	7.0	9.6
SEP	0.1	1.6	0.3	2.0	8.4	11.8	20.0	24.6	8.9	0.2
OCT	9.3	14.3	14.5	20.2	20.3	23.5	29.1	30.0	5.8	6.2
NOV	3.6	5.6	10.1	14.9	16.4	20.7	27.4	28.2	2.2	15.2
DEC	0.1	0.3	2.1	6.4	9.1	15.5	22.4	29.7	0.1	2.7
mean	**1.5**	**2.4**	**3.4**	**6.9**	**9.1**	**14.0**	**21.0**	**24.4**	**3.5**	**4.7**
std dev	2.9	4.2	4.8	6.5	6.7	8.2	8.2	8.3	4.1	5.0
median	0.1	0.5	1.2	4.6	8.8	13.7	21.2	28.6	1.6	3.5
max	9.3	14.3	14.5	20.2	20.3	24.4	31.1	34.7	11.9	15.2
min	0.0	0.0	0.0	0.0	0.5	3.1	9.8	11.6	0.0	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations 1995-2018 versus 2019.

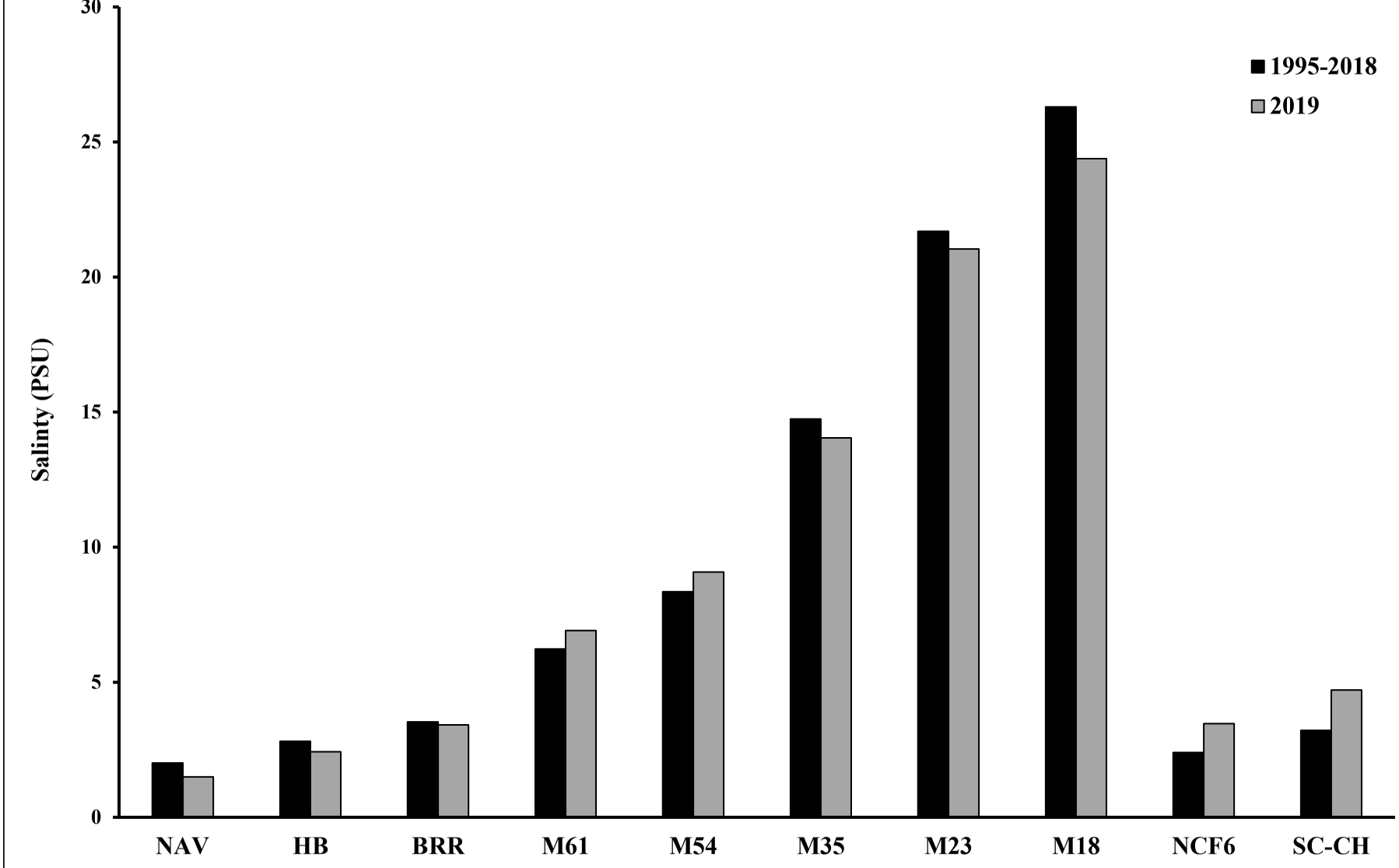


Table 2.3 Conductivity (mS/cm) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	0.09	0.09	0.09	2.62	3.06	6.59	18.13	19.51
FEB	0.11	1.22	2.81	2.82	7.23	16.89	24.85	44.71
MAR	0.09	0.09	0.10	5.25	7.08	11.51	22.63	26.64
APR	0.07	0.08	0.07	0.09	0.95	5.71	16.61	21.46
MAY	0.09	0.10	0.10	3.75	4.24	10.07	23.70	23.33
JUN	0.24	0.33	4.07	15.18	22.48	32.33	43.75	46.19
JUL	8.17	8.50	12.07	18.00	22.09	36.96	47.80	52.83
AUG	0.48	3.45	8.83	21.00	26.03	38.62	47.92	48.86
SEP	0.13	3.15	0.59	3.87	14.27	19.90	32.16	38.60
OCT	15.94	23.55	23.93	32.36	32.45	37.13	45.08	46.30
NOV	6.45	9.86	17.04	23.56	26.80	32.98	42.48	43.68
DEC	0.17	0.68	3.88	11.27	15.47	25.45	35.59	45.77
mean	**2.67**	**4.26**	**6.13**	**11.65**	**15.18**	**22.85**	**33.39**	**38.16**
std dev	5.02	6.94	7.84	10.30	10.66	12.59	11.87	11.95
median	0.15	0.95	3.35	8.26	14.87	22.68	33.88	44.19
max	15.94	23.55	23.93	32.36	32.45	38.62	47.92	52.83
min	0.07	0.08	0.07	0.09	0.95	5.71	16.61	19.51

	NC11	AC	DP	BBT	IC	NCF6
JAN	0.07	0.07	0.07	0.07	0.07	0.09
FEB	0.08	0.09	0.10	0.09	0.10	0.11
MAR	0.09	0.09	0.09	0.08	0.09	0.12
APR	0.09	0.11	0.11	0.09	0.10	0.14
MAY	0.10	0.11	0.11	0.10	0.11	1.73
JUN	0.11	0.13	0.23	0.21	0.26	19.94
JUL	0.12	0.28	0.21	0.16	0.20	8.17
AUG	0.11	0.12	0.18	0.15	0.16	12.23
SEP	0.12	0.23	0.18	0.12	0.15	15.36
OCT	0.13	0.14	0.21	0.15	0.19	10.22
NOV	0.15	0.18	0.19	0.16	0.21	4.15
DEC	0.14	0.22	0.17	0.13	0.17	0.28
mean	**0.11**	**0.15**	**0.15**	**0.13**	**0.15**	**6.04**
std dev	0.02	0.06	0.06	0.04	0.06	6.98
median	0.11	0.12	0.18	0.12	0.15	2.94
max	0.15	0.28	0.23	0.21	0.26	19.94
min	0.07	0.07	0.07	0.07	0.07	0.09

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	0.07	0.13	0.13	0.28	0.47	0.10	0.12	0.10	0.11
FEB	0.08	0.14	0.13	0.34	0.43	0.11	0.13	0.13	2.18
MAR	0.10	0.13	0.12	0.29	0.36	0.10	0.10	0.12	0.16
APR	0.08	0.15	0.14	0.43	0.60	0.10	0.12	0.11	0.18
MAY	0.11	0.21	0.17	0.80	2.62	0.14	0.20	0.19	7.78
JUN	0.06	0.30	0.28	0.70	1.57	0.17	0.46	0.38	17.23
JUL	0.10	0.24		1.31	4.75	0.13	0.46	0.35	11.91
AUG	0.11	0.39	0.36	1.58	4.85	0.24	0.72	0.35	16.49
SEP	0.11	0.18	0.15	0.65	2.10	0.13	0.22	0.12	0.49
OCT	0.16	0.22	0.19	1.03	1.90	0.16	0.32	0.19	11.03
NOV		0.25	0.21	1.22	0.78	0.18	0.23	0.23	24.90
DEC	0.14	0.19	0.17	0.66	0.72	0.15	0.18	0.16	4.95
mean	**0.10**	**0.21**	**0.19**	**0.77**	**1.76**	**0.14**	**0.27**	**0.20**	**8.12**
std dev	0.03	0.08	0.08	0.43	1.60	0.04	0.19	0.11	8.27
median	0.10	0.20	0.17	0.68	1.17	0.13	0.21	0.17	6.37
max	0.16	0.39	0.36	1.58	4.85	0.24	0.72	0.38	24.90
min	0.06	0.13	0.12	0.28	0.36	0.10	0.10	0.10	0.11

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	0.09	0.05	0.06	0.13	0.10	0.11	0.07	0.11	0.12
FEB	0.09	0.05	0.06	0.13	0.09	0.11	0.07	0.12	0.14
MAR	0.09	0.05	0.06	0.12	0.09	0.13	0.07	0.12	0.16
APR	0.08	0.05	0.06	0.12	0.09	0.12	0.07	0.10	0.12
MAY	0.12	0.07	0.08	0.16	0.11	0.25	0.11	0.14	0.25
JUN	0.13	0.07	0.09	0.15	0.11	0.15	0.10	0.13	0.26
JUL	0.15	0.06	0.10	0.18	0.12	0.40	0.09	0.14	0.24
AUG	0.13	0.06	0.08	0.08	0.07	0.13	0.10	0.14	0.28
SEP	0.09	0.06	0.08	0.07	0.11	0.21	0.09	0.13	0.26
OCT	0.13	0.06	0.08	0.17	0.12	0.16	0.08	0.13	0.23
NOV	0.12	0.06	0.09	0.17	0.12	0.17	0.09	0.13	0.21
DEC	0.11	0.06	0.08	0.16	0.11	0.15	0.08	0.13	0.19
mean	**0.11**	**0.06**	**0.08**	**0.14**	**0.10**	**0.17**	**0.09**	**0.13**	**0.20**
std dev	0.02	0.01	0.01	0.04	0.02	0.08	0.01	0.01	0.06
median	0.11	0.06	0.08	0.14	0.11	0.15	0.08	0.13	0.22
max	0.15	0.07	0.10	0.18	0.12	0.40	0.11	0.14	0.28
min	0.08	0.05	0.06	0.07	0.07	0.11	0.07	0.10	0.12

Table 2.4 pH 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	7.1	6.7	7.3	7.2	7.8	7.5	7.7	7.8
FEB	6.7	6.9	7.3	7.1	7.3	7.8	8.0	8.1
MAR	6.7	6.7	7.0	6.8	7.1	7.5	8.0	7.9
APR	6.6	6.6	6.7	6.7	6.9	7.2	7.9	7.9
MAY	6.8	6.9	7.0	6.8	7.1	7.2	7.6	7.9
JUN	6.9	6.9	7.0	7.1	7.3	7.6	7.9	7.9
JUL	6.9	7.1	7.2	7.3	7.8	8.0	8.0	8.0
AUG	6.8	6.8	7.0	7.1	7.3	7.8	7.9	7.9
SEP	6.2	6.6	6.9	6.5	6.8	7.1	7.6	7.8
OCT	6.9	7.1	7.1	7.4	7.5	7.7	7.8	7.9
NOV	7.0	7.2	7.3	7.4	7.6	7.8	8.0	8.0
DEC	6.8	7.3	7.4	7.4	7.6	7.9	8.1	8.1
mean	**6.8**	**6.9**	**7.1**	**7.1**	**7.3**	**7.6**	**7.9**	**7.9**
std dev	0.2	0.2	0.2	0.3	0.3	0.3	0.2	0.1
median	6.8	6.9	7.1	7.1	7.3	7.7	7.9	7.9
max	7.1	7.3	7.4	7.4	7.8	8.0	8.1	8.1
min	6.2	6.6	6.7	6.5	6.8	7.1	7.6	7.8

	NC11	AC	DP	BBT	IC	NCF6
JAN	6.1	6.2	6.3	6.1	6.2	6.0
FEB	6.2	6.2	6.3	6.0	6.2	6.2
MAR	6.3	6.5	6.7	6.5	6.8	6.6
APR	6.3	6.5	6.6	6.3	6.4	6.5
MAY	6.7	6.6	6.7	6.3	6.7	6.6
JUN	6.5	6.8	6.8	6.8	6.8	7.0
JUL	6.7	6.8	6.7	6.6	6.7	6.7
AUG	6.2	6.7	6.8	6.4	6.4	6.8
SEP	6.2	6.8	6.4	6.1	6.2	6.6
OCT	6.8	6.8	6.7	6.5	6.6	6.6
NOV	6.7	6.9	6.9	6.6	6.8	6.8
DEC	6.3	7.0	6.9	6.6	6.8	6.7
mean	**6.4**	**6.7**	**6.7**	**6.4**	**6.6**	**6.6**
std dev	0.2	0.3	0.2	0.2	0.3	0.3
median	6.3	6.8	6.7	6.5	6.7	6.6
max	6.8	7.0	6.9	6.8	6.8	7.0
min	6.1	6.2	6.3	6.0	6.2	6.0

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	4.7	6.1	6.4	6.2	6.4	6.7	6.4	6.1	6.3
FEB	5.5	6.6	7.0	6.5	6.5	6.6	6.6	6.5	6.4
MAR	6.0	6.7	7.2	6.5	6.5	6.5	6.3	6.3	6.3
APR	5.7	6.7	6.9	6.5	6.6	6.8	6.6	6.3	6.5
MAY	6.4	7.0	6.9	6.8	6.7	7.8	7.0	6.9	6.8
JUN	5.2	7.0	6.8	6.6	6.8	8.1	7.5	7.1	7.0
JUL	6.2	7.2		6.9	7.1	7.6	7.4	7.2	6.9
AUG	6.3	7.0	7.2	7.1	6.9	8.1	7.4	7.1	7.0
SEP	5.5	6.5	6.5	7.0	6.7	6.7	6.5	5.7	6.6
OCT	6.5	6.7	6.5	6.8	6.9	7.4	7.0	6.6	6.8
NOV		7.0	7.5	7.3	7.4	7.5	7.6	8.4	6.8
DEC	6.6	6.6	7.1	6.7	6.7	6.6	6.9	7.5	6.5
mean	**5.9**	**6.8**	**6.9**	**6.7**	**6.8**	**7.2**	**6.9**	**6.8**	**6.7**
std dev	0.6	0.3	0.3	0.3	0.3	0.6	0.5	0.7	0.3
median	6.0	6.7	6.9	6.8	6.7	7.1	7.0	6.8	6.7
max	6.6	7.2	7.5	7.3	7.4	8.1	7.6	8.4	7.0
min	4.7	6.1	6.4	6.2	6.4	6.5	6.3	5.7	6.3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	5.6	3.8	5.5	6.3	6.0	6.1	5.5	6.1	6.3
FEB	6.0	3.9	5.4	6.2	6.0	6.3	6.4	6.4	6.6
MAR	6.1	3.8	5.7	6.4	6.2	6.4	6.3	6.5	6.8
APR	5.9	3.9	5.6	6.3	6.1	6.3	6.3	6.2	6.4
MAY	6.5	4.6	6.3	7.2	6.8	7.0	6.3	7.0	7.4
JUN	6.4	4.8	6.1	6.9	6.9	6.7	6.1	7.0	6.5
JUL	6.5	4.2	6.2	7.0	6.9	7.0	6.0	7.2	7.4
AUG	6.5	3.8	5.5	5.5	5.9	6.1	6.3	7.3	7.3
SEP	5.7	3.6	5.5	6.6	6.3	6.5	6.1	6.6	6.8
OCT	6.2	3.7	5.8	6.5	6.2	6.1	6.2	6.7	6.5
NOV	5.5	3.6	5.6	6.5	6.3	6.2	5.2	6.4	6.5
DEC	5.3	3.3	5.4	6.4	6.2	6.2	6.2	6.4	6.6
mean	**6.0**	**3.9**	**5.7**	**6.5**	**6.3**	**6.4**	**6.1**	**6.7**	**6.8**
std dev	0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.4
median	6.1	3.8	5.6	6.5	6.2	6.3	6.2	6.6	6.6
max	6.5	4.8	6.3	7.2	6.9	7.0	6.4	7.3	7.4
min	5.3	3.3	5.4	5.5	5.9	6.1	5.2	6.1	6.3

Table 2.5 Dissolved Oxygen (mg/l) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	10.7	10.5	10.5	9.9	9.9	9.6	9.4	9.5
FEB	10.7	10.5	10.5	10.2	9.8	9.6	9.4	8.8
MAR	**8.5**	8.8	8.7	8.5	8.6	8.9	9.1	8.9
APR	5.8	5.9	5.9	5.7	5.8	6.8	7.9	7.7
MAY	6.1	6.7	6.8	6.1	6.4	6.4	6.6	7.3
JUN	4.5	4.4	4.4	4.7	5.0	5.9	6.0	6.1
JUL	5.0	5.9	5.6	5.7	7.6	7.3	6.1	6.4
AUG	4.2	4.2	4.9	4.2	4.7	6.2	5.4	5.7
SEP	3.3	2.9	3.7	3.1	3.8	4.7	5.7	5.7
OCT	4.5	4.8	4.9	5.4	6.0	6.9	6.7	6.9
NOV	6.1	6.1	6.0	6.1	6.7	7.2	7.4	7.5
DEC	9.2	9.1	9.0	8.8	8.8	8.9	8.9	8.3
mean	**6.6**	**6.7**	**6.7**	**6.5**	**6.9**	**7.4**	**7.4**	**7.4**
std dev	2.6	2.5	2.4	2.3	2.0	1.6	1.5	1.3
median	6.0	6.0	6.0	5.9	6.6	7.1	7.1	7.4
max	10.7	10.5	10.5	10.2	9.9	9.6	9.4	9.5
min	3.3	2.9	3.7	3.1	3.8	4.7	5.4	5.7

	NC11	AC	DP	BBT	IC	NCF6
JAN	9.4	9.3	9.1	7.5	8.5	7.7
FEB	10.0	9.8	9.7	8.6	9.5	9.2
MAR	9.9	9.9	9.9	8.7	9.8	8.4
APR	9.4	9.3	9.0	8.0	8.6	8.1
MAY	7.0	6.5	6.9	5.2	6.9	5.5
JUN	5.6	5.8	4.4	4.4	4.4	5.0
JUL	6.3	5.9	5.2	4.4	4.8	5.4
AUG	6.2	5.9	5.5	4.2	4.9	4.3
SEP	5.7	4.6	3.8	3.8	3.7	3.3
OCT	6.4	6.2	4.1	3.3	3.4	3.3
NOV	8.3	8.0	7.5	6.3	6.7	6.1
DEC	10.5	10.2	10.0	9.7	9.8	8.6
mean	**7.9**	**7.6**	**7.1**	**6.2**	**6.8**	**6.2**
std dev	1.9	2.0	2.4	2.2	2.4	2.1
median	7.7	7.3	7.2	5.8	6.8	5.8
max	10.5	10.2	10.0	9.7	9.8	9.2
min	5.6	4.6	3.8	3.3	3.4	3.3

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	7.7	9.6	11.2	10.4	10.6	11.1	9.2	7.5	7.9
FEB	9.2	11.0	12.6	10.8	10.9	11.4	10.4	8.5	9.4
MAR	10.5	11.4	13.4	11.7	11.8	11.2	9.7	8.4	8.7
APR	6.9	6.1	7.9	6.4	6.1	8.2	6.6	5.0	5.5
MAY	4.4	6.7	6.8	7.4	7.9	11.0	6.4	5.1	5.2
JUN	2.6	6.5	5.7	4.9	5.4	10.2	5.4	5.4	4.6
JUL	0.8	6.5		3.4	9.3	8.0	4.5	5.2	4.4
AUG	8.0	5.4	4.3	3.3	7.3	9.2	2.1	6.1	5.1
SEP	4.0	5.5	1.6	5.4	8.1	8.1	4.5	2.1	3.7
OCT	2.5	6.1	2.3	4.4	8.5	9.0	4.1	2.1	3.9
NOV		10.9	9.1	9.8	10.1	12.7	10.2	7.0	7.5
DEC	8.0	9.3	8.9	9.3	8.5	11.2	9.0	8.5	8.7
mean	**5.9**	**7.9**	**7.6**	**7.3**	**8.7**	**10.1**	**6.8**	**5.9**	**6.2**
std dev	3.2	2.3	3.9	3.0	1.9	1.6	2.8	2.2	2.1
median	6.9	6.6	7.9	6.9	8.5	10.6	6.5	5.8	5.4
max	10.5	11.4	13.4	11.7	11.8	12.7	10.4	8.5	9.4
min	0.8	5.4	1.6	3.3	5.4	8.0	2.1	2.1	3.7

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	10.3	9.5	10.6	11.6	11.6	12.8	12.4	10.9	11.0
FEB	9.1	8.3	9.4	9.6	9.5	9.8	10.0	9.8	10.2
MAR	8.3	8.1	8.5	9.0	9.0	8.5	8.9	9.8	11.0
APR	6.2	5.2	6.6	6.7	6.3	5.7	5.6	7.8	7.6
MAY	4.6	3.0	5.5	5.1	6.2	5.9	1.1	7.8	6.6
JUN	5.3	3.7	6.2	6.2	6.4	5.7	4.8	7.5	5.1
JUL	5.0	5.9	5.9	6.7	6.4	5.9	4.8	8.1	7.7
AUG	4.9	5.1	6.0	4.5	6.0	4.5	1.7	7.2	5.3
SEP	4.7	5.2	6.2	6.9	7.1	6.3	2.4	7.7	7.2
OCT	6.4	6.9	7.9	7.9	7.8	6.4	6.2	8.8	7.6
NOV	8.5	7.7	9.5	9.7	9.7	8.9	7.7	10.2	9.1
DEC	8.9	7.1	9.5	9.3	9.1	7.8	7.4	9.8	9.0
mean	**6.9**	**6.3**	**7.7**	**7.8**	**7.9**	**7.4**	**6.1**	**8.8**	**8.1**
std dev	2.0	2.0	1.8	2.1	1.8	2.3	3.4	1.3	2.0
median	6.3	6.4	7.3	7.4	7.5	6.4	5.9	8.5	7.7
max	10.3	9.5	10.6	11.6	11.6	12.8	12.4	10.9	11.0
min	4.6	3.0	5.5	4.5	6.0	4.5	1.1	7.2	5.1

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations 1995-2018 versus 2019.

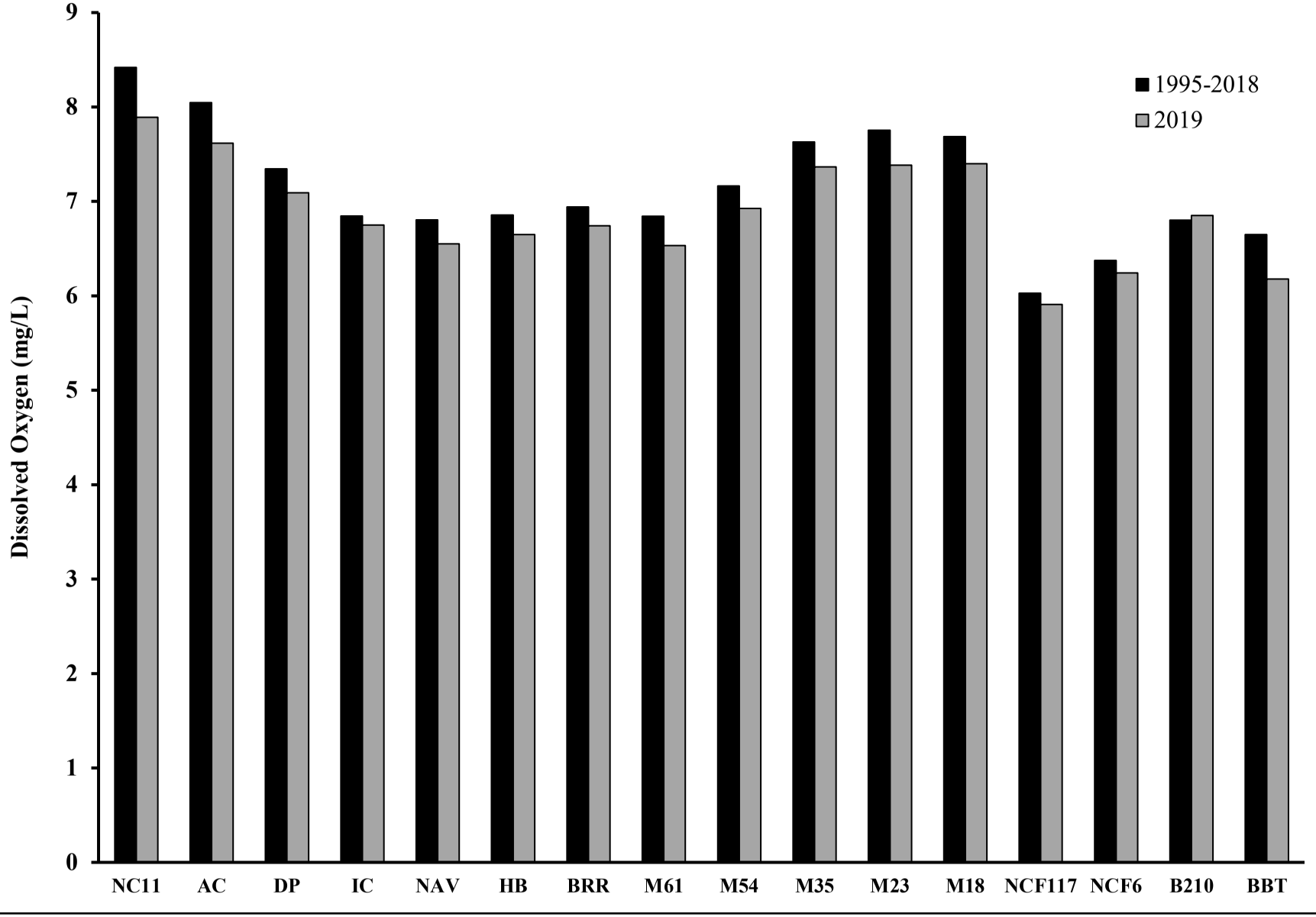


Table 2.6 Field Turbidity (NTU) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	14	12	12	8	9	8	5	5
FEB	11	10	10	8	11	5	3	5
MAR	13	14	11	8	9	8	5	6
APR	33	33	28	19	28	14	7	6
MAY	16	16	13	10	10	8	8	4
JUN	12	11	14	9	8	7	5	3
JUL	8	8	8	6	9	5	2	3
AUG	11	9	7	7	7	8	7	3
SEP	3	3	4	3	1	1	2	2
OCT	5	5	15	7	5	7	6	8
NOV	6	3	4	3	3	3	4	4
DEC	3	2	3	2	2	1	3	13
mean	**11**	**11**	**11**	**8**	**9**	**6**	**5**	**5**
std dev	8	8	7	4	7	4	2	3
median	11	10	11	8	9	7	5	5
max	33	33	28	19	28	14	8	13
min	3	2	3	2	1	1	2	2

	NC11	AC	DP	BBT	IC	NCF6
JAN	32	32	32	20	27	4
FEB	8	11	11	4	7	7
MAR	22	21	20	7	18	4
APR	14	15	13	5	11	2
MAY	20	17	16	6	7	7
JUN	6	7	8	7	10	7
JUL	6	7	9	6	8	11
AUG	6	7	8	5	5	13
SEP	5	6	6	3	6	4
OCT	4	6	5	3	5	7
NOV	4	5	6	2	4	2
DEC	6	7	7	4	6	7
mean	**11**	**12**	**12**	**6**	**10**	**6**
std dev	9	8	8	5	7	3
median	6	7	9	5	7	7
max	32	32	32	20	27	13
min	4	5	5	2	4	2

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	7	3	2	3	8	6	4	4	4
FEB	8	2	1	2	7	5	5	3	13
MAR	7	1	0	3	10	7	7	2	3
APR	6	6	2	3	7	5	7	4	5
MAY	10	7	3	6	5	6	7	3	12
JUN	9	11	5	3	4	4	6	3	14
JUL	7	5		4	13	2	6	3	8
AUG	7	1	3	3	16	4	6	1	14
SEP	2	5	7	1	10	6	9	2	7
OCT	2	2	30	0	5	2	5	3	9
NOV		0	0	1	4	2	3	3	11
DEC	3	0	1	2	2	2	1	3	8
mean	**6**	**4**	**5**	**3**	**8**	**4**	**6**	**3**	**9**
std dev	3	3	9	2	4	2	2	1	4
median	7	3	2	3	7	5	6	3	9
max	10	11	30	6	16	7	9	4	14
min	2	0	0	0	2	2	1	1	3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	2	4	1	3	2	1	4	21	36
FEB	1	6	1	3	0	0	2	8	5
MAR	1	11	0	7	1	0	2	6	3
APR	2	4	0	3	0	0	4	14	7
MAY	3	6	2	3	3	4	17	5	8
JUN	2	7	2	3	3	4	3	4	25
JUL	2	2	2	3	2	3	4	3	5
AUG	4	2	3	4	4	4	17	4	8
SEP	2	0	2	3	2	3	2	3	3
OCT	2	1	3	5	2	2	2	5	3
NOV	1	1	1	0	0	0	1	4	2
DEC	1	1	1	2	1	0	1	10	3
mean	**2**	**4**	**2**	**3**	**2**	**2**	**5**	**7**	**9**
std dev	1	3	1	2	1	2	6	5	11
median	2	3	2	3	2	2	3	5	5
max	4	11	3	7	4	4	17	21	36
min	1	0	0	0	0	0	1	3	2

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2018 versus 2019.

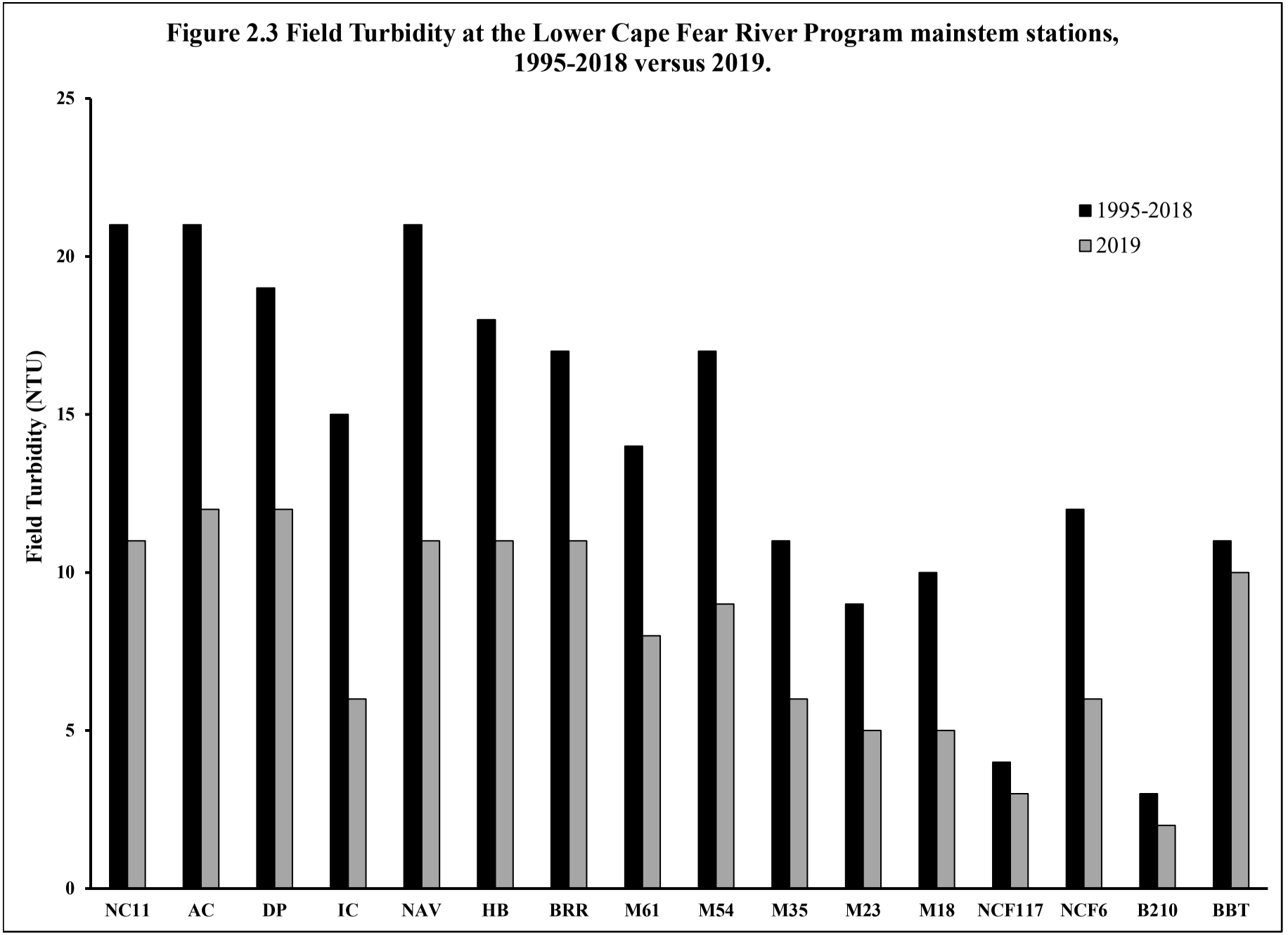


Table 2.7 Total Suspended Solids (mg/L) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	14.7	10.6	9.8	6.8	7.6	7.7	7.5	6.7
FEB	10.8	9.6	8.3	8.4	15.2	10.7	8.5	17.9
MAR	8.3	6.9	6.0	8.7	9.8	12.5	12.1	17.6
APR	22.4	18.2	19.3	16.3	33.3	19.6	14.1	12.9
MAY	20.2	15.7	14.0	11.0	11.9	11.0	8.8	10.5
JUN	8.9	10.3	14.1	14.1	16.7	16.5	19.4	19.3
JUL	14.2	12.9	14.3	14.7	23.0	17.7	12.8	17.9
AUG	10.3	10.8	12.6	16.1	17.0	19.9	22.7	13.8
SEP	6.3	5.8	5.0	6.1	6.9	7.7	10.8	16.7
OCT	12.7	11.9	15.1	17.8	16.6	21.9	22.6	24.2
NOV	9.5	5.0	8.3	13.6	11.0	11.4	17.0	16.0
DEC	3.3	2.8	4.0	5.1	6.5	8.1	12.2	26.7
mean	**11.8**	**10.0**	**10.9**	**11.6**	**14.6**	**13.7**	**14.0**	**16.7**
std dev	5.5	4.4	4.7	4.4	7.7	5.1	5.3	5.5
median	10.6	10.5	11.2	12.3	13.6	12.0	12.5	17.2
max	22.4	18.2	19.3	17.8	33.3	21.9	22.7	26.7
min	3.3	2.8	4.0	5.1	6.5	7.7	7.5	6.7

	NC11	AC	DP	IC	NCF6
JAN	20.2	21.8	23.4	18.2	3.5
FEB	8.8	10.4	10.8	6.0	7.7
MAR	22.5	22.8	22.0	19.0	5.4
APR	15.6	16.9	14.7	11.0	5.9
MAY	17.9	22.2	20.2	7.3	9.1
JUN	3.2	7.0	5.1	8.0	17.9
JUL	4.2	3.6	5.5	9.7	21.1
AUG	4.7	5.9	9.4	5.6	26.6
SEP	1.3	4.3	5.9	10.3	6.9
OCT	4.0	5.5	3.1	4.1	15.5
NOV	2.7	4.6	4.7	1.3	3.8
DEC	3.6	4.3	5.3	6.0	7.4
mean	**9.1**	**10.8**	**10.8**	**8.9**	**8.9**
std dev	7.7	7.8	7.4	5.3	5.3
median	4.5	6.5	7.7	8.0	7.7
max	22.5	22.8	23.4	4.4	19.0
min	1.3	3.6	3.1	6.6	1.3

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN		1.3		1.3	5.1	3.3	3.3	3.2	5.3
FEB		3.1		2.6	4.5	5.4	4.3	2.7	18.8
MAR		1.3		2.7	4.7	5.6	5.1	7.2	1.3
APR		6.5		4.0	5.1	2.8	6.7	3.3	5.2
MAY		8.5		3.6	3.9	1.3	1.4	2.9	19.1
JUN		15.8		4.8	5.6	3.0	7.3	3.3	23.7
JUL		4.9		4.4	8.4	6.2	5.4	3.9	17.0
AUG		1.4		5.2	9.6	6.4	1.3	1.4	24.0
SEP		5.7		1.3	10.6	1.3	2.9	5.4	15.7
OCT		3.7		3.4	8.2	6.7	3.6	32.6	20.6
NOV		1.4		1.3	3.1	1.3	1.3	5.1	21.4
DEC		1.3		1.3	1.3	1.3	1.3	4.0	15.3
mean		**4.6**		**3.0**	**5.8**	**3.7**	**3.7**	**6.3**	**15.6**
std dev		4.3		1.5	2.8	2.2	2.1	8.4	7.6
median		3.4		3.1	5.1	3.2	3.5	3.6	17.9
max		15.8		5.2	10.6	6.7	7.3	32.6	24.0
min		1.3		1.3	1.3	1.3	1.3	1.4	1.3

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1.4					1.4			
FEB	1.3					1.3			
MAR	1.3								
APR	3.5					2.7			
MAY	1.3					2.6			
JUN	1.3					4.4			
JUL	1.4					1.3			
AUG	4.2					7.1			
SEP	1.3					3.7			
OCT	1.3					2.9			
NOV	1.3					1.3			
DEC	1.3					1.3			
mean	**1.7**					**2.7**			
std dev	1.0					1.8			
median	1.3					2.6			
max	4.2					7.1			
min	1.3					1.3			

Table 2.8 Light Attenuation (k) 2019 at the Lower Cape Fear River Program stations8

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN								
FEB								
MAR								
APR	4.74	4.79	4.26	4.31	5.43	3.83		
MAY	4.01	3.27	2.88	3.18	3.06	2.53	2.24	2.61
JUN								
JUL								
AUG								
SEP								
OCT								
NOV								
DEC								
mean	**4.38**	**4.03**	**3.57**	**3.75**	**4.25**	**3.18**	**2.24**	**2.61**
std dev	0.52	1.07	0.98	0.80	1.68	0.92		
max	4.74	4.79	4.26	4.31	5.43	3.83	2.24	2.61
min	4.01	3.27	2.88	3.18	3.06	2.53	2.24	2.61

	NC11	AC	DP	BBT	IC	NCF6
JAN						
FEB	2.39	2.73	2.32	3.19	2.74	3.64
MAR	3.05	3.15	2.08	3.04	3.03	3.36
APR	3.52	2.96	2.75	3.39	2.93	3.30
MAY	2.51	2.66	2.52	4.12	2.00	2.71
JUN						
JUL						
AUG						
SEP						
OCT						
NOV						
DEC						
mean	**2.87**	**2.88**	**2.42**	**3.44**	**2.68**	**3.25**
std dev	0.52	0.22	0.29	0.48	0.47	0.39
max	3.52	3.15	2.75	4.12	3.03	3.64
min	2.39	2.66	2.08	3.04	2.00	2.71

Table 2.9 Total Nitrogen (µg/l) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	460	560	460	590	480	720	1,020	960
FEB	1,140	1,050	550	1,090	1,140	430	310	50
MAR	1,140	1,190	970	950	1,030	860	530	480
APR	1,310	1,100	1,130	1,030	1,280	1,050	580	540
MAY	1,220	1,180	1,080	1,330	1,230	1,070	900	1,050
JUN	1,540	1,370	1,120	1,490	2,340	1,890	950	1,330
JUL	1,340	880	1,030	1,200	850	600	50	50
AUG	760	720	630	500	410	140	50	200
SEP	1,300	800	1,000	1,100	850	860	800	600
OCT	760	600	500	830	600	700	600	500
NOV	960	760	1,150	1,300	1,000	720	1,390	780
DEC	1,460	4,220	1,300	1,160	1,520	1,190	980	1,380
mean	**1,116**	**1,203**	**910**	**1,048**	**1,061**	**853**	**680**	**660**
std dev	322	983	292	293	522	435	406	453
median	1,180	965	1,015	1,095	1,015	790	700	570
max	1,540	4,220	1,300	1,490	2,340	1,890	1,390	1,380
min	460	560	460	500	410	140	50	50

	NC11	AC	DP	IC	NCF6
JAN	570	1,170	570	860	1,020
FEB	1,170	1,220	1,320	1,260	2,220
MAR	1,090	980	660	1,030	1,150
APR	1,120	810	910	2,430	850
MAY	900	1,380	930	1,120	1,090
JUN	1,590	2,030	1,230	2,000	1,520
JUL	700	1,000	1,570	1,460	1,100
AUG	560	960	290	250	300
SEP	2,390	860	1,220	930	1,040
OCT	970	960	1,150	960	1,000
NOV	1,730	2,110	2,310	1,660	1,330
DEC	1,690	1,610	2,090	2,950	1,030
mean	**1,207**	**1,258**	**1,188**	**1,409**	**1,138**
std dev	548	442	592	748	447
median	1,105	1,085	1,185	1,190	1,065
max	2,390	2,110	2,310	2,950	2,220
min	560	810	290	250	300

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	900	1,140	1,040	4,320	4,360	830	1,390	910	520
FEB	1,720	1,840	1,260	4,280	4,260	1,180	1,970	1,380	1,320
MAR	1,640	1,670	1,780	4,840	4,860	1,360	1,890	1,310	1,300
APR	1,860	1,240	940	3,590	3,350	1,550	3,700	1,670	1,250
MAY	1,650	1,240	650	1,530	1,000	1,170	5,180	1,340	1,430
JUN	2,500	2,430	1,920	4,490	2,300	2,370	9,890	1,430	2,140
JUL	1,600	1,520		1,280	1,640	1,080	2,440	980	800
AUG	500	490	400	1,090	300	430	5,920	200	1,670
SEP	1,800	1,350	1,300	1,130	1,390	1,200	2,090	1,500	1,000
OCT	1,600	1,220	1,800	1,090	1,200	1,700	3,600	1,230	830
NOV		460	50	1,370	400	310	4,180	640	3,220
DEC	1,790	1,220	600	2,700	3,040	1,190	2,850	1,370	1,490
mean	**1,596**	**1,318**	**1,067**	**2,643**	**2,342**	**1,198**	**3,758**	**1,163**	**1,414**
std dev	517	536	613	1,551	1,597	548	2,377	414	713
median	1,650	1,240	1,040	2,115	1,970	1,185	3,225	1,325	1,310
max	2,500	2,430	1,920	4,840	4,860	2,370	9,890	1,670	3,220
min	500	460	50	1,090	300	310	1,390	200	520

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,640	1,240	950	2,760	2,840	2,120	930	2,080	1,620
FEB	1,430	1,620	880	2,380	2,080	1,650	1,080	1,620	1,320
MAR	1,240	900	760	2,100	1,610	970	430	1,090	820
APR	1,440	1,100	1,290	1,910	1,380	1,310	2,230	1,210	1,680
MAY	1,300	5,020	1,310	1,600	1,400	3,000	1,950	1,440	520
JUN	1,640	3,140	1,990	2,280	1,840	1,300	1,290	1,700	930
JUL	350	400	630	640	640	2,240	440	180	300
AUG	1,530	2,400	1,980	1,960	1,500	2,920	1,760	1,410	540
SEP	1,260	1,600	1,930	2,020	1,550	2,200	1,400	1,040	380
OCT	700	1,300	800	920	800	800	900	800	700
NOV	1,120	3,800	1,250	2,240	1,890	1,490	800	600	2,360
DEC	490	300	340	1,520	570	830	120	1,510	1,700
mean	**1,178**	**1,902**	**1,176**	**1,861**	**1,508**	**1,736**	**1,111**	**1,223**	**1,073**
std dev	437	1,432	553	607	642	759	644	521	652
median	1,280	1,450	1,100	1,990	1,525	1,570	1,005	1,310	875
max	1,640	5,020	1,990	2,760	2,840	3,000	2,230	2,080	2,360
min	350	300	340	640	570	800	120	180	300

Table 2.10 Nitrate/Nitrite (µg/l) 2019 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	460	560	460	590	480	420	320	260
FEB	540	550	550	590	540	430	310	60
MAR	640	590	570	450	430	360	230	180
APR	310	300	330	330	380	350	280	240
MAY	420	480	480	430	430	370	300	250
JUN	840	870	720	490	340	190	50	30
JUL	340	180	130	500	50	10	10	10
AUG	560	520	430	300	210	40	10	10
SEP	10	10	10	10	50	60	10	10
OCT	60	10	10	230	10	10	10	10
NOV	60	60	450	400	400	320	190	180
DEC	660	620	600	460	420	490	180	80
mean	**408**	**396**	**395**	**398**	**312**	**254**	**158**	**110**
std dev	263	278	231	163	184	181	132	104
median	440	500	455	440	390	335	185	70
max	840	870	720	590	540	490	320	260
min	10	10	10	10	10	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	570	570	570	560	520
FEB	770	720	720	760	620
MAR	390	380	60	430	450
APR	420	410	410	1,630	350
MAY	400	380	430	420	390
JUN	1,290	1,430	1,130	1,000	320
JUL	10	10	470	460	10
AUG	260	660	90	50	10
SEP	990	160	420	30	40
OCT	270	160	150	60	10
NOV	830	1,010	810	260	130
DEC	790	710	690	450	330
mean	**583**	**550**	**496**	**509**	**265**
std dev	361	396	314	456	217
median	495	490	450	440	325
max	1,290	1,430	1,130	1,630	620
min	10	10	60	30	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	200	1,140	840	4,320	4,260	830	1,390	610	520
FEB	320	1,040	560	3,580	3,660	380	1,070	580	620
MAR	440	1,070	880	3,940	3,960	560	990	610	500
APR	160	340	40	2,490	1,950	450	1,000	470	150
MAY	50	440	50	730	300	370	3,880	340	430
JUN	10	330	120	2,490	200	370	8,090	230	440
JUL	10	520		180	340	280	240	80	10
AUG	10	190	10	690	10	30	5,420	10	170
SEP	10	50	10	130	190	10	290	10	10
OCT	10	20	10	190	100	10	1,400	30	30
NOV		460	10	870	100	110	2,580	140	320
DEC	390	420	10	1,800	2,240	390	1,850	370	390
mean	**146**	**502**	**231**	**1,784**	**1,443**	**316**	**2,350**	**290**	**299**
std dev	168	384	350	1,546	1,689	247	2,352	238	217
median	50	430	40	1,335	320	370	1,395	285	355
max	440	1,140	880	4,320	4,260	830	8,090	610	620
min	10	20	10	130	10	10	240	10	10

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1,040	40	350	2,160	1,840	1,420	430	980	920
FEB	830	20	280	1,680	1,380	950	380	1,020	720
MAR	540	10	160	1,300	810	370	130	490	320
APR	540	10	590	1,010	580	310	230	410	680
MAY	400	220	410	600	400	1,700	50	840	120
JUN	240	40	290	680	440	300	90	700	130
JUL	150	10	430	440	340	1,840	40	80	100
AUG	230	10	280	60	10	220	60	510	40
SEP	160	10	230	1,220	650	1,200	100	440	80
OCT	10	10	10	20	10	10	10	10	10
NOV	320	10	150	1,040	490	590	10	600	760
DEC	290	10	140	1,020	570	430	20	610	600
mean	**396**	**33**	**277**	**936**	**627**	**778**	**129**	**558**	**373**
std dev	298	60	156	627	525	623	143	311	336
median	305	10	280	1,015	530	510	75	555	225
max	1,040	220	590	2,160	1,840	1,840	430	1,020	920
min	10	10	10	20	10	10	10	10	10

Figure 2.4 Nitrate + Nitrite at the Lower Cape Fear River Program mainstem stations, 1995-2018 versus 2019.

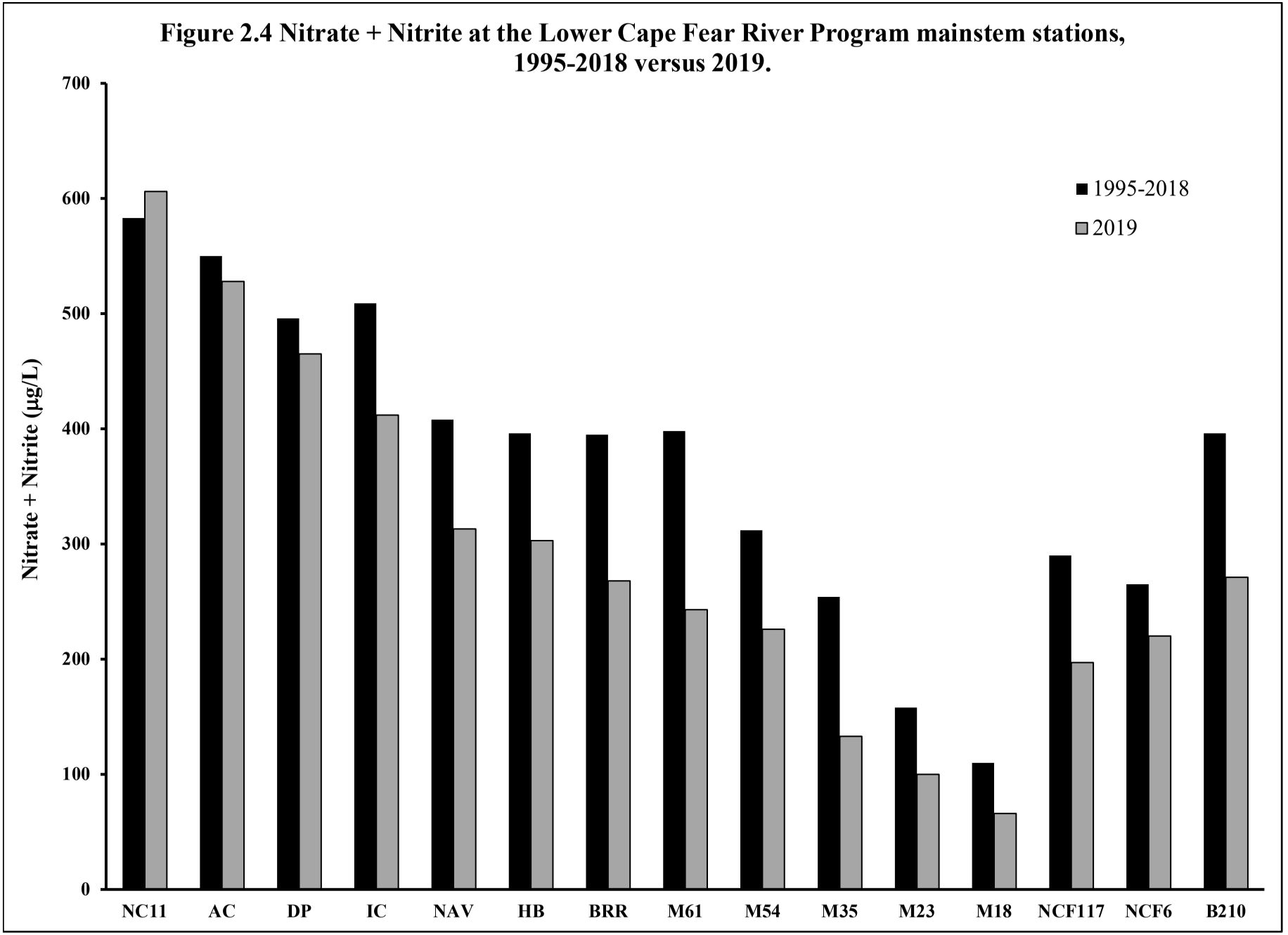


Table 2.11 Ammonia (µg/l) 2019 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	50	60	40	60	70	80	80	80
FEB	80	90	80	110	140	130	110	390
MAR	80	100	90	80	100	90	100	50
APR	130	80	90	90	90	100	70	50
MAY	80	70	70	100	100	100	70	170
JUN	40	20	10	70	100	110	710	620
JUL	80	170	60	60	10	10	10	10
AUG	180	130	80	80	10	10	10	10
SEP	110	130	140	190	70	50	10	10
OCT	10	10	10	10	10	10	10	10
NOV	140	120	60	60	10	10	710	10
DEC	10	20	40	20	70	90	10	10
mean	**83**	**83**	**64**	**78**	**65**	**66**	**158**	**118**
std dev	52	50	37	46	45	45	260	193
median	80	85	65	75	70	85	70	30
max	180	170	140	190	140	130	710	620
min	10	10	10	10	10	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	50	50	50	40	40
FEB	40	40	40	60	50
MAR	50	50	60	60	80
APR	40	170	50	60	60
MAY	100	340	50	120	220
JUN	10	10	50	30	60
JUL	40	110	90	60	50
AUG	130	80	130	140	110
SEP	170	240	150	190	80
OCT	10	10	30	10	10
NOV	170	170	170	270	170
DEC	90	200	110	50	10
mean	**75**	**123**	**82**	**91**	**78**
std dev	57	103	47	76	62
median	50	95	55	60	60
max	170	340	170	270	220
min	10	10	30	10	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	230	40	40	310	60	90	50	50	50
FEB	210	30	10	250	100	50	110	50	60
MAR	90	10	10	70	40	60	80	30	30
APR	230	90	60	170	180	140	120	130	100
MAY	280	100	140	130	80	100	100	90	100
JUN	10	30	40	190	220	20	60	10	100
JUL	70	70		100	60	70	500	10	70
AUG	140	60	10	120	70	120	360	30	10
SEP	280	140	70	140	100	170	260	100	170
OCT	40	20	10	20	20	10	90	10	10
NOV		110	100	100	90	90	120	160	10
DEC	10	10	10	20	10	80	70	10	50
mean	**145**	**59**	**45**	**135**	**86**	**83**	**160**	**57**	**63**
std dev	105	43	44	86	61	46	140	52	48
median	140	50	40	125	75	85	105	40	55
max	280	140	140	310	220	170	500	160	170
min	10	10	10	20	10	10	50	10	10

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	90	220	110	60	50	30	101	230	170
FEB	40	310	50	40	30	10	30	110	30
MAR	70	260	120	110	90	50	50	80	50
APR	80	250	110	90	40	70	90	100	110
MAY	60	2,390	120	50	40	30	510	40	90
JUN	100	1,870	30	60	40	50	70	70	80
JUL	60	210	60	60	50	70	60	70	100
AUG	120	160	70	1,690	390	620	450	470	170
SEP	120	200	110	230	110	120	220	110	80
OCT	10		10	10	10	10	10	10	10
NOV	80	90	90	10	120	10	10	110	80
DEC	10	10	10	10	10	10	10	10	10
mean	**70**	**543**	**74**	**202**	**82**	**90**	**134**	**118**	**82**
std dev	37	798	42	473	103	170	172	125	53
median	75	220	80	60	45	40	65	90	80
max	120	2,390	120	1,690	390	620	510	470	170
min	10	10	10	10	10	10	10	10	10

Table 2.12 Total Kjeldahl Nitrogen (µg/l) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	50	50	50	50	50	300	700	700
FEB	600	500	50	500	600	50	50	50
MAR	500	600	400	500	600	500	300	300
APR	1,000	800	800	700	900	700	300	300
MAY	800	700	600	900	800	700	600	800
JUN	700	500	400	1,000	2,000	1,700	900	1,300
JUL	1,000	700	900	700	800	600	50	50
AUG	200	200	200	200	200	100	50	200
SEP	1,300	800	1,000	1,100	800	800	800	600
OCT	700	600	500	600	600	700	600	500
NOV	900	700	700	900	600	400	1,200	600
DEC	800	3,600	700	700	1,100	700	800	1,300
mean	**713**	**813**	**525**	**654**	**754**	**604**	**529**	**558**
std dev	346	907	316	311	486	425	377	423
median	750	650	550	700	700	650	600	550
max	1,300	3,600	1,000	1,100	2,000	1,700	1,200	1,300
min	50	50	50	50	50	50	50	50

	NC11	AC	DP	IC	NCF6
JAN	50	600	50	300	500
FEB	400	500	600	500	1,600
MAR	700	600	600	600	700
APR	700	400	500	800	500
MAY	500	1,000	500	700	700
JUN	300	600	100	1,000	1,200
JUL	700	1,000	1,100	1,000	1,100
AUG	300	300	200	200	300
SEP	1,400	700	800	900	1,000
OCT	700	800	1,000	900	1,000
NOV	900	1,100	1,500	1,400	1,200
DEC	900	900	1,400	2,500	700
mean	**629**	**708**	**696**	**900**	**875**
std dev	354	254	479	602	372
median	700	650	600	850	850
max	1,400	1,100	1,500	2,500	1,600
min	50	300	50	200	300

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	700	50	200	50	100	50	50	300	50
FEB	1,400	800	700	700	600	800	900	800	700
MAR	1,200	600	900	900	900	800	900	700	800
APR	1,700	900	900	1,100	1,400	1,100	2,700	1,200	1,100
MAY	1,600	800	600	800	700	800	1,300	1,000	1,000
JUN	2,500	2,100	1,800	2,000	2,100	2,000	1,800	1,200	1,700
JUL	1,600	1,000		1,100	1,300	800	2,200	900	800
AUG	500	300	400	400	300	400	500	200	1,500
SEP	1,800	1,300	1,300	1,000	1,200	1,200	1,800	1,500	1,000
OCT	1,600	1,200	1,800	900	1,100	1,700	2,200	1,200	800
NOV		50	50	500	300	200	1,600	500	2,900
DEC	1,400	800	600	900	800	800	1,000	1,000	1,100
mean	**1,455**	**825**	**841**	**863**	**900**	**888**	**1,413**	**875**	**1,121**
std dev	537	569	585	473	562	563	776	393	695
median	1,600	800	700	900	850	800	1,450	950	1,000
max	2,500	2,100	1,800	2,000	2,100	2,000	2,700	1,500	2,900
min	500	50	50	50	100	50	50	200	50

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	600	1,200	600	600	1,000	700	500	1,100	700
FEB	600	1,600	600	700	700	700	700	600	600
MAR	700	900	600	800	800	600	300	600	500
APR	900	1,100	700	900	800	1,000	2,000	800	1,000
MAY	900	4,800	900	1,000	1,000	1,300	1,900	600	400
JUN	1,400	3,100	1,700	1,600	1,400	1,000	1,200	1,000	800
JUL	200	400	200	200	300	400	400	100	200
AUG	1,300	2,400	1,700	1,900	1,500	2,700	1,700	900	500
SEP	1,100	1,600	1,700	800	900	1,000	1,300	600	300
OCT	700	1,300	800	900	800	800	900	800	700
NOV	800	3,800	1,100	1,200	1,400	900	800	50	1,600
DEC	200	300	200	500	50	400	100	900	1,100
mean	**783**	**1,875**	**900**	**925**	**888**	**958**	**983**	**671**	**700**
std dev	374	1,388	544	465	430	608	638	325	388
median	750	1,450	750	850	850	850	850	700	650
max	1,400	4,800	1,700	1,900	1,500	2,700	2,000	1,100	1,600
min	200	300	200	200	50	400	100	50	200

Table 2.13 Total Phosphorus (µg/l) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	70	90	80	80	80	110	80	80
FEB	100	120	50	90	100	50	30	60
MAR	170	150	150	140	140	130	120	120
APR	900	160	650	230	340	180	140	700
MAY	250	290	730	180	220	190	240	180
JUN	10	90	10	140	170	200	330	140
JUL	230	240	190	140	120	110	100	180
AUG	320	220	360	200	260	120	210	160
SEP	670	410	280	340	600	940	1,050	1,030
OCT	150	120	110	120	100	100	90	90
NOV	2,040	690	520	770	960	1,060	420	1,680
DEC	210	350	600	2,210	1,180	190	2,060	110
mean	**427**	**244**	**311**	**387**	**356**	**282**	**406**	**378**
std dev	545	167	244	578	351	325	564	485
median	220	190	235	160	195	155	175	150
max	2,040	690	730	2,210	1,180	1,060	2,060	1,680
min	10	90	10	80	80	50	30	60

	NC11	AC	DP	IC	NCF6
JAN	100	90	90	80	120
FEB	80	90	100	110	160
MAR	100	100	170	100	80
APR	150	70	80	290	10
MAY	680	220	150	120	740
JUN	170	70	120	130	760
JUL	540	280	500	220	200
AUG	460	380	370	430	280
SEP	430	410	350	240	110
OCT	280	370	340	290	180
NOV	590	480	640	700	950
DEC	90	170	110	90	80
mean	**306**	**228**	**252**	**233**	**233**
std dev	212	144	177	174	306
median	225	195	160	175	170
max	680	480	640	700	700
min	80	70	80	80	80

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	150	70	60	90	140	90	160	120	70
FEB	150	100	60	80	200	80	140	90	80
MAR	360	210	120	130	200	180	150	120	110
APR	380	160	120	150	270	190	290	190	100
MAY	180	160	80	100	220	110	540	100	110
JUN	340	510	180	390	390	200	1,690	150	220
JUL	280	360		240	290	200	1,900	190	260
AUG	210	650	140	460	240	240	3,020	70	220
SEP	1,010	820	900	780	1,200	1,210	1,090	1,130	930
OCT	390	390	880	470	710	560	1,590	320	310
NOV		100	60	130	390	140	660	210	540
DEC	280	120	80	130	140	80	270	90	130
mean	**339**	**304**	**244**	**263**	**366**	**273**	**958**	**232**	**257**
std dev	229	235	307	208	292	308	877	279	240
median	280	185	120	140	255	185	600	135	175
max	1,010	820	900	780	1,200	1,210	3,020	1,130	930
min	150	70	60	80	140	80	140	70	70

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	60	220	40	70	30	80	40	120	140
FEB	50	150	10	50	10	80	30	50	100
MAR	300	310	140	260	120	190	200	130	160
APR	90	230	170	310	220	310	250	120	150
MAY	240	760	100	280	210	900	190	170	270
JUN	370	710	890	940	920	430	100	100	270
JUL	200	170	110	180	190	1,060	80	110	270
AUG	260	170	120	170	110	440	180	120	250
SEP	280	360	280	370	250	580	240	130	390
OCT	390	260	320	480	360	420	280	520	410
NOV	60	10	20	140	120	490	60	10	30
DEC	110	70	50	120	40	190	70	90	110
mean	**201**	**285**	**188**	**281**	**215**	**431**	**143**	**139**	**213**
std dev	118	221	231	233	234	291	86	121	112
median	220	225	115	220	155	425	140	120	205
max	390	760	890	940	920	1,060	280	520	410
min	50	10	10	50	10	80	30	10	30

Figure 2.5 Total Phosphorus at the Lower Cape Fear River Program mainstem stations, 1995-2018 versus 2019.

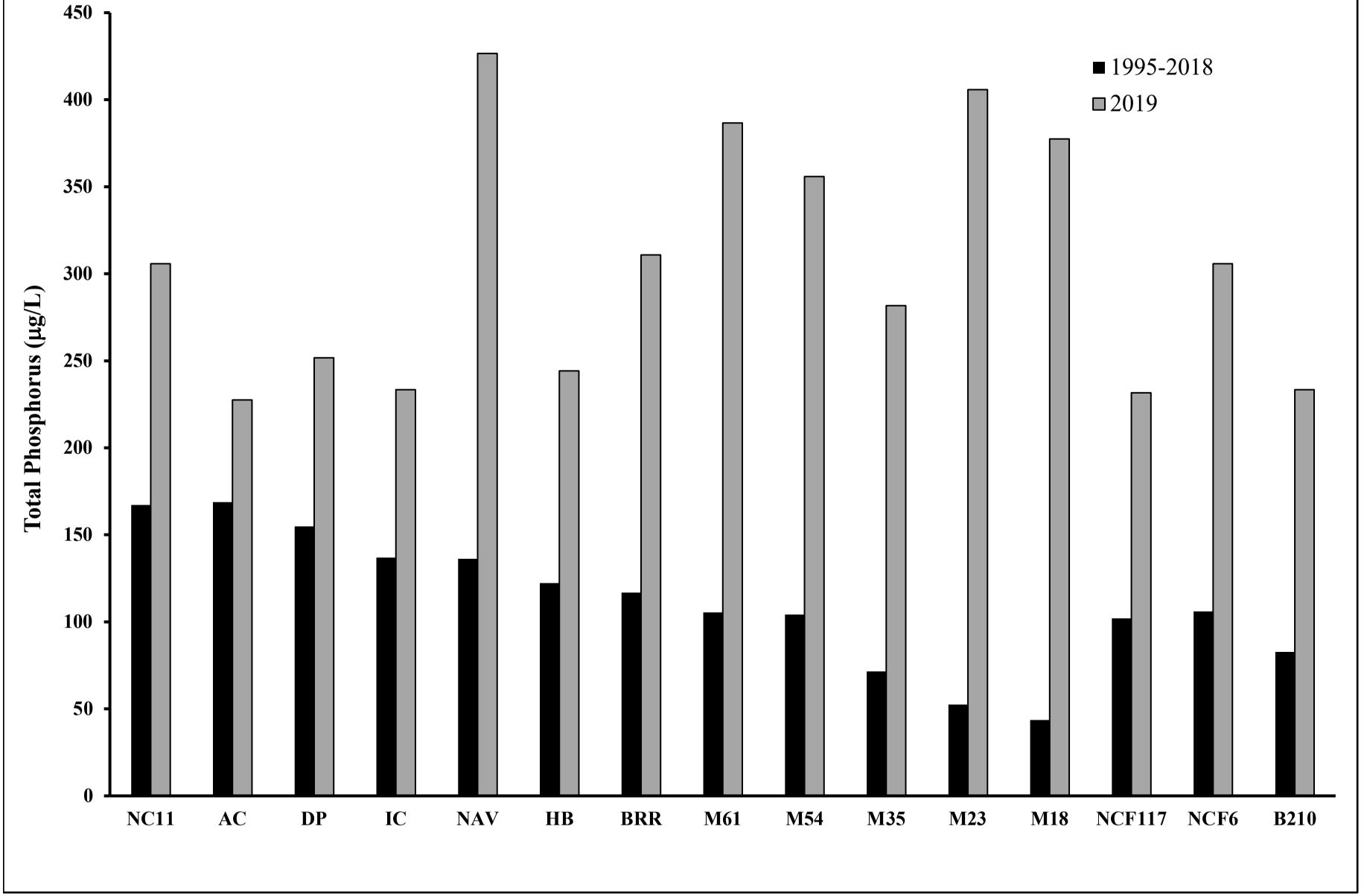


Table 2.14 Orthophosphate (µg/l) 2019 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	20	20	20	20	20	20	20	20
FEB	10	20	10	20	20	20	10	10
MAR	30	30	40	30	30	20	20	10
APR	30	30	30	30	0	40	20	20
MAY	30	30	30	40	40	30	20	20
JUN	50	60	50	40	30	20	20	10
JUL	40	30	50	40	20	30	20	40
AUG	60	60	50	40	30	20	20	10
SEP	50	60	60	60	50	50	20	20
OCT	40	40	40	40	40	30	20	20
NOV	40	60	50	30	40	30	20	20
DEC	60	60	60	50	50	50	30	20
mean	**38**	**42**	**41**	**37**	**31**	**30**	**20**	**18**
std dev	15	17	16	12	14	11	4	8
median	40	35	45	40	30	30	20	20
max	60	60	60	60	50	50	30	40
min	10	20	10	20	0	20	10	10

	NC11	AC	DP	BBT	IC	NCF6
JAN	30	40	40	40	30	20
FEB	30	20	30	30	30	20
MAR	10	10	20	20	10	20
APR	10	10	10	20	10	10
MAY	30	30	30	30	30	40
JUN	50	60	60	60	60	30
JUL	60	80	70	50	60	10
AUG	80	90	90	50	70	20
SEP	90	120	70	50	60	40
OCT	90	90	90	50	70	40
NOV	120	110	120	50	90	40
DEC	40	70	50	30	40	20
mean	**53**	**61**	**57**	**40**	**47**	**26**
std dev	35	38	33	13	25	12
median	45	65	55	45	50	20
max	120	120	120	60	90	40
min	10	10	10	20	10	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	100	20	20	40	40	20	70	30	30
FEB	70	10	10	20	40	10	50	20	30
MAR	120	10	10	20	30	20	50	20	20
APR	230	40	40	40	60	20	100	70	30
MAY	80	30	40	20	30	20	290	30	30
JUN	120	40	30	50	50	30	1150	40	40
JUL	50	70		40	20	50	1100	40	30
AUG	30	60	10	130	10	20	1570	10	
SEP	160	60	60	60	120	40	240	80	50
OCT	70	50	30	40	130	30	830	50	40
NOV		20	10	20	50	20	300	40	30
DEC	130	10	10	20	30	10	150	20	20
mean	**105**	**35**	**25**	**42**	**51**	**24**	**492**	**38**	**32**
std dev	56	22	17	31	37	12	527	21	9
median	100	35	20	40	40	20	265	35	30
max	230	70	60	130	130	50	1570	80	50
min	30	10	10	20	10	10	50	10	20

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	20	60	10	30	10	40	10	10	20
FEB	30	100	10	20	10	50	10	10	20
MAR	20	100	10	30	10	80	10	10	20
APR	40	90	20	30	10	110	10	10	30
MAY	50	360	30	70	40	490	10	10	50
JUN	40	210	30	80	40	180	20	30	60
JUL	80	100	20	90	70	570	20	50	100
AUG	70	60	50	90	50	110	20		
SEP	50	30	20	40	30	200	5	20	80
OCT	50	30	30	110	40	90	20	20	80
NOV	30	20	10	60	20	180	5	10	40
DEC	20	20	10	60	20	120	5	10	30
mean	**42**	**98**	**21**	**59**	**29**	**185**	**12**	**17**	**48**
std dev	19	98	12	29	19	170	6	13	28
median	40	75	20	60	25	115	10	10	40
max	80	360	50	110	70	570	20	50	100
min	20	20	10	20	10	40	5	10	20

Table 2.15 Chlorophyll *a* (µg/l) 2019 at the Lower Cape Fear River Program stations.

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

	NC11	AC	DP	BBT	IC	NCF6
JAN	1	1	1	0	1	1
FEB	8	7	7	3	6	2
MAR	10	10	10	4	9	3
APR	14	16	14	4	9	3
MAY	7	6	6	4	5	3
JUN	3	3	1	2	2	10
JUL	6	4	3	2	3	19
AUG	2	2	2	1	2	6
SEP	5	2	1	1	1	3
OCT	7	5	1	1	1	3
NOV	1	1	1	1	1	2
DEC	2	2	2	2	2	1
mean	**6**	**5**	**4**	**2**	**4**	**5**
std dev	4	4	4	1	3	5
median	6	4	2	2	2	3
max	14	16	14	4	9	19
min	1	1	1	0	1	1

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1	1	1	2	2	2	1	1	1
FEB	2	2	2	4	5	20	4	2	9
MAR	2	2	2	2	3	3	2	2	2
APR	9	2	2	3	3	2	2	1	4
MAY	5	2	2	10	2	1	0	1	6
JUN	3	6	20	7	31	2	2	3	6
JUL	1	4		14	15	3	1	9	15
AUG	21	2	24	22	12	3	3	12	23
SEP	9	1	1	5	52	4	1	1	4
OCT	18	2	175	12	19	6	4	2	9
NOV		2	1	2	2	0	3	2	4
DEC	2	2	1	2	4	2	0	1	2
mean	**7**	**2**	**21**	**7**	**13**	**4**	**2**	**3**	**7**
std dev	7	1	52	6	15	5	1	4	6
median	3	2	2	5	5	3	2	2	5
max	21	6	175	22	52	20	4	12	23
min	1	1	1	2	2	0	0	1	1

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1	2	1	1	1	1	2	3	4
FEB	1	3	1	2	1	1	8	2	2
MAR	1	4	1	1	2	1	8	2	2
APR	2	3	1	2	1	1	9	1	2
MAY	1	2	0	0	0	1	58	1	1
JUN	1	8	0	1	0	2	27	1	1
JUL	1	5	1	1	0	1	6	3	3
AUG	2	4	1	2	1	4	13	2	4
SEP	1	1	0	1	1	1	13	2	0
OCT	2	2	0	1	1	1	10	3	1
NOV	1	1	0	1	1	1	3	3	1
DEC	1	1	0	1	1	1	4	2	1
mean	**1**	**3**	**1**	**1**	**1**	**1**	**13**	**2**	**2**
std dev	0	2	1	1	1	1	16	1	1
median	1	3	1	1	1	1	9	2	2
max	2	8	1	2	2	4	58	3	4
min	1	1	0	0	0	1	2	1	0

Figure 2.6 Chlorophyll *a* at the Lower Cape Fear River Program mainstem stations, 1995-2018 versus 2019.

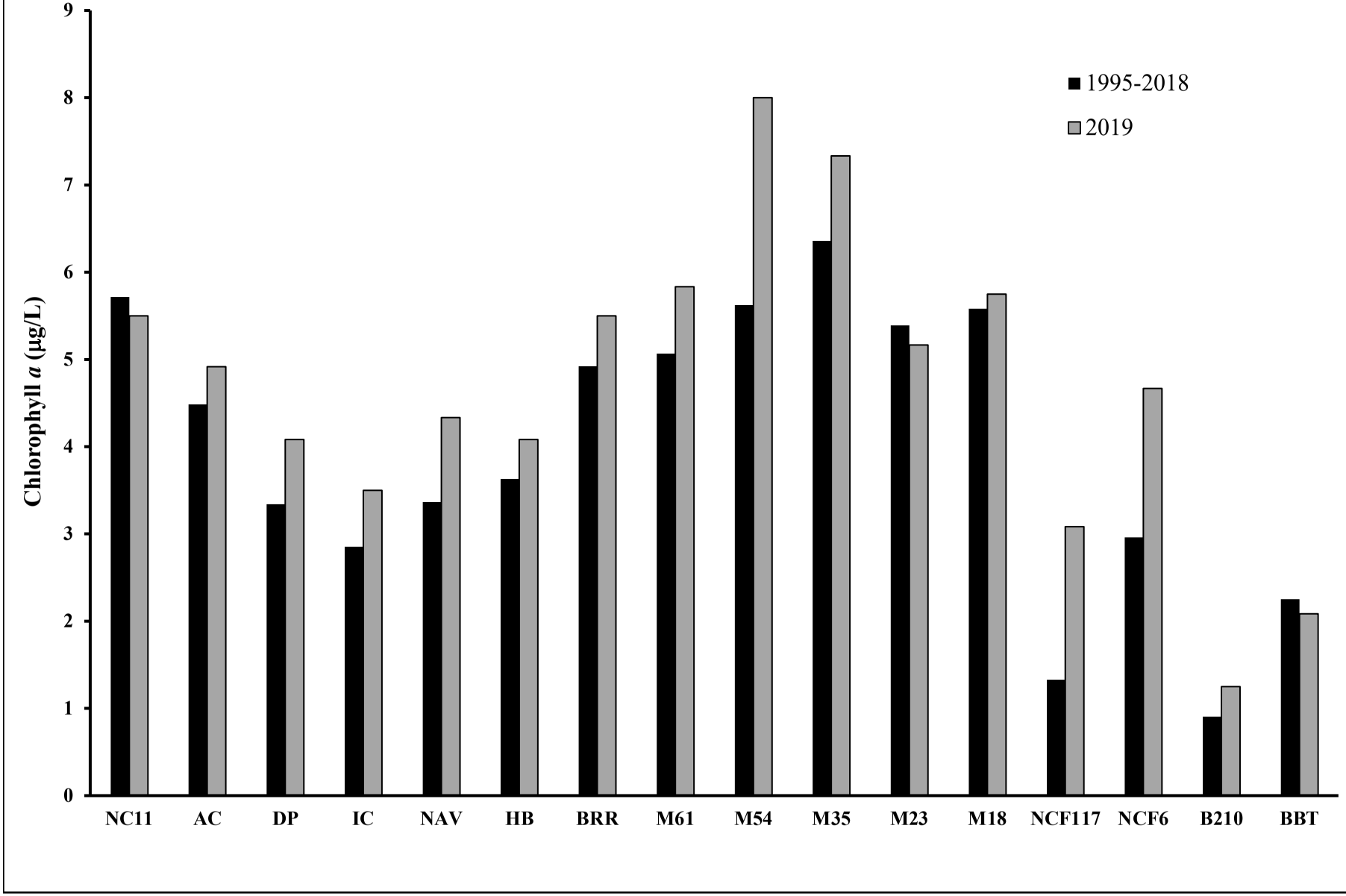


Table 2.16 Fecal Coliform (cfu/100 mL) and Enterococcus (MPN) 2019 at the Lower Cape Fear River Program stations.

	NC11	AC	DP	IC	NCF6	NAV	HB
JAN	50	59	110	86	23	14	23
FEB	5	10	10	5	19	17	23
MAR	41	68	37	64	50	55	19
APR	10	5	10	14	41	5	5
MAY	10	10	5	28	28	5	5
JUN	240	5	5	23	77	79	68
JUL	5	5	10	19	23	105	145
AUG	5	16	5	5	32	19	14
SEP	32	5	14	14	22	110	135
OCT	5	5	5	5	23	73	68
NOV	5	5	14	37	41	5	41
DEC	10	5	32	5	10	14	23
mean	**35**	**17**	**21**	**25**	**32**	**42**	**47**
std dev	64	21	29	25	17	39	46
max	240	68	110	86	77	110	145
min	5	5	5	5	10	5	5
Geomean	14	9	13	16	29	24	29

ENTEROCOCCUS

	BRR	M61	M54	M35	M23	M18
JAN	20	5	5	63	5	5
FEB	5	5	5	52	10	5
MAR	5	16	22	45	30	85
APR	10	5	5	5	10	10
MAY	1	1	1	1	132	19
JUN	31	20	10	5	5	5
JUL	31	20	10	5	5	5
AUG	42	274	313	190	550	550
SEP	630	10	10	10	5	5
OCT	99	69	89	180	85	462
NOV	6	7	5	1	1	1
DEC	11	21	19	15	22	145
mean	**74**	**38**	**41**	**48**	**72**	**108**
std dev	170	73	85	65	149	184
max	630	274	313	190	550	550
min	1	1	1	1	1	1
Geomean	18	13	12	15	16	19

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	32	115	10	23	50	10	95	14	5
FEB	60	19	28	14	10	5	68	77	5
MAR	135	64	19	23	10	82	200	50	37
APR	82	155	55	135	165	130	82	10	14
MAY	1,000	319	105	115	160	295	290	32	5
JUN	19	125	37	14	150	37	46	10	50
JUL	5	235		32	160	155	23	5	68
AUG	1,000	105	64	180	500	591	210	14	64
SEP	180	637	682	10,500	2,800	1,300	100	145	240
OCT	118	125	273	210	1050	185	140	23	23
NOV		120	32	55	200	290	140	23	37
DEC	14	82	41	41	110	140	150	10	22
mean	**240**	**175**	**122**	**945**	**447**	**268**	**129**	**34**	**48**
std dev	362	158	190	2,882	761	348	73	39	62
max	60	637	682	10,500	2,800	1,300	290	145	240
min	5	19	10	14	10	5	23	5	5
Geomean	77	126	56	77	147	115	106	21	25

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	28	5	5	50	46	5	37	235	230
FEB	55	32	165	180	73	64	100	182	170
MAR	10	5	5	130	23		50	64	14
APR	57	190	41	135	125	120	110	319	228
MAY	55	105	91	95	32	37	240	182	205
JUN	10	205	23	46	19	86	125	115	100
JUL	10	19	10	10	59	23	195	500	82
AUG	37	125	68	228	82	55	410	1,050	220
SEP	14	23	23	95	68	19	37	160	280
OCT	110	245	115	455	364	319	182	364	215
NOV	28	100	105	55	46	41	5	255	109
DEC	37	28	68	68	37	37	19	200	175
mean	**38**	**90**	**60**	**129**	**81**	**73**	**126**	**302**	**169**
std dev	28	82	49	115	90	84	112	252	74
max	110	245	165	455	364	319	410	1,050	280
min	10	5	5	10	19	5	5	64	14
Geomean	28	47	36	89	57	45	75	235	139

Figure 2.7 Geometric Mean Fecal Coliform (NC11-B210) and Enterococcus (BRR-M18) at the LCFRP mainstem stations, 1996-2018 (Entero 2012-2014) vs. 2019.