Environmental Assessment of the Lower Cape Fear River System, 2020

By

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Executive Summary

Background – Multi-parameter water quality sampling for the Lower Cape Fear River Program (LCFRP) http://www.uncw.edu/cms/aelab/LCFRP/index.htm, has been ongoing since June 1995. Scientists from the University of North Carolina Wilmington's (UNCW) Aquatic Ecology Laboratory perform the sampling effort. The LCFRP currently encompasses 32 water sampling stations throughout the lower Cape Fear, Black, and Northeast Cape Fear River watersheds (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 2020. There were no data collected in April 2020 due to restrictions from the Covid-19 pandemic. 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. 2015). 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; however these chemicals are still found in river water that enters the Cape Fear Public Utility Authority water treatment plant. 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.

<u>Summary of water quality data results from 2020</u> – **Hurricane Isaias** impacted southeastern North Carolina August 3rd with rain and tornadoes, and made landfall at Ocean Isle Beach. The Category 1 hurricane passed rapidly with little impact to water quality in the Cape Fear region (Chapter 2).

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.

DO concentrations in the tributary streams were briefly impacted by the hurricane, but some sites are chronically bad year-after-year. In 2020 GS (Goshen Swamp) was below standard 45% of occasions samples; ANC (Angola Creek), SR (upper South River), NCF117 and NCF6 (both on the Northeast Cape Fear River) were 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 2020, we rated 28% as poor for dissolved oxygen, 6% as fair, and 66% as good.

Annual mean turbidity levels for 2020 were lower than the long-term average at all stations. Highest mean riverine turbidities (18-16 NTU) were at NC11-DP (Fig. 1.1) with turbidities generally low in the middle to lower estuary. The estuarine stations did not exceed the estuarine turbidity standard on our sampling trips. Turbidity was considerably lower in the Northeast Cape Fear River and Black River than in the mainstem river. Turbidity levels were low in the freshwater streams, with all streams rated as good for 2020. Suspended solids were generally low except at NC11 and AC, the upper river sites.

Average chlorophyll *a* concentrations across most sites were low in 2020. The standard of 40 µg/L was exceeded once each at Stations GS and SR, and there were several smaller algal blooms as well. We note the highest chlorophyll *a* levels in the river and estuary typically occur late spring to late-summer. Nuisance cyanobacterial blooms did not occur in the river and upper estuary in 2020. For the 2020 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 2020. Sites with the highest counts in general were BRN (Browns Creek), PB (Panther Branch), HAM (Hammond Creek), LCO (Little Coharie Creek), 6RC (Six Runs Creek), ROC (Rockfish Creek), NC403 (uppermost Northeast Cape fear river site) and LRC (Little Rockfish Creek). However, the main river and estuary sites were generally in good condition in 2020. For bacterial water quality overall, 32% of the sites rated as poor, 10% as fair, and 58% as good..

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 (Great Coharie Creek).

A 20-year analysis of nitrate concentrations found several stream stations with both high concentrations and continuing upward trends, especially Six Runs Creek (6RC), Rockfish Creek (ROC), Great Coharie Creek (GCO) and Little Coharie Creek (LCO). Note that all of these creeks have no point sources but their watersheds contain numerous swine CAFOs, as well as a considerable number of poultry CAFOs.

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1.0 Introduction

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The Lower Cape Fear River Program is a unique science and education program that has a mission to develop an understanding of processes that control and influence the ecology of the Cape Fear River, and to provide a mechanism for information exchange and public education. This program provides a forum for dialogue among the various Cape Fear River user groups and encourages interaction among them. Overall policy is set by an Advisory Board consisting of representatives from citizen's groups, local government, industries, academia, the business community, and regulatory agencies. This report represents the scientific conclusions of the UNCW researchers participating in this program and does not necessarily reflect opinions of all other program participants. This report focuses on the period January through December 2020.

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 26-year (1995-2020) data base that is available to the public, and is used as a teaching tool. Using this monitoring data as a framework the program goals also include focused scientific projects and investigation of pollution episodes. The scientific aspects of the program are carried out by investigators from the University of North Carolina Wilmington Center for Marine Science. The monitoring program was developed by the Lower Cape Fear River Program Technical Committee, which consists of representatives from UNCW, the North Carolina Division of Environmental Quality, The NC Division of Marine Fisheries, the US Army Corps of Engineers, technical representatives from streamside industries, the Cape Fear Public Utility Authority, Cape Fear Community College, Cape Fear River Watch, the North Carolina Cooperative Extension Service, the US Geological Survey, forestry and agriculture organizations, and others. This integrated and cooperative program was the first of its kind in North Carolina. The physical, chemical and biological data are state-certified and submitted to the US EPA.

Broad-scale monthly water quality sampling at 16 stations in the estuary and lower river system began in June 1995 (UNCW Aquatic Ecology Laboratory, directed by Dr. Michael Mallin). Sampling was increased to 34 stations in February of 1996, 35 stations in February 1998, and 36 stations in 2005, then lowered to 33 in 2011; currently it stands at 32 water quality stations. The Lower Cape Fear River Program added another component concerned with studying the benthic macrofauna of the system in 1996. This component is directed by Dr. Martin Posey and Mr. Troy Alphin of the UNCW Biology Department and includes the benefit of additional data collected by the

Benthic Ecology Laboratory under various grant-funded projects in the Cape Fear Estuary. These data are collected and analyzed depending upon the availability of funding. The third major biotic component (added in January 1996) was an extensive fisheries program directed by Dr. Mary Moser of the UNCW Center for Marine Science Research, with subsequent (1999) overseeing by Mr. Michael Williams and Dr. Thomas Lankford of UNCW-CMS. This program involved cooperative sampling with the North Carolina Division of Marine Fisheries and the North Carolina Wildlife Resources Commission. The fisheries program ended in December 1999, but was renewed with additional funds from the Z. Smith Reynolds Foundation from spring – winter 2000.

1.1. Site Description

The mainstem of the Cape Fear River is formed by the merging of the Haw and the Deep Rivers in Chatham County in the North Carolina Piedmont. However, its drainage basin reaches as far upstream as the Greensboro area (Fig. 1.1). The mainstem of the river has been altered by the construction of several dams and water control structures. In the Coastal Plain, the river is joined by two major tributaries, the Black and the Northeast Cape Fear Rivers (Fig. 1.1). These 5^{th} order blackwater streams drain extensive riverine swamp forests and add organic color to the mainstem. The watershed (about 9,164 square miles) is the most heavily industrialized in North Carolina with 203 permitted wastewater discharges with a permitted flow of approximately 429 million gallons per day, and (as of 2010) over 2.07 million people residing in the basin (NCDENR Basinwide Information Management System (BIMS) & 2010 Census). Approximately 23% of the land use in the watershed is devoted to agriculture and livestock production (2006 National Land Cover Dataset), with livestock production dominated by swine and poultry operations. Thus, the watershed receives considerable point and non-point source loading of pollutants. However, the estuary is a well-flushed system, with flushing time ranging from 1 to 22 days with a median flushing time of about seven days, much shorter than the other large N.C. estuaries to the north (Ensign et al. 2004).

Water quality is monitored by boat at eight stations in the Cape Fear Estuary (from Navassa to Southport) and one station in the Northeast Cape Fear Estuary (Table 1.1; Fig. 1.1). We note that after July 2011 sampling was discontinued at estuarine stations M42 and SPD, per agreement with the North Carolina Division of Water Quality; and in 2012 sampling was expanded at Smith Creek at the Castle Hayne Road bridge (Table 1.1) and initiated at a new site along the South River (SR-WC). Riverine stations sampled by boat include NC11, AC, DP, IC, and BBT (Table 1.1; Fig. 1.1). NC11 is located upstream of any major point source discharges in the lower river and estuary system, and is considered to be representative of water quality entering the lower system (we note that the City of Wilmington and portions of Brunswick County get their drinking water from the river just upstream of Lock and Dam #1). Station BBT is located on the Black River between Thoroughfare (a stream connecting the Cape Fear and Black Rivers) and the mainstem Cape Fear, and is influenced by both rivers. We consider B210 and NCF117 to represent water quality entering the lower Black and Northeast Cape Fear Rivers, respectively. Data has also been collected at stream and river stations throughout the Cape Fear, Northeast Cape Fear, and Black River watersheds (Table 1.1; Fig. 1.1; Mallin et al. 2001).

1.2. Report Organization

Section 1 of this report provides a summary and introduction, and Section 2 of this report presents a detailed overview of physical, chemical, and biological water quality data from the 32 individual stations, and provides tables of raw data as well as figures showing spatial or temporal trends. LCFRP data are freely available to the public. The LCFRP has a website that contains maps and an extensive amount of past water quality, benthos, and fisheries data gathered by the Program available at: www.uncw.edu/cms/aelab/LCFRP/. Additionally, there is an on-line data base. http://lcfrp.uncw.edu/riverdatabase/

References Cited

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

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

Table 1.1 Description of sampling locations for the Lower Cape Fear River Program, 2020.

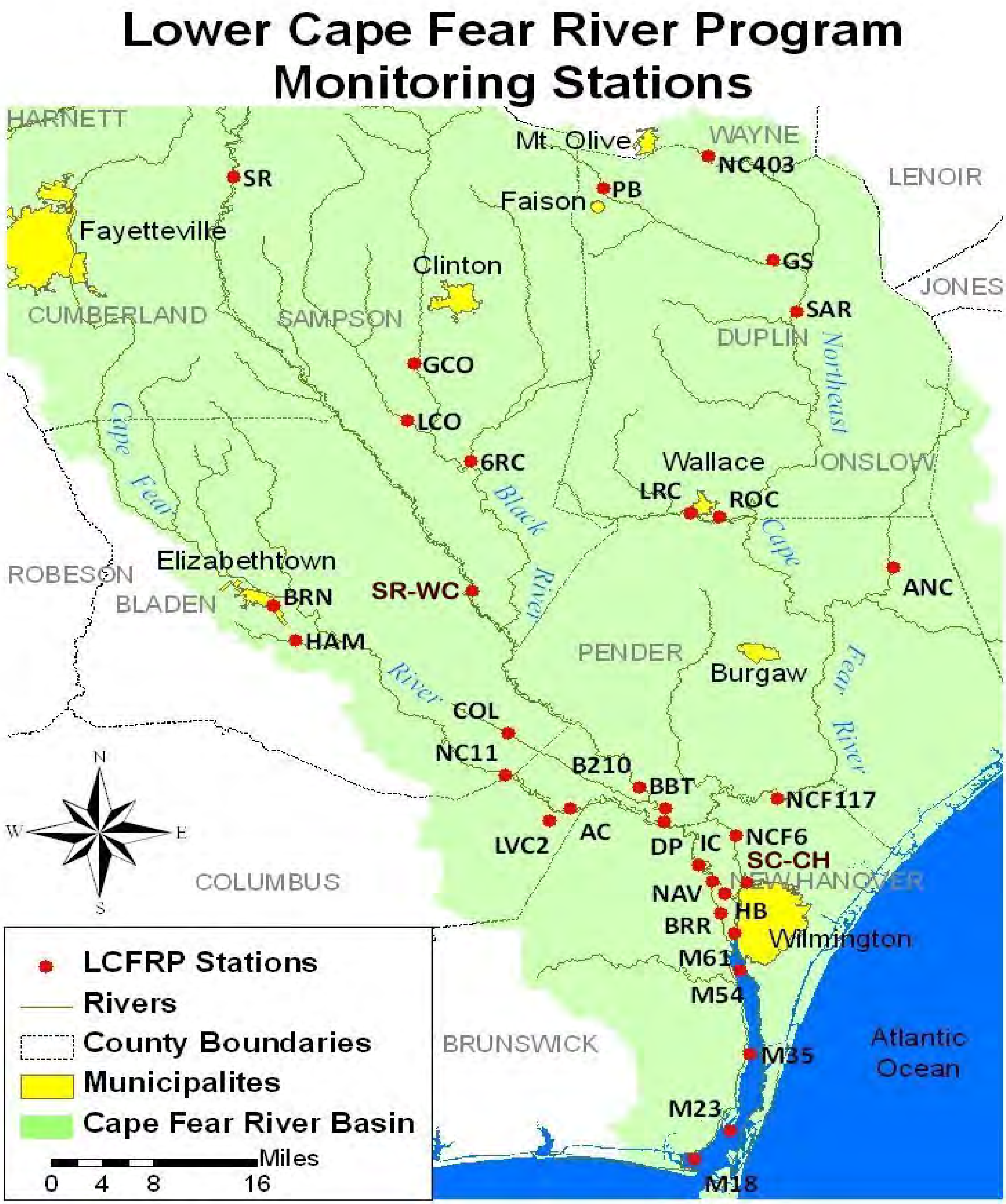
Collected by Boat

AEL Station	DWR Station #	Description	Comments	County	Lat	Lon	Stream Class.	HUC
NC11	B8360000	Cape Fear River at NC 11 nr East Arcadia	Below Lock and Dam 1, Represents water entering lower basin	Bladen	34.3969	-78.2675	WS-IV Sw	03030005
AC	B8450000	Cape Fear River at Neils Eddy Landing nr Acme	1 mile below IP, DWR ambient station	Columbus	34.3555	-78.1794	C Sw	03030005
DP	B8465000	Cape Fear River at Intake nr Hooper Hill	AT DAK intake, just above confluence with Black R.	Brunswick	34.3358	-78.0534	C Sw	03030005
BBT		Black River below Lyons Thorofare	UNCW AEL station	Pender	34.3513	-78.0490	C Sw ORW+	0303005
IC	B9030000	Cape Fear River ups Indian Creek nr Phoenix	Downstream of several point source discharges	Brunswick	34.3021	-78.0137	C Sw	0303005
NAV	B9050025	Cape Fear River dns of RR bridge at Navassa	Downstream of several point source discharges	Brunswick	34.2594	-77.9877	SC	0303005
HB	B9050100	Cape Fear River at S. end of Horseshoe Bend nr Wilmington	Upstream of confluence with NE Cape Fear River	Brunswick	34.2437	-77.9698	SC	0303005
BRR	B9790000	Brunswick River dns NC 17 at park nr Belville	Near Belville discharge	Brunswick	34.2214	-77.9787	SC	03030005
M61	B9800000	Cape Fear River at Channel Marker 61 at Wilmington	Downstream of several point source discharges	New Hanover	34.1938	-77.9573	SC	03030005
M54	B9795000	Cape Fear River at Channel Marker 54	Downstream of several point source discharges	New Hanover	34.1393	-77.946	SC	03030005
M35	B9850100	Cape Fear River at Channel Marker 35	Upstream of Carolina Beach discharge	Brunswick	34.0335	-77.937	SC	03030005
M23	B9910000	Cape Fear River at Channel Marker 23	Downstream of Carolina Beach discharge	Brunswick	33.9456	-77.9696	SA HQW	03030005
M18	B9921000	Cape Fear River at Channel Marker 18	Near mouth of Cape Fear River	Brunswick	33.913	-78.017	SC	03030005
NCF6	B9670000	NE Cape Fear nr Wrightsboro	Downstream of several point source discharges	New Hanover	34.3171	-77.9538	C Sw	0303007

Collected by Land

AEL Station	DWR Station #	Description	Comments	County	Lat	Lon	Stream Class.	HUC
6RC	B8740000	Six Runs Creek at SR 1003 nr Ingold	Upstream of Black River, CAFOs in watershed	Sampson	34.7933	-78.3113	C Sw ORW+	03030006
LCO	B8610001	Little Coharie Creek at SR 1207 nr Ingold	Upstream of Great Coharie, CAFOs in watershed	Sampson	34.8347	-78.3709	C Sw	03030006
GCO	B8604000	Great Coharie Creek at SR 1214 nr Butler Crossroads	Downstream of Clinton, CAFOs in watershed	Sampson	34.9186	-78.3887	C Sw	03030006
SR	B8470000	South River at US 13 nr Cooper	Downstream of Dunn	Sampson	35.156	-78.6401	C Sw	03030006
BRN	B8340050	Browns Creek at NC87 nr Elizabethtown	CAFOs in watershed	Bladen	34.6136	-78.5848	C	03030005
HAM	B8340200	Hammond Creek at SR 1704 nr Mt. Olive	CAFOs in watershed	Bladen	34.5685	-78.5515	C	03030005
COL	B8981000	Colly Creek at NC 53 at Colly	Pristine area	Bladen	34.4641	-78.2569	C Sw	03030006
B210	B9000000	Black River at NC 210 at Still Bluff	1st bridge upstream of Cape Fear River	Pender	34.4312	-78.1441	C Sw ORW+	03030006
NC403	B9090000	NE Cape Fear River at NC 403 nr Williams	Downstream of Mt. Olive Pickle, CAFOs in watershed	Duplin	35.1784	-77.9807	C Sw	0303007
PB	B9130000	Panther Branch (Creek) nr Faison	Downstream of Bay Valley Foods	Duplin	35.1345	-78.1363	C Sw	0303007
GS	B9191000	Goshen Swamp at NC 11 and NC 903 nr Kornegay	CAFOs in watershed	Duplin	35.0281	-77.8516	C Sw	0303007
SAR	B9191500	NE Cape Fear River SR 1700 nr Sarecta	Downstream of several point source discharges	Duplin	34.9801	-77.8622	C Sw	0303007
ROC	B9430000	Rockfish Creek at US 117 nr Wallace	Upstream of Wallace discharge	Duplin	34.7168	-77.9795	C Sw	0303007
LRC	B9460000	Little Rockfish Creek at NC 11 nr Wallace	DWR Benthic station	Duplin	34.7224	-77.9814	C Sw	0303007
ANC	B9490000	Angola Creek at NC 53 nr Maple Hill	DWR Benthic station	Pender	34.6562	-77.7351	C Sw	0303007
SR WC	B8920000	South River at SR 1007 (Wildcat/Ennis Bridge Road)	Upstream of Black River	Sampson	34.6402	-78.3116	C Sw ORW+	03030006
NCF117	B9580000	NE Cape Fear River at US 117 at Castle Hayne	DWR ambient station, Downstream of point source discharges	New Hanover	34.3637	-77.8965	B Sw	0303007
SC-CH	B9720000	Smith Creek at US 117 and NC 133 at Wilmington	Urban runoff, Downstream of Wilmington Northside WWTP	New Hanover	34.2586	-77.9391	C Sw	0303007

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



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

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2.1 - Introduction

This section of the report includes a discussion of the physical, chemical, and biological water quality parameters, concentrating on the January-December 2020 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.

<u>Physical Parameters</u>

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

Field parameters other than light attenuation were measured at each site using a YSI 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-2011	Yes
Specific Conductivity	SM 2510 B-2011	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 2020. Discussion of the data focuses both on the river channel stations and stream stations, which sometimes reflect poorer water quality than the channel stations. The contributions of the two large blackwater tributaries, the Northeast Cape Fear River and the Black River, are represented by conditions at NCF117 and B210, respectively. The Cape Fear region experienced minor impacts from Hurricane Isaias in early August 2020; therefore this report reflects its impacts that summer.

<u>Physical Parameters</u>

Water temperature

Water temperatures at all stations ranged from 5.7 to 30.9^{o}C, and individual station annual averages ranged from 17.9 to 20.2^{o}C (Table 2.1). Highest temperatures occurred during July and lowest temperatures during December. Stream stations were generally cooler than river stations, most likely because of shading and lower nighttime air temperatures affecting the shallower waters.

Salinity

Salinity at the estuarine stations (NAV through M18; also NCF6 in the Northeast Cape Fear River) ranged from 0.0 to 31.3 practical salinity units (psu) and station annual means ranged from 0.0 to 19.8 psu (Table 2.2). Lowest salinities occurred in late spring and early summer of 2020 and again in November. The annual mean salinities for 2020 were somewhat lower than the twenty-five year average for 1995-2019 (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 0.0 to 7.0 psu.

Conductivity

Conductivity at the estuarine stations ranged from 0.07 to 48.26 mS/cm and from 0.05 to 1.65 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 8.1 and station annual means ranged from 3.8 (at COL) to 7.8 (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 2020 ranged from 2.0 to 11.8 mg/L (both at GS) and station annual means ranged from 5.5 to 8.6 mg/L (Table 2.5). Overall, average dissolved oxygen levels for 2020 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. Although Hurricane Isaias impacted the area in early August, it had little impact on dissolved oxygen levels.

NAV, IC, HB, and BRR were below 5.0 mg/L on 36% of occasions sampled, and M61 was below 5.0 mg/L on 46% of occasions. Based on number of occasions the river stations were below 5 mg/L dissolved oxygen UNCW rated NAV, HB, IC, BRR and M61 as poor for 2020; 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.

Most tributary Stations were rated fair or good in 2020, except ANC and GS, 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. 2004). Hypoxia is thus a continuing problem but improved with only 34% of stations impacted compared to 50% of the sites impacted in 2019.

Field Turbidity

Field turbidity levels ranged from 0 to 37 Nephelometric turbidity units (NTU) and station annual means ranged from 2 to 18 NTU (Table 2.6). The State standard for estuarine turbidity is 25 NTU. Highest mean turbidities were at the upper river sites NC11-DP (18 NTU), with turbidities generally low in the middle to lower estuary (Figure 2.3). The estuarine stations did not exceed the estuarine turbidity standard on our 2020 sampling trips. As in the previous year, mean turbidity levels for 2020 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 NCDEQ 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 38.8 mg/L with station annual means from 3.0 to 17.6 mg/L (Table 2.7). The overall highest river values were at NC11, 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 several occasions but only at NC11 and AC in the 2020 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

Due to instrumentation problems, compounded by the Covid-19 pandemic, light attenuation values will not be reported for 2020.

<u>Chemical Parameters – Nutrients</u>

Total Nitrogen

Total nitrogen (TN) is calculated from TKN (see below) plus nitrate; it is not analyzed in the laboratory. TN ranged from 50 (detection limit) to 7,780 µg/L (at ROC) and station annual means ranged from 639 to 2,017 µg/L (at ROC; Table 2.8). 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 at NC11, then declining into the lower estuary, most likely reflecting uptake of nitrogen into the food chain through algal productivity and subsequent grazing by planktivores as well as through dilution and marsh denitrification. The highest median TN value at the stream stations was at NC403 with 1,640 µg/L; other sites with elevated TN were ROC, PB, ANC, 6RC and LRC.

Nitrate+Nitrite

Nitrate+nitrite (henceforth referred to as nitrate) is the main species of inorganic nitrogen in the Lower Cape Fear River. Concentrations system wide ranged from 10 (detection limit) to 6,160 µg/L (at ROC) and station annual means ranged from 23 to 912 µg/L (at 6RC; Table 2.9). The highest average riverine nitrate levels were at NC11 through DP (344-211 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 = 149 μg/L) and the Black River (B210 = 215 μg/L). Lowest river nitrate occurred during August-September.

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. 2004; Mallin and Cahoon 2020). Thus, we conservatively consider nitrate concentrations exceeding 500 µg-N/L in Cape Fear watershed streams to be potentially problematic to stream environmental health.

We performed a 20-year (2000-2019) analysis of nitrate changes at select stations (Fig. 2.4). Prior to 2000 there were several large hurricanes impacting water quality of the Lower Cape Fear River system, so we wanted to factor out impacts of those acute events. Results showed several statistical increases in nitrate concentrations, especially at 6RC, ROC, GCO and LCO (Fig. 2.4). All of those watersheds contain numerous swine CAFOs, as well as many poultry CAFOs. We note that Colly Creek (COL) which as very few CAFOs but abundant wetlands showed no increase over that same period. Angola Creek (ANC) which has several CAFOs but a considerable amount of wetlands coverage showed a significant increase in nitrate, but concentrations were very low (Fig. 2.4). Overall, there has been a significant nitrate increase in several stations which is likely a result of watershed livestock production and the type of waste disposal from those operations.

Ammonium/ammonia

Ammonium concentrations ranged from 10 (detection limit) to 1,680 μg/L and station annual means ranged from 36 to 399 μg/L (Table 2.11). River areas with the highest mean ammonium levels this monitoring period included AC and DP, which are downstream of a pulp mill discharge, and M54, M23 and M18 in the mid-to-lower estuary. At the stream stations Colly Creek (COL) showed two occasions of high ammonium, an improvement from 2019 (Table 2.10). 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.

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 2020 included 6RC, N403, 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 3,850 μg/L (at LRC) and station annual means ranged from 469 to 1,493 μg/L (Table 2.11). 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 1,530 μg/L (at LRC) and station annual means ranged from 120 to 560 μg/L (LRC; Table 2.12). For the mainstem and upper estuary, average TP for 2020 was considerably higher than the 1995-2019 average (Figure 2.5).

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. 2004; Mallin and Cahoon 2020). Streams frequently exceeding this critical concentration included ANC and ROC. SAR, GS, and SC-CH each yielded two values exceeding 500 μg/L. Stations NC403 and PB are downstream of wastewater discharges, while ROC, GS and ANC are in non-point agricultural areas.

Orthophosphate

Orthophosphate ranged from 5 to 550 μg/L (at ROC) and station annual means ranged from 7 to 188 μg/L (Table 2.13). 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 previously 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. Metals were not collected in 2020, but sampling was reinitiated in summer 2021.

Biological Parameters

Chlorophyll a

During this monitoring period, chlorophyll *a* was low in the river and estuary locations (Table 2.14). The state standard was not exceeded in the river or estuary samples in 2020 but approached it (38 µg/L at M35) in August. 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 approaches 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 111 µg/L, and station annual means ranged from 1-16 µg/L, generally low because of high river discharge in 2020 (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 (1995-2020) average monthly flow at Lock and Dam #1 was approximately 3,685 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 2020, discharge in May-September was 7,584 CFS, much higher than the 2009-2012 average, and nuisance cyanobacterial blooms did not occur in the river and upper estuary in 2020.

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 2016-2020. 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 2020 (Table 2.14). 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. 2004; 2015; 2020; 2015). A stream station bloom exceeding the state standard of 40 µg/L occurred on one occasion at Station GS (44 µg/L) and on one occasion at SR (111 µg/L), and lesser blooms occurred on occasion at PB, SC-CH and ANC (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 30,000 CFU/100 mL and station annual geometric means ranged from 27 to 352 CFU/100 mL (Table 2.15). The state human contact standard (200 CFU/100 mL) was exceeded in the mainstem river in only one month (January) in 2020 (Table 2.15). During 2020 some stream stations showed elevated fecal coliform pollution levels. HAM, PB and LRC exceeded 200 CFU/100 mL 50% of the time sampled and ROC and BRN 45% of the time sampled. Other stations had periodic elevated counts particularly May-August – August may have been influenced by Hurricane Isaias. 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 had no exceedences of the standard in 2020.

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 2020 this standard was exceeded in the estuary samples once each at M23 and M18. Geometric mean enterococci counts for 2020 were lower than those of the 2012-2019 period for the lower Cape Fear Estuary (Fig. 2.7). Overall, elevated fecal coliform and *Enterococcus* counts are problematic in this system, with 42% of the stations rated as fair or poor in 2020, the same as 2019.

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Table 2.1 Water temperature (^{o}C) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	9.1	9.7	9.7	10.4	10.2	10.1	9.8	9.7
FEB	10.1	9.7	9.8	10.4	10.1	10.8	11.2	11.4
MAR	10.8	10.7	11.0	11.2	11.3	11.5	12.3	12.4
APR								
MAY	21.2	21.4	21.5	22.1	22.2	22.4	23.1	23.2
JUN	25.0	25.2	25.3	25.6	25.5	25.6	24.2	23.9
JUL	28.0	28.1	28.0	28.2	28.3	28.4	28.4	28.5
AUG	27.9	28.0	27.9	29.0	28.4	28.9	28.8	28.6
SEP	29.4	30.1	30.6	30.3	30.4	30.9	30.2	30.9
OCT	20.3	21.1	21.4	21.9	21.9	22.4	22.8	23.4
NOV	13.6	13.7	13.9	14.1	14.1	14.4	15.1	15.9
DEC	10.3	10.2	10.4	11.4	11.5	12.2	13.2	14.1
mean	**18.7**	**18.9**	**19.0**	**19.5**	**19.4**	**19.8**	**19.9**	**20.2**
std dev	8.1	8.3	8.3	8.1	8.1	8.1	7.7	7.7
median	20.3	21.1	21.4	21.9	21.9	22.4	22.8	23.2
max	29.4	30.1	30.6	30.3	30.4	30.9	30.2	30.9
min	9.1	9.7	9.7	10.4	10.1	10.1	9.8	9.7

	NC11	AC	DP	BBT	IC	NCF6
JAN	9.6	9.7	9.9	10.1	10.2	12.2
FEB	11.4	11.5	11.7	12.2	12.0	12.8
MAR	16.6	16.7	16.6	16.8	16.6	16.6
APR						
MAY	21.6	21.7	22.6	22.6	22.4	23.8
JUN	23.0	22.9	23.0	21.7	23.2	22.6
JUL	28.3	28.3	28.9	26.7	27.8	27.5
AUG	26.6	26.5	26.4	26.3	26.4	26.7
SEP	26.3	26.4	26.2	26.2	26.3	26.7
OCT	19.3	19.5	19.7	19.8	23.0	21.5
NOV	16.5	16.7	17.4	16.3	16.9	18.8
DEC	9.6	9.8	10.0	9.0	9.8	10.8
mean	**19.0**	**19.1**	**19.3**	**18.9**	**19.5**	**20.0**
std dev	6.8	6.8	6.8	6.5	6.7	6.2
median	19.3	19.5	19.7	19.8	22.4	21.5
max	28.3	28.3	28.9	26.7	27.8	27.5
min	9.6	9.7	9.9	9.0	9.8	10.8

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	10.1	7.7	8.9	8.9	7.3	9.6	8.7	12.8	12.2
FEB	14.6	13.6	14.7	13.8	13.6	14.2	14.6	10.6	10.8
MAR	17.6	18.1	20.4	18.0	16.5	16.6	16.8	13.9	14.7
APR									
MAY	21.9	21.4	21.9	22.9	22.9	23.6	21.9	22.0	23.0
JUN	25.3	24.9	24.7	25.9	26.7	25.4	25.0	23.6	24.3
JUL	28.0	27.7	26.7	28.8	27.3	27.3	28.0	30.6	30.3
AUG	26.5	26.2	27.1	27.5	27.4	26.9	25.7	26.7	27.3
SEP	21.1	20.9	21.0	21.7	22.3	23.8	21.8	21.8	23.3
OCT	21.0	21.2	21.1	22.0	22.5	22.7	22.1	21.9	21.8
NOV	18.7	18.3	18.7	19.0	19.9	20.0	18.3	17.7	20.0
DEC	10.9	9.1	9.8	10.7	9.4	11.8	11.1	13.6	13.3
mean	**19.6**	**19.0**	**19.5**	**19.9**	**19.6**	**20.2**	**19.5**	**19.6**	**20.1**
std dev	6.0	6.6	6.1	6.6	7.1	6.2	6.2	6.3	6.5
median	21.0	20.9	21.0	21.7	22.3	22.7	21.8	21.8	21.8
max	28.0	27.7	27.1	28.8	27.4	27.3	28.0	30.6	30.3
min	10.1	7.7	8.9	8.9	7.3	9.6	8.7	10.6	10.8

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	15.1	17.4	16.0	17.0	16.8	17.3	17.4	17.2	17.2
FEB	8.9	8.3	7.9	7.8	8.6	9.2	9.1	10.3	9.7
MAR	19.9	19.0	20.0	20.3	20.1	19.3	18.2	15.5	15.0
APR									
MAY	21.3	22.0	19.4	19.2	19.2	18.9	18.0	21.4	19.7
JUN	25.6	25.8	25.2	26.3	26.2	26.6	27.1	25.5	24.3
JUL	28.0	26.7	27.6	26.9	26.3	26.8	26.5	26.7	26.0
AUG	25.9	25.2	24.8	24.8	24.9	24.9	25.5	25.0	24.2
SEP	25.4	24.6	23.9	24.8	24.5	25.1	25.0	25.0	24.1
OCT	19.9	19.2	19.0	19.1	19.3	20.0	20.4	19.4	18.2
NOV	16.1	12.1	14.6	13.7	12.6	12.1	12.3	12.4	11.8
DEC	6.8	5.7	5.8	5.7	6.0	5.8	6.9	7.1	6.6
mean	**19.4**	**18.7**	**18.6**	**18.7**	**18.6**	**18.7**	**18.8**	**18.7**	**17.9**
std dev	7.0	7.2	7.0	7.2	7.0	7.2	7.0	6.7	6.6
median	19.9	19.2	19.4	19.2	19.3	19.3	18.2	19.4	18.2
max	28.0	26.7	27.6	26.9	26.3	26.8	27.1	26.7	26.0
min	6.8	5.7	5.8	5.7	6.0	5.8	6.9	7.1	6.6

Table 2.2 Salinity (psu) during 2020 at the Lower Cape Fear River Program estuarine stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18	NCF6	SC-CH
JAN	0.1	0.7	1.5	6.3	6.9	10.9	17.0	21.2	0.3	0.6
FEB	0.0	0.1	0.1	2.2	2.8	5.7	12.7	15.7	0.0	6.5
MAR	0.1	0.1	0.1	0.3	0.7	4.3	8.0	19.9	0.1	0.1
APR										
MAY	0.0	0.0	0.0	0.0	0.1	1.7	8.8	10.8	0.0	0.1
JUN	0.0	0.0	0.0	0.1	0.1	1.1	6.1	11.2	0.0	0.1
JUL	0.1	2.5	0.8	3.0	6.6	12.8	26.1	30.5	0.1	2.1
AUG	0.0	0.1	0.1	0.7	2.2	10.4	17.1	20.7	0.1	0.1
SEP	0.1	0.5	0.7	2.8	7.4	14.4	26.0	31.3	7.0	0.1
OCT	0.1	1.9	0.1	2.1	3.8	9.1	19.8	27.9	0.1	1.9
NOV	0.0	0.0	0.0	0.0	0.2	1.4	7.7	6.2	2.1	5.7
DEC	0.0	0.0	0.1	1.5	2.7	7.5	17.3	22.7	0.1	0.1
mean	**0.0**	**0.5**	**0.3**	**1.7**	**3.0**	**7.2**	**15.1**	**19.8**	**0.9**	**1.6**
std dev	0.0	0.9	0.5	1.9	2.8	4.7	7.1	8.2	2.1	2.4
median	0.0	0.1	0.1	1.5	2.7	7.5	17.0	20.7	0.1	0.1
max	0.1	2.5	1.5	6.3	7.4	14.4	26.1	31.3	7.0	6.5
min	0.0	0.0	0.0	0.0	0.1	1.1	6.1	6.2	0.0	0.1

Figure 2.1 Salinity at the Lower Cape Fear River Program estuarine stations 1995-2019 versus 2020.

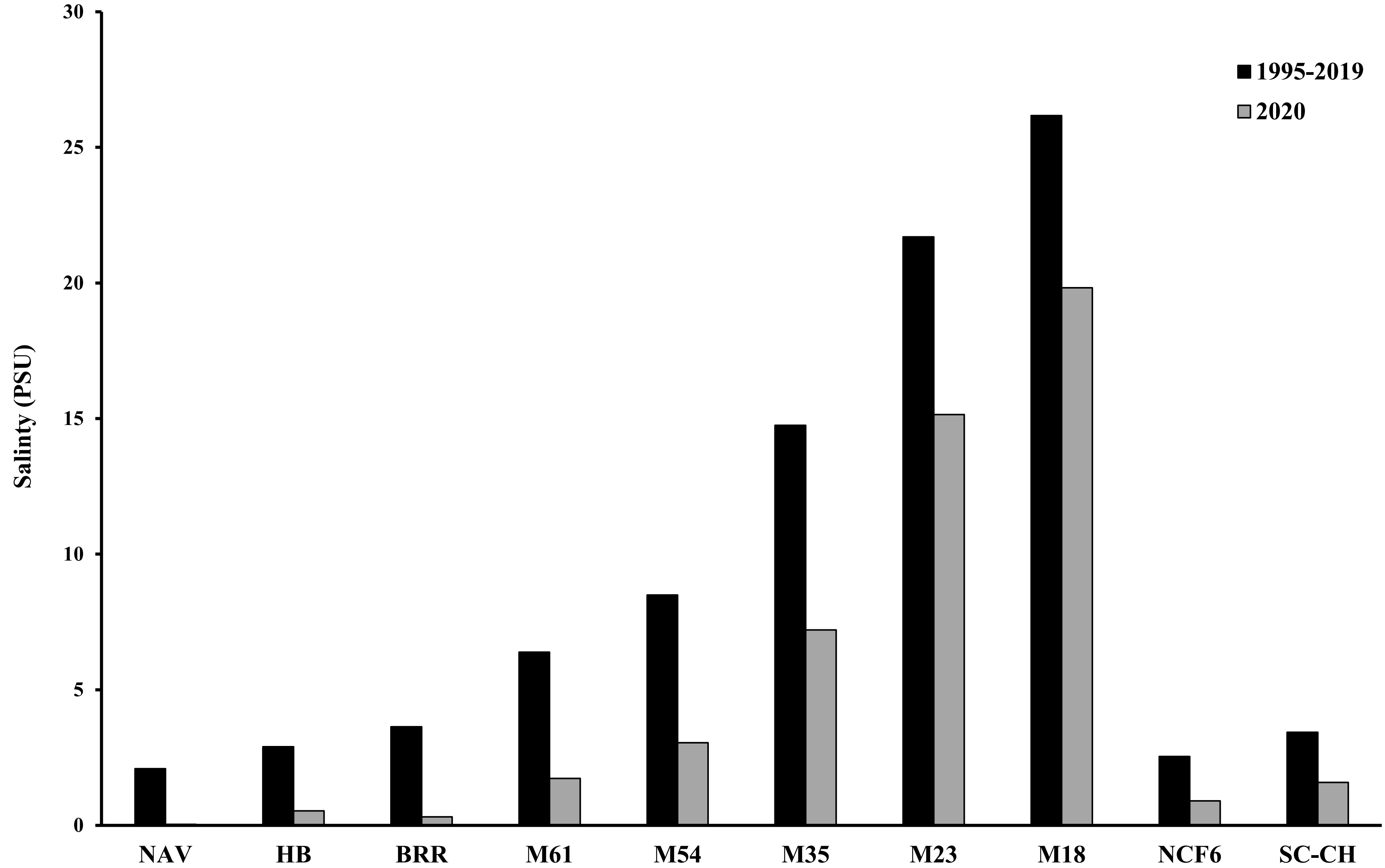

Table 2.3 Conductivity (mS/cm) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	0.11	1.44	3.18	10.96	12.22	18.37	27.68	33.93
FEB	0.09	0.11	0.12	4.03	5.25	10.08	21.12	25.67
MAR	0.10	0.10	0.11	0.53	1.37	7.66	13.96	31.94
APR								
MAY	0.07	0.07	0.08	0.10	0.28	3.16	14.90	17.04
JUN	0.10	0.09	0.10	0.10	0.11	2.18	11.08	19.68
JUL	0.21	4.70	1.50	5.50	11.60	21.40	40.35	47.17
AUG	0.10	0.12	1.12	1.33	4.15	10.35	25.62	33.31
SEP	0.15	0.92	1.47	5.23	12.77	23.97	40.86	48.26
OCT	0.11	3.59	0.14	3.96	6.85	15.65	31.64	43.32
NOV	0.08	0.08	0.08	0.09	0.39	2.61	13.32	10.85
DEC	0.10	0.09	0.12	2.92	4.96	13.00	28.12	35.90
mean	**0.11**	**1.03**	**0.73**	**3.16**	**5.45**	**11.67**	**24.42**	**31.55**
std dev	0.04	1.62	1.00	3.32	4.88	7.57	10.55	12.26
median	0.10	0.11	0.12	2.92	4.96	10.35	25.62	33.31
max	0.21	4.70	3.18	10.96	12.77	23.97	40.86	48.26
min	0.07	0.07	0.08	0.09	0.11	2.18	11.08	10.85

	NC11	AC	DP	BBT	IC	NCF6
JAN	0.08	0.09	0.10	0.10	0.10	0.61
FEB	0.07	0.08	0.08	0.07	0.07	0.09
MAR	0.09	0.21	0.11	0.10	0.10	0.12
APR						
MAY	0.07	0.08	0.08	0.07	0.07	0.07
JUN	0.08	0.09	0.09	0.08	0.11	0.10
JUL	0.09	0.10	0.16	0.08	0.11	0.11
AUG	0.09	0.10	0.09	0.08	0.09	0.11
SEP	0.12	0.11	0.13	0.13	0.15	12.20
OCT	0.09	0.11	0.11	0.10	0.11	0.15
NOV	0.13	0.13	0.12	0.11	0.11	3.98
DEC	0.10	0.11	0.10	0.09	0.10	0.12
mean	**0.09**	**0.11**	**0.11**	**0.09**	**0.10**	**1.60**
std dev	0.02	0.04	0.02	0.02	0.02	3.70
median	0.09	0.10	0.10	0.09	0.10	0.12
max	0.13	0.21	0.16	0.13	0.15	12.20
min	0.07	0.08	0.08	0.07	0.07	0.07

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	0.15	0.17	0.15	0.46	0.37	0.14	0.16	0.15	1.26
FEB	0.09	0.14	0.13	0.38	0.50	0.10	0.12	0.09	0.12
MAR	0.08	0.15	0.14	0.41	0.81	0.11	0.20	0.10	0.16
APR									
MAY	0.08	0.13	0.12	0.46	0.57	0.12	0.10	0.07	0.10
JUN	0.07	0.13	0.11	0.43	0.72	0.13	0.10	0.08	0.10
JUL	0.11	0.33	0.27	1.18	0.42	0.14	0.26	0.12	3.94
AUG	0.09	0.16	0.14	0.41	1.65	0.12	0.22	0.11	0.19
SEP	0.10	0.20	0.18	0.65	1.10	0.12	0.15	0.11	0.28
OCT	0.08	0.21	0.18	1.21	1.44	0.10	0.11	0.10	3.63
NOV	0.10	0.20	0.18	0.95	1.16	0.14	0.19	0.15	10.04
DEC	0.09	0.14	0.14	0.44	0.56	0.11	0.12	0.10	0.12
mean	**0.09**	**0.18**	**0.16**	**0.63**	**0.84**	**0.12**	**0.16**	**0.11**	**1.81**
std dev	0.02	0.06	0.04	0.32	0.43	0.01	0.05	0.03	3.08
median	0.09	0.16	0.14	0.46	0.72	0.12	0.15	0.10	0.19
max	0.15	0.33	0.27	1.21	1.65	0.14	0.26	0.15	10.04
min	0.07	0.13	0.11	0.38	0.37	0.10	0.10	0.07	0.10

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

Table 2.4 pH (su) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	7.3	7.5	7.6	7.4	7.7	8.0	8.1	8.1
FEB	6.5	6.7	6.8	7.0	7.2	7.6	7.9	8.0
MAR	6.9	6.9	7.1	6.9	7.0	7.2	7.6	8.0
APR								
MAY	7.0	6.4	6.4	6.3	6.6	6.9	7.3	7.5
JUN	5.9	6.1	6.2	5.9	6.1	6.7	7.1	7.5
JUL	6.1	6.4	6.6	6.5	7.0	7.4	7.9	8.1
AUG	7.3	7.3	7.6	7.0	8.0	7.9	7.9	7.9
SEP	6.6	6.5	6.6	6.8	7.1	7.5	7.9	8.0
OCT	6.5	6.5	6.9	6.7	6.8	7.2	7.9	8.0
NOV	6.4	6.5	6.3	6.4	6.5	6.5	7.0	6.8
DEC	6.6	6.5	6.8	6.8	7.0	7.4	8.0	8.0
mean	**6.6**	**6.7**	**6.8**	**6.7**	**7.0**	**7.3**	**7.7**	**7.8**
std dev	0.4	0.4	0.5	0.4	0.5	0.5	0.4	0.4
median	6.6	6.5	6.8	6.8	7.0	7.4	7.9	8.0
max	7.3	7.5	7.6	7.4	8.0	8.0	8.1	8.1
min	5.9	6.1	6.2	5.9	6.1	6.5	7.0	6.8

	NC11	AC	DP	BBT	IC	NCF6
JAN	5.5	5.9	6.2	6.3	6.4	6.7
FEB	6.0	6.2	6.5	6.3	6.4	6.1
MAR	6.7	6.9	6.7	6.4	6.5	6.3
APR						
MAY	6.3	6.4	6.3	6.1	6.2	5.7
JUN	6.9	6.7	6.6	6.3	6.7	6.4
JUL	6.5	6.4	6.5	5.9	6.8	6.0
AUG	6.5	6.6	6.5	6.2	6.2	6.2
SEP	6.7	6.7	6.6	6.5	6.5	6.8
OCT	6.7	6.8	6.8	6.6	6.7	6.8
NOV	7.0	7.0	7.0	6.7	6.7	6.6
DEC	6.7	6.7	6.7	6.5	6.8	6.3
mean	**6.5**	**6.6**	**6.6**	**6.3**	**6.5**	**6.4**
std dev	0.4	0.3	0.2	0.2	0.2	0.4
median	6.7	6.7	6.6	6.3	6.5	6.3
max	7.0	7.0	7.0	6.7	6.8	6.8
min	5.5	5.9	6.2	5.9	6.2	5.7

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	6.6	6.6	6.8	6.7	6.7	6.6	6.9	6.7	6.3
FEB	4.9	6.8	7.2	6.8	6.8	6.9	6.7	6.2	6.5
MAR	5.4	6.9	7.2	7.1	6.7	7.0	6.7	6.3	6.7
APR									
MAY	5.3	6.3	6.1	6.5	6.6	7.0	6.4	5.1	6.1
JUN	5.1	6.3	6.0	6.4	6.6	6.8	6.4	5.6	5.8
JUL	6.6	6.9	6.7	6.8	6.8	6.9	6.7	6.5	6.1
AUG	5.7	6.7	6.6	6.8	7.0	7.6	6.9	6.2	6.7
SEP	5.4	6.7	6.5	6.7	6.8	7.0	6.7	5.9	6.8
OCT	4.8	6.8	6.7	6.9	6.9	6.9	6.5	6.3	6.5
NOV	6.2	6.8	6.6	6.6	6.8	7.0	7.0	6.6	6.8
DEC	5.3	6.7	6.8	6.6	6.8	6.8	6.5	6.2	6.4
mean	**5.6**	**6.7**	**6.7**	**6.7**	**6.8**	**7.0**	**6.7**	**6.1**	**6.4**
std dev	0.6	0.2	0.4	0.2	0.1	0.2	0.2	0.5	0.3
median	5.4	6.7	6.7	6.7	6.8	6.9	6.7	6.2	6.5
max	6.6	6.9	7.2	7.1	7.0	7.6	7.0	6.7	6.8
min	4.8	6.3	6.0	6.4	6.6	6.6	6.4	5.1	5.8

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	5.5	3.3	5.2	6.2	5.6	5.9	6.0	5.8	6.0
FEB	6.0	4.0	5.8	6.6	6.3	6.7	6.6	6.5	6.7
MAR	5.9	3.8	5.8	6.6	6.4	6.6	6.5	6.7	7.0
APR									
MAY	5.9	4.0	5.1	5.9	5.9	6.0	5.8	6.5	6.6
JUN	5.6	4.1	5.0	6.7	6.3	6.4	6.2	7.1	7.1
JUL	5.6	3.6	6.6	6.7	6.5	6.6	6.1	6.2	6.5
AUG	5.8	4.1	5.5	6.6	6.4	6.4	6.1	6.7	6.6
SEP	6.4	4.0	6.2	6.9	6.7	6.7	6.2	6.8	7.1
OCT	6.2	4.1	6.3	6.7	6.7	6.6	6.3	6.7	6.8
NOV	5.6	3.4	4.8	6.0	5.9	6.2	6.2	6.2	6.6
DEC	5.8	3.7	5.4	6.3	6.0	6.5	6.4	6.1	6.6
mean	**5.8**	**3.8**	**5.6**	**6.5**	**6.2**	**6.4**	**6.2**	**6.5**	**6.7**
std dev	0.3	0.3	0.6	0.3	0.4	0.3	0.2	0.4	0.3
median	5.8	4.0	5.5	6.6	6.3	6.5	6.2	6.5	6.6
max	6.4	4.1	6.6	6.9	6.7	6.7	6.6	7.1	7.1
min	5.5	3.3	4.8	5.9	5.6	5.9	5.8	5.8	6.0

Table 2.5 Dissolved Oxygen (mg/l) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	9.8	9.7	9.7	9.2	9.7	10.0	10.1	9.8
FEB	10.4	10.2	10.3	9.8	9.8	9.8	9.7	9.7
MAR	**9.7**	9.7	9.7	9.7	9.6	9.7	9.8	9.4
APR								
MAY	5.1	5.0	5.1	4.7	5.3	5.7	6.4	6.1
JUN	4.2	3.9	4.0	4.1	4.5	5.3	6.4	6.5
JUL	4.0	3.7	4.2	4.3	4.5	5.4	6.0	6.3
AUG	4.7	4.4	4.5	3.7	4.0	5.0	6.1	6.3
SEP	4.3	4.4	4.8	4.8	5.4	5.7	6.1	6.6
OCT	6.0	5.0	6.1	5.6	5.8	6.1	6.5	6.6
NOV	7.0	6.9	6.8	6.4	6.8	7.0	7.6	7.7
DEC	9.0	8.9	9.3	8.7	8.7	8.8	8.5	8.3
mean	**6.7**	**6.5**	**6.8**	**6.5**	**6.7**	**7.1**	**7.6**	**7.6**
std dev	2.5	2.6	2.5	2.4	2.3	2.0	1.7	1.5
median	6.0	5.0	6.1	5.6	5.8	6.1	6.5	6.6
max	10.4	10.2	10.3	9.8	9.8	10.0	10.1	9.8
min	4.0	3.7	4.0	3.7	4.0	5.0	6.0	6.1

	NC11	AC	DP	BBT	IC	NCF6
JAN	10.2	10.0	9.8	9.7	9.6	8.9
FEB	9.3	9.2	8.8	7.8	8.1	6.9
MAR	8.8	8.6	8.4	7.7	8.0	7.2
APR						
MAY	5.9	5.8	5.5	4.4	4.8	3.9
JUN	6.7	6.5	6.3	4.9	6.3	4.0
JUL	6.1	5.6	5.3	3.9	4.5	3.8
AUG	6.4	6.1	5.9	4.2	4.8	3.1
SEP	6.6	6.3	4.8	4.8	4.6	4.6
OCT	8.2	7.7	7.7	6.9	7.2	4.5
NOV	8.9	8.8	8.5	7.5	7.3	6.3
DEC	10.5	10.3	10.2	9.4	10.1	8.2
mean	**8.0**	**7.7**	**7.4**	**6.5**	**6.8**	**5.6**
std dev	1.7	1.7	1.9	2.1	2.0	2.0
median	8.2	7.7	7.7	6.9	7.2	4.6
max	10.5	10.3	10.2	9.7	10.1	8.9
min	5.9	5.6	4.8	3.9	4.5	3.1

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	9.2	10.1	10.4	10.0	9.5	11.0	10.1	8.0	8.7
FEB	11.2	8.8	11.8	10.4	10.0	10.2	8.2	9.1	9.4
MAR	9.3	7.9	11.2	9.3	6.5	9.7	8.2	8.2	8.2
APR									
MAY	3.4	6.1	5.4	7.1	6.3	7.4	5.5	4.0	4.9
JUN	4.4	5.6	4.7	6.7	6.0	7.1	5.3	4.2	4.5
JUL	3.4	5.7	2.0	5.4	4.8	6.6	4.8	3.6	4.8
AUG	4.0	5.5	2.8	5.9	8.4	8.8	5.2	3.1	3.9
SEP	4.1	6.4	3.9	7.0	6.7	7.9	6.8	4.1	5.2
OCT	3.7	6.2	3.6	7.2	6.6	8.1	5.8	3.9	5.1
NOV	4.8	6.7	3.9	7.4	6.9	6.9	6.6	5.6	6.4
DEC	8.0	9.6	9.6	9.8	9.9	10.2	8.2	6.5	7.9
mean	**6.0**	**7.1**	**6.3**	**7.8**	**7.4**	**8.5**	**6.8**	**5.5**	**6.3**
std dev	2.9	1.7	3.7	1.7	1.7	1.5	1.7	2.1	1.9
median	4.4	6.4	4.7	7.2	6.7	8.1	6.6	4.2	5.2
max	11.2	10.1	11.8	10.4	10.0	11.0	10.1	9.1	9.4
min	3.4	5.5	2.0	5.4	4.8	6.6	4.8	3.1	3.9

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	7.7	5.7	7.5	7.3	6.6	6.6	6.2	8.0	8.0
FEB	10.1	9.5	10.5	10.7	10.5	10.3	10.1	10.5	10.7
MAR	6.3	5.7	6.8	7.1	6.7	5.9	5.9	9.3	8.9
APR									
MAY	6.2	5.2	7.3	7.0	6.8	6.3	6.7	8.0	6.7
JUN	4.9	4.7	5.3	5.4	5.2	5.1	3.7	7.3	6.3
JUL	4.1	5.1	5.8	5.9	5.9	5.1	4.1	7.0	6.1
AUG	5.0	5.1	5.2	5.7	5.7	5.3	3.7	7.1	5.8
SEP	4.6	5.5	6.6	6.2	6.7	5.8	3.2	7.5	5.9
OCT	5.2	6.1	7.3	7.0	7.7	6.3	4.8	8.4	7.3
NOV	6.1	7.4	6.9	6.3	7.8	8.2	7.2	9.7	9.4
DEC	10.8	10.5	11.2	11.2	11.2	11.6	10.5	11.5	11.5
mean	**6.5**	**6.4**	**7.3**	**7.3**	**7.3**	**7.0**	**6.0**	**8.6**	**7.9**
std dev	2.2	1.9	1.9	1.9	1.9	2.2	2.5	1.5	2.0
median	6.1	5.7	6.9	7.0	6.7	6.3	5.9	8.0	7.3
max	10.8	10.5	11.2	11.2	11.2	11.6	10.5	11.5	11.5
min	4.1	4.7	5.2	5.4	5.2	5.1	3.2	7.0	5.8

Figure 2.2 Dissolved Oxygen at the Lower Cape Fear River Program mainstem stations 1995-2019 versus 2020.

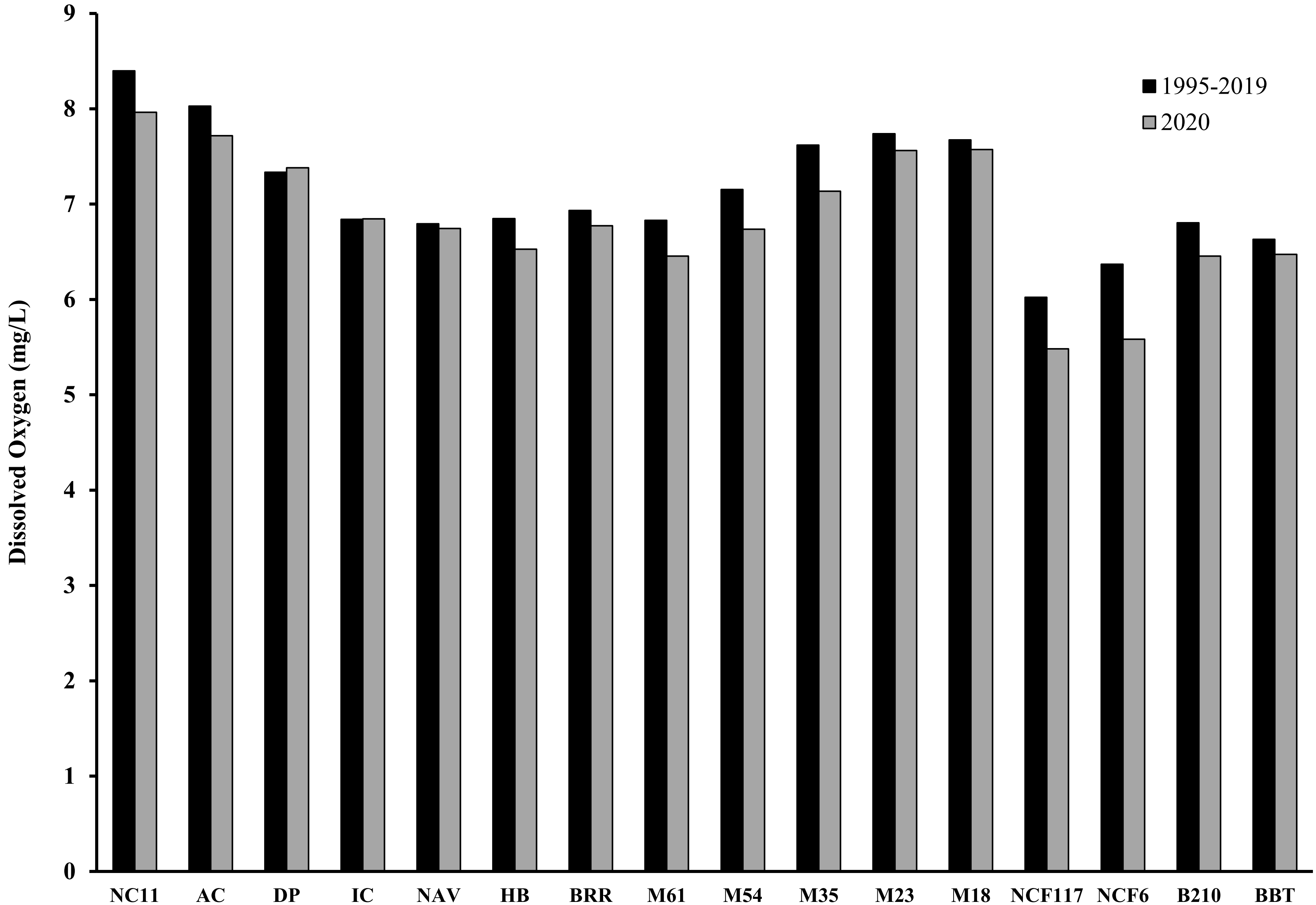

Table 2.6 Field Turbidity (NTU) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	12	15	10	10	7	6	7	13
FEB	17	18	21	13	14	10	6	5
MAR	10	9	9	9	10	10	7	5
APR								
MAY	15	15	13	14	18	14	7	6
JUN	9	6	5	5	5	5	8	9
JUL	6	7	5	4	3	1	2	5
AUG	11	10	8	5	7	4	4	3
SEP	4	4	5	4	3	2	3	2
OCT	6	5	5	4	4	2	4	6
NOV	13	13	12	9	11	9	5	6
DEC	13	11	13	8	9	5	5	4
mean	**11**	**10**	**10**	**8**	**8**	**6**	**5**	**6**
std dev	4	5	5	4	5	4	2	3
median	11	10	9	8	7	5	5	5
max	17	18	21	14	18	14	8	13
min	4	4	5	4	3	1	2	2

	NC11	AC	DP	BBT	IC	NCF6
JAN	36	34	36	29	29	14
FEB	35	37	31	14	21	4
MAR	6	7	8	5	7	4
APR						
MAY	33	31	22	8	12	4
JUN	27	24	21	8	15	5
JUL	8	7	6	3	5	4
AUG	13	13	21	6	10	4
SEP	4	4	4	4	5	3
OCT	14	13	9	8	9	5
NOV	8	7	5	5	4	3
DEC	18	18	18	10	16	4
mean	**18**	**18**	**16**	**9**	**12**	**5**
std dev	12	12	11	7	8	3
median	14	13	18	8	10	4
max	36	37	36	29	29	14
min	4	4	4	3	4	3

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

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	3	5	3	9	7	2	7	20	13
FEB	2	2	2	4	1	0	4	7	6
MAR	3	3	2	5	3	2	4	9	6
APR									
MAY	5	4	30	35	7	7	27	7	4
JUN	4	5	1	6	2	3	6	8	5
JUL	4	4	3	5	14	4	5	11	8
AUG	3	2	2	5	2	2	2	14	5
SEP	4	2	3	4	4	5	3	9	3
OCT	5	2	2	6	3	2	3	7	4
NOV	7	2	4	4	2	2	3	8	5
DEC	5	1	2	1	3	2	6	5	4
mean	**4**	**3**	**5**	**8**	**4**	**3**	**6**	**10**	**6**
std dev	1	1	8	9	4	2	7	4	3
median	4	2	2	5	3	2	4	8	5
max	7	5	30	35	14	7	27	20	13
min	2	1	1	1	1	0	2	5	3

Figure 2.3 Field Turbidity at the Lower Cape Fear River Program mainstem stations, 1995-2019 versus 2020.

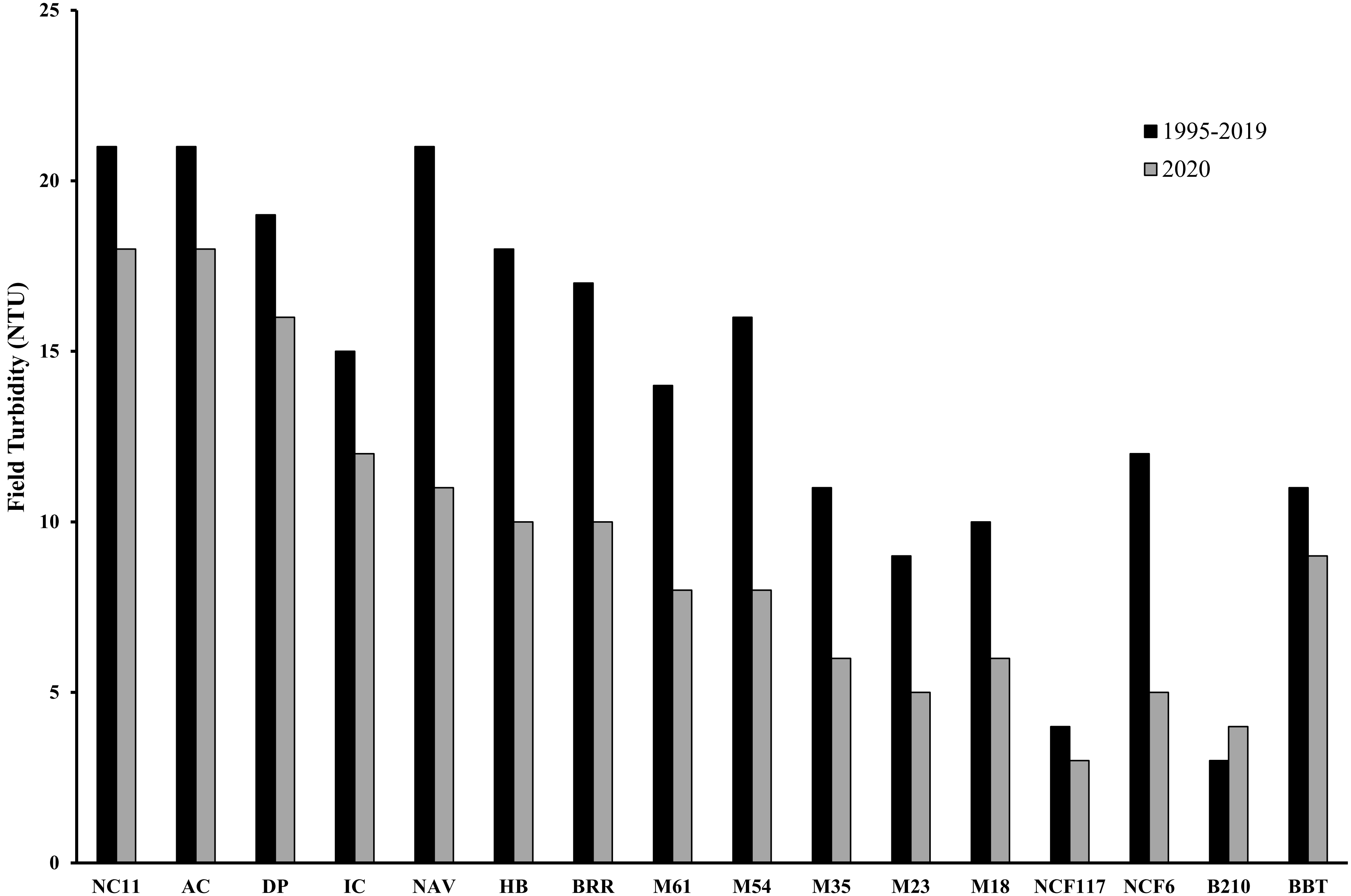

Table 2.7 Total Suspended Solids (mg/L) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	10.9	12.1	11.5	12.4	11.5	10.8	19.6	30.8
FEB	11.9	12.5	11.5	13.6	13.5	11.9	12.1	14.6
MAR	7.0	7.3	7.0	7.5	10.1	11.2	10.6	16.3
APR								
MAY	13.5	12.1	11.0	18.1	23.3	15.4	12.6	8.9
JUN	8.8	6.0	6.2	7.6	6.4	7.1	12.4	18.8
JUL	6.6	9.6	7.9	6.9	8.1	6.3	12.1	20.7
AUG	13.0	9.6	8.8	5.4	9.9	11.7	14.4	12.2
SEP	2.9	4.0	5.9	8.8	9.7	10.3	13.6	15.2
OCT	5.4	7.1	3.1	5.1	6.2	5.9	7.1	16.6
NOV	10.5	9.5	8.4	5.1	9.5	8.0	8.0	8.7
DEC	7.8	7.9	7.3	10.2	10.3	10.8	7.7	21.6
mean	**8.9**	**8.9**	**8.1**	**9.2**	**10.8**	**9.9**	**11.8**	**16.8**
std dev	3.3	2.7	2.6	4.1	4.7	2.9	3.6	6.3
median	8.8	9.5	7.9	7.6	9.9	10.8	12.1	16.3
max	13.5	12.5	11.5	18.1	23.3	15.4	19.6	30.8
min	2.9	4.0	3.1	5.1	6.2	5.9	7.1	8.7

	NC11	AC	DP	IC	NCF6
JAN	35.8	38.8	19.6	35.5	20.0
FEB	26.8	29.6	24.6	14.3	3.7
MAR	3.3	3.9	6.4	5.7	5.7
APR					
MAY	30.0	30.7	24.0	14.6	5.0
JUN	29.8	31.6	21.9	17.2	7.5
JUL	5.6	4.5	3.8	3.4	8.2
AUG	14.0	15.2	19.6	9.2	5.6
SEP	3.0	2.5	2.6	5.7	10.2
OCT	15.1	13.9	6.5	3.6	9.1
NOV	9.8	7.2	3.1	1.3	4.7
DEC	13.7	15.6	17.3	15.9	4.7
mean	**17.0**	**17.6**	**13.6**	**11.5**	**11.5**
std dev	11.7	13.0	9.0	9.7	9.7
median	14.0	15.2	17.3	8.9	9.2
max	35.8	38.8	24.6	5.4	35.5
min	3.0	2.5	2.6	8.9	1.3

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN		1.3		4.7	1.3	2.8	4.5	3.8	18.2
FEB		4.8		4.4	4.0	5.6	7.7	3.7	6.5
MAR		2.9		5.5	3.9	3.3	18.9	4.3	14.8
APR									
MAY		2.6		6.6	5.9	10.0	5.0	4.7	9.8
JUN		5.5		7.0	5.4	3.3	6.7	2.5	11.0
JUL		6.4		4.3	13.2	2.5	2.6	3.4	20.3
AUG				6.5	6.8	9.6	8.3	3.0	10.2
SEP		5.0		2.5	3.3	1.3	4.5	3.1	5.5
OCT		6.8		3.3	4.7	7.8	6.6	3.6	5.7
NOV		1.3		2.5	12.4	10.5	1.3	12.1	2.6
DEC		1.3		3.7	4.5	4.1	6.3	3.4	4.6
mean		**3.8**		**4.6**	**5.9**	**5.5**	**6.6**	**4.3**	**9.9**
std dev		2.2		1.6	3.7	3.4	4.6	2.6	5.8
median		3.9		4.4	4.7	4.1	6.3	3.6	9.8
max		6.8		7.0	13.2	10.5	18.9	12.1	20.3
min		1.3		2.5	1.3	1.3	1.3	2.5	2.6

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	4.2					1.3			
FEB	2.7					1.3			
MAR	3.8					3.4			
APR									
MAY	4.2					6.9			
JUN	4.2					4.0			
JUL	3.6					3.4			
AUG	1.5					1.3			
SEP	3.4					6.6			
OCT	3.8					2.6			
NOV	6.0					1.3			
DEC	3.8					1.3			
mean	**3.7**					**3.0**			
std dev	1.1					2.1			
median	3.8					2.6			
max	6.0					6.9			
min	1.5					1.3			

Table 2.8 Total Nitrogen (µg/l) during 2020 at the Lower Cape Fear River Program stations.

* This number is an addition of TKN and NO3. If < value is reported we use 1/2 that value in the calculation.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	200	300	400	400	200	50	200	50
FEB	1,440	1,360	1,560	1,500	1,240	1,840	900	1,000
MAR	390	510	100	370	300	460	500	600
APR								
MAY	690	690	790	760	840	800	680	620
JUN	870	940	850	1,250	870	870	840	590
JUL	980	1,050	1,070	1,210	890	840	530	530
AUG	1,170	1,280	1,110	1,100	1,240	1,060	1,020	760
SEP	1,270	930	930	1,070	1,040	1,040	880	500
OCT	1,200	840	710	1,020	980	830	470	640
NOV	1,100	800	840	1,180	950	780	670	950
DEC	1,230	710	720	1,170	600	800	680	790
mean	**958**	**855**	**825**	**1,003**	**832**	**852**	**670**	**639**
std dev	388	311	378	353	340	432	236	254
median	1,100	840	840	1,100	890	830	680	620
max	1,440	1,360	1,560	1,500	1,240	1,840	1,020	1,000
min	200	300	100	370	200	50	200	50

	NC11	AC	DP	IC	NCF6
JAN	1,590	490	490	500	430
FEB	1,730	1,540	1,440	1,190	1,540
MAR	1,040	1,040	790	730	880
APR					
MAY	930	860	780	840	710
JUN	850	800	890	870	870
JUL	970	880	1,110	850	880
AUG	810	840	830	940	1,110
SEP	1,050	820	860	860	810
OCT	1,490	790	700	840	900
NOV	1,310	500	620	550	920
DEC	1,510	700	870	900	1,060
mean	**1,207**	**842**	**853**	**825**	**919**
std dev	328	282	251	186	272
median	1,050	820	830	850	880
max	1,730	1,540	1,440	1,190	1,540
min	810	490	490	500	430

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1,500	1,100	500	2,660	1,110	1,200	1,520	900	340
FEB	1,880	2,550	1,850	5,870	5,410	2,410	2,980	1,780	1,710
MAR	1,220	930	500	2,320	2,300	740	1,010	480	580
APR									
MAY	850	750	520	1,640	2,140	810	1,150	920	900
JUN	1,520	710	810	1,190	1,230	3,850	1,060	900	920
JUL	2,110	950	1,930	1,780	1,920	1,840	7,780	1,560	1,260
AUG	1,740	1,050	910	1,900	980	1,000	1,790	1,420	840
SEP	2,020	900	1,040	1,140	1,160	1,210	1,320	1,060	980
OCT	1,800	900	940	840	980	1,500	1,130	910	980
NOV	1,570	820	790	1,100	1,860	960	1,630	760	1,320
DEC	1,430	620	1,050	1,390	1,090	1,410	820	670	950
mean	**1,604**	**1,025**	**985**	**1,985**	**1,835**	**1,539**	**2,017**	**1,033**	**980**
std dev	364	525	491	1,401	1,283	907	1,999	395	364
median	1,570	900	910	1,640	1,230	1,210	1,320	910	950
max	2,110	2,550	1,930	5,870	5,410	3,850	7,780	1,780	1,710
min	850	620	500	840	980	740	820	480	340

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	900	1,300	700	1,100	1,130	600	700	1,200	1,900
FEB	2,190	1,840	1,580	2,850	1,460	1,870	1,880	2,570	2,130
MAR	1,260	1,000	800	1,180	1,460	190	910	1,720	1,290
APR									
MAY	680	1,700	1,310	1,540	1,510	1,260	1,580	1,190	980
JUN	1,090	1,930	800	1,740	1,280	840	960	1,420	1,270
JUL	1,160	1,790	1,190	1,720	1,330	1,160	1,030	1,400	1,310
AUG	1,250	1,390	1,190	1,040	1,440	1,000	980	1,040	980
SEP	1,240	1,380	1,320	2,480	1,380	1,060	1,290	1,140	910
OCT	1,100	2,230	960	1,240	1,100	820	720	740	1,980
NOV	930	1,170	880	1,170	1,090	680	900	1,760	1,870
DEC	1,220	730	930	2,760	2,110	1,010	910	1,680	1,760
mean	**1,184**	**1,496**	**1,060**	**1,711**	**1,390**	**954**	**1,078**	**1,442**	**1,489**
std dev	380	444	275	681	283	425	364	488	449
median	1,160	1,390	960	1,540	1,380	1,000	960	1,400	1,310
max	2,190	2,230	1,580	2,850	2,110	1,870	1,880	2,570	2,130
min	680	730	700	1,040	1,090	190	700	740	910

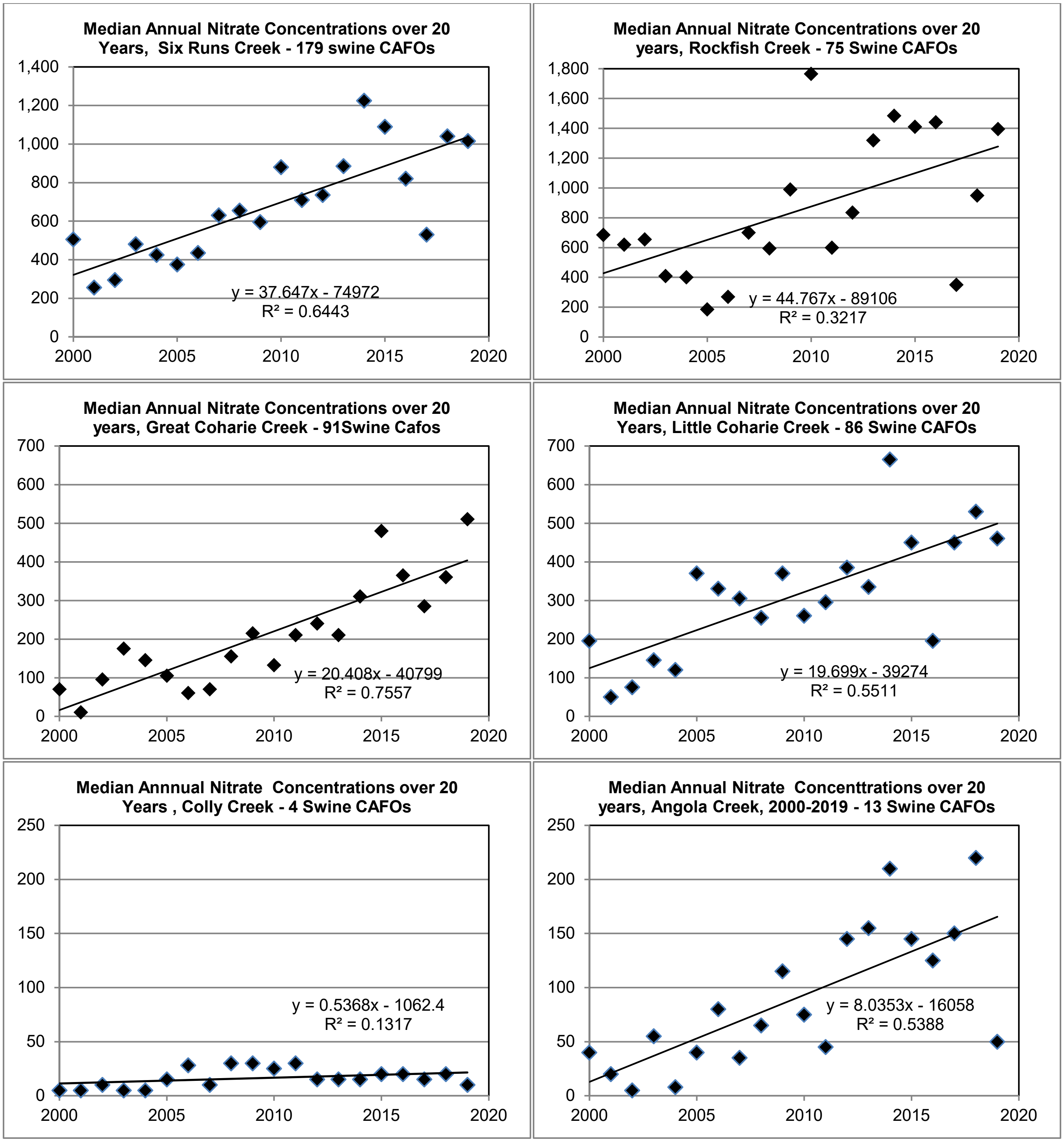

Figure 2.4. 20-year changes in nitrate at selected non-point source sites in the Lower Cape Fear basin; note general increasing trend except for wetland-rich Colly Creek. CAFO numbers are approximates.

Table 2.9 Nitrate/Nitrite (μg/l) during 2020 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	10	10	10	10	10	10	10	10
FEB	140	160	160	10	40	40	10	10
MAR	190	110	10	70	10	60	10	10
APR								
MAY	290	290	290	360	340	300	280	220
JUN	270	140	250	250	270	270	240	190
JUL	200	260	300	260	220	170	60	10
AUG	420	390	380	300	330	220	160	100
SEP	360	10	40	300	10	10	10	10
OCT	280	10	10	280	10	10	10	10
NOV	350	10	10	320	10	10	10	280
DEC	500	10	10	460	10	10	10	180
mean	**274**	**127**	**134**	**238**	**115**	**101**	**74**	**94**
std dev	136	135	146	146	143	116	103	105
median	280	110	40	280	10	40	10	10
max	500	390	380	460	340	300	280	280
min	10	10	10	10	10	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	90	90	90	0	30
FEB	530	540	540	490	140
MAR	740	740	790	430	380
APR					
MAY	430	360	380	340	210
JUN	50	100	290	270	70
JUL	80	100	180	60	10
AUG	10	10	10	10	10
SEP	20	10	10	10	10
OCT	540	10	10	10	10
NOV	670	10	10	10	10
DEC	620	10	10	10	10
mean	**344**	**180**	**211**	**149**	**81**
std dev	293	253	264	193	119
median	430	90	90	10	10
max	740	740	790	490	380
min	10	10	10	0	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	10	100	10	460	310	10	120	10	40
FEB	280	1,350	850	4,670	3,910	1,110	1,180	680	410
MAR	20	130	10	1,720	1,500	240	510	180	80
APR									
MAY	50	250	120	940	1,540	310	550	420	400
JUN	10	10	10	130	60	10	40	10	10
JUL	180	10	310	580	480	610	6,160	290	250
AUG	10	10	10	100	30	10	210	10	40
SEP	130	10	40	90	30	290	80	10	190
OCT	140	10	70	10	100	540	30	10	220
NOV	80	10	10	90	970	120	70	10	180
DEC	340	90	360	130	100	340	10	10	240
mean	**114**	**180**	**164**	**811**	**821**	**326**	**815**	**149**	**187**
std dev	114	395	260	1,379	1,174	330	1,808	226	137
median	80	10	40	130	310	290	120	10	190
max	340	1,350	850	4,670	3,910	1,110	6,160	680	410
min	10	10	10	10	30	10	10	10	10

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	200	10	10	10	30	10	10	10	10
FEB	590	40	380	1,750	460	1,070	380	770	1,030
MAR	260	10	100	680	460	190	110	620	290
APR									
MAY	80	10	210	1,240	510	60	480	490	280
JUN	100	10	80	780	370	60	70	540	420
JUL	220	30	330	920	560	370	180	480	370
AUG	220	50	140	510	280	40	30	310	200
SEP	10	30	150	1,190	320	30	50	370	90
OCT	10	10	130	320	420	10	60	10	10
NOV	10	10	40	810	490	10	60	740	1,060
DEC	670	40	260	1,820	1,380	470	310	770	1,130
mean	**215**	**23**	**166**	**912**	**480**	**211**	**158**	**465**	**445**
std dev	225	16	117	558	332	325	160	272	426
median	200	10	140	810	460	60	70	490	290
max	670	50	380	1,820	1,380	1,070	480	770	1,130
min	10	10	10	10	30	10	10	10	10

Table 2.10 Ammonia (μg/l) during 2020 at the Lower Cape Fear River stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	10	30	10	20	30	10	170	170
FEB	10	70	30	40	110	70	70	120
MAR	10	10	50	60	80	70	60	160
APR								
MAY	40	40	40	50	80	60	70	110
JUN	60	50	40	80	50	50	60	10
JUL	60	60	30	70	160	40	140	60
AUG	40	50	50	70	130	80	120	250
SEP	80	90	50	100	70	10	300	330
OCT	50	60	50	50	60	10	10	10
NOV	60	50	90	70	230	50	10	20
DEC	80	60	100	80	70	10	40	10
mean	**45**	**52**	**49**	**63**	**97**	**42**	**95**	**114**
std dev	26	21	26	22	57	28	85	107
median	50	50	50	70	80	50	70	110
max	80	90	100	100	230	80	300	330
min	10	10	10	20	30	10	10	10

	NC11	AC	DP	IC	NCF6
JAN	70	40	50	50	40
FEB	20	10	10	10	10
MAR	50	160	90	60	30
APR					
MAY	70	70	50	60	60
JUN	110	130	110	100	70
JUL	70	70	150	60	20
AUG	40	70	50	50	40
SEP	90	90	100	90	40
OCT	30	60	50	50	40
NOV	100	90	90	80	90
DEC	80	120	120	150	100
mean	**66**	**83**	**79**	**69**	**49**
std dev	29	42	41	36	28
median	70	70	90	60	40
max	110	160	150	150	100
min	20	10	10	10	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	190	10	10	1,680	20	70	10	20	30
FEB	30	40	10	80	60	50	130	20	20
MAR	40	20	10	90	30	20	40	20	40
APR									
MAY	170	30	10	310	100	70	100	60	40
JUN	110	60	50	170	130	90	170	60	70
JUL	160	60	100	110	100	180	90	30	70
AUG	60	50	20	860	100	60	80	50	70
SEP	180	50	50	80	70	130	40	70	100
OCT	110	100	40	70	80	70	60	70	90
NOV	110	40	40	110	210	50	460	70	80
DEC	200	60	70	830	90	120	90	90	60
mean	**124**	**47**	**37**	**399**	**90**	**83**	**115**	**51**	**61**
std dev	61	24	29	517	51	45	123	25	25
median	110	50	40	110	90	70	90	60	70
max	200	100	100	1,680	210	180	460	90	100
min	30	10	10	70	20	20	10	20	20

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	100	50	80	60	10	20	50	40	70
FEB	20	10	10	120	10	10	10	60	20
MAR	10	80	10	40	20	10	60	50	30
APR									
MAY	30	160	30	220	30	60	110	40	50
JUN	80	280	60	190	80	70	140	70	70
JUL	40	340	40	70	50	60	50	30	40
AUG	110	100	40	90	60	430	40	60	420
SEP	60	80	50	390	80	50	80	80	60
OCT	30	80	10	10	10	10	10	30	20
NOV	50	80	40	60	40	50	30	160	70
DEC	10	70	70	100	10	20	50	150	70
mean	**49**	**121**	**40**	**123**	**36**	**72**	**57**	**70**	**84**
std dev	35	101	24	108	28	121	40	45	113
median	40	80	40	90	30	50	50	60	60
max	110	340	80	390	80	430	140	160	420
min	10	10	10	10	10	10	10	30	20

Table 2.11 Total Kjeldahl Nitrogen (μg/l) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	200	300	400	400	200	50	200	50
FEB	130	120	140	150	120	180	90	100
MAR	200	400	100	300	300	400	500	600
APR								
MAY	400	400	500	400	500	500	400	400
JUN	600	800	600	1,000	600	600	600	400
JUL	780	790	770	950	670	670	470	530
AUG	750	890	730	800	910	840	860	660
SEP	910	930	890	770	1,040	1,040	880	500
OCT	920	840	710	740	980	830	470	640
NOV	750	800	840	860	950	780	670	670
DEC	730	710	720	710	600	800	680	610
mean	**579**	**635**	**582**	**644**	**625**	**608**	**529**	**469**
std dev	295	277	269	283	323	302	246	217
median	730	790	710	740	600	670	500	530
max	920	930	890	1,000	1,040	1,040	880	670
min	130	120	100	150	120	50	90	50

	NC11	AC	DP	IC	NCF6
JAN	1,500	400	400	400	400
FEB	1,200	1,000	900	700	1,400
MAR	300	300	50	300	500
APR					
MAY	500	500	400	500	500
JUN	800	700	600	600	800
JUL	890	780	930	790	880
AUG	810	840	830	940	1,110
SEP	1,030	820	860	860	810
OCT	950	790	700	840	900
NOV	640	500	620	550	920
DEC	890	700	870	900	1,060
mean	**865**	**666**	**651**	**671**	**844**
std dev	326	214	275	215	296
median	890	700	700	700	880
max	1,500	1,000	930	940	1,400
min	300	300	50	300	400

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1,500	1,000	500	2,200	800	1,200	1,400	900	300
FEB	1,600	1,200	1,000	1,200	1,500	1,300	1,800	1,100	1,300
MAR	1,200	800	500	600	800	500	500	300	500
APR									
MAY	800	500	400	700	600	500	600	500	500
JUN	1,520	710	810	1,060	1,170	3,850	1,020	900	920
JUL	1,930	950	1,620	1,200	1,440	1,230	1,620	1,270	1,010
AUG	1,740	1,050	910	1,800	950	1,000	1,580	1,420	800
SEP	1,890	900	1,000	1,050	1,130	920	1,240	1,060	790
OCT	1,660	900	870	840	880	960	1,100	910	760
NOV	1,490	820	790	1,010	890	840	1,560	760	1,140
DEC	1,090	530	690	1,260	990	1,070	820	670	710
mean	**1,493**	**851**	**826**	**1,175**	**1,014**	**1,215**	**1,204**	**890**	**794**
std dev	343	212	334	466	275	913	435	326	294
median	1,520	900	810	1,060	950	1,000	1,240	900	790
max	1,930	1,200	1,620	2,200	1,500	3,850	1,800	1,420	1,300
min	800	500	400	600	600	500	500	300	300

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	700	1,300	700	1,100	1,100	600	700	1,200	1,900
FEB	1,600	1,800	1,200	1,100	1,000	800	1,500	1,800	1,100
MAR	1,000	1,000	700	500	1,000	50	800	1,100	1,000
APR									
MAY	600	1,700	1,100	1,300	1,000	1,200	1,100	700	700
JUN	990	1,930	720	960	910	780	890	880	850
JUL	940	1,760	860	800	770	790	850	920	940
AUG	1,030	1,340	1,050	530	1,160	960	950	730	780
SEP	1,240	1,350	1,170	1,290	1,060	1,030	1,240	770	820
OCT	1,100	2,230	830	920	680	820	660	740	1,980
NOV	930	1,170	840	360	600	680	840	1,020	810
DEC	550	690	670	940	730	540	600	910	630
mean	**971**	**1,479**	**895**	**891**	**910**	**750**	**921**	**979**	**1,046**
std dev	297	449	200	315	186	299	268	316	461
median	990	1,350	840	940	1,000	790	850	910	850
max	1,600	2,230	1,200	1,300	1,160	1,200	1,500	1,800	1,980
min	550	690	670	360	600	50	600	700	630

Table 2.12 Total Phosphorus (µg/l) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	100	90	80	90	70	70	70	60
FEB	140	100	130	130	120	200	150	170
MAR	80	70	40	120	110	60	100	50
APR								
MAY	110	100	100	220	150	130	90	60
JUN	550	290	710	640	520	650	170	100
JUL	160	340	130	100	80	240	80	190
AUG	200	160	190	150	140	90	170	280
SEP	570	200	170	180	170	140	140	120
OCT	680	340	410	480	640	680	410	380
NOV	220	110	230	180	90	310	50	50
DEC	300	330	180	350	260	260	170	370
mean	**283**	**194**	**215**	**240**	**214**	**257**	**145**	**166**
std dev	205	106	182	169	182	207	93	119
median	200	160	170	180	140	200	140	120
max	680	340	710	640	640	680	410	380
min	80	70	40	90	70	60	50	50

	NC11	AC	DP	IC	NCF6
JAN	250	200	150	230	100
FEB	340	120	60	60	60
MAR	260	160	250	100	110
APR					
MAY	160	160	140	110	160
JUN	140	130	140	120	130
JUL	170	170	180	130	130
AUG	30	10	40	20	90
SEP	180	170	240	200	160
OCT	150	200	180	130	250
NOV	290	470	1,400	610	1,420
DEC	270	320	200	250	270
mean	**204**	**192**	**271**	**178**	**178**
std dev	83	112	362	152	372
median	180	170	180	130	130
max	340	470	1,400	610	610
min	30	10	40	20	20

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	140	70	40	110	80	80	200	50	80
FEB	560	130	100	190	160	120	350	100	170
MAR	880	150	140	160	150	140	250	150	170
APR									
MAY	530	100	90	150	180	100	240	160	160
JUN	550	90	90	150	170	50	210	130	150
JUL	130	290	420	290	170	260	1,010	160	90
AUG	370	30	70	250	250	230	630	160	200
SEP	840	510	730	890	480	480	960	630	600
OCT	710	330	220	270	310	210	300	180	220
NOV	880	880	870	350	470	1,530	1,340	380	920
DEC	570	80	310	440	220	290	430	170	300
mean	**560**	**242**	**280**	**295**	**240**	**317**	**538**	**206**	**278**
std dev	253	244	270	210	124	401	375	155	244
median	560	130	140	250	180	210	350	160	170
max	880	880	870	890	480	1,530	1,340	630	920
min	130	30	40	110	80	50	200	50	80

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	110	60	60	160	100	150	70	130	160
FEB	120	230	80	140	90	120	80	120	100
MAR	100	100	40	130	50	210	100	220	220
APR									
MAY	250	260	120	260	90	210	380	300	110
JUN	100	230	40	150	70	240	190	100	220
JUL	150	170	80	10	10	80	10	120	230
AUG	190	220	10	70	10	180	10	360	320
SEP	230	410	170	240	190	400	170	130	240
OCT	420	610	420	440	580	760	650	710	450
NOV	310	320	220	50	200	180	220	190	170
DEC	70	80	80	100	40	80	50	70	70
mean	**186**	**245**	**120**	**159**	**130**	**237**	**175**	**223**	**208**
std dev	103	152	111	114	154	186	182	176	103
median	150	230	80	140	90	180	100	130	220
max	420	610	420	440	580	760	650	710	450
min	70	60	10	10	10	80	10	70	70

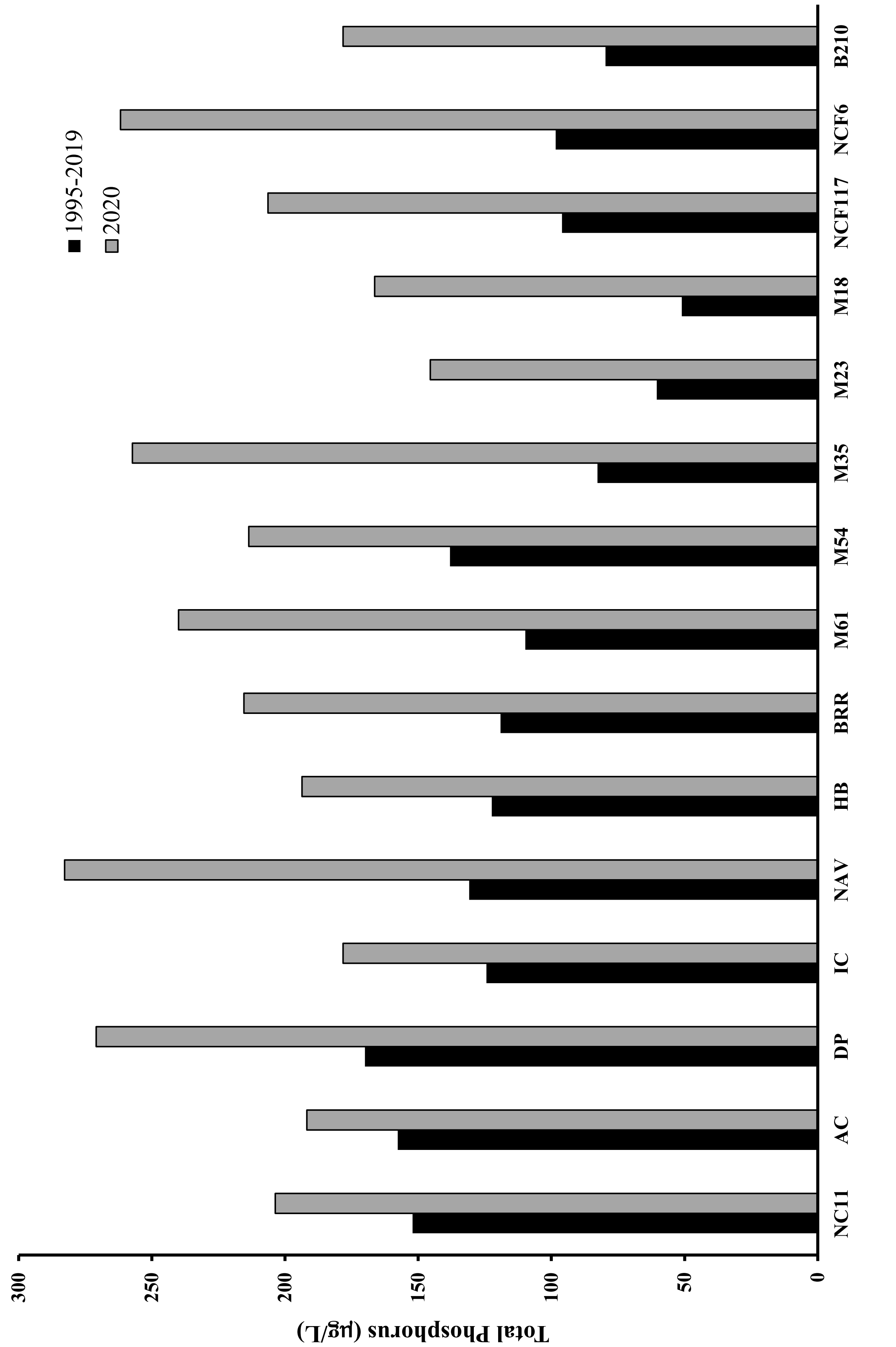

Figure 2.5 Total Phosphorus at the Lower Cape Fear River Program mainstem stations, 1995-2019 versus 2020.

Table 2.13 Orthophosphate (µg/l) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	10	10	10	10	10	10	10	10
FEB	20	10	20	10	20	20	10	10
MAR	10	10	10	20	10	10	10	10
APR								
MAY	30	40	30	50	50	40	30	30
JUN	30	40	30	60	50	40	40	30
JUL	50	50	50	50	40	30	20	10
AUG	40	40	40	40	40	30	20	10
SEP	50	50	50	40	40	30	20	10
OCT	30	50	40	50	40	30	30	20
NOV	20	30	30	50	50	40	30	40
DEC	40	40	40	40	40	30	20	20
mean	**30**	**34**	**32**	**38**	**35**	**28**	**22**	**18**
std dev	14	16	14	17	15	11	10	11
median	30	40	30	40	40	30	20	10
max	50	50	50	60	50	40	40	40
min	10	10	10	10	10	10	10	10

	NC11	AC	DP	BBT	IC	NCF6
JAN	20	20	20	20	20	10
FEB	10	20	10	10	10	20
MAR	20	30	20	10	20	10
APR						
MAY	50	50	40	30	30	70
JUN	60	60	50	40	50	60
JUL	60	50	70	40	50	50
AUG	40	20	30	40	40	70
SEP	60	60	60	50	50	40
OCT	50	50	50	50	50	60
NOV	50	60	50	40	40	50
DEC	40	40	40	30	40	40
mean	**42**	**42**	**40**	**33**	**36**	**44**
std dev	18	17	18	14	14	22
median	50	50	40	40	40	50
max	60	60	70	50	50	70
min	10	20	10	10	10	10

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	30	5	10	10	10	10	40	10	10
FEB	140	10	10	10	10	10	30	10	10
MAR	120	10	10	10	10	5	30	20	10
APR									
MAY	340	40	30	50	50	20	100	80	70
JUN	380	40	40	60	60	12	110	60	70
JUL	120	60	40	60	5	40	550	60	20
AUG	270	50	50	50	80	30	50	50	40
SEP	290	60	30	110	70	30	130	60	40
OCT	180	40	40	50	70		110	40	50
NOV	100	30	30	100	50	30	70	40	40
DEC	100	30	30	50	50	30	40	40	40
mean	**188**	**34**	**29**	**51**	**42**	**22**	**115**	**43**	**36**
std dev	114	19	14	33	28	12	149	22	22
median	140	40	30	50	50	25	70	40	40
max	380	60	50	110	80	40	550	80	70
min	30	5	10	10	5	5	30	10	10

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	10	20	5	20	5	30	5	10	10
FEB	10	10	5	10	5	20	10	10	10
MAR	10	20	10	20	10	50	5	10	10
APR									
MAY	30	60	50	120	40	110	10	20	50
JUN	50	90	70	50	30	100	10	20	60
JUL	60	100	20	50	30	140	5	40	120
AUG	50	60	10	50	20	30	5	30	90
SEP	40	60	10	50	20	160	10	30	90
OCT	40	50	10	50	20	60	0	20	50
NOV	30	30	10	50	20	20	5	30	30
DEC									
mean	**33**	**50**	**20**	**47**	**20**	**72**	**7**	**22**	**52**
std dev	18	30	22	30	11	52	3	10	39
median	35	55	10	50	20	55	5	20	50
max	60	100	70	120	40	160	10	40	120
min	10	10	5	10	5	20	0	10	10

Table 2.14 Chlorophyll *a* (µg/l) during 2020 at the Lower Cape Fear River Program stations.

	NAV	HB	BRR	M61	M54	M35	M23	M18
JAN	1	2	2	3	3	4	4	9
FEB	4	5	5	4	5	7	7	11
MAR	5	5	6	5	5	4	4	6
APR								
MAY	2	2	2	2	3	2	2	2
JUN	5	4	4	3	3	3	4	3
JUL	2	3	3	6	4	6	6	12
AUG	1	2	1	4	6	38	33	16
SEP	3	5	9	11	21	6	8	8
OCT	1	1	1	1	1	2	3	4
NOV	1	1	1	1	1	1	1	1
DEC	1	1	1	1	1	1	2	3
mean	**2**	**3**	**3**	**4**	**5**	**7**	**7**	**7**
std dev	2	2	3	3	6	11	9	5
median	2	2	2	3	3	4	4	6
max	5	5	9	11	21	38	33	16
min	1	1	1	1	1	1	1	1

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

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	1	1	1	3	2	1	1	1	1
FEB	2	2	2	4	4	2	2	1	2
MAR	2	3	3	4	3	2	1	1	3
APR									
MAY	6	1	2	8	4	9	2	1	2
JUN	5	1	1	7	3	3	2	1	2
JUL	27	3	44	9	12	2	2	2	26
AUG	13	1	1	11	8	14	1	1	7
SEP	5	1	3	5	8	3	1	1	7
OCT	1	1	3	9	4	7	2	1	1
NOV	5	1	2	6	34	2	0	1	0
DEC	2	1	1	3	5	5	1	0	1
mean	**6**	**1**	**6**	**6**	**8**	**5**	**1**	**1**	**5**
std dev	8	1	13	3	9	4	1	0	7
median	5	1	2	6	4	3	1	1	2
max	27	3	44	11	34	14	2	2	26
min	1	1	1	3	2	1	0	0	0

	B210	COL	SR-WC	6RC	LCO	GCO	SR	BRN	HAM
JAN	1	2	1	4	3	3	7	3	2
FEB	1	2	1	1	1	1	3	2	1
MAR	1	1	1	1	0	1	4	1	1
APR									
MAY	1	2	2	7	3	4	10	2	2
JUN	1	4	1	1	1	1	7	5	1
JUL	1	2	1	2	2	3	8	3	2
AUG	1	1	1	1	1	1	2	2	0
SEP	0	6	1	1	1	2	111	2	1
OCT	0	1	0	1	1	1	5	2	1
NOV	1	0	0	1	1	1	2	1	0
DEC									
mean	**1**	**2**	**1**	**2**	**1**	**2**	**16**	**2**	**1**
std dev	0	2	1	2	1	1	34	1	1
median	1	2	1	1	1	1	6	2	1
max	1	6	2	7	3	4	111	5	2
min	0	0	0	1	0	1	2	1	0

Figure 2.6 Chlorophyll *a* at the Lower Cape Fear River Program mainstem stations, 1995-2019 versus 2020.

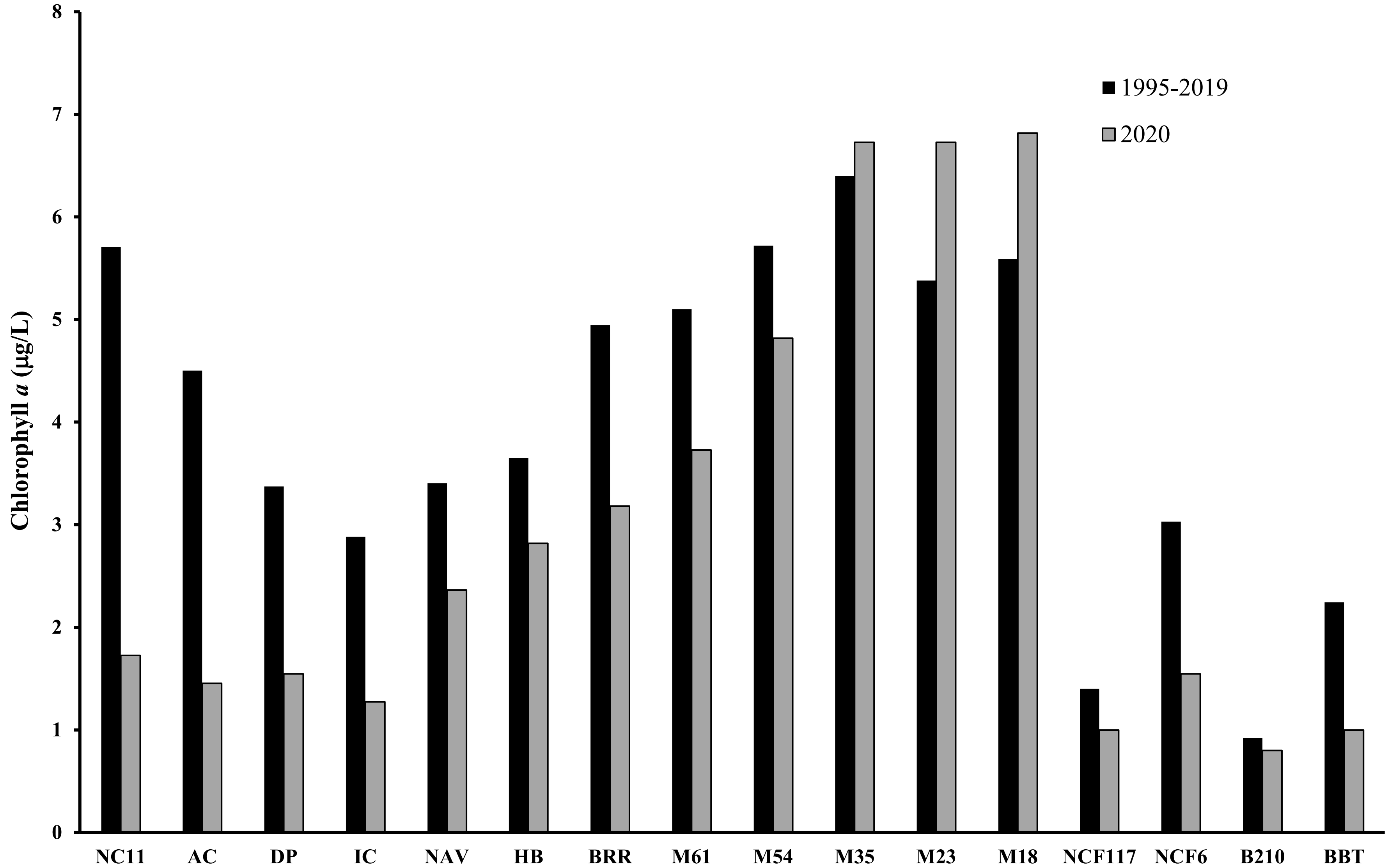

Table 2.15 Fecal Coliform (cfu/100 mL) and Enterococcus (MPN) during 2020 at the Lower Cape Fear River Program stations.

	NC11	AC	DP	IC	NCF6	NAV	HB
JAN	864	864	364	1,500	120	32	32
FEB	73	100	37	5	37	46	28
MAR	5	14	3	19	19	19	14
APR							
MAY	158	95	68	68	55	83	59
JUN	130	175	125	68	37	32	23
JUL	32	23	23	50	32	37	55
AUG	50	59	41	110	86	86	50
SEP	5	28	32	32	155	57	73
OCT	14	10	5	10	50	46	245
NOV	23	5	5	28	55	27	14
DEC	20	25	22	16	19	28	19
mean	**125**	**127**	**66**	**173**	**60**	**45**	**56**
std dev	239	238	100	421	41	21	63
max	864	864	364	1,500	155	86	245
min	5	5	3	5	19	19	14
Geomean	39	43	27	41	49	40	38

ENTEROCOCCUS

	BRR	M61	M54	M35	M23	M18
JAN	5	20	41	20	10	5
FEB	31	31	41	10	5	20
MAR	10	5	5	5	5	5
APR						
MAY	173	150	134	20	5	5
JUN	63	31	20	5	10	5
JUL	31	30	5	10	20	10
AUG	19	47	128	262	1,300	687
SEP	41	20	10	5	5	5
OCT	10	20	31	10	5	5
NOV	5	20	5	5	10	10
DEC	10	31	30	10	41	20
mean	**36**	**37**	**41**	**33**	**129**	**71**
std dev	47	37	44	73	371	195
max	173	150	134	262	1,300	687
min	5	5	5	5	5	5
Geomean	20	27	22	12	14	11

	ANC	SAR	GS	NC403	PB	LRC	ROC	NCF117	SC-CH
JAN	59	185	82	170	73	175	140	41	50
FEB	68	135	32	32	91	295	773	210	155
MAR	10	59	19	23	77	41	82	55	59
APR									
MAY	46	190	95	175	265	290	205	41	50
JUN	130	910	455	2,050	1,250	637	500	115	82
JUL	135	135	1,200	955	30,000	819	155	73	319
AUG	110	180	195	1,100	591	255	275	23	155
SEP	140	210	115	125	773	55	86	37	64
OCT	113	135	41	77	205	59	200	32	64
NOV	59	120	55	46	190	864	100	59	19
DEC	50	500	32	68	115	86	773	145	59
mean	**84**	**251**	**211**	**438**	**3,057**	**325**	**299**	**76**	**98**
std dev	42	235	335	625	8,527	293	250	55	81
max	68	910	1,200	2,050	30,000	864	773	210	319
min	10	59	19	23	73	41	82	23	19
Geomean	69	188	92	157	352	199	218	60	75

	B210	COL	SRWC	6RC	LCO	GCO	SR	BRN	HAM
JAN	115	160	768	10,600	1,100	46	205	1,650	1,180
FEB	64	5	41	175	32	41	46	64	59
MAR	46	19	50	64	19	5	37	125	180
APR									
MAY	23	82	27,500	11,000	15,000	2,400	17,000	180	250
JUN	37	82	3	137	68	140	100	280	235
JUL	43	68	37	43	637	91	100	182	210
AUG	41	115	270	175	260	215	110	1,800	270
SEP	46	195	115	135	64	37	28	1,100	220
OCT	77	91	50	319	115	500	145	205	77
NOV	82	105	73	115	110	105	110	195	145
DEC	28	19	14	55	46	68	19	41	120
mean	**55**	**86**	**2,629**	**2,074**	**1,586**	**332**	**1,627**	**529**	**268**
std dev	26	56	7,868	4,115	4,254	667	4,862	628	296
max	115	195	27,500	11,000	15,000	2,400	17,000	1,800	1,180
min	23	5	3	43	19	5	19	41	59
Geomea	49	59	98	260	173	98	117	262	191

Figure 2.7 Geometric Mean Fecal Coliform (NC11-B210) and Enterococcus (BRR-M18) at the LCFRP mainstem stations, 1996-2019 (Entero 2012-2014) vs. 2020.