NCDP Scientific Advisory Council Agenda

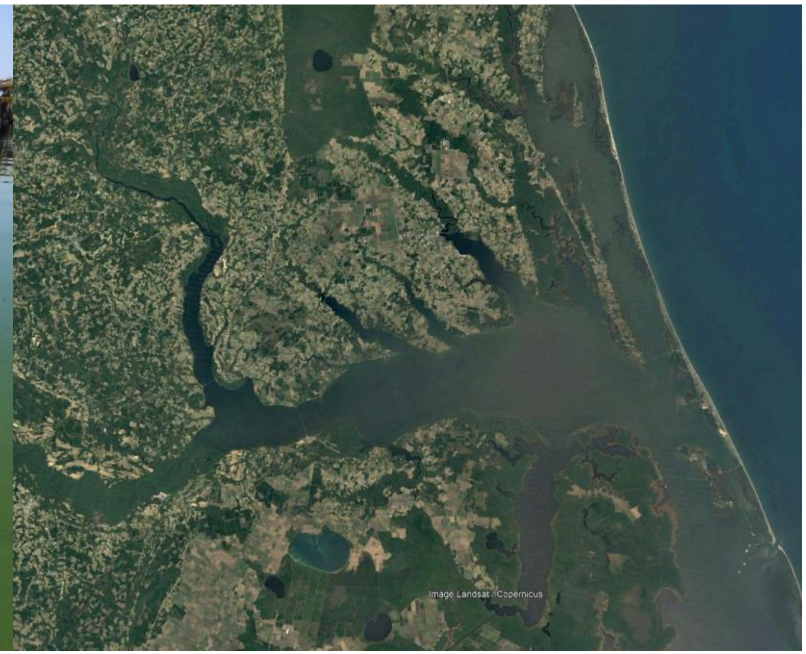
10:00am – 3:30pm
June 27, 2019
Agronomic Division Building Conference Room
4300 Reedy Creek Road, Raleigh, NC 27607

Desired Outcomes:

- Shared understanding of the Chlorophyll *a* document status.
- Shared understanding of the APNEP Phase I report.
- Shared understanding of recent and upcoming research in the Chowan/Albemarle.
- Shared understanding of the NCDP document revisions.

Time	Topic	Speaker(s)
10:00	Convene • *Introductions* • *Approval/Comments on meeting minutes – November and December 2018* • *Administrative Business*	Jenny Halsey (facilitator)
10:15	Chlorophyll *a* Document Update	Jim Bowen, Lauren Petter, Nathan Hall, Marty Lebo, Clifton Bell
10:45	APNEP Phase I Report Review	Jim Hawhee
11:00	Break	
11:15	Searching for drivers of a system-wide change in trophic status of the greater Albemarle Sound ecosystem	Nathan Hall
12:00	Lunch	
12:30	Identifying Pollution Trends for Management Prioritization in the Albemarle	Mike O'Driscoll
1:00	Food Web Transfer of Cyanobacterial Toxins in the Chowan River and western Albemarle Sound, North Carolina	Astrid Schnetzer
1:30	NCDP Document Updates	Jim Hawhee
2:00	Wrap-up, closing remarks, and adjourn	Jenny Halsey (facilitator)
2:15	Adjourn	

Searching for drivers of a system-wide change in trophic status of the greater Albemarle Sound ecosystem



North Carolina Nutrient Criteria Development Plan
Scientific Advisory Council
Nathan Hall, UNC-IMS, 27 June 2019

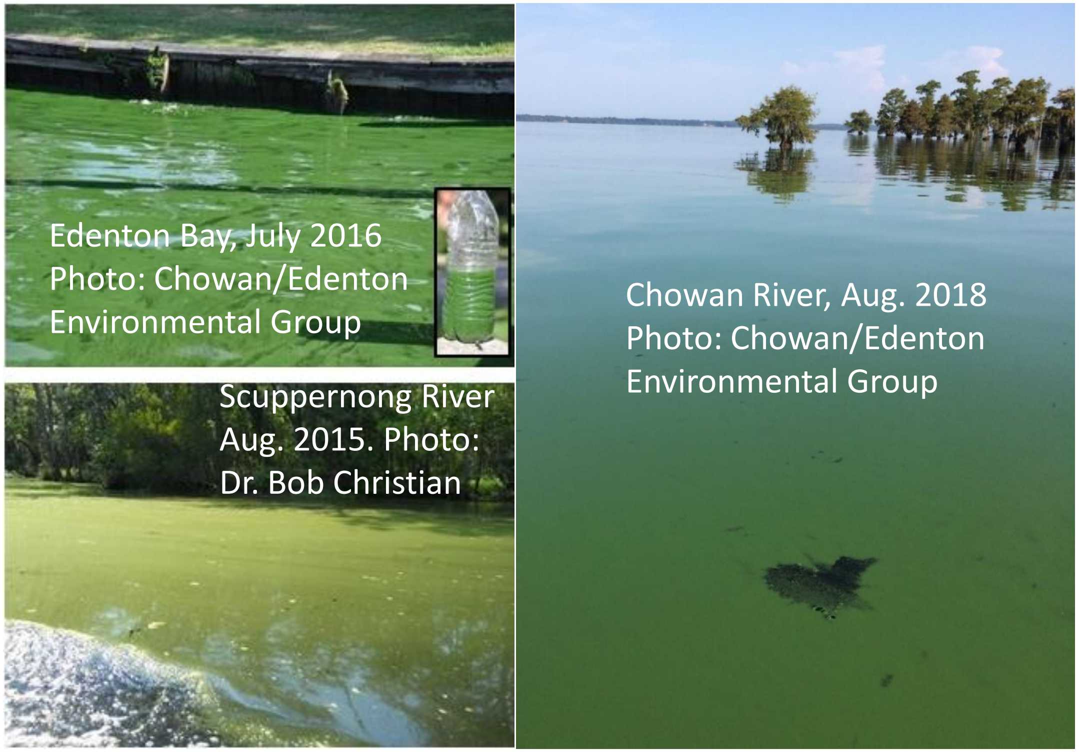


Figure 1. Recent cyanobacteria blooms in the Albemarle Sound ecosystem.

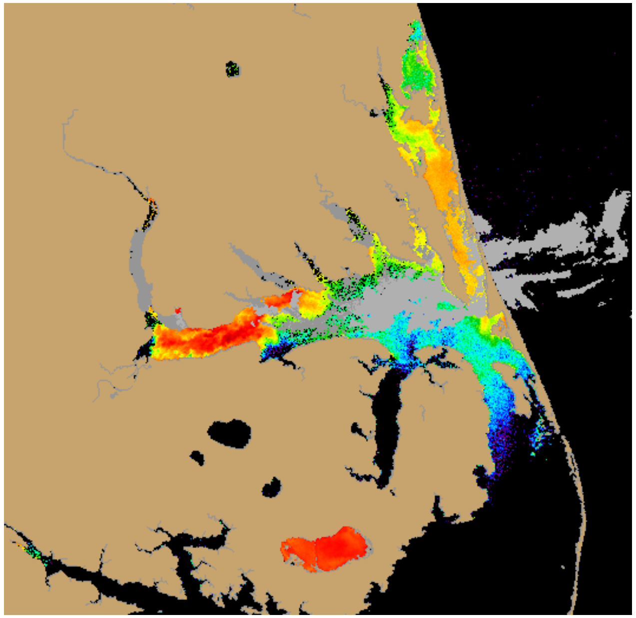


Figure. 4. Example of a bloom map on NOAA's website from July 20, 2017 showing bloom levels of cyanobacteria in western Albemarle Sound, Lake Mattamuskeet, and Currituck Sound.

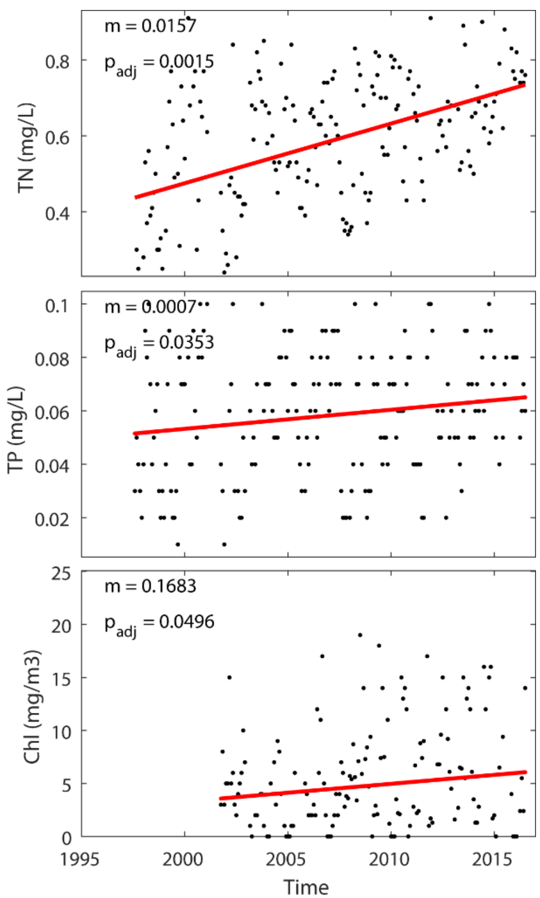
Blooms dominated by the potentially toxigenic N-fixing cyanobacteria *Dolichospermum*, a.k.a. *Anabaena sp*.

Are blooms indicative of larger-scale pattern of changing trophic status?

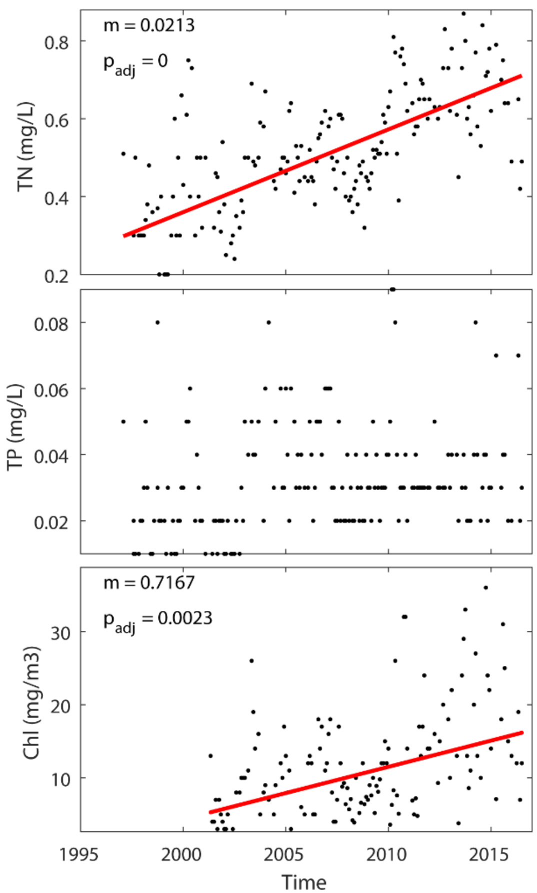
NC DEQ Ambient Monitoring System stations

Long-term Trend Analyses Using Seasonal Kendal Tests

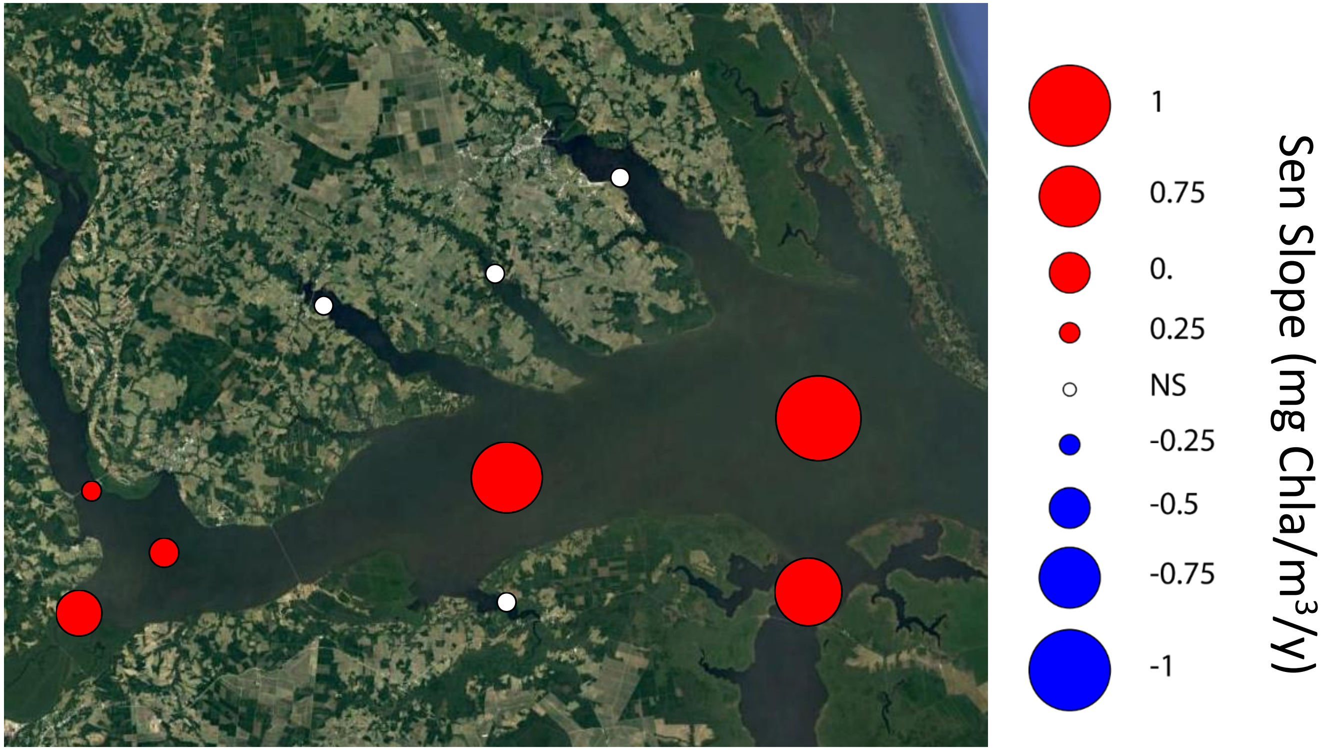
Chowan R. near mouth



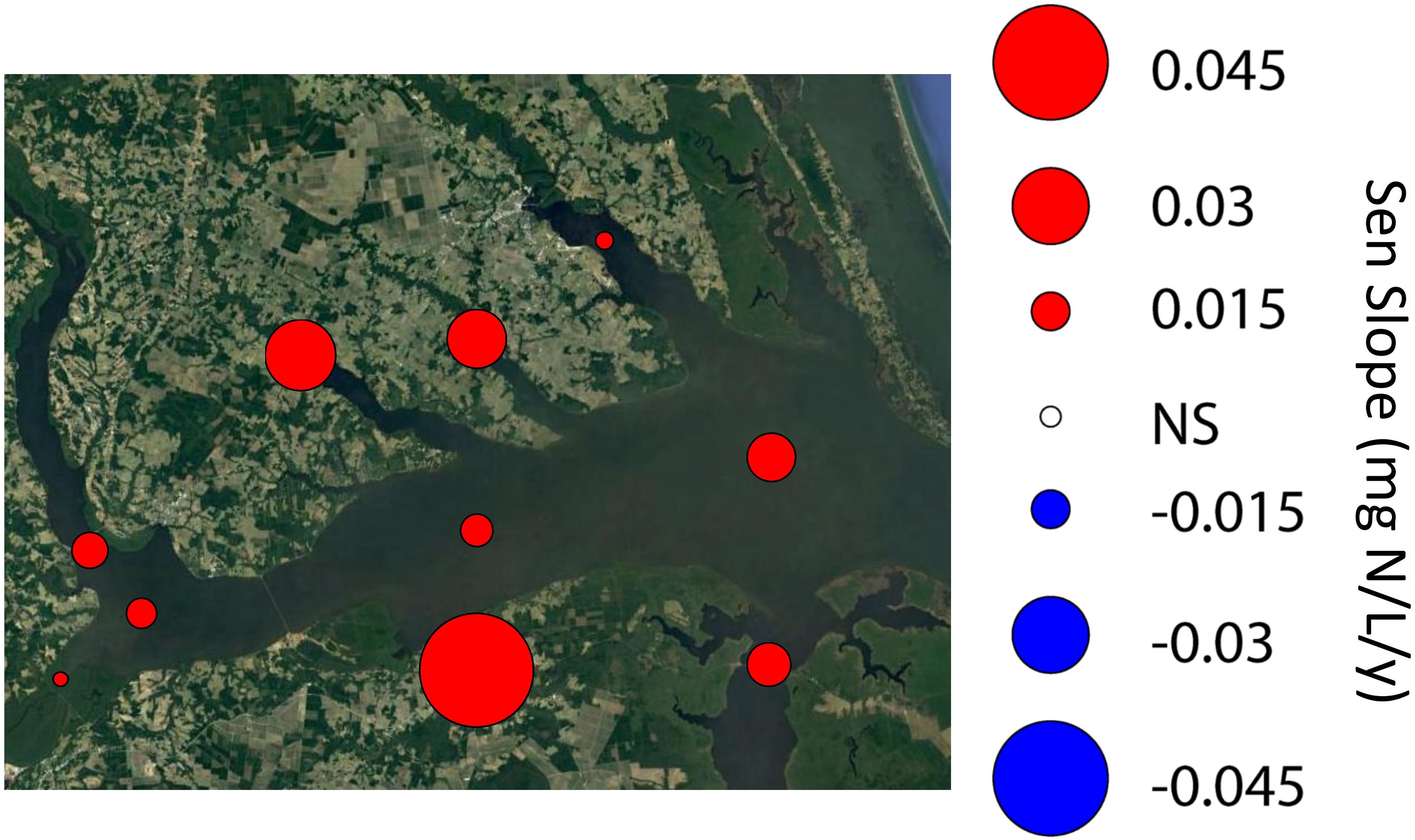
M39C East Central Albemarle Sound



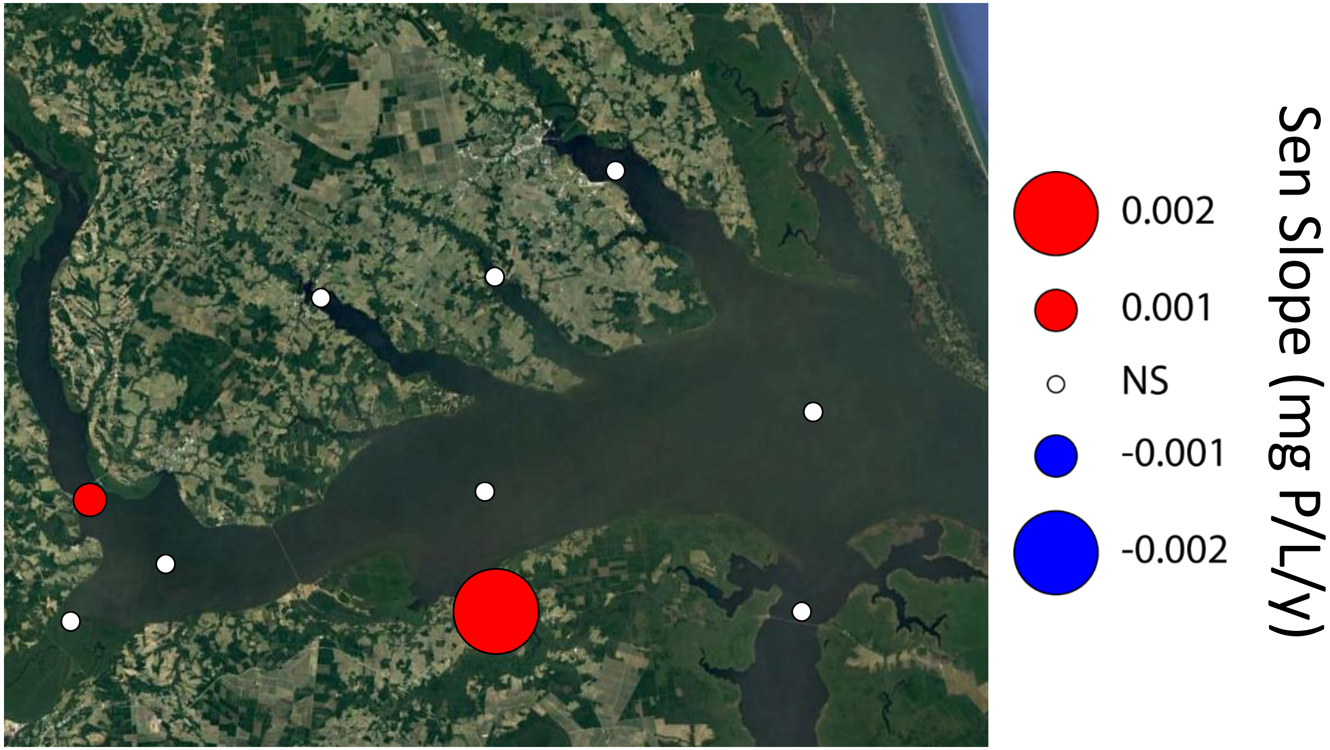
Summary Map of Trend Slopes for Phytoplankton Biomass as Chlorophyll *a*



Summary Map of Trend Slopes for Total N



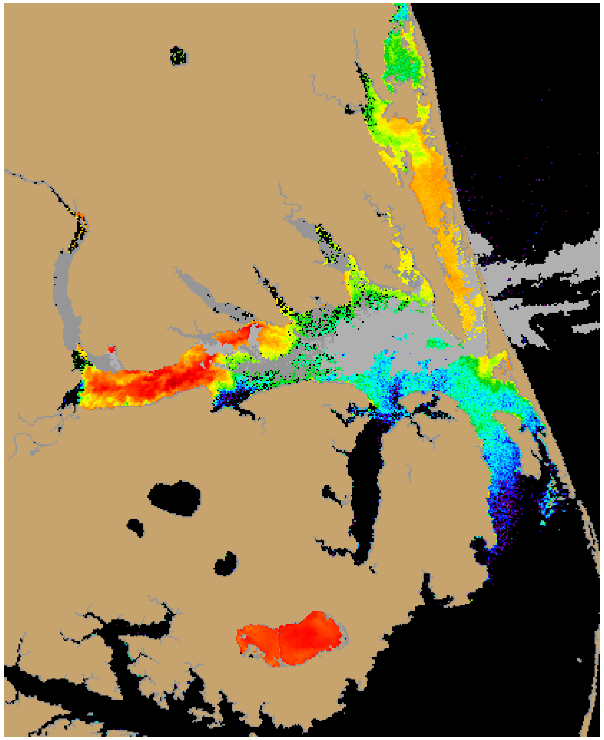
Summary Map of Trend Slopes for Total P

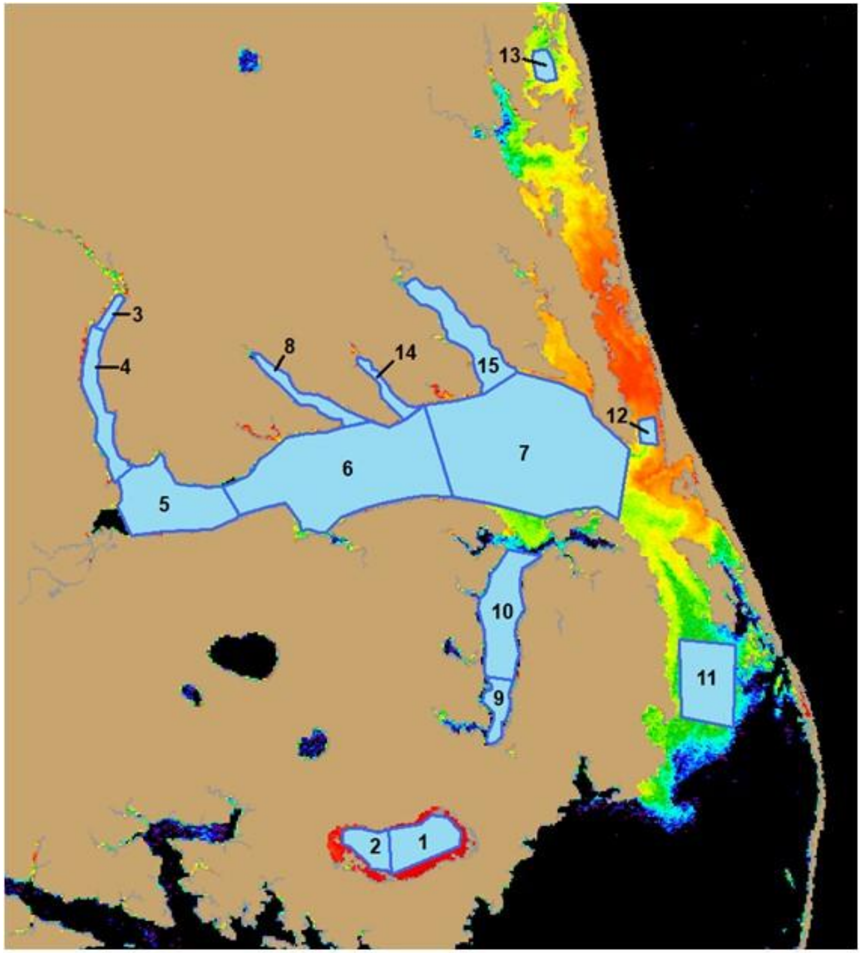


Remote Sensing to Reach Farther East and Deeper into Tributaries

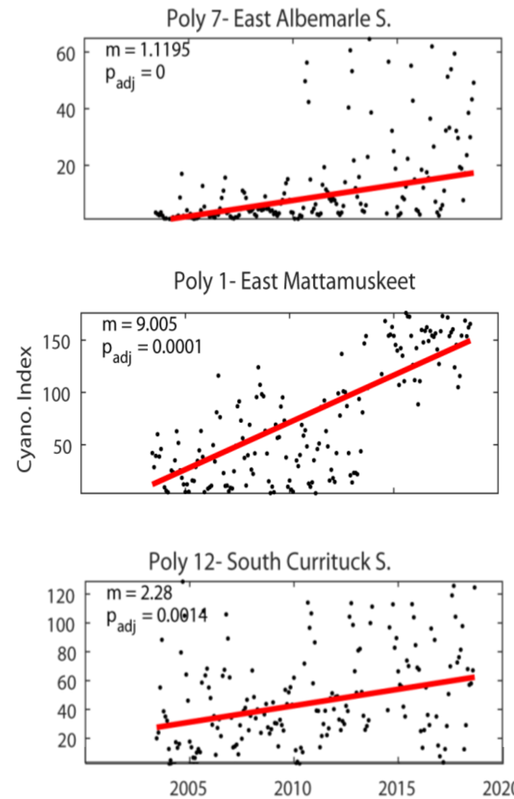
MODIS imagery of cyanobacteria index

(Wynn et al. 2010; Tomlinson et al. 2016)





Trends in MODIS derived monthly average cyanobacteria index for 15 polygons



Corroborates trend in DEQ's Chl-a

Shows state change in 2013-2014

MODIS is only consistent data record

Recap

Blooms: Recent but recurrent and awful!

Chl-a: 6 of 10 DEQ stations have increasing chl-a

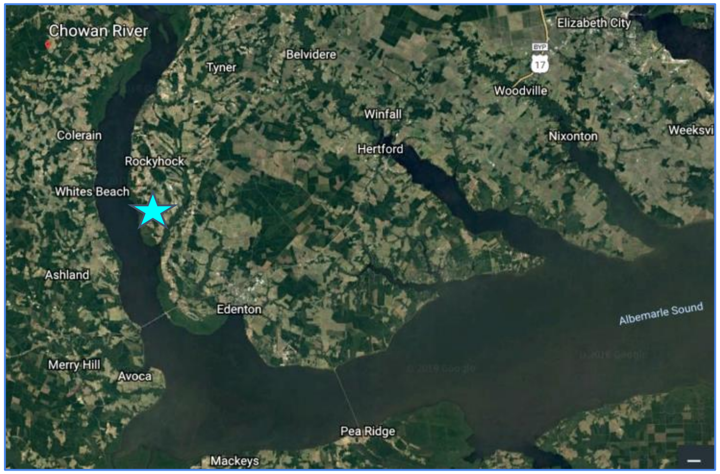
TN: 10 of 10 station have increasing TN

TP: 2 of 10 stations have increasing TP

What's driving these changes?

What is the limiting nutrient? Has it increased? Why?

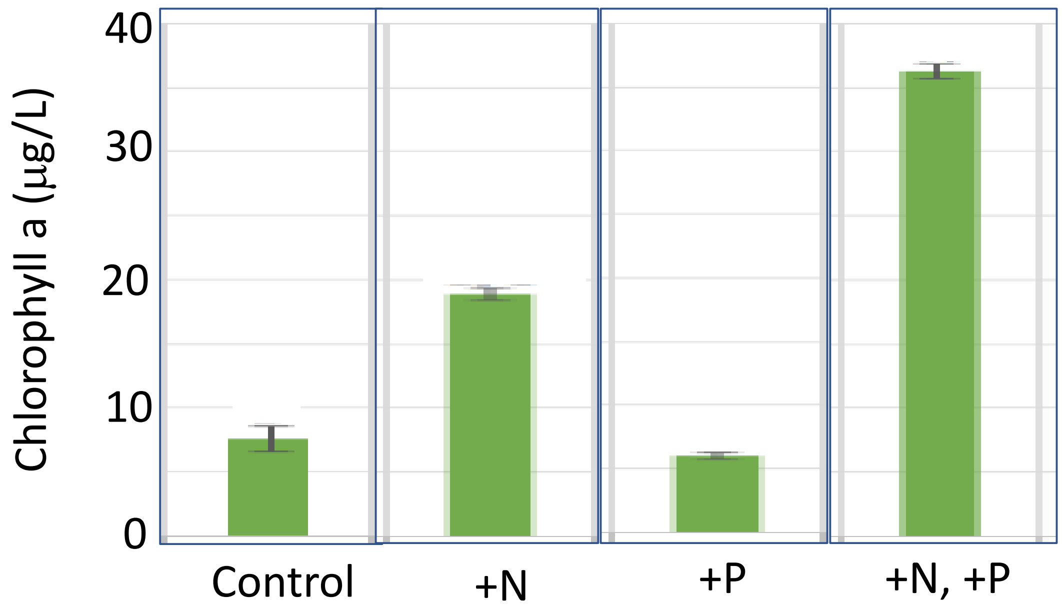
Bioassays Designed to Test Limiting Nutrient (N, P or both)



Felix Evans,
Undergraduate Researcher

- Sampled from the Chowan River surface at site of summer bloom
- Four treatments, Control, +N, +P, N+P, in triplicate
- Incubated for 2 to 5 days

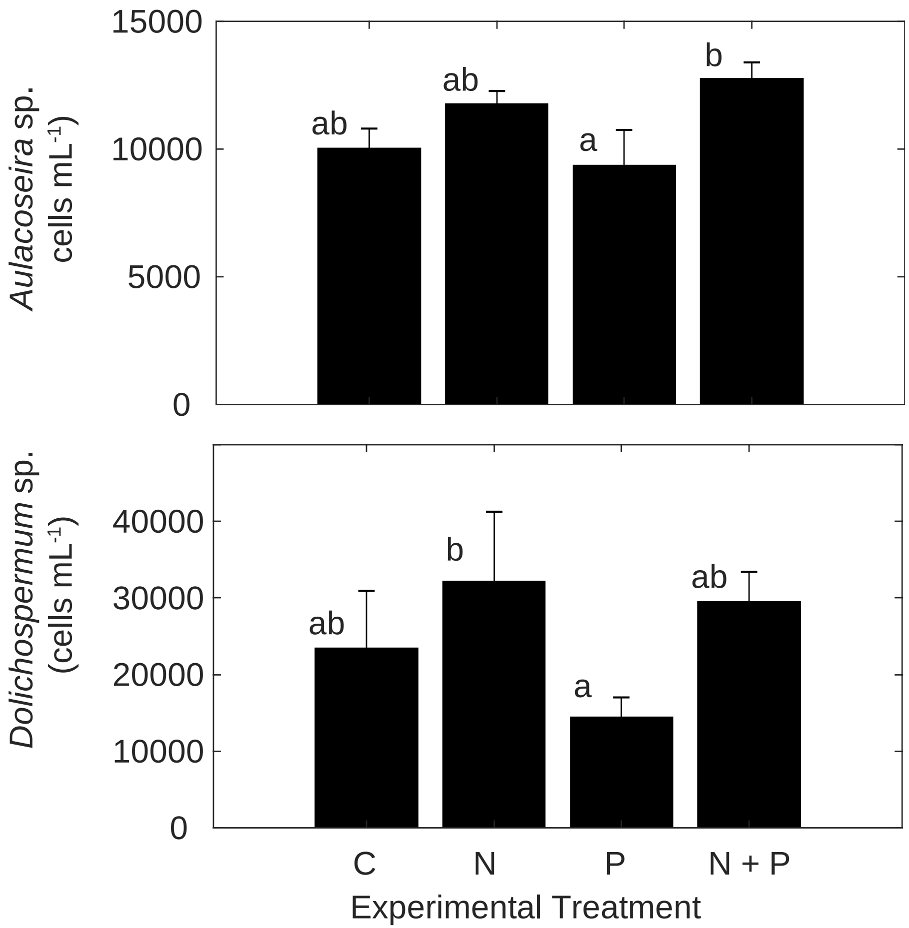
Experiment Indicates N-limitation of Phytoplankton Production
1-5 Oct 2018



Felix Evans, Fall 2018

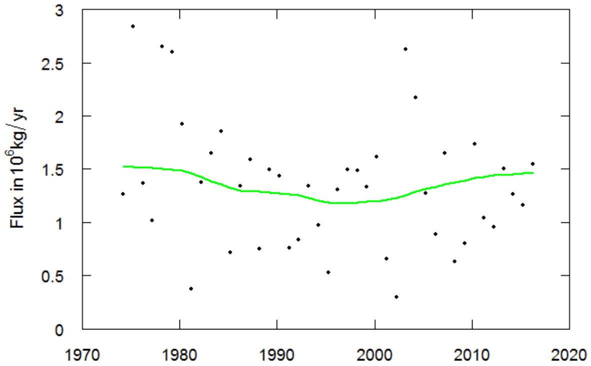
Experiment Indicates N-limitation of Phytoplankton Production 28-30 May 2019

Sea Grant Sponsored Community Collaborative Research Project with the Chowan/ Edenton Environmental Group

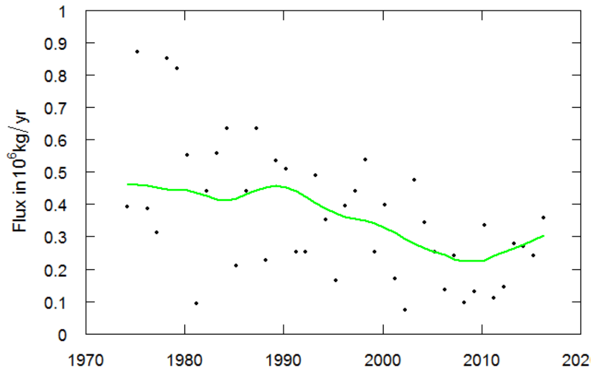


No major changes in nutrient loads from the major rivers

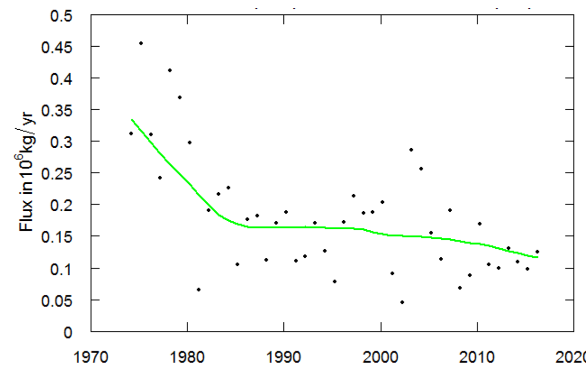
Chowan Total N load



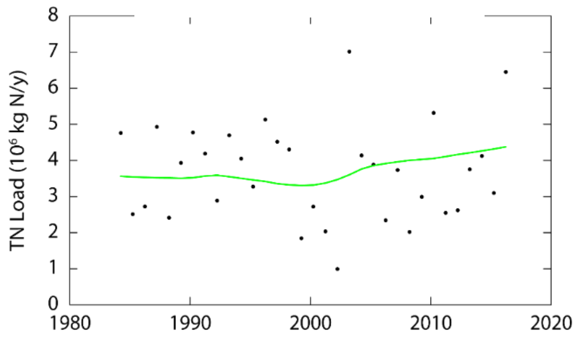
Chowan Nitrate load



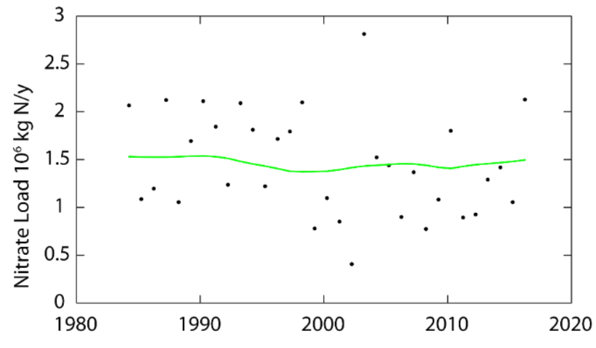
Chowan Total P load



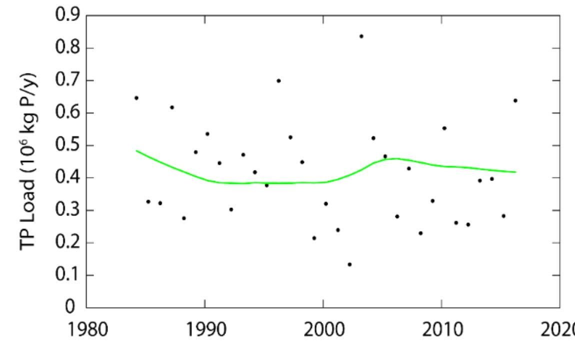
Roanoke Total N load



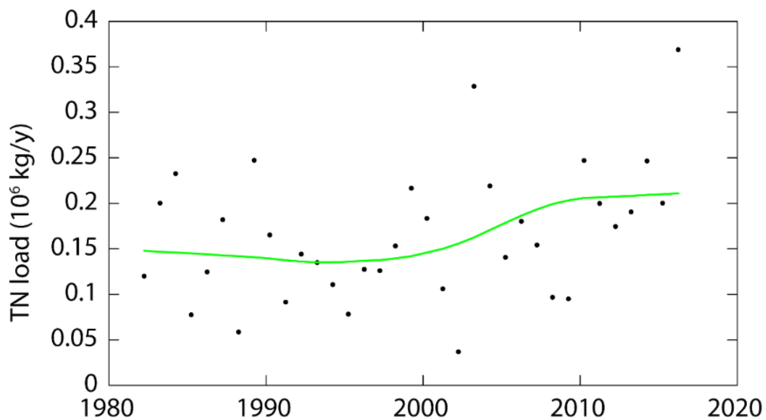
Roanoke Nitrate load

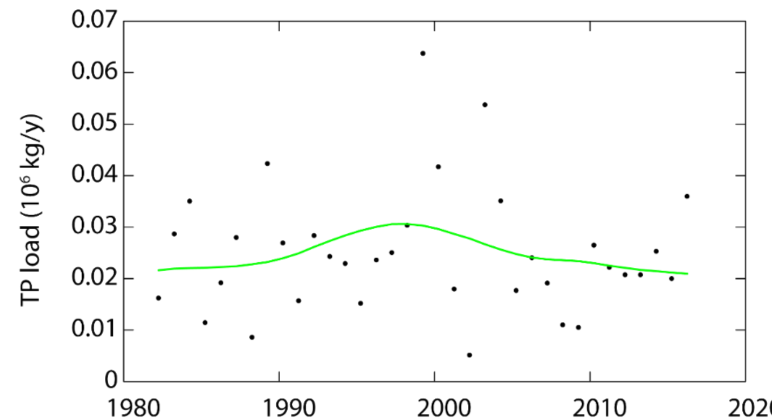


Roanoke Total P load

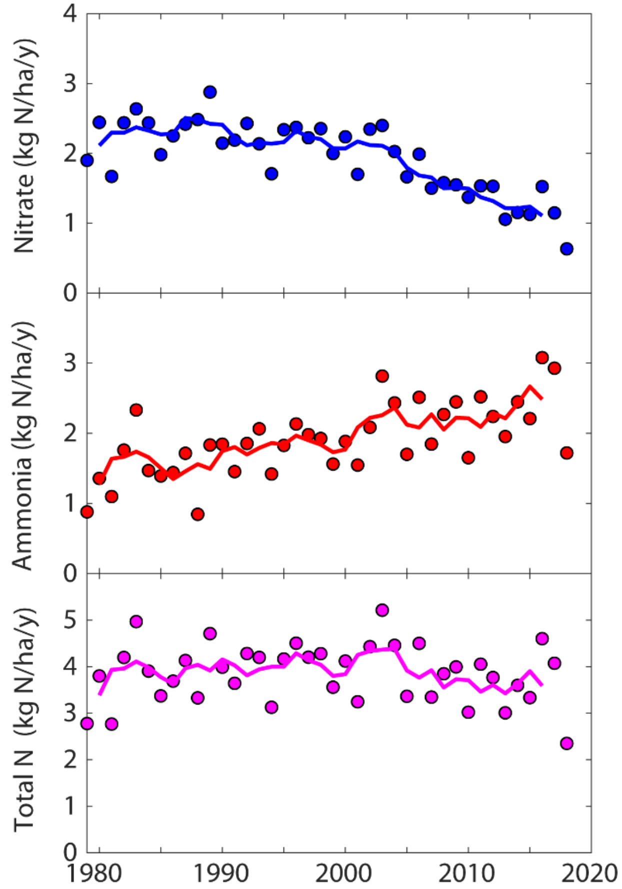


Some increase in TN in a Chowan River tributary, Potecasi Creek

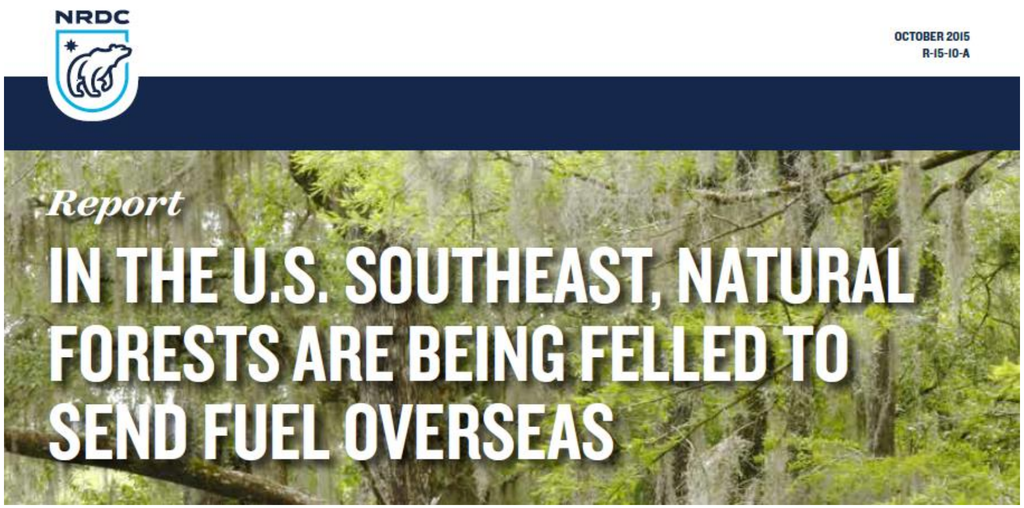




Atmospheric N deposition is an unlikely culprit



Swamp forest loss as potential nutrient source



Clear cut swamp forest on Roanoke R.

Estimating Potential Impact of Swamp Forest Clearcutting

Load Increase = Clear Cut Area (ha) × Yield Increase (kg/ha/y)

Clear Cut Area

NRDC estimates 13,000 ha harvested in NE North Carolina in past three years (NRDC 2015)

Yield Increase

TP: 0.12 - 0.36 kg P/ha/y

TN: 2.1 – 2.2 kg N/ha/y pine silviculture (Lebo and Herrmann 1998)

TP: 0.2 kg P/ha/y

TN: 51 kg N/ha/y drained hardwood swamp forest (Grace 2004)

Load Increase

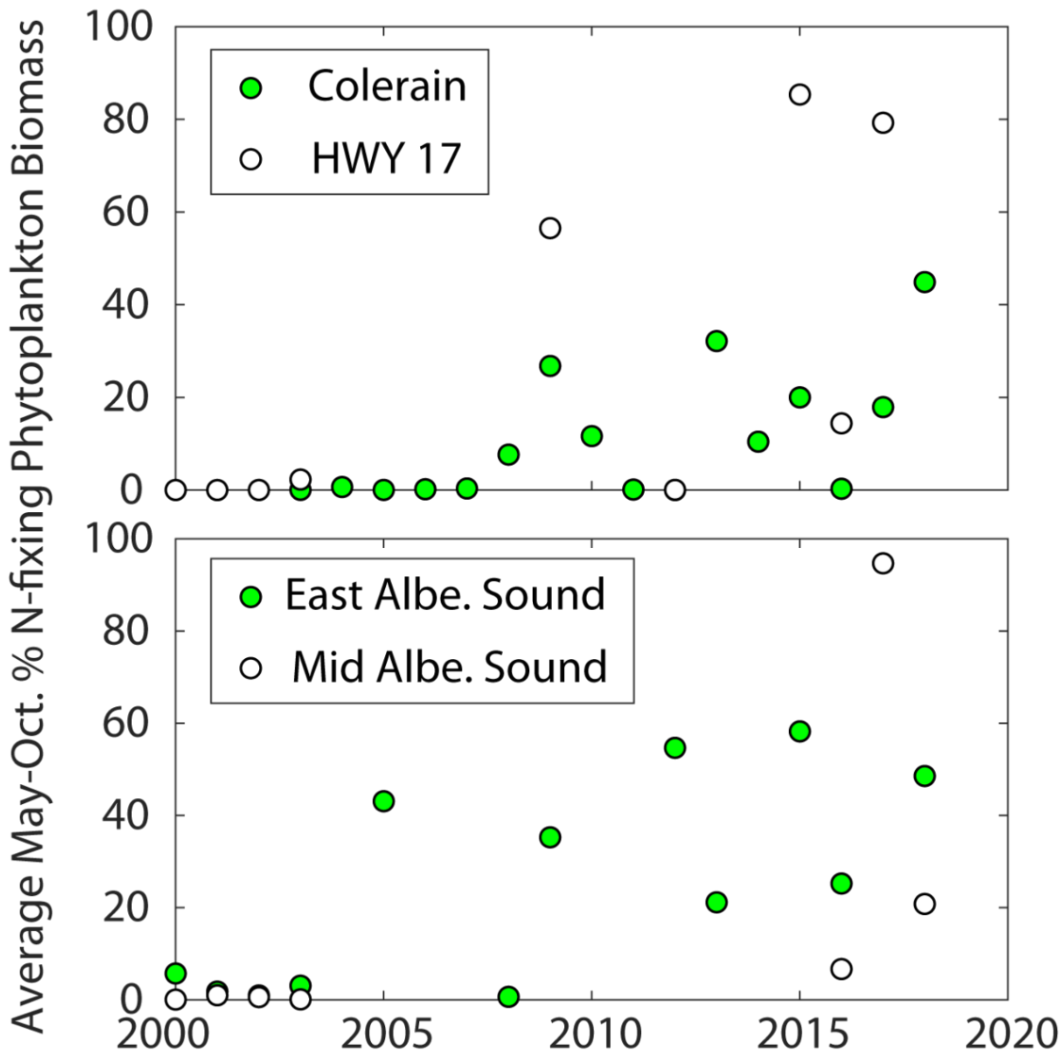
TP: 0.12 - 0.36 kg P/ha/y × 13,000 ha = 1560 - 4680 kg P/y

TN: 2.1 - 51 kg/ha/y × 13,000 ha = 27300 - 660000 kg N/y

Increases in Biomass of N-fixing Cyanobacteria

Chowan River

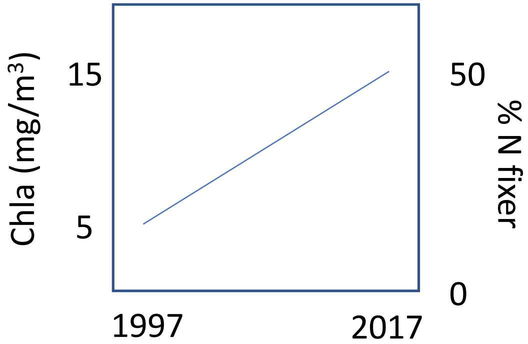
Albemarle Sound



Estimating Potential Increase of Internal N Load from N-Fixers

N Load Increase = N fixing biomass increase * N fixation rate

Biomass Increase



Albemarle Sound Volume

~ 5 mg/m^3 increase in N-fixing Chla * 5×10^9 m^3 = 25×10^9 mg Chla

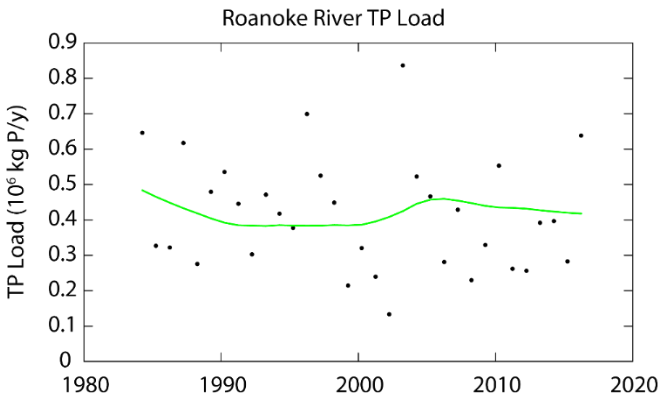
N-fixation Rate

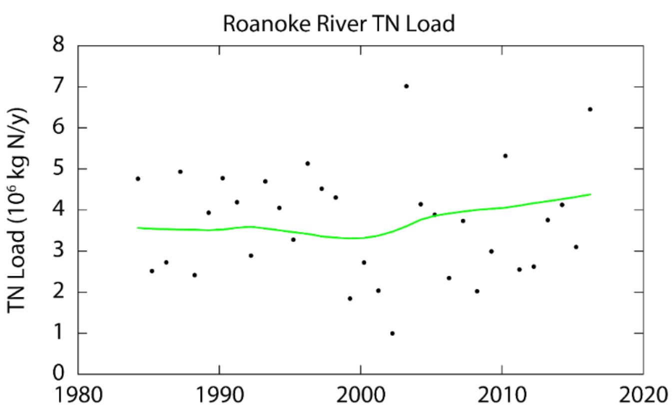
Assume growth rate of 0.3/d and cellular Chla to N ratio of 1 mmol N per 1 mg Chla

25×10^9 mmol N * 0.3/d = 7.2×10^9 mmol N/d

7.2×10^9 mmol N/d * 180 d/y *14×10^{-6} kg/mmol = 18×10^6 kg N/y

Estimated Internal Load Increase: 18×10^6 kg N/y





Estimated Load Increase
Relative to Roanoke River Load

TP

Major Rivers: 0%
Potecasi Cr.: 0%
Swamp Forest Loss: 0.4-1.2%

TN

Major Rivers: 5-15%
Potecasi Cr.: 1%
Atmospheric Deposition 0%
Swamp Forest Loss: 0.7-17%
Nitrogen Fixation 450%

Potential Drivers of Increase in N-fixing Taxa

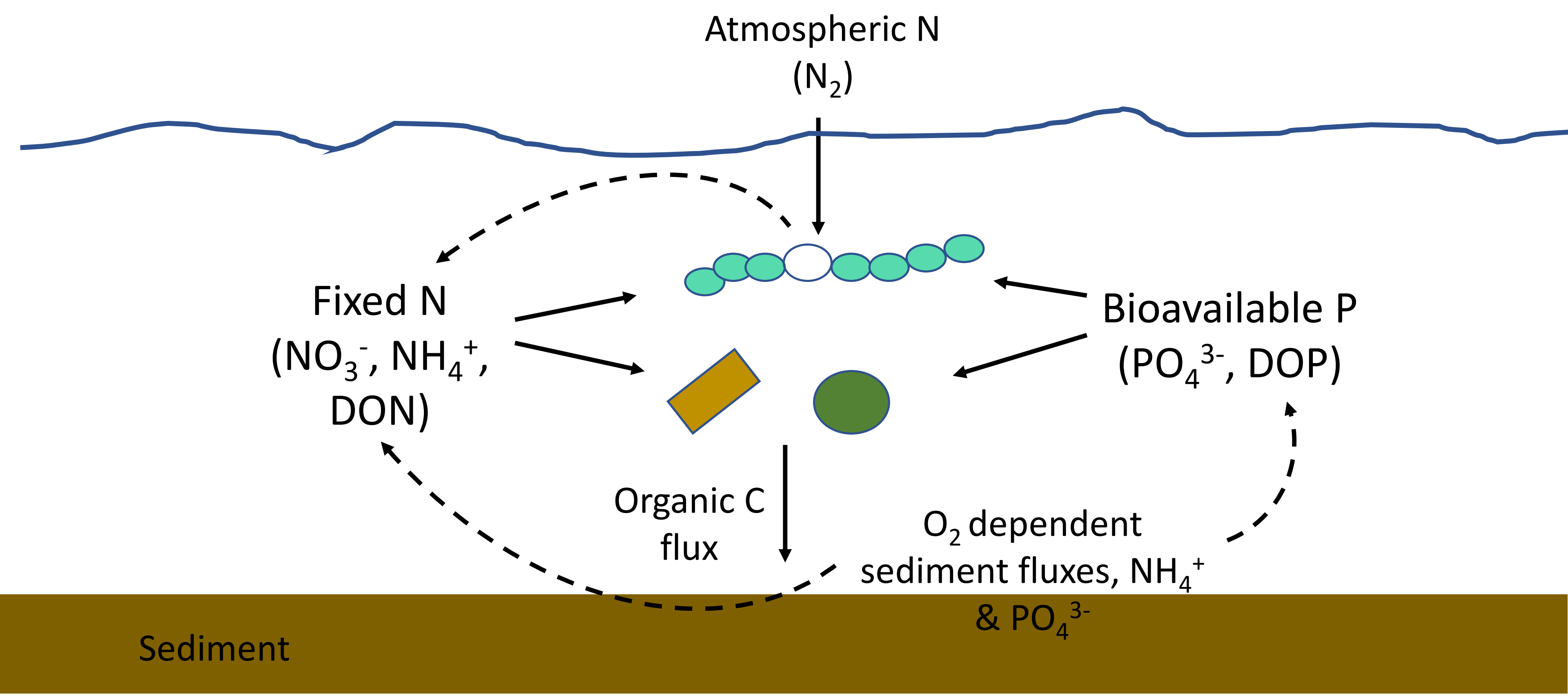
1) Increased external P loads
2) Increased internal P loads

} only Chowan R. and Scuppernong R. showed evidence

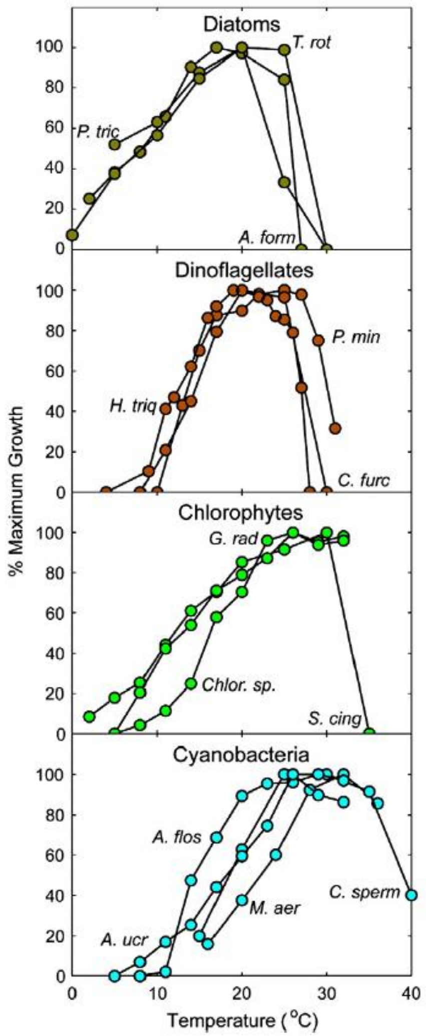
3) Warming

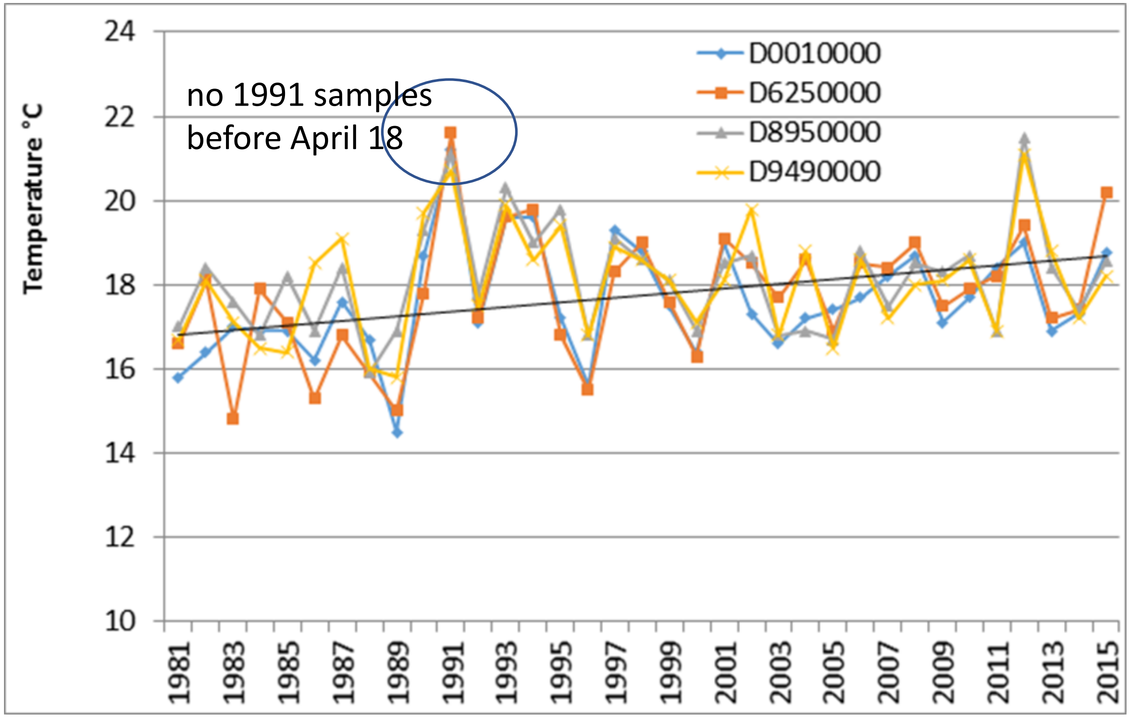
4) Food web changes- e.g. trophic cascades

In N limited systems, increased productivity might stimulate internal P loading during summer

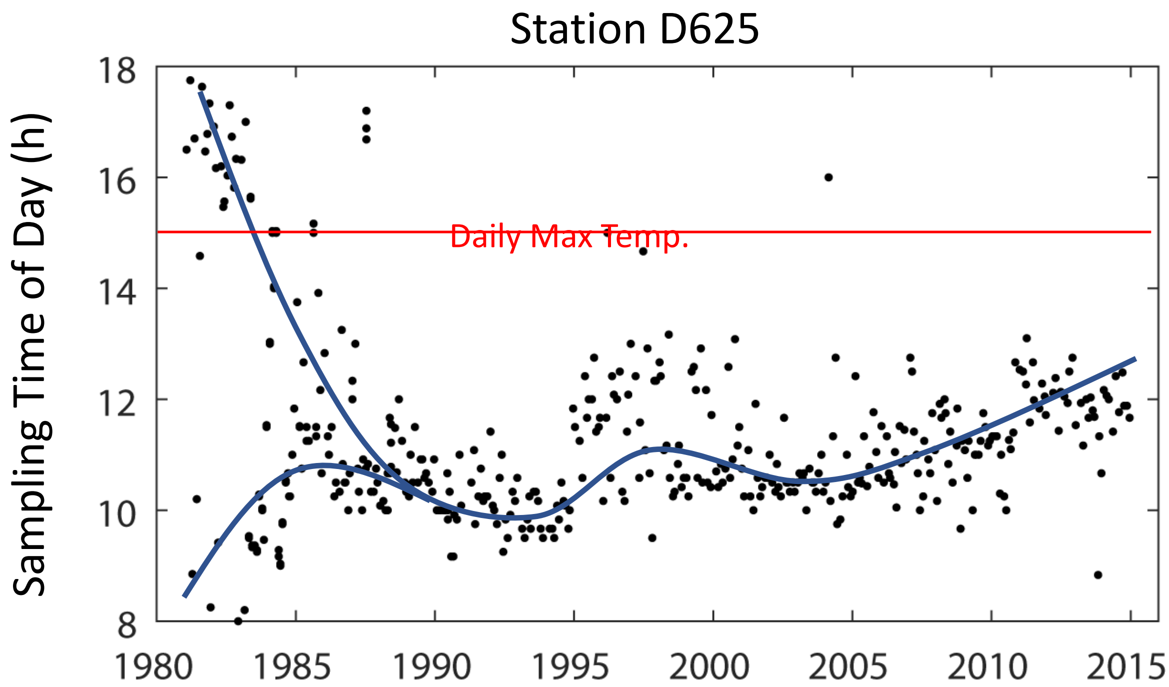


Possibly Warming Is Favoring N-fixing Cyanobacteria





Observed Temperature Increase is Also Confounded by Sampling Biases



Conclusions So Far

1) Albemarle Sound is experiencing a system-wide change in trophic status

2) Small TN increases in rivers. Creeks deserve more attention

3) Nutrient loads due to swamp forest loss are probably minor but also deserve more study

4) Nitrogen fixation is a possible explanation for increases in TN and chlorophyll *a* – we need actual measurements of N fixation to see if they are actively fixing N

5) Factors underlying the shift toward higher proportions of N-fixing cyanobacteria are not clear

Recent Nutrient and Ecological Flow Studies in the Albemarle-Pamlico Basin

Identifying Pollutant Trends for Management Prioritization in the Albemarle-Pamlico Watersheds

Isabel Hillman, Duke University
Mike O'Driscoll, ECU/Duke University
Julie DeMeeter, The Nature Conservancy
Brian Boutin, The Nature Conservancy

Existing Data for Evaluating Coastal Plain Ecological Flows in the Albemarle-Pamlico Basin

Mike O'Driscoll, ECU/Duke University
Isabel Hillman, Duke University
Cait Skibiel, ECU
Ryan Bond, ECU
Charlie Humphrey, ECU
Christa Sanderford, ECU
Albemarle-Pamlico National Estuary Partnership

Identifying Pollution Trends for Management Prioritization in the Albemarle-Pamlico Watersheds

By Isabel Hillman

4/23/2019

Advisors:
Dr. Mike O'Driscoll, Associate Professor, East Carolina University,
Adjunct Associate Professor of Water Resources, Duke University
Dr. Julie DeMeester, The Nature Conservancy
Dr. Brian Boutin, The Nature Conservancy

Masters project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment at Duke University

2019

Existing Data for Evaluating Coastal Plain Ecological Flows in the Albemarle-Pamlico Estuary Region

By Michael O'Driscoll [1,2], Ryan Bond[3], Isabel Hillman[2], Caitlin Skibiel[4], Charles Humphrey[5], and Christa Sanderford[5]

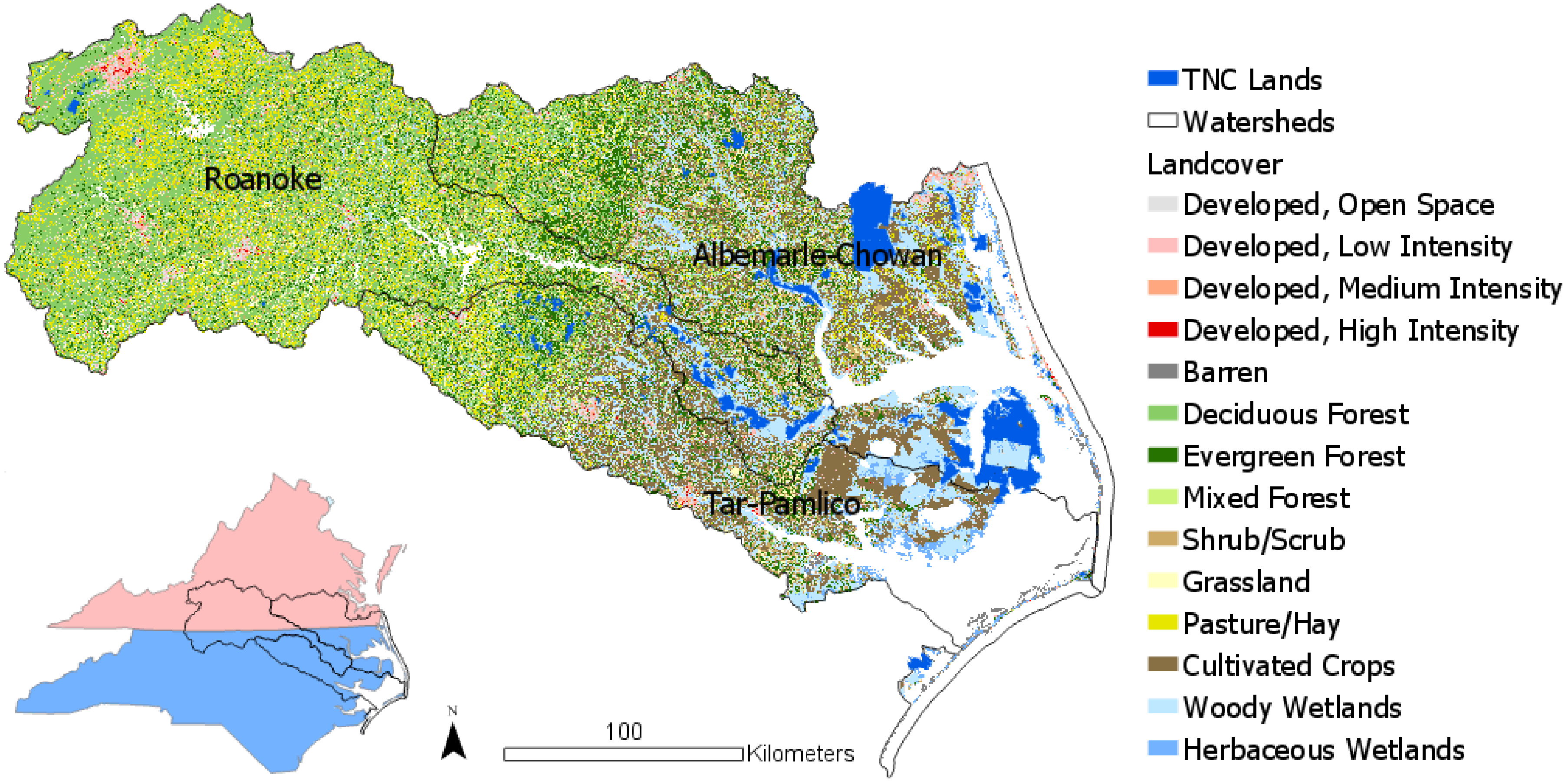
[1]Department of Coastal Studies, East Carolina University
[2]Nicholas School of the Environment, Duke University
[3]Department of Geological Sciences, East Carolina University
[4]Coastal Resources Management Program, East Carolina University
[5]Environmental Health Sciences Program, East Carolina University

DRAFT submitted August 23, 2018

Duke | Nicholas School of the Environment
East Carolina University

Identifying Pollutant Trends for Management Prioritization in the Albemarle-Pamlico Watersheds

Isabel Hillman,
MP Project,
Duke University



- 3 watersheds, Roanoke, Tar-Pamlico, Albemarle-Chowan (14 million acres)
- Presentation - Focused on nitrogen based on model and data availability

Research Questions

1. Where are pollutant exports concentrated across the landscape?
2. What management options are available to address them?
3. Who are the stakeholders/relevant landowners that might participate?

Photo: Tar-Pamlico algal bloom, WITN

Models (InVEST and SPARROW)

Integrated Valuation of Ecosystem Services Tradeoffs (InVEST)	Spatially Referenced Regression on Watershed Attributes (SPARROW)
Nitrogen, Phosphorus	Nitrogen, Phosphorus, Sediment
Mass balanced equation	Mass balanced equation
Annual average	Annual average
Inputs: catchments, land cover, precipitation, DEM, nutrient export and retention efficiency	Inputs: source (pollutants) and transport (landscape attributes)
Outputs: nutrient export by pixel and catchment	Outputs: nutrient accumulation and export by catchment
Not calibrated	**Calibrated with water quality data**
Able to run scenarios	**Unable to run scenarios**
Run by Isabel Hillman, 2019	Created by USGS, and results shared

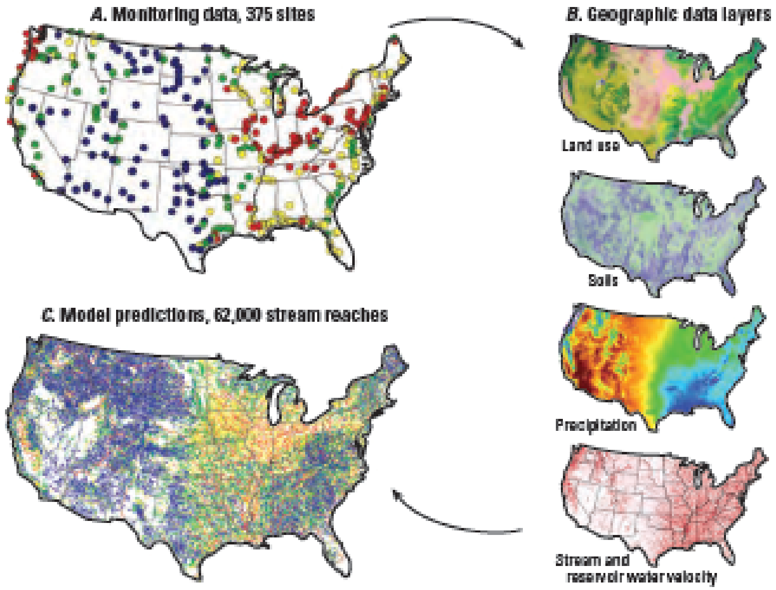
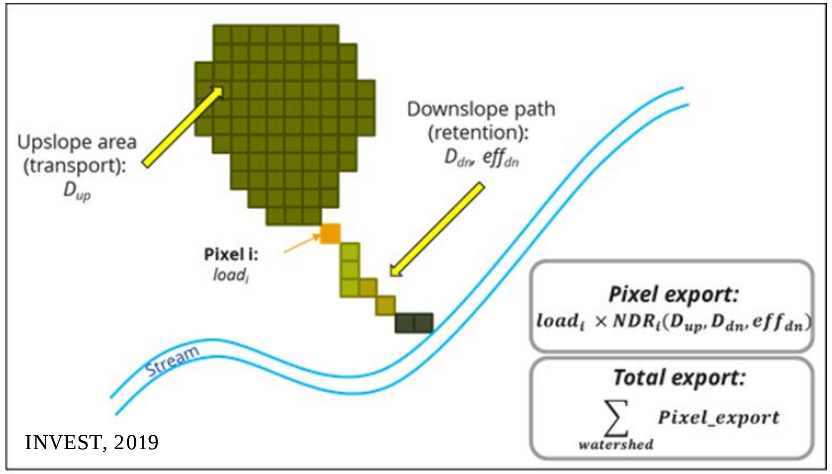
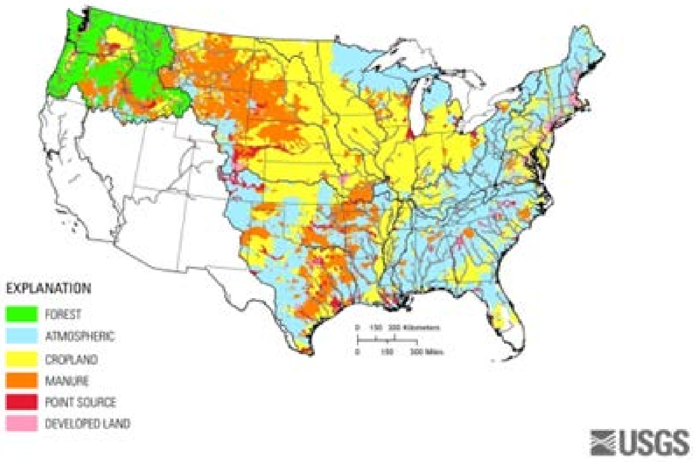


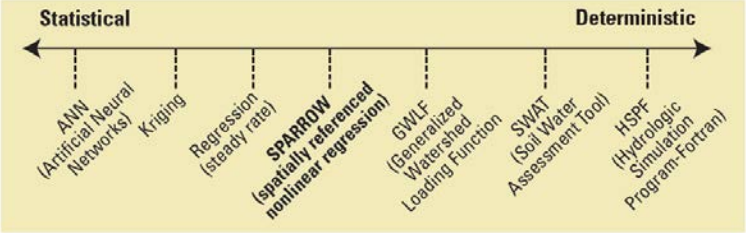
Figure 2. SPARROW models define spatial patterns in water quality, based on data collected at numerous monitoring sites *(A)*. Estimates of constituent loads at these sites are related to constituent sources, land use, and other factors that affect water quality (soils, precipitation), as well as stream characteristics (channel, velocity) *(B)*. Based on these relations, the model is used to predict water quality in unmonitored stream reaches for an entire region *(C)*.



INVEST, 2019

Largest Nitrogen Sources

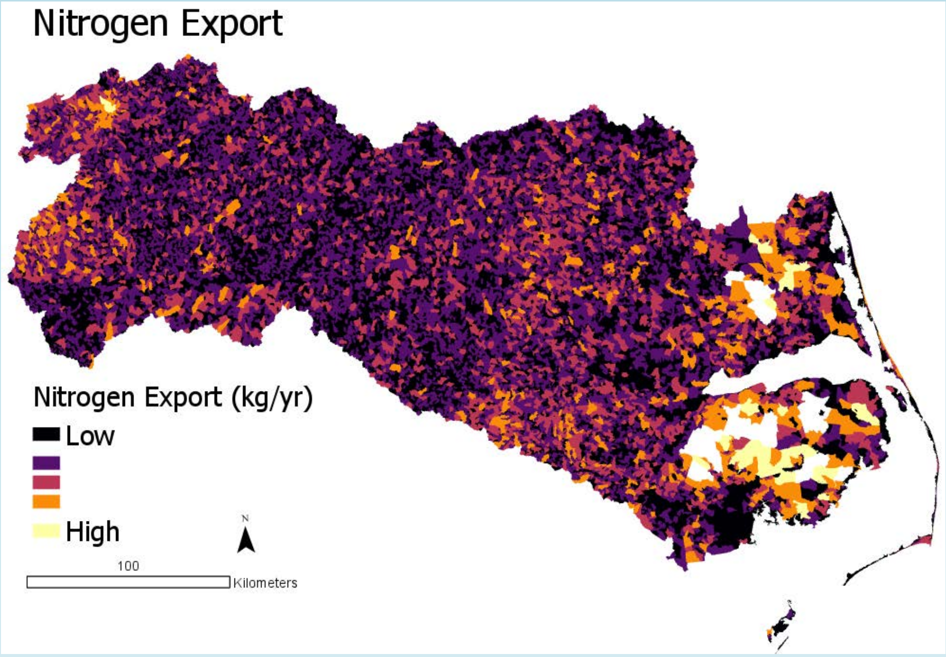


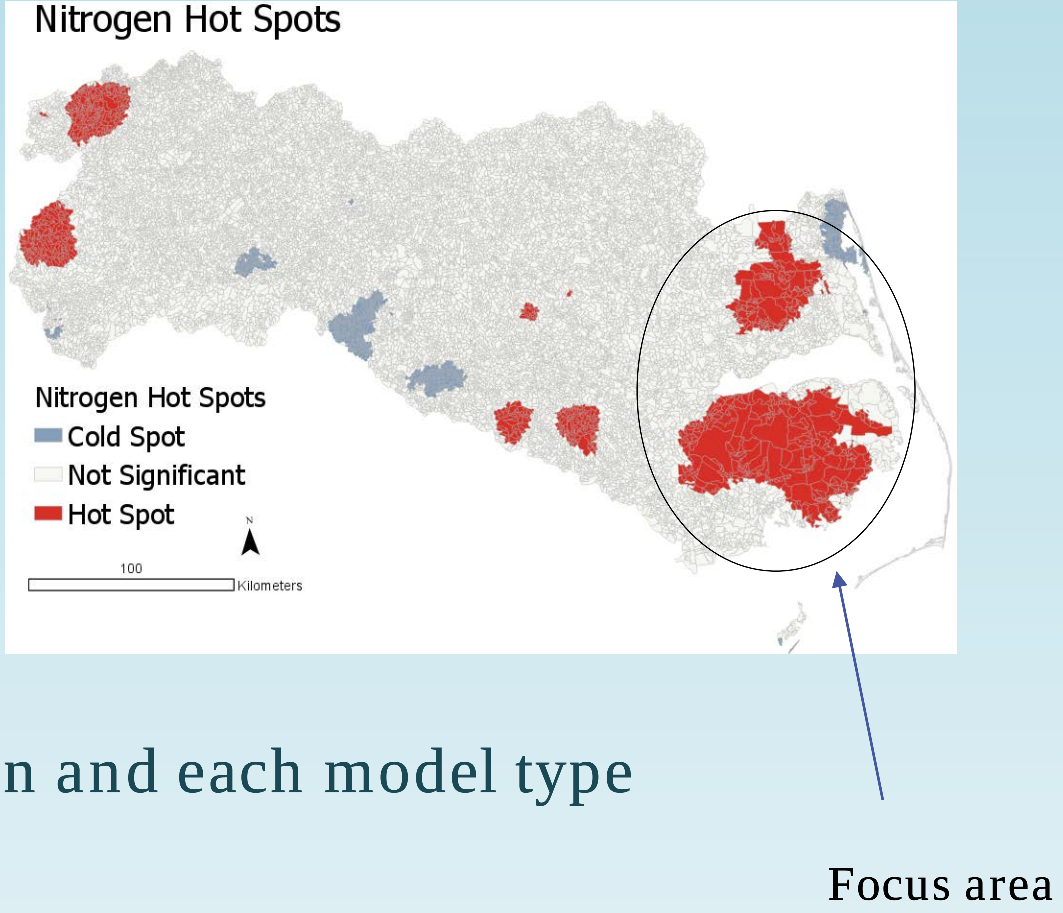


https://pubs.usgs.gov/fs/2009/3019/pdf/fs_2009_3019.pdf

http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/ndr.html#data-needs

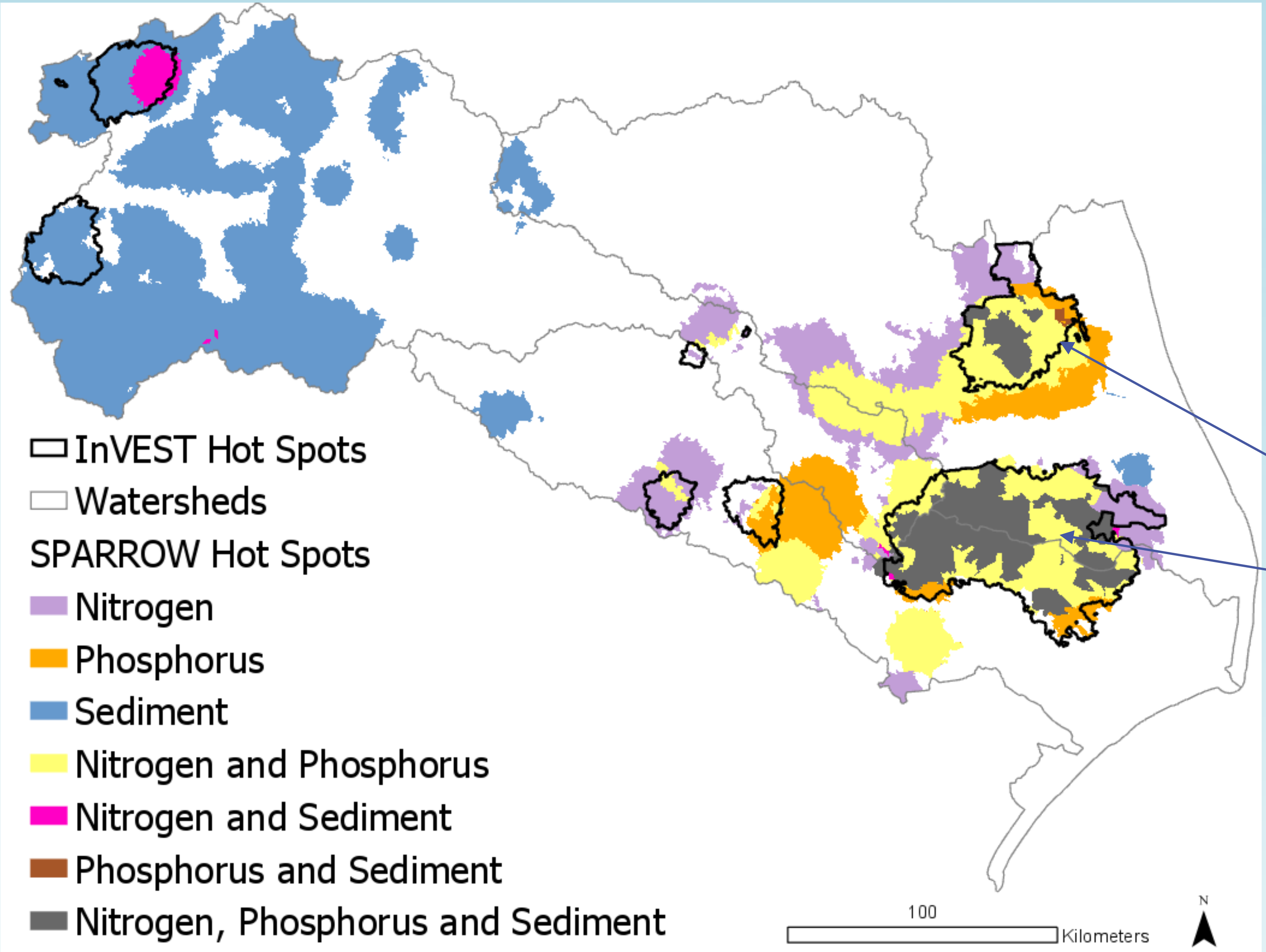
Hot Spots (InVEST)





- Calculated hot spots for nitrogen and each model type

SPARROW Hot Spot Comparison



Areas where Hot Spots overlapped between models

Selected this region for prioritization

Potential Management Options- InVEST Scenarios

Photos: Friends of the Mississippi River, Pennington Seed, California Agriculture, TerraCarbon,

Based on implementation of potential BMP's - TNC selected several options to evaluate:

- Riparian buffers
- Cover crops
- Ditch retention structures (ditch-stream intersections)
- Peatland restoration

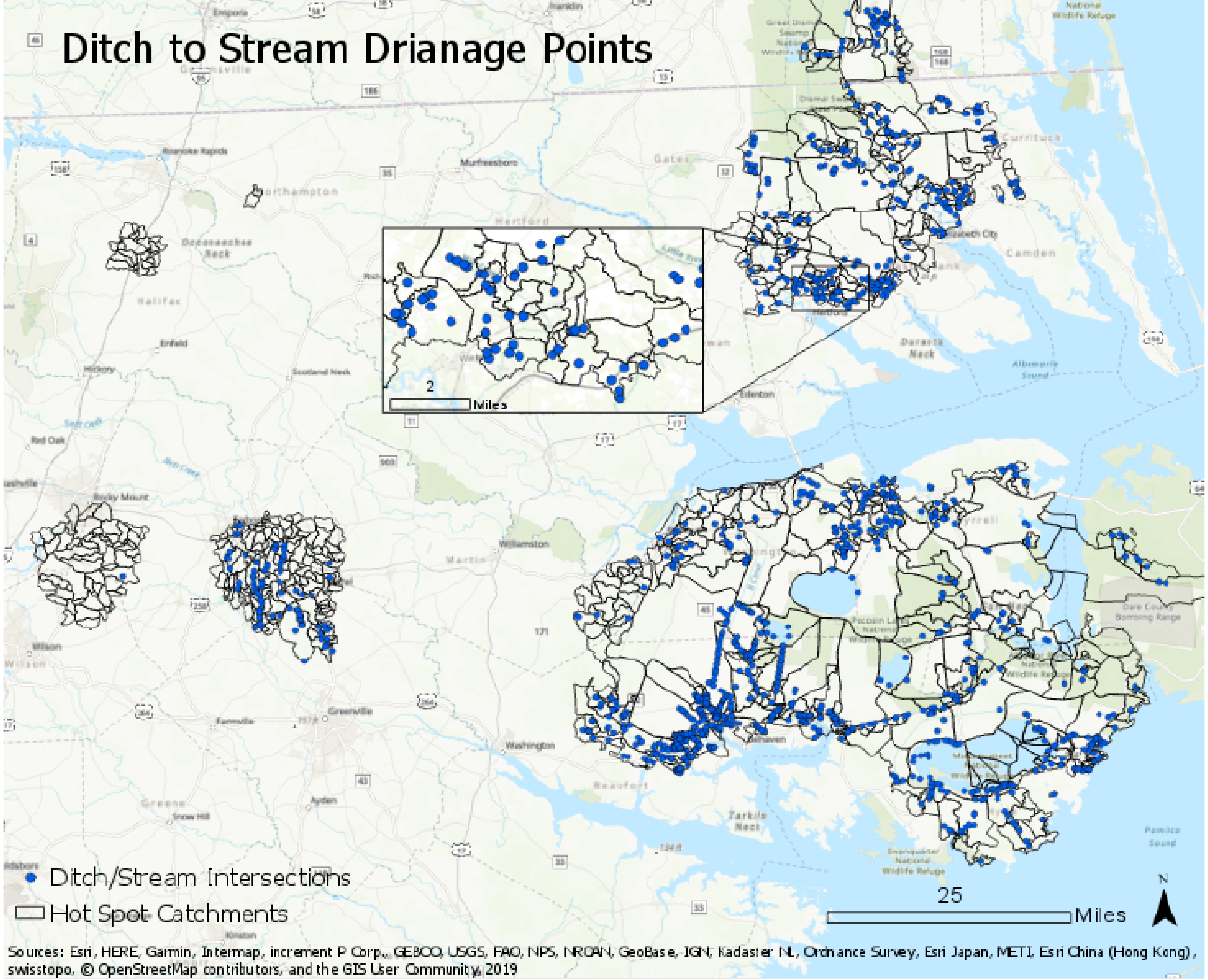


Figure 14. Ditch to stream drainage points within hot spots, based on the 2018 National

Tradeoffs

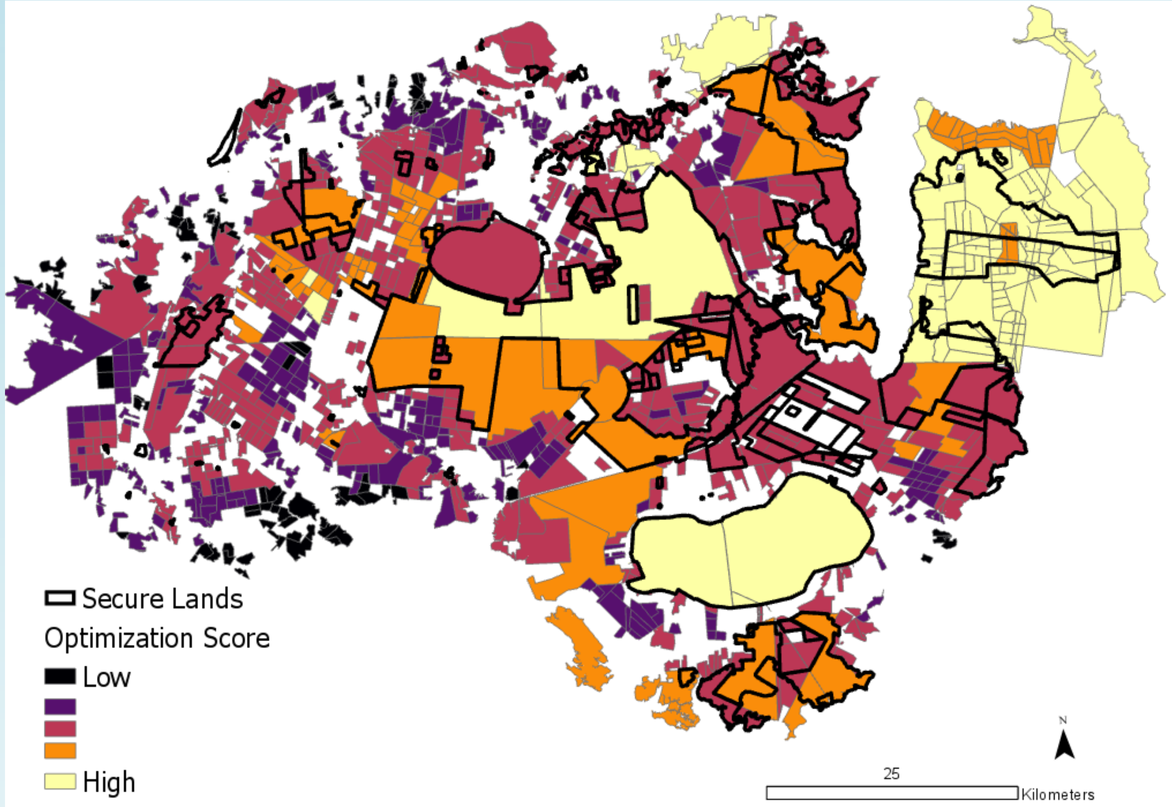
- Tradeoffs for each management option
- Efficiency vs. greatest potential for impact
- E.g. cover crops may be less efficient per acre for reducing N but since large extent of croplands could have the largest impact of the options (if broadly implemented)

Management Action	Nitrogen Reduction per Acre (kg/yr)	% Reduction in Hot Spots
Peatland Restoration	9.6	2%
30m Buffer	4.7	31%
Cover Crop	1.4-2.4	30-53%

Landowner reaction? Cost?

Parcel Optimization

- TNC wanted an approach to prioritize landowners to contact
- Scored each parcel over 150 acres based on:
  - Parcel size
  - Acres of agriculture
  - Acres of peatland
  - Length of ditches
  - Distance to secured land

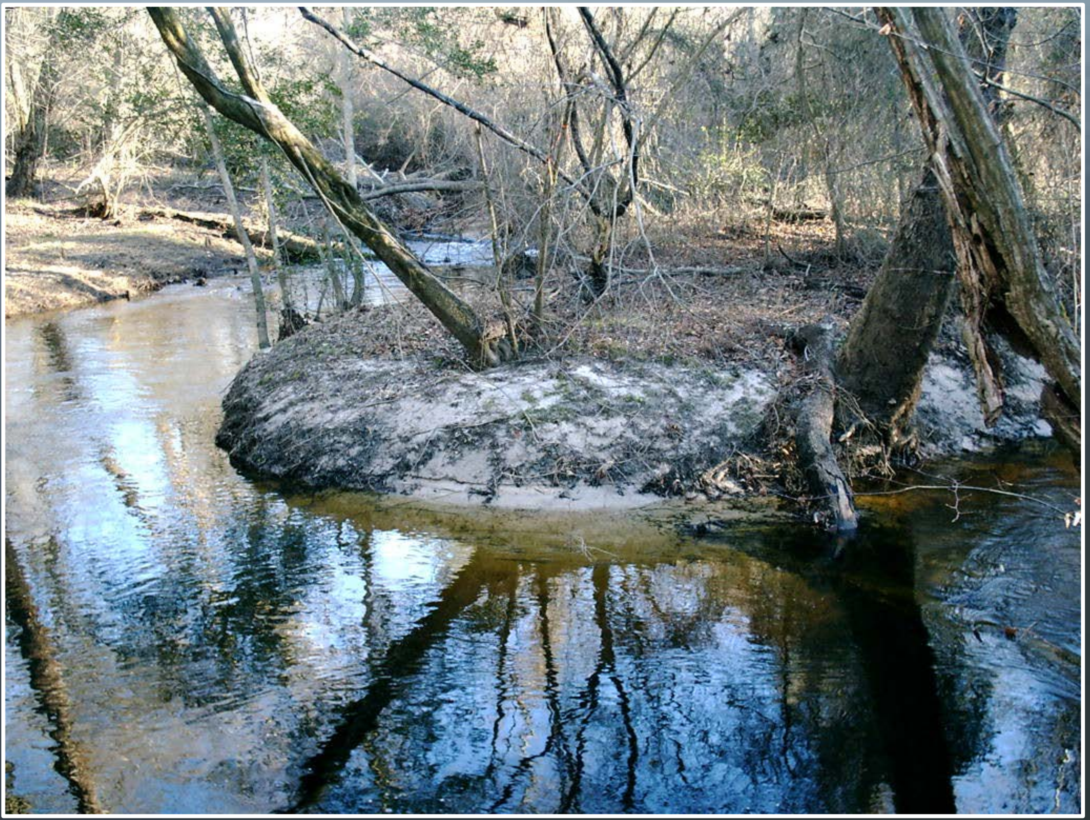


Conclusions

- Nutrient concentrations vary across the landscape
- Focused conservation efforts within hot spots can maximize reductions in N
- While there are several management options to choose from, the appropriate action will be case specific due to landowner preferences, economic considerations, etc.
- Model limitations
  - InVEST reasonable for comparing relative loading across region, doesn't account for point sources
  - SPARROW – more accurate due to calibration with streamflow and concentration data,
  - BUT only as good as the calibration data used, relatively few gauging stations in the NC outer coastal plain
- USGS SPARROW Model(s) can be useful to understand the spatial variability in nutrient loading and potential sources for the Albemarle-Pamlico Drainage Basin→ can provide helpful information for nutrient criteria development for Albemarle Sound

Existing Data for Evaluating Coastal Plain Ecological Flows in the Albemarle-Pamlico Basin

2-for-1 Offer



Michael O'Driscoll, Associate Professor, Dept. of Coastal Studies, East Carolina University

Caitlin Skibiel, CRM Student, East Carolina University

Ryan Bond, Graduate Student, East Carolina University

Charlie Humphrey, Associate Professor, East Carolina University

Isabel Hillman, MEM Student, Duke University

Coley Hughes Cordeiro, APNEP

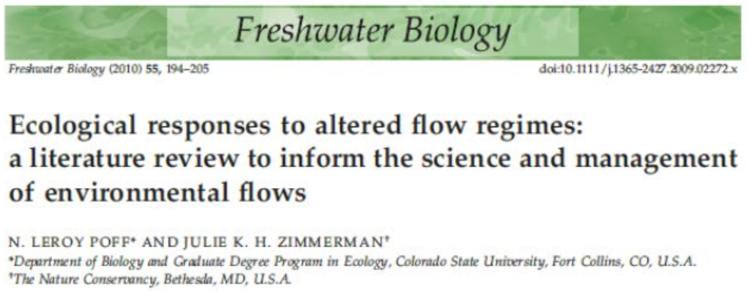
APNEP Coastal Ecological Flows Action Team

Outline

- Ecological flows and their significance
- Challenges in coastal watersheds
- Limitations based on the data availability
- Low flows
- Relevance to nutrient criteria development

Coastal ecological flow assessment

- Flow alterations have been shown to affect fish and macroinvertebrates.
- Recent evidence suggests that groundwater inputs and low flows may be declining along many Coastal Plain rivers.
- Changes in climate, land use, and water use may affect streamflow and water quality.
- Based on Session Law 2010-143, DEQ is required to develop basinwide hydrological models for each of NC's 17 river basins to predict the places, times, and frequencies at which ecological flows may be adversely affected in North Carolina (NC DEQ 2013).
- NC ecological flow efforts in the Piedmont didn't cover the majority of the Coastal Plain, these streams may differ based on low slope, tidal influence, and salinity.

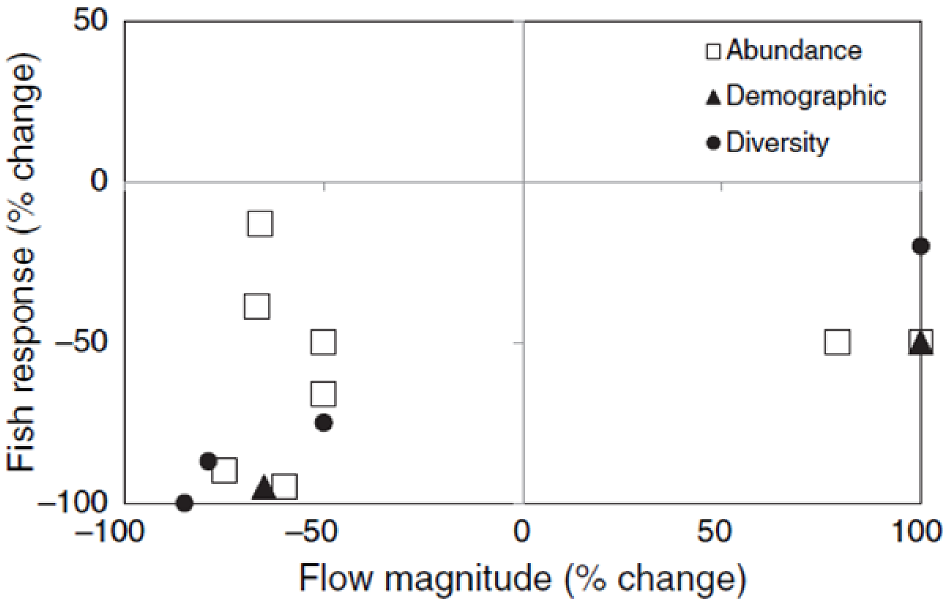

Freshwater Biology

Freshwater Biology (2010) 55, 194–205 doi:10.1111/j.1365-2427.2009.02272.x

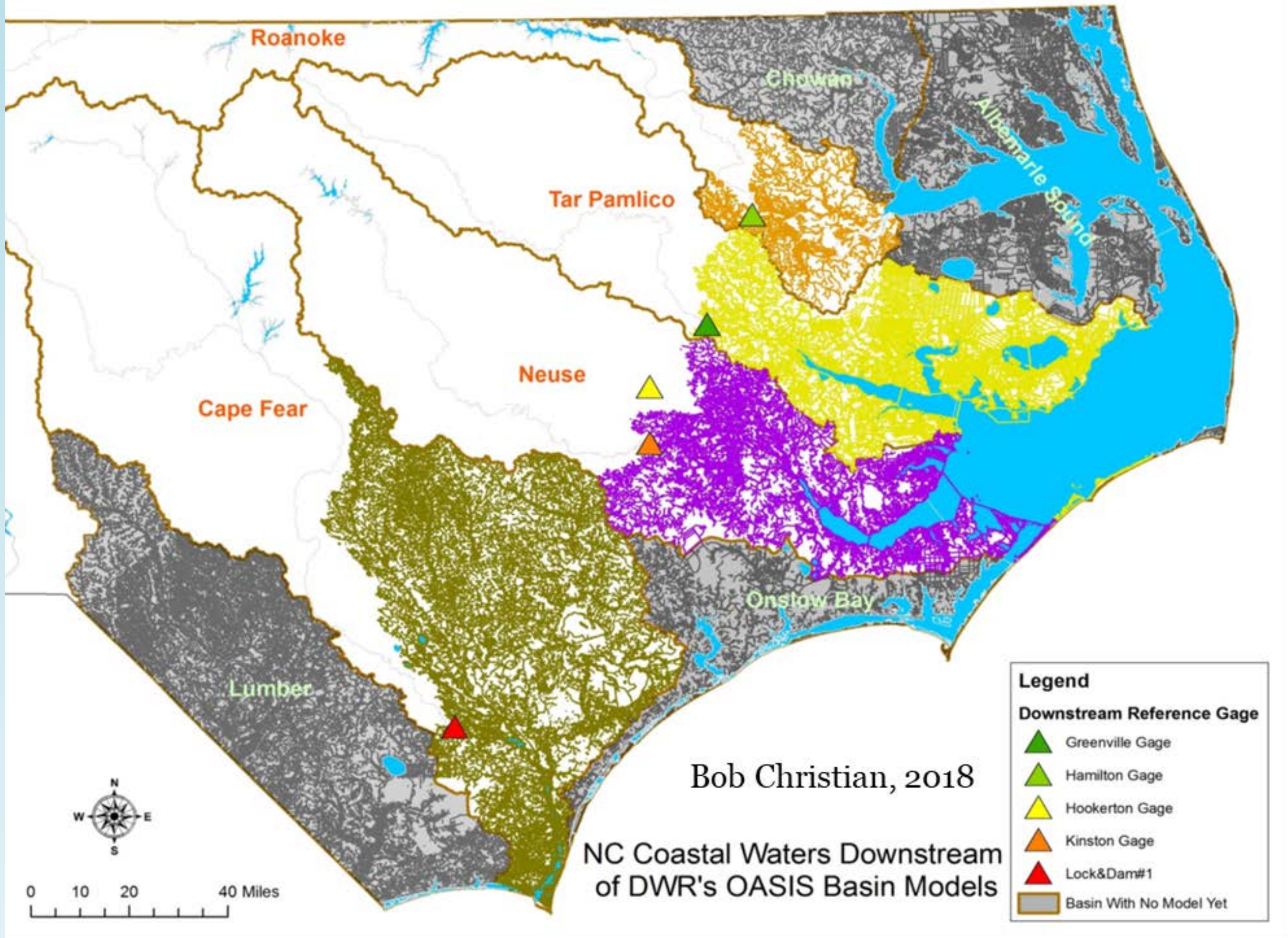
Ecological responses to altered flow regimes: a literature review to inform the science and management of environmental flows

N. LEROY POFF* AND JULIE K. H. ZIMMERMAN†

*Department of Biology and Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO, U.S.A.
†The Nature Conservancy, Bethesda, MD, U.S.A.



What data is out there to support the development of Coastal Plain ecological flow guidelines for the Albemarle-Pamlico Basin?



Existing Data for Evaluating Coastal Plain Ecological Flows in the Albemarle-Pamlico Estuary Region

By Michael O'Driscoll [1,2], Ryan Bond[3], Isabel Hillman[2], Caitlin Skibiel[4], Charles Humphrey[5], and Christa Sanderford[5]

[1]Department of Coastal Studies, East Carolina University
[2]Nicholas School of the Environment, Duke University
[3]Department of Geological Sciences, East Carolina University
[4]Coastal Resources Management Program, East Carolina University
[5]Environmental Health Sciences Program, East Carolina University

DRAFT submitted August 23, 2018

Albemarle - Pamlico National Estuary Partnership

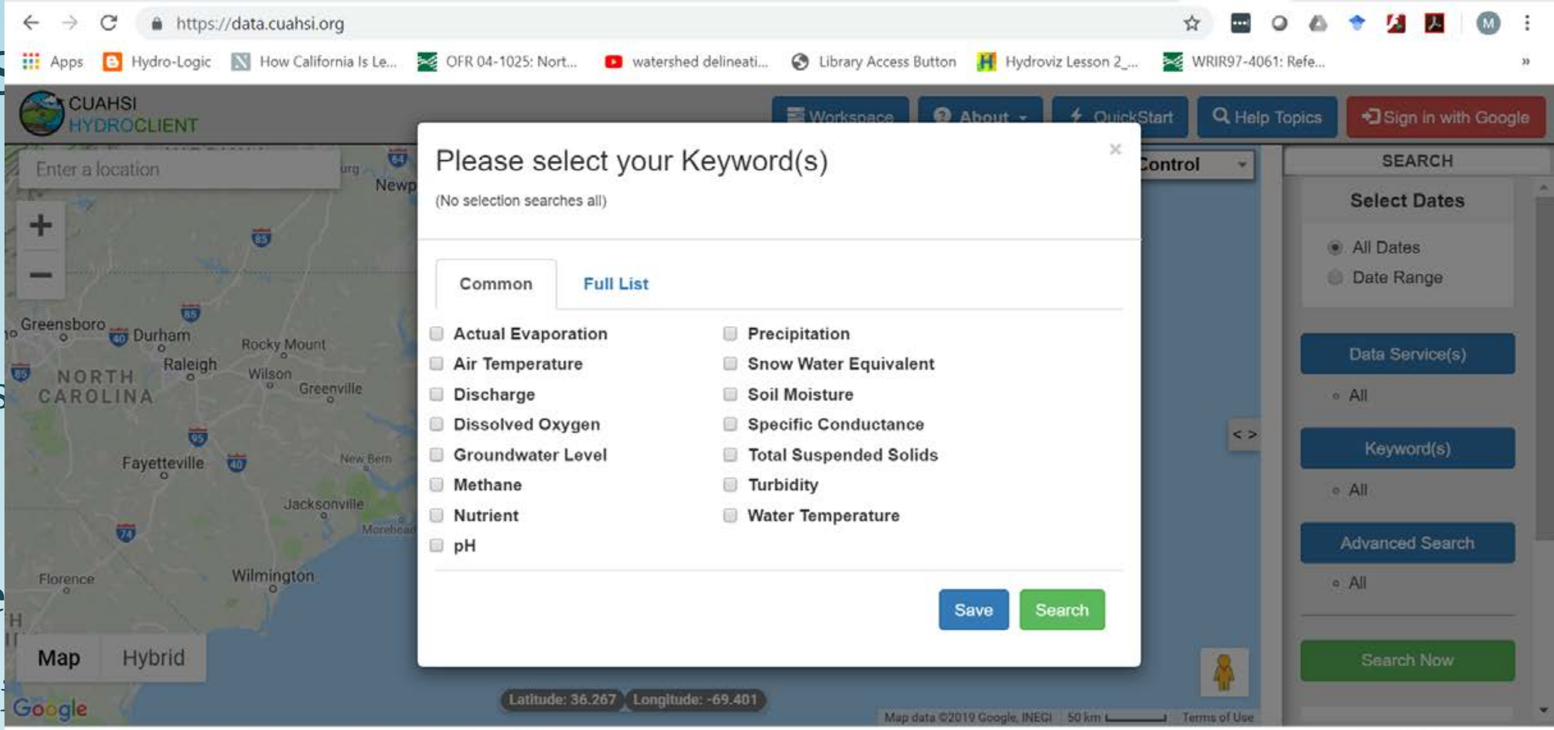
Duke NICHOLAS SCHOOL OF THE ENVIRONMENT

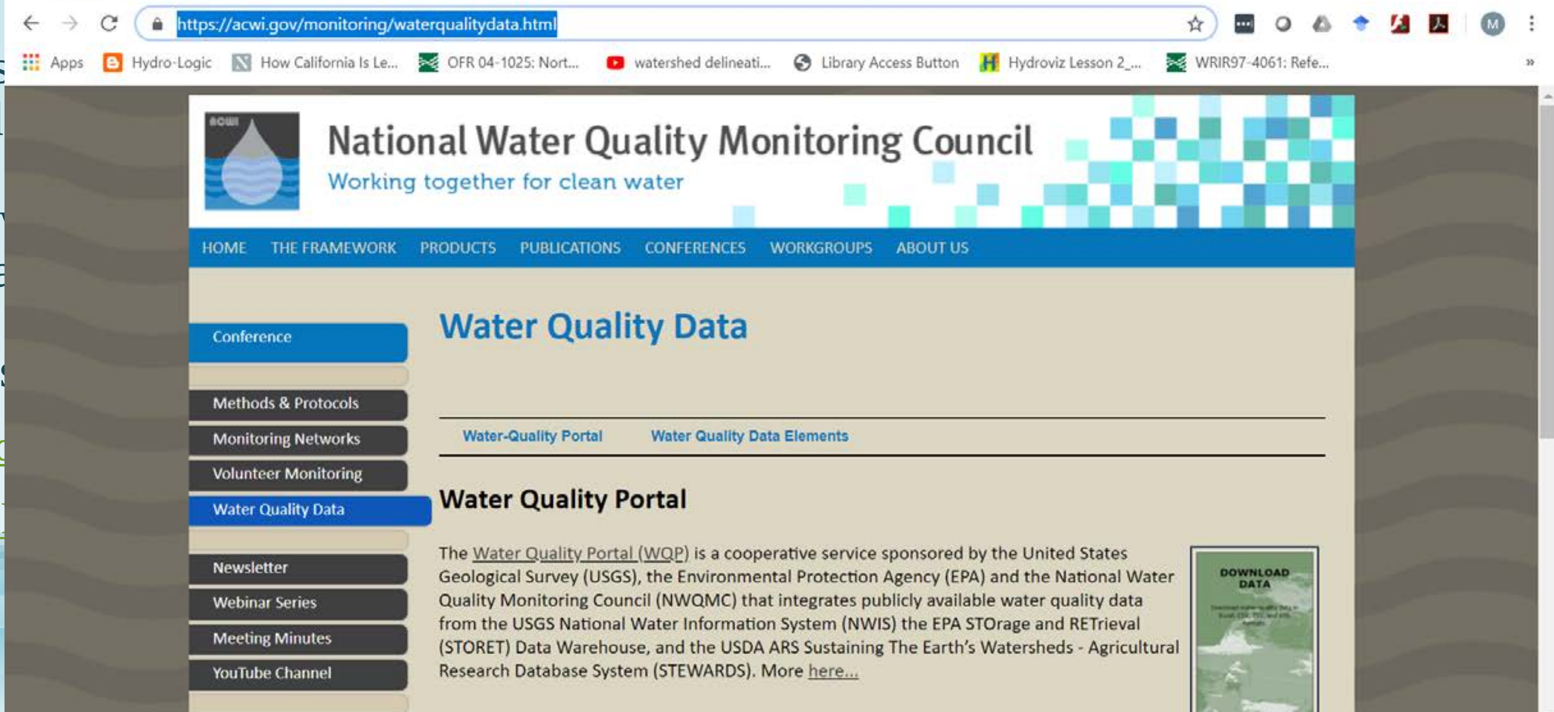
East Carolina University

Abundant Data (> 100 websites with water/ecological flow related data), but…. some Notable Data Gaps

What are limitations bas
(Data Gaps)

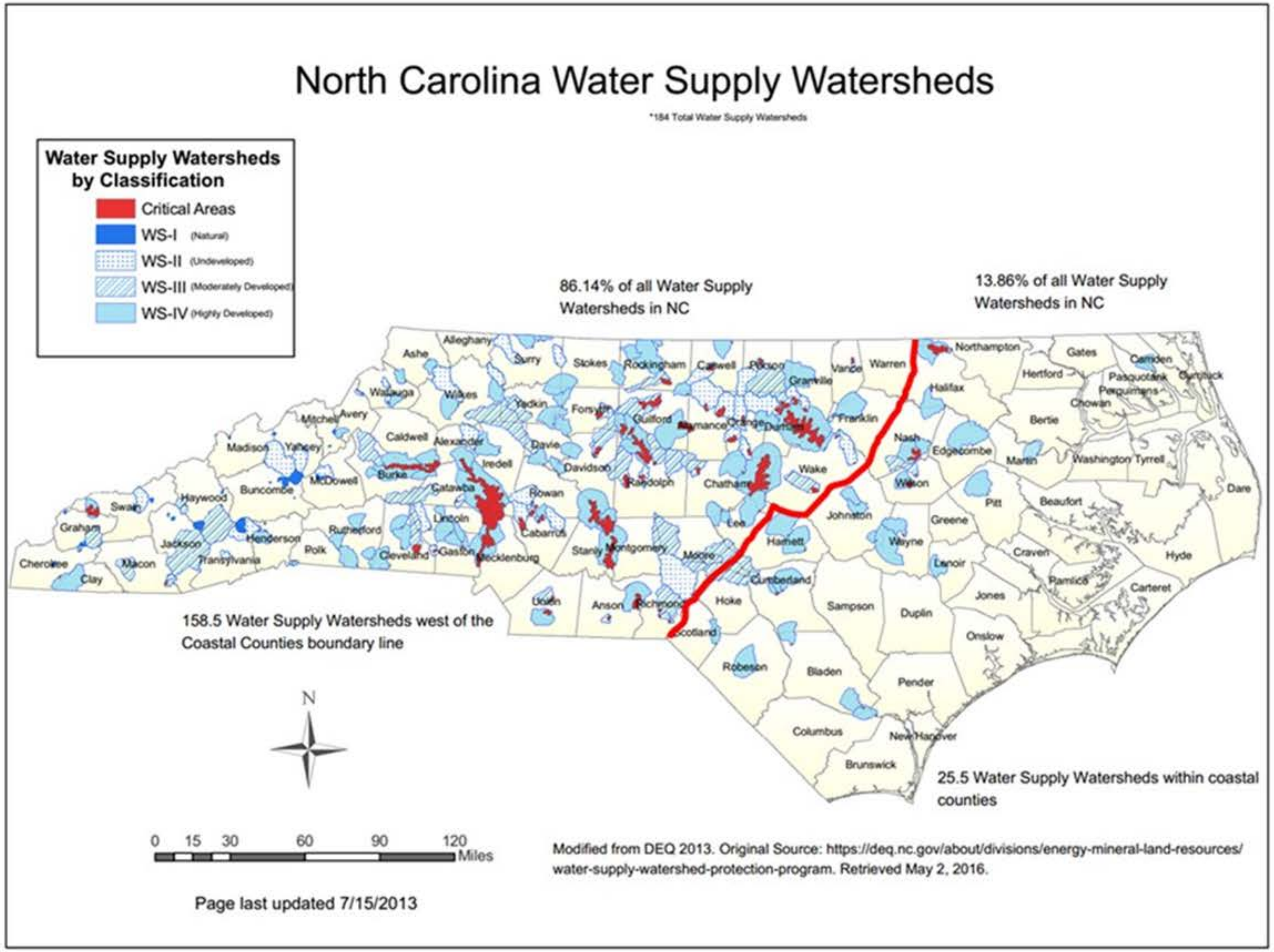
- Streamflow- low order and tidal coastal s
- Groundwater- more info on gw inputs to
- Salinity - most data in estuaries, for future
- Evapotranspiration - Only one Ameriflux si
- Ecological response-In Ecological Respons studies for the CP only 9 (4 on unregulated
- Water use- There were a variety of gaps in budgets in the region. However, approxima
- Our focus was on water quantity, but we als
  - CUAHSI Hydroclient https://data.cuahsi.c
  - National Water Quality Monitoring Council



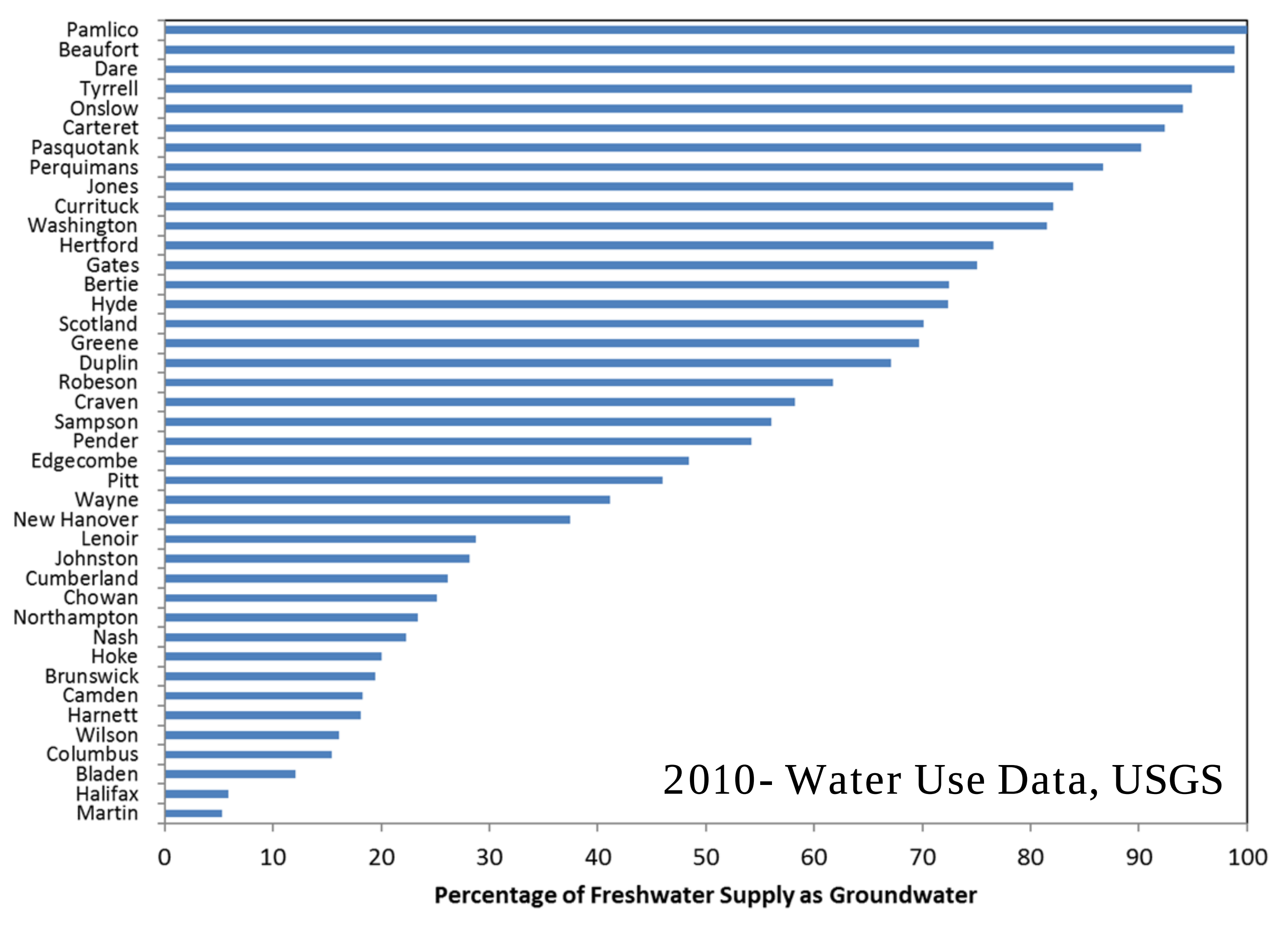


SW Supplies- Dominant in Piedmont GW in Coastal Plain

- North Carolina Coastal Plain communities are less likely to rely on surface water supplies than Piedmont /Mountain communities.
- Coastal Plain counties accounted for approximately 9% of the state's freshwater usage, but 62% (431 MGD) of groundwater usage (694 MGD) in 2010.



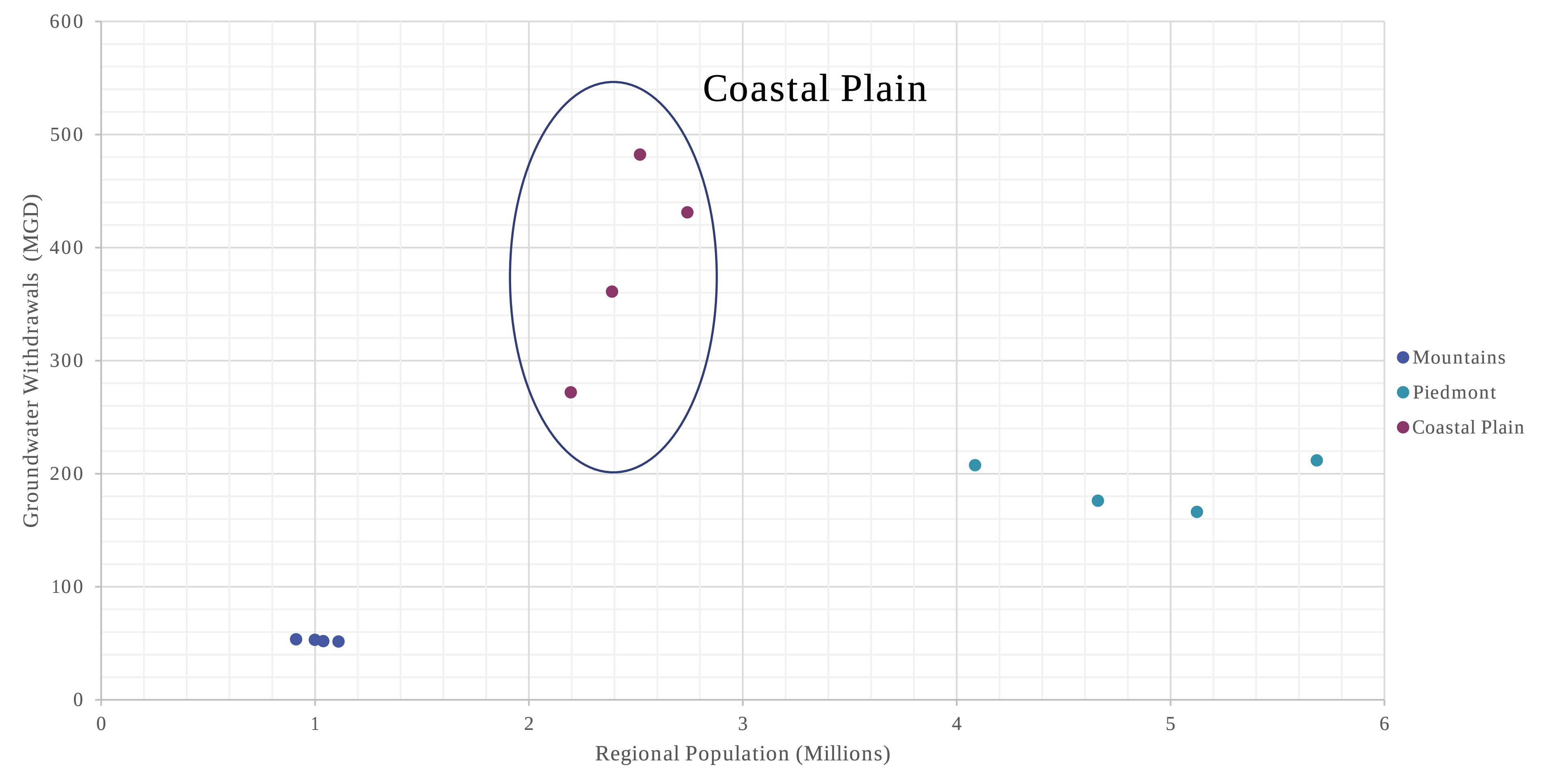
Coastal Plain Counties:
Heavy Reliance on Groundwater



- 54% of Coastal Plain Counties utilized groundwater for more than 1/2 of their supply.

- The total groundwater use from Coastal Plain counties was 62% (431 million gallons/day) of groundwater usage statewide (694 million gallons/day) (2010)

Groundwater Withdrawals by Region (1995-2010)



Largest GW withdrawals by county

- CP- Beaufort (88.9 MGD)
- P- Wake (29.5 MGD)
- M- Buncombe (6.1 MGD)

Due to reliance on groundwater in the Coastal Plain: potential for groundwater withdrawals to influence streamflow

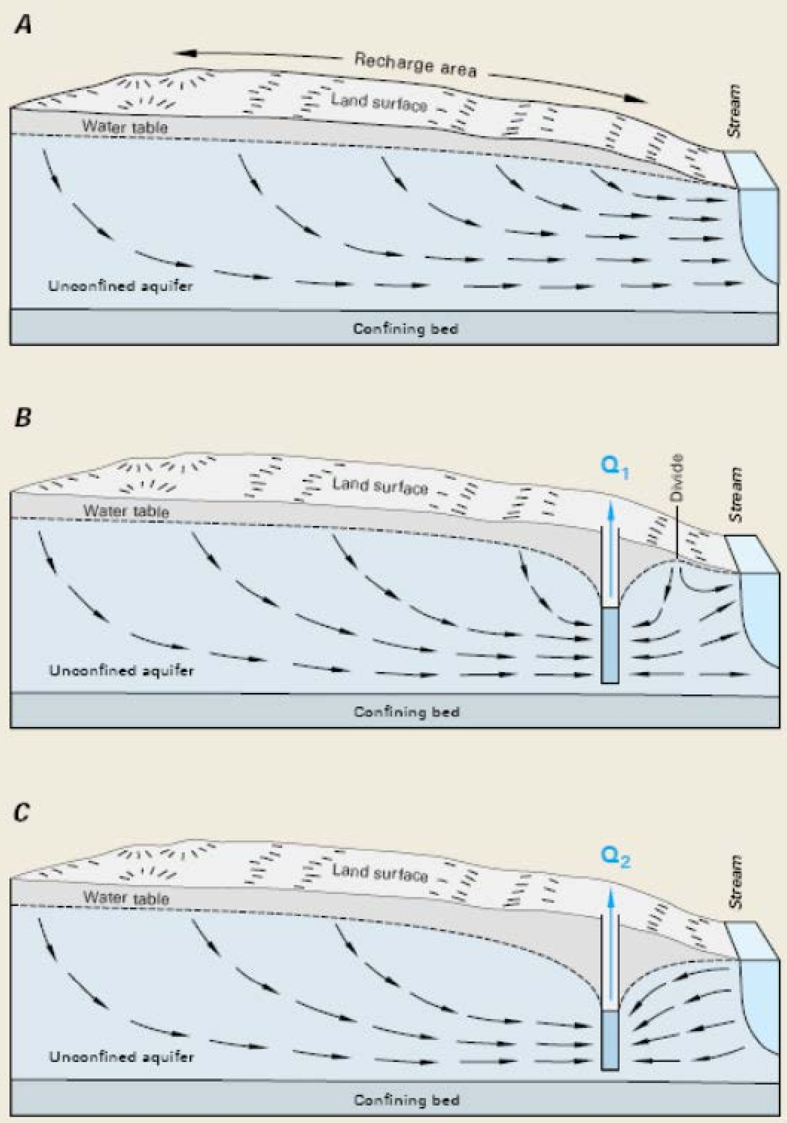
Groundwater Pumping May Affect the Water Table and Streams

-can remove source of baseflow from streamflow

-over time can reverse stream-groundwater relationship

- may lead to declines in baseflow over time

What is the relative role of meteorological controls and water withdrawals on changes in low-flow statistics?



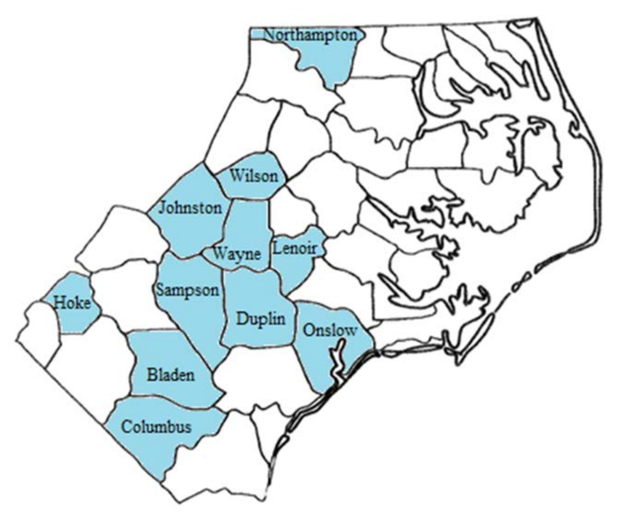
Winter et al. 1998

Challenges Tracking Water Use in the Coastal Plain

- Reporting based on different rules that were put in place at various times and reporting thresholds may vary
- Generally speaking online data is not available before 1997 (paper data back to 1991)
- Comparisons of estimates across the different groups may not always be in agreement
- Example: Coastal Plain agricultural water use estimates for 2010
  USGS estimate: 350 MGD
  NC Dept. of Agriculture and Consumer Services: 21 MGD

	USGS 2010	NCDA&CS 2010	
County	Total (Mgal/day)	Total (Mgal/day)	Difference (Mgal/day)
Bladen County	42.74	2.01	40.73
Columbus County	12.59	0.00	12.59
Duplin County	28.34	2.02	26.32
Hoke County	21.72	0.00	21.72
Johnston County	14.13	0.88	13.25
Lenoir County	15.72	0.16	15.56
Northampton County	18.32	0.28	18.04
Onslow County	10.20	0.09	10.11
Sampson County	31.23	3.07	28.16
Wayne County	10.55	0.52	10.03
Wilson County	14.16	0.00	14.16

Coastal Plain counties where estimates from USGS and NCDA&CS differ by more than 10 million gallons per day (approximately 15 cubic feet/s) (I. Hillman)



Growing number of states and watersheds are recognizing the need to improve water accounting………

complexity arises from having hundreds of independently governed water systems, each with its own water accounts; from the widespread practice of managing linked surface water and groundwater as separate systems; and from a lack of clarity on how much water is reserved for environmental purposes.

Modified from Escriva-Bou et al. 2016, Accounting for California's Water

More detailed water use data to answer several major questions………

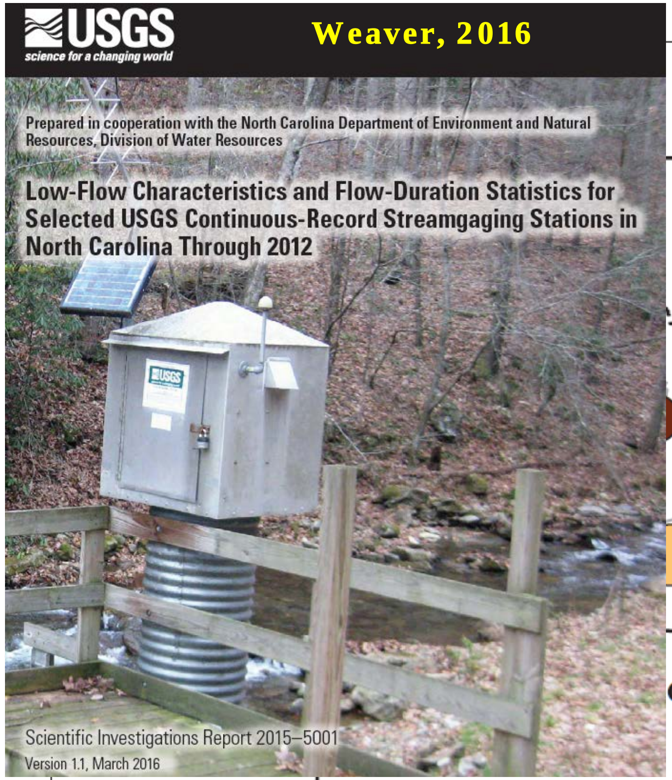
- Why are low flows along Coastal Plain streams declining over the last several decades?
- What is the relative role of meteorological controls and water withdrawals (or anthropogenic influences) on declines in low-flows along Coastal Plain rivers?
- How does groundwater pumping and surface water withdrawals affect low-flow characteristics?
- At what magnitude do these low flow declines affect ecological integrity?
- How do declines in low flow affect water quality and harmful algal blooms?

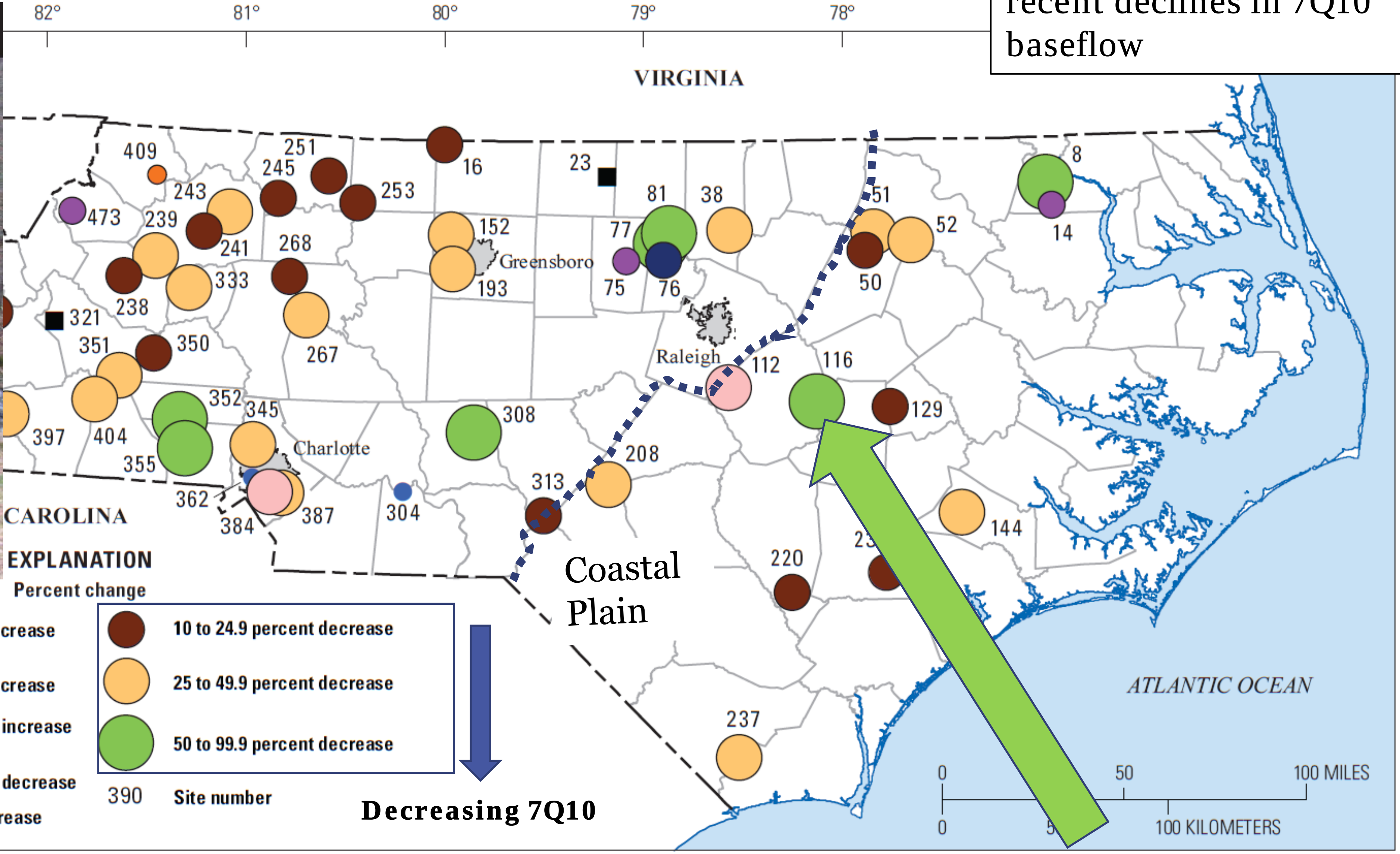
Low flows

Tar River at Falkland

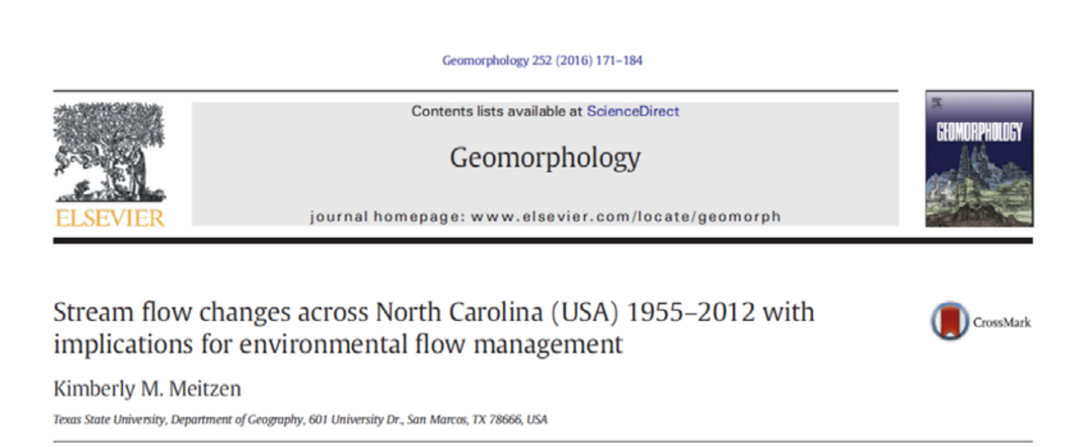
Recent USGS Low-Flow Characterization: Evidence that baseflow is declining in the NC Coastal Plain (pre-1998 vs pre-2011)

ALL Coastal Plain stream gauge sites that were evaluated showed recent declines in 7Q10 baseflow





Example: Little River near Princeton, NC: 2.4 cfs to 0.95 cfs (decline of 60.4%)



Geomorphology 252 (2016) 171–184

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Stream flow changes across North Carolina (USA) 1955–2012 with implications for environmental flow management

Kimberly M. Meitzen

Texas State University, Department of Geography, 601 University Dr., San Marcos, TX 78666, USA

Recent work by Meitzen, 2016
Also showed low flow declines in NC Coastal Plain
Particularly in summer

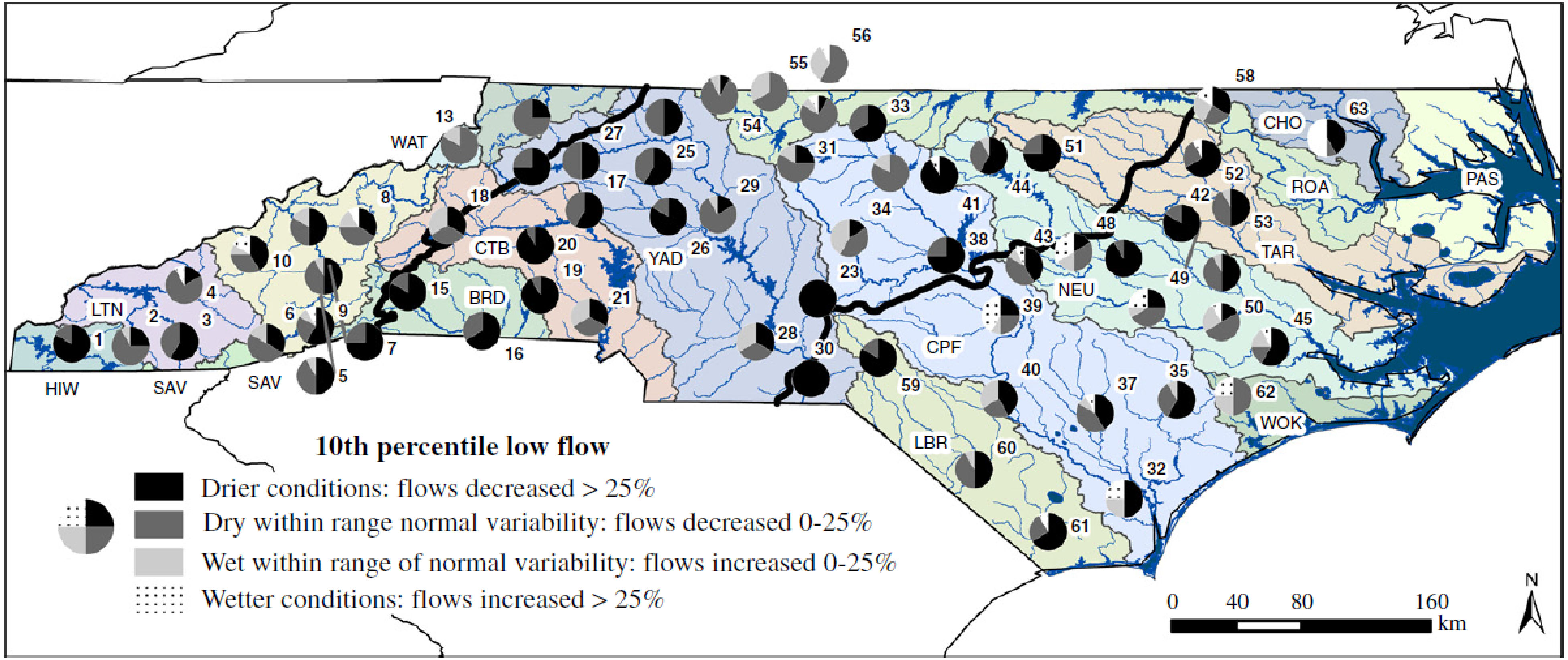
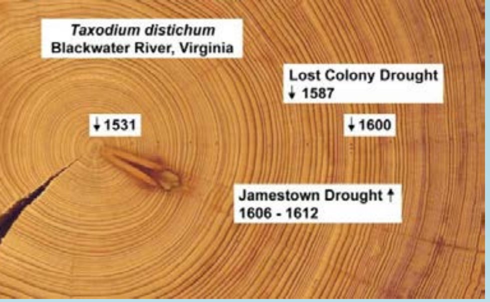


Fig. 4. Flow changes to the 10th percentile low flows.

Changes in streamflow between 1995-1980 and 1984-2012 periods

Meitzen, 2016



Annual rings are thicker when water is plentiful, thinner when it is not. (R.D. Griffin/University of Arkansas Tree-Ring Laboratory).

Drought Cycles in Eastern North Carolina

North Carolina Climate Changes Reconstructed from Tree Rings: A.D. 372 to 1985

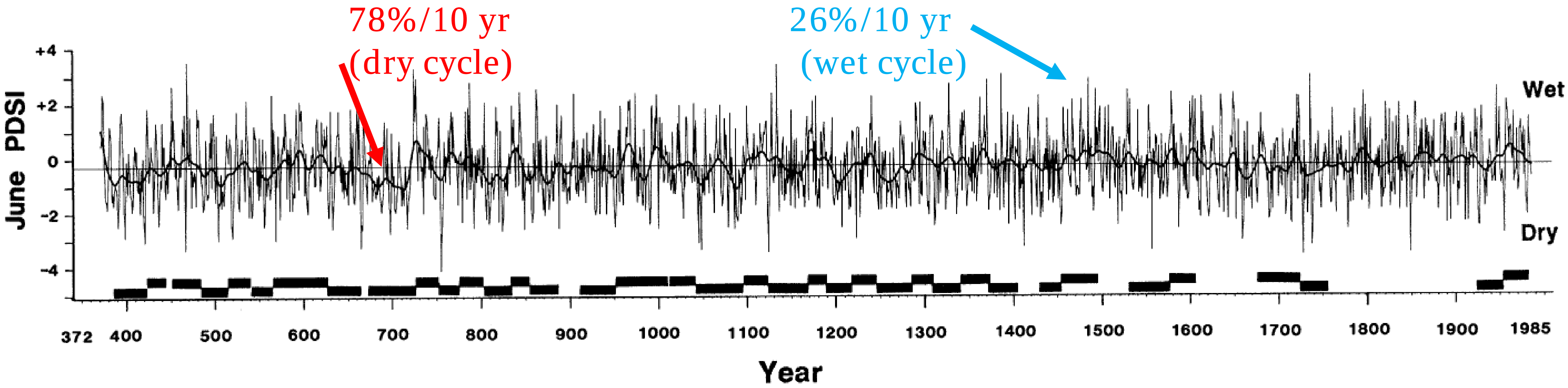
D. W. Stahle; M. K. Cleaveland; J. G. Hehr

Science, New Series, Vol. 240, No. 4858 (Jun. 10, 1988), 1517-1519.

From bald cypress tree rings from the Black River, NC- Stahle et al. (1988) reconstructed a ~1600 yr drought history

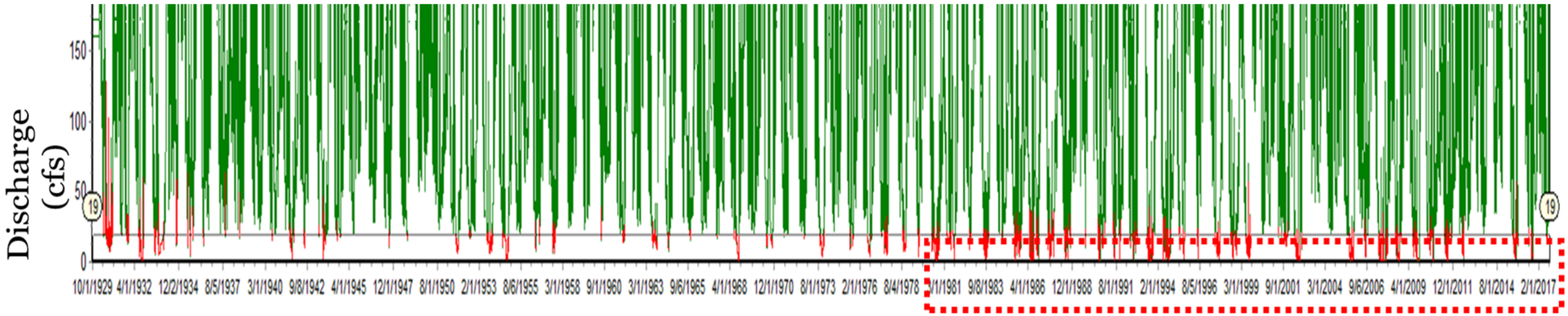
Drought cycles ~ 30 years

NC Severe Drought Probability : 56% /10 yr



PDSI- Palmer Drought Severity Index

Low flows are getting lower along many Coastal Plain Rivers



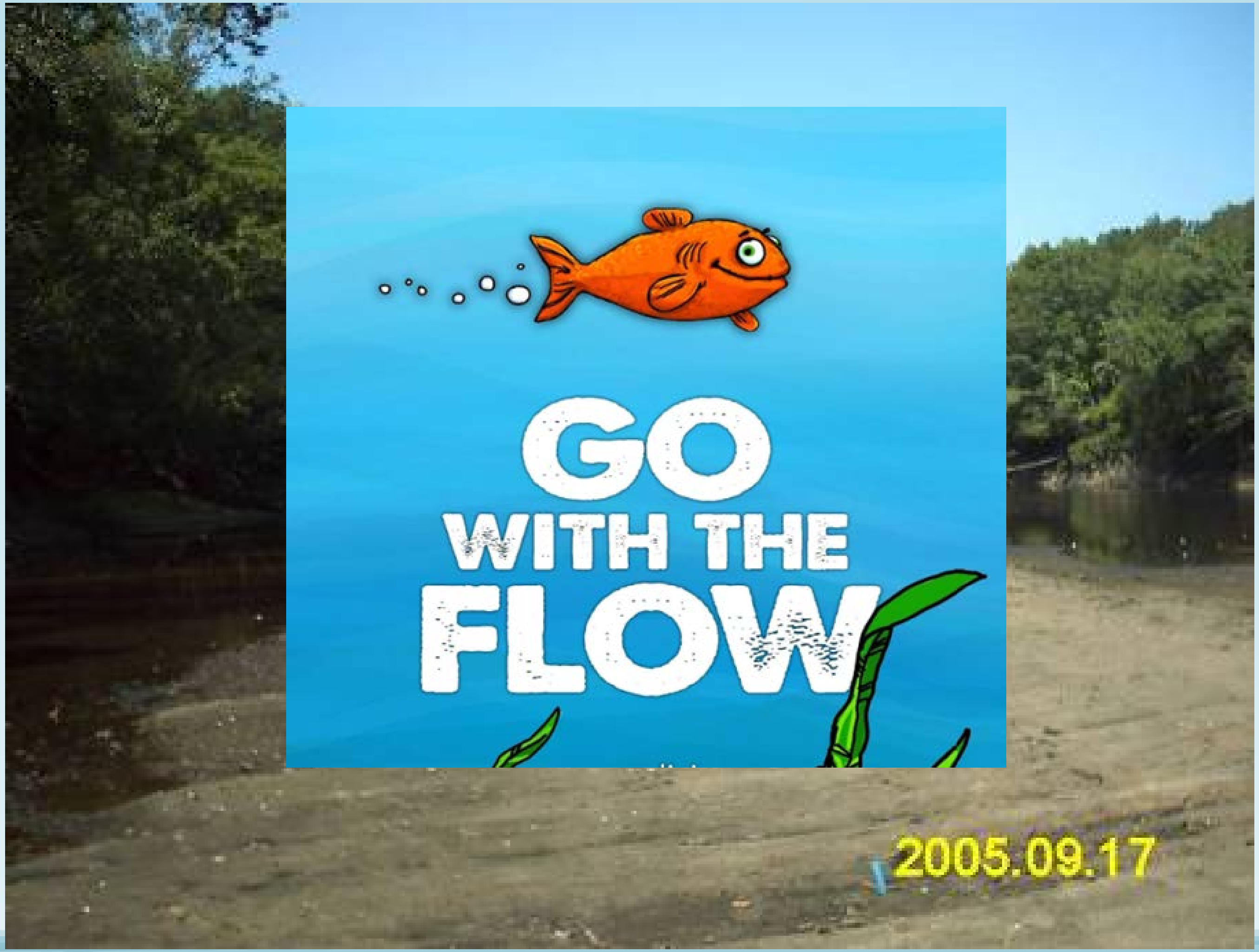
Suggests groundwater inputs to the stream are declining.
Potential reasons may include:

- reductions in groundwater recharge
- shifting precipitation and/or evapotranspiration patterns
- effects of groundwater (GW) and surface water (SW) withdrawals
- interbasin transfers of water and/or wastewater

Example: Little River near Princeton, NC: 2.4 cfs to 0.95 cfs (decline of 60.4%) = 1.45 ft3/s decline= 125,280 ft3/d =937,159 gallons/d= 0.94 Million Gallons/day
(approximately 10 large unregistered withdrawers of less than 100,000 gallons/day could cause this level of decline)

Quantifying low flow conditions

7Q10 is a useful metric to characterize low flows. It is determined by statistical analysis of stream flow records, and represents the lowest stream flow average for seven consecutive days (in a given year) with a recurrence interval of ten years.



Low-flow conditions can lead to:

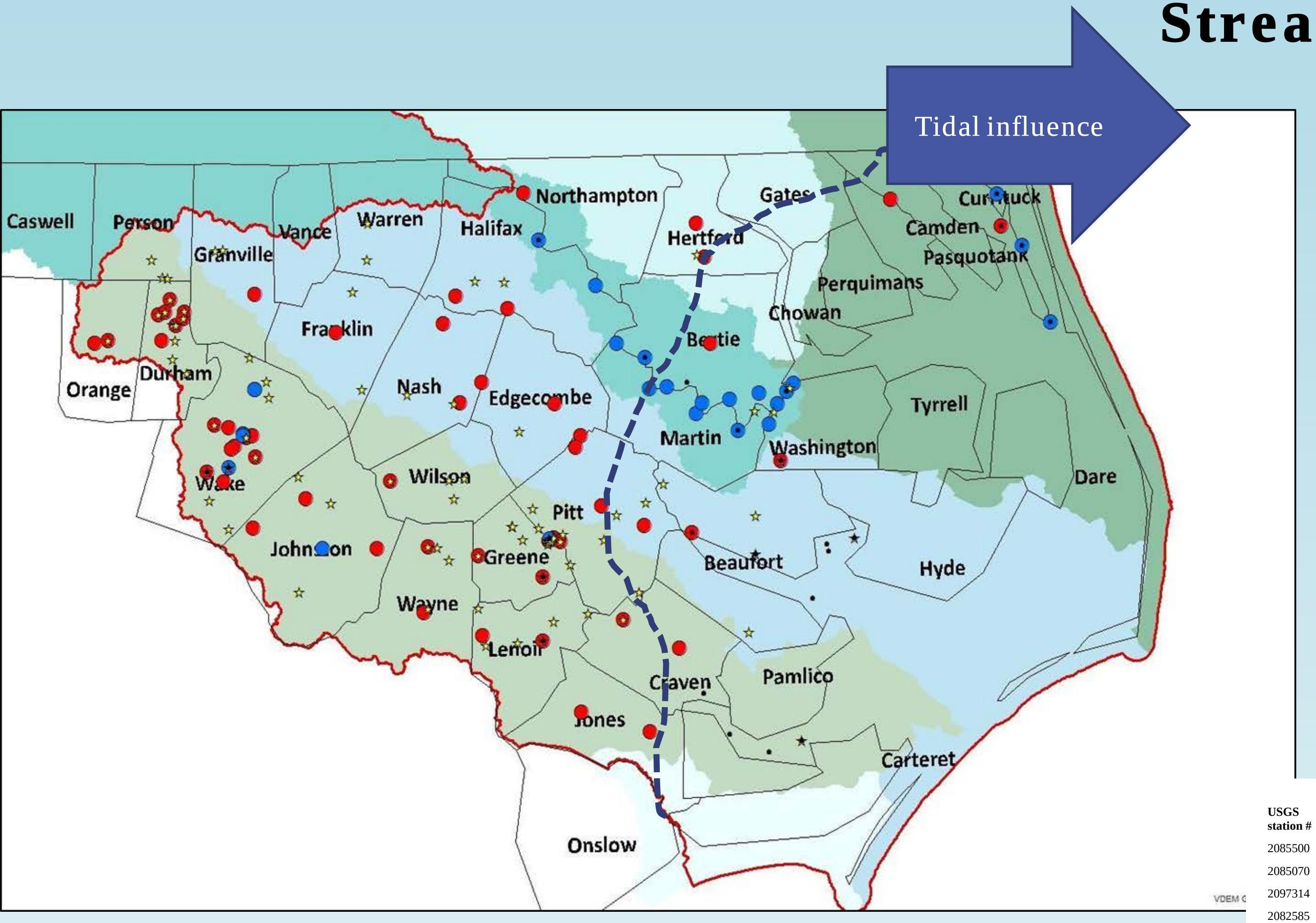
- reduced water supply
- deteriorated water quality
- diminished power generation
- disturbed riparian habitats

problems are likely to become more frequent under enhanced climate variability and increasing water demands.

Groundwater inputs are critical to low flow maintenance (baseflow=100% groundwater inputs)

Average vs 7Q10 low flows at Tar River - Falkland, NC

Streamflow and Stage Network- USGS



No long-term flow data available in zone of tidal influence (stage/discharge USGS ● red circles)

Long-term flow records:
19 currently operational gages with
➢ **30 year records**

USGS station #	Station Name	Lat	Long	County	Drainage Area (mi^2)	Period of record	Years of Record
2085500	FLAT RIVER AT BAHAMA	36.182	-78.879	Durham	149	July 1925 to current	92
2085070	ENO RIVER NEAR DURHAM	36.072	-78.908	Durham	141	August 1963 to current	51
2097314	NEW HOPE CREEK NEAR BLANDS	35.885	-78.966	Durham	75.9	October 1982 to current	35
2082585	TAR RIVER AT NC 97	35.95472	-77.78722	Edgecombe	925	August 1976 to current	41
2083000	FISHING CREEK NEAR ENFIELD	36.151	-77.693	Edgecombe	526	October 1923 to current	94
2083500	TAR RIVER AT TARBORO	35.894	-77.533	Edgecombe	2183	July1896 to December 1900; October 1931 to current	90
2081747	TAR R AT US 401 AT LOUISBURG	36.093	-78.297	Franklin	427	October 1963 to current	54
2081500	TAR RIVER NEAR TAR RIVER	36.195	-78.583	Granville	167	October 1939 to current	78
2091000	NAHUNTA SWAMP NEAR SHINE	35.489	-77	Greene	80.4	April 1954 to current	63
2091500	CONTENTNEA CREEK AT HOOKERTON	35.428	-77.582	Greene	733	November 1928 to current	89
2082950	LITTLE FISHING CREEK NEAR WHITE OAK	36.186	-77.876	Halifax	177	October 1959 to current	58
2053200	POTECASI CREEK NEAR UNION	36.371	-77.027	Hertford	225	March 1958 to current	59
2053500	AHOSKIE CREEK AT AHOSKIE	36.28	-77	Hertford	63	January 1950 to current	67
2092500	TRENT RIVER NEAR TRENTON	35.065	-77.457	Jones	168	January 1951 to current	66
2088500	LITTLE RIVER NEAR PRINCETON	35.511	-78.161	Johnston	229	February 1930 to current	87
2082770	SWIFT CREEK AT HILLIARDSTON	36.112	-77.921	Nash	166	July 1963 to current	54
2085000	ENO RIVER AT HILLSBOROUGH	36.072	-79.104	Orange	66	October 1927 to August 1971; October 1985 to current	76
2084160	CHICOD CR AT SR1760	35.56167	-77.23083	Pitt	45	October 1975 to March 1987; May 1992 to current	35
208732885	MARSH C NR NEW HOPE	35.81694	-78.59306	Wake	6.84	January 1984 to current	33

Map of where current USGS streamflow gages are in NC Albemarle-Pamlico Basin watersheds. Red gages indicate stage and discharge sites. Blue gages indicate stage only. Yellow stars indicate inland water quality data available. Black circles indicate water quality data available in the estuary.

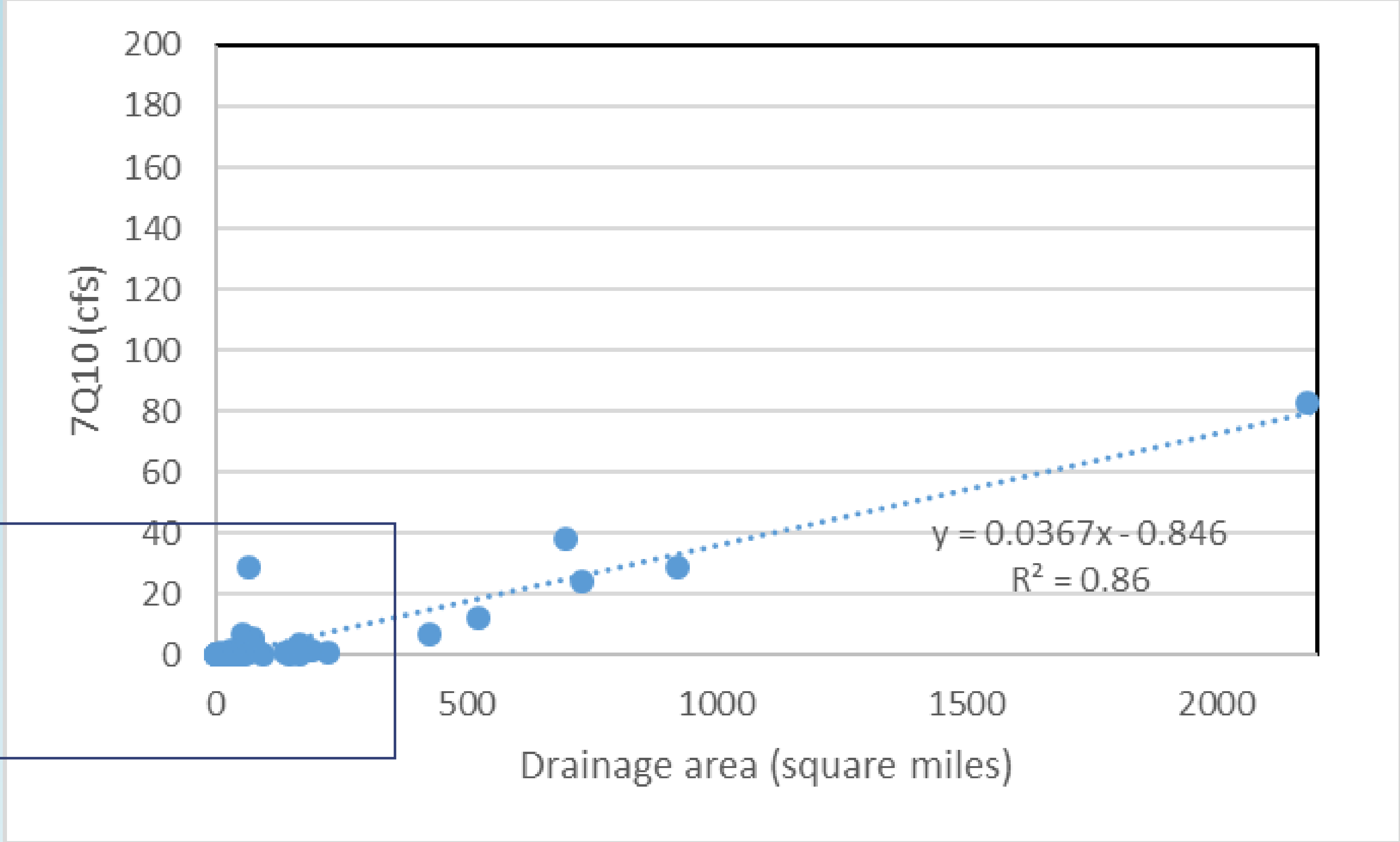
Preliminary low-flow analyses on streams w/ > 30 years of discharge data in A-P Basin (Hillman et al. 2018)

Station Name	Zero Day Slope	Base Flow Index Slope	Extreme Low Flow Frequency Slope
FLAT RIVER AT BAHAMA	↑	↓	↑
ENO RIVER NEAR DURHAM	–	↓	↑
NEW HOPE CREEK NEAR BLANDS	↑	↓	↓
TAR RIVER AT NC 97	–	↑	↓
FISHING CREEK NEAR ENFIELD	–	↓	↑
TAR RIVER AT TARBORO	–	↓	↑
TAR R AT US 401 AT LOUISBURG	–	↓	↑
TAR RIVER NEAR TAR RIVER	↑	↓	↑
NAHUNTA SWAMP NEAR SHINE	–	↓	↑
CONTENTNEA CREEK AT HOOKERTON	–	↑	↑
LITTLE FISHING CREEK NEAR WHITE OAK	–	↓	↑
POTECASI CREEK NEAR UNION	↑	↑	↑
AHOSKIE CREEK AT AHOSKIE	↓	↑	↓
TRENT RIVER NEAR TRENTON	↑	↓	↑
LITTLE RIVER NEAR PRINCETON	↑	↓	↑
SWIFT CREEK AT HILLIARDSTON	–	↓	↑
ENO RIVER AT HILLSBOROUGH	–	↓	↑
CHICOD CR AT SR1760	↓	↑	↓
MARSH C NR NEW HOPE	↑	↓	↑

Shaded boxes indicate declining low flows over time

13/19 streams indicated at least 2 indicators of lower flows over time

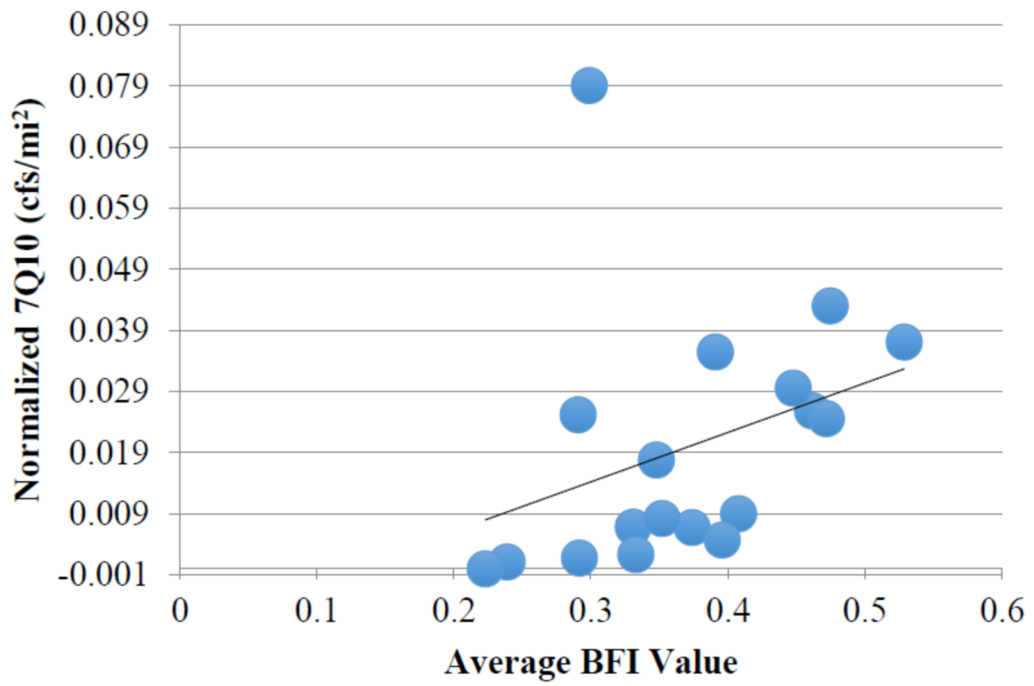
7Q10 vs Drainage Area for A-P streams



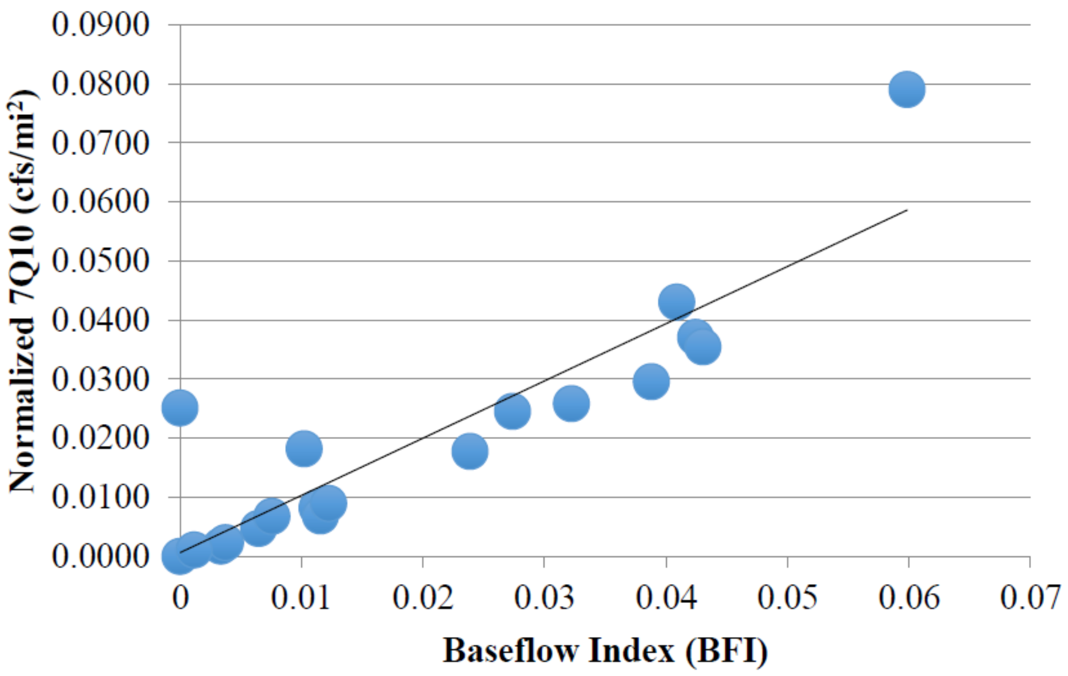
Smaller watersheds(<250 mi^2)- May be affected by lower magnitude withdrawals, especially in summer

Lower order streams- more likely to dry up (watershed area < 250 mi^2)
Higher order streams- like Tar and Neuse have more gages, most of the low-order streams lack gages (limited capability to understand which lower order streams are drying up more frequently)

Baseflow Index- May help to predict 7Q10 for ungaged streams or streams with shorter discharge records



USGS approach
(% gw of annual runoff)

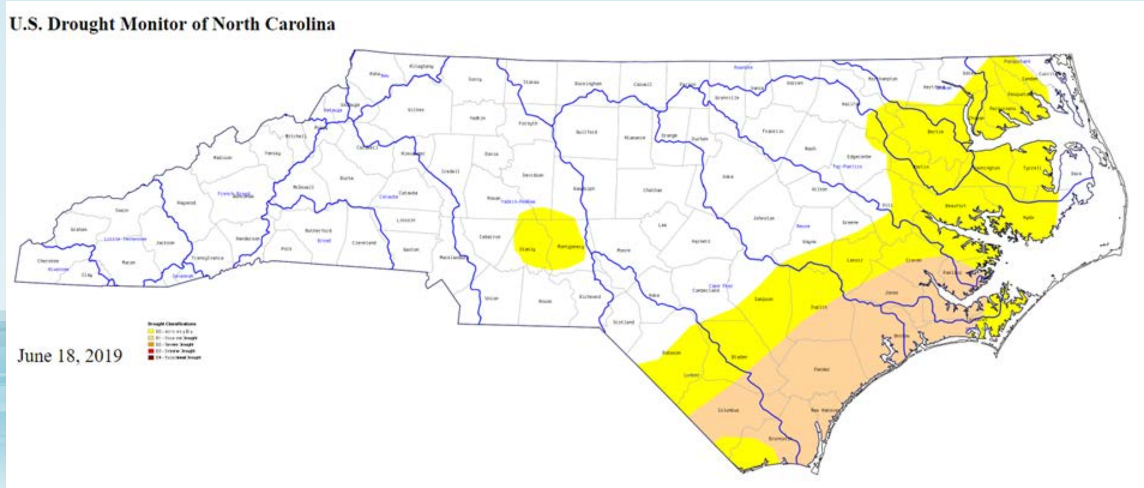


TNC approach
(7-day min. flow/annual mean flow)

How do low flows influence water quality?

- Reduced residence time
- Increased water temperatures and reduced dissolved oxygen
- Decline in thermal refugia areas for fish
- Reduced dilution (permitting issues if 7Q10 is declining)
- Saltwater intrusion
- How will climate and land-use change and growing water demands affect low flows in the future?

- More work is needed to
  - understand the relative role of meteorological controls and water withdrawals on changes in low-flows
  - the interactions between low-flows and water quality
  - the effects of low-flows on ecological integrity



Cyanobacterial Blooms and Cyanotoxin Dynamics in the Chowan River, NC

Schnetzer (NCSU)

Partners: Citizen Scientists, Putnam (NC Sea Grant), Jill Paxson (DEQ)

Main objectives:

i. Monthly testing for the presence of four cyanotoxins: anatoxin, cylindrospermopsin, microcystin and saxitoxin at seven locations. - *completed*

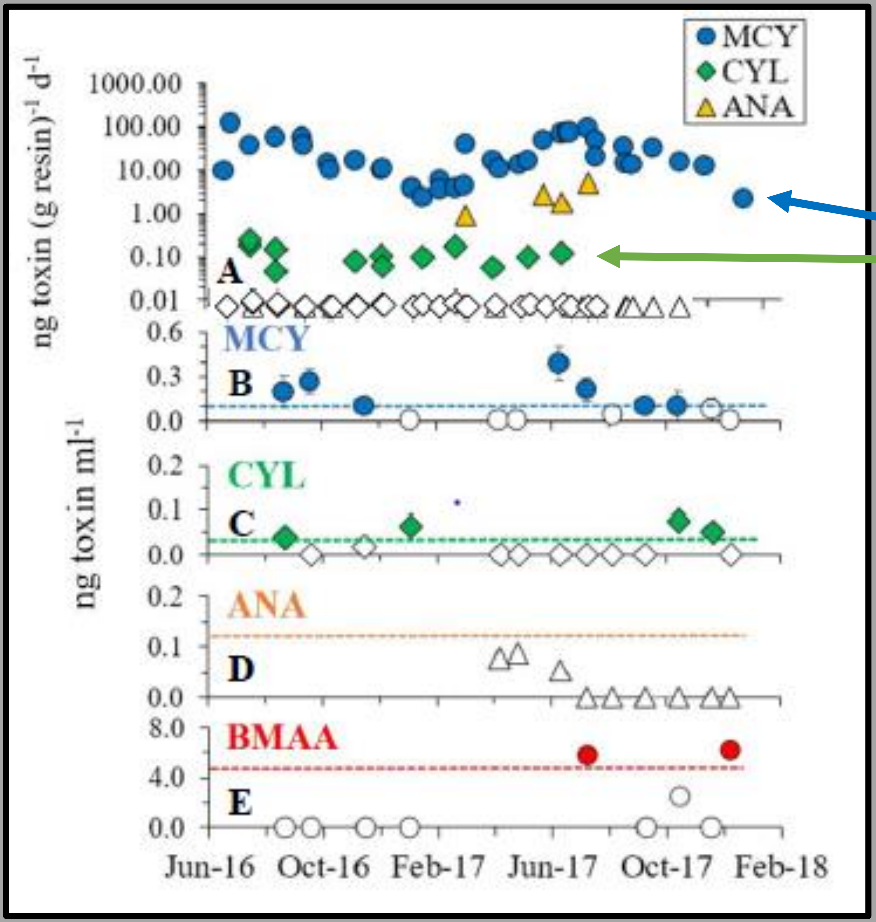
ii. Analyses of spatiotemporal toxin dynamics in relation to biological and physiochemical information. - *underway*

Blue symbols (CR1 – CR4) indicate SPATT deployment sites.

Red symbols (D1 - D3) shows sites where DEQ's Ambient Monitoring Program deployed SPATTs and collected grab samples for toxin analyses.

Monthly sampling and some event-driven collections.

Cyanotoxins presence and year-round dynamics



- MCY, CYL, ANA and BMAA present between July 2016 to January 2018
- No STX
- MCY and CYL most commonly detected
  ➔ Possible low-level chronic exposure to multiple toxins (SPATTs)

➔ Issues of missing acute bloom events (degraded toxin signals?)

➔ Food web impacts?

Food Web Transfer of Cyanobacterial Toxins in the Chowan River and western Albemarle Sound NC

Schnetzer (NCSU) & Godwin (DMF)

Partners: Putnam (NC Sea Grant Outreach), Karl (CEEG), Hall (UNC-CH) & Stevenson et al. (DEQ)

Main objectives of CCRG project

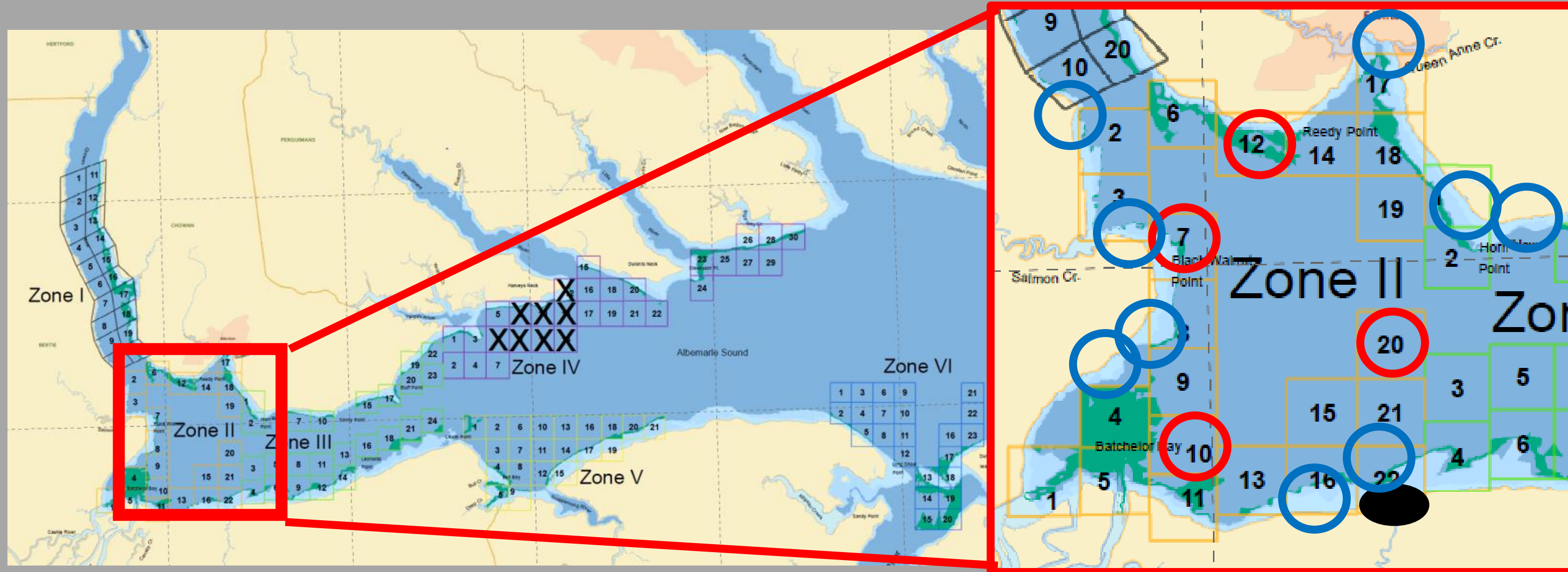
i. Testing of cyanotoxin loads (mainly MCY and CYL) in commonly caught fish species (main targets: viscera, liver and tissue samples) and clams.

ii. Analyze temporal toxin dynamics (dissolved and cell-bound fractions plus SPATT monitoring) in relation to animal loads.

Sea Grant North Carolina

Community Collaborative Research Grant (CCRG)

Sea Grant North Carolina



Red symbols – gill nets
Blue symbols - seining
Black oval – clam bed



Main collection to date:
Perch, gizzard, catfish, *Rangia* sp.

Sampling Timeline:

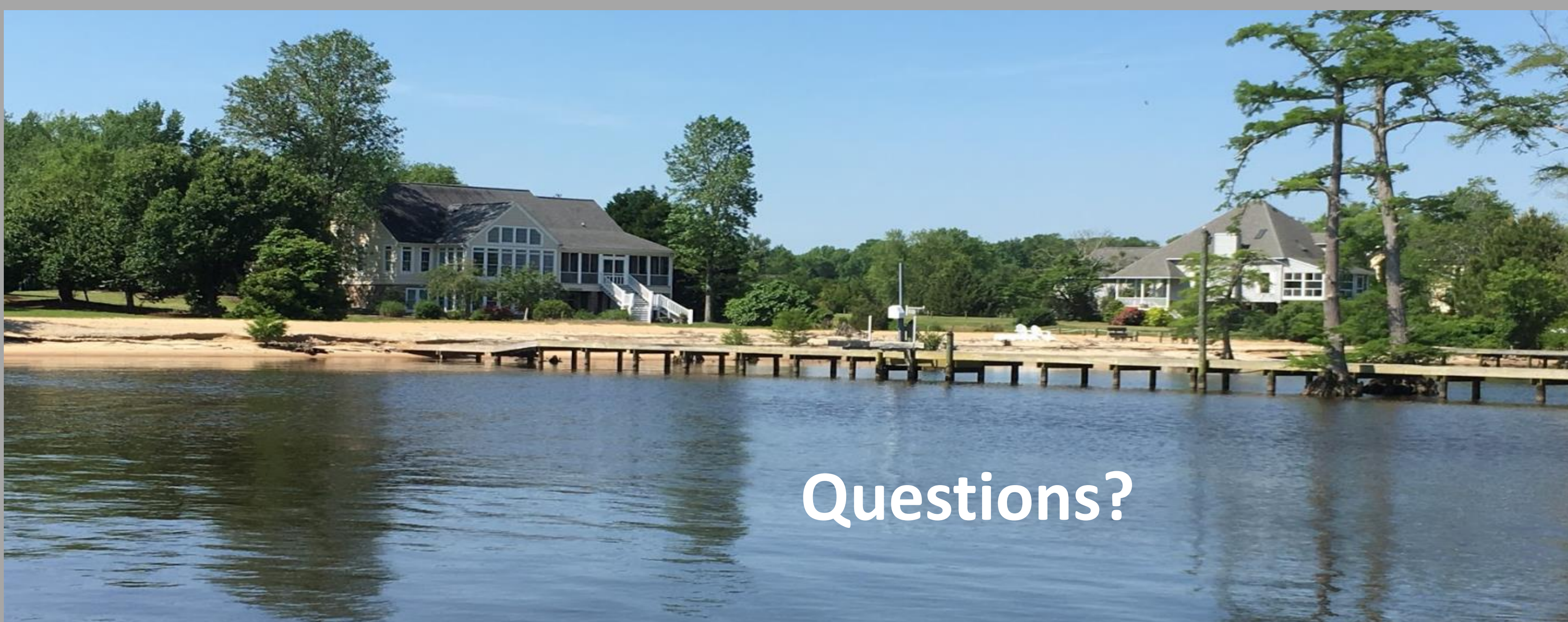
- Weekly to bimonthly sampling of fish, clams, water and zooplankton
- Bimonthly to monthly SPATT deployment

Food Web Transfer of Cyanobacterial Toxins in the Chowan River and western Albemarle Sound NC

Additional Project Goals

- Event-driven sampling to capture acute bloom(s): DEQ (Jill) and CEEG (Colleen)

- Information Forums in Edenton (September and after completion) - stakeholders, public and recreational users – *all partners involved*



Nutrient Criteria Development Plan Document Revisions

June 27, 2019

Original NCDP

- Agreed to on June 20, 2014
- SAC roles in document not representative
- No mention of CIC
- Outdated timelines

High Rock Lake

Task No.[1]	Task	Anticipated Completion Date
11	The stakeholder process will begin after the nutrient response model is completed. Quarterly meetings are planned and will begin January 2015. Nutrient criteria development with the SAC and stakeholder input. The consultations with the SAC will include the potential approach to be used in developing statewide nutrient criteria for lakes and reservoirs based on the modeling results. a. Begin consultation with the SAC — January 2015 b. HRL Stakeholder Meetings: 1. HRL Stakeholder Mtg. 1 — January 2015 2. HRL Stakeholder Mtg. 2 — April 2015 3. HRL Stakeholder Mtg. 3 — July 2015 4. HRL Stakeholder Mtg. 4 — October 2015 5. HRL Stakeholder Mtg. 5 — January 2016 c. Present tentative NNC[2] to SAC — February 2016 d. Present refined NNC to SAC — April 2016 e. Present proposed NNC to WQ Committee — July 2016 f. Present proposed NNC to EMC — November 2016	December 2016
12	Adoption of nutrient criteria for HRL per NC Administrative Procedure Act (APA)	July 2018

…tasks 8-12 are depicted in the Gantt chart (Appendix 1).
…Nutrient Criteria

Rule adoption 1 year ago!

North Carolina Nutrient Criteria Development Plan

June 20, 2014

Submitted to the
United States Environmental Protection Agency - R…

by the

North Carolina Department of Environment and…
Division of Water Resources
Raleigh, North Carolina

- Helping develop the management approach for each water body type.
- Reviewing proposed nutrient criteria, including revised chlorophyll-*a* criteria for new (not existing) nutrient management strategies.
- Periodically assisting in the preparation of reports that present the progress of developing nutrient criteria.
- Advising the DWR on social and economic issues pertaining to nutrient management and implementation.

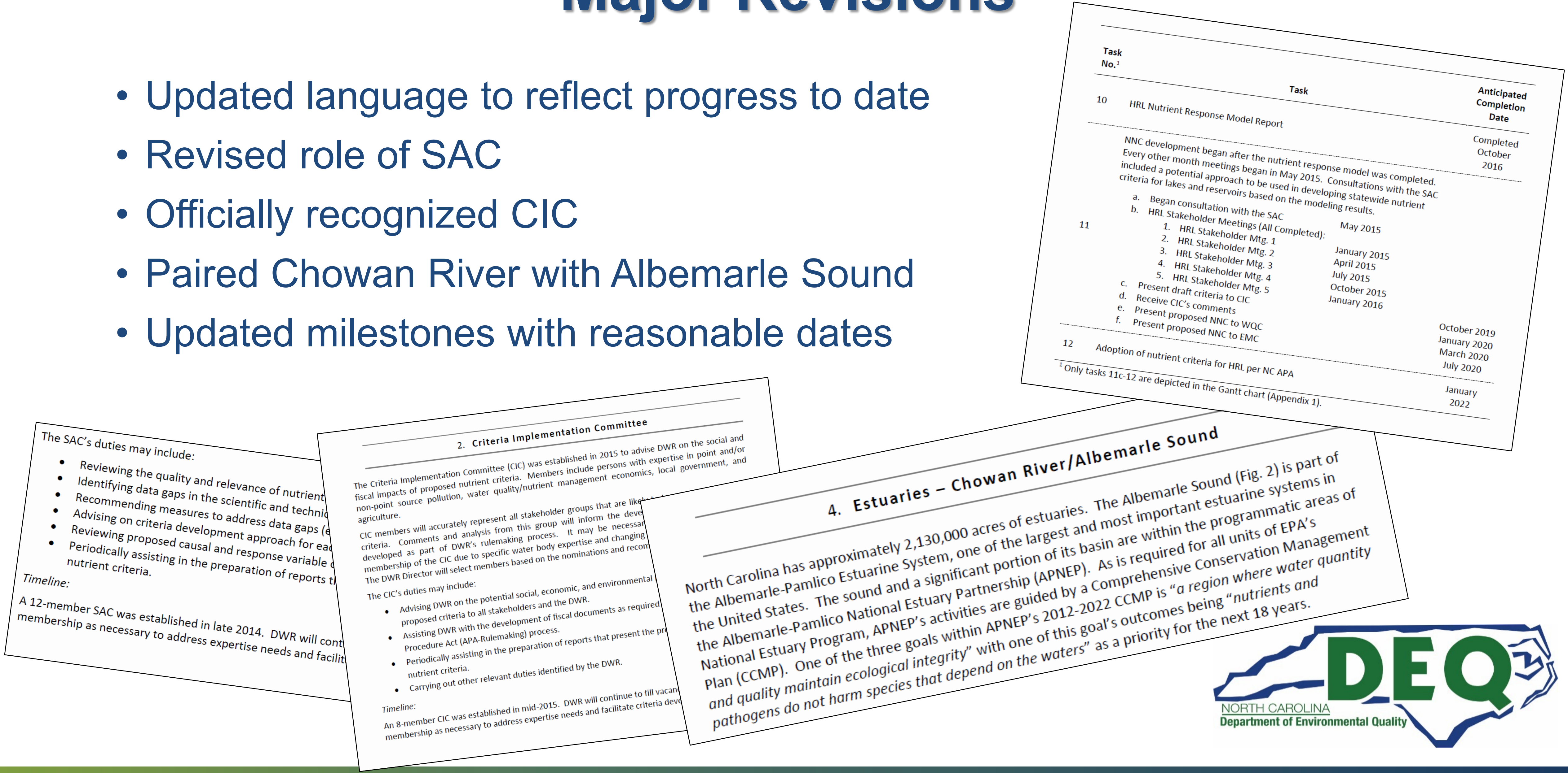
Timeline:

Establishment of the SAC will be completed by November 2014.

NORTH CAROLINA
Department of Environmental Quality

Major Revisions

- Updated language to reflect progress to date
- Revised role of SAC
- Officially recognized CIC
- Paired Chowan River with Albemarle Sound
- Updated milestones with reasonable dates



NORTH CAROLINA
Department of Environmental Quality

Questions?

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

JUN 05 2019

Mrs. Linda Culpepper
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1621 Mail Service Center
Raleigh, North Carolina 27699-1621

Dear Mrs. Culpepper:

This letter documents a mutual agreement between the North Carolina Department of Environmental Quality (the Department) and the United States Environmental Protection Agency with regards to the State's revised numeric nutrient criteria development plan, titled North Carolina Nutrient Criteria Development Plan (the Revised Plan). The Revised Plan is dated May 16, 2019 and was submitted for EPA review on the same date.

The EPA recognizes that this Revised Plan represents continued efforts by the State to address the complex issue of nutrient pollution. We appreciate the cooperation of your staff in working with the EPA Region 4 to revise the plan. By this agreement, the EPA is acknowledging that this Revised Plan reflects a reasonable course of action by which the State can proceed to develop numeric nutrient criteria. However, the EPA's agreement at this time does not reflect an in-depth review or judgement that the resulting criteria will or will not be protective or are consistent with the Clean Water Act and should not be interpreted as an approval of North Carolina's water quality standards (WQS). Based upon our review, we believe that the elements of the Revised Plan detail an acceptable process by which the State can develop nutrient criteria for adoption into the State's WQS.

We recognize that the development of nutrient criteria for all state waters, with a focus on specific waterbodies first, has been the State's priority and a significant level of effort has been devoted to this goal in recent years. Excellent progress has been made on the development of recommendations related to High Rock Lake and we commend your staff for their significant efforts to support criteria development conversations to date. We encourage you to continue moving towards completion of the adoption process for this water, but also continue to develop and adopt nutrient criteria for other waters in the State as outlined in the Revised Plan. If you find that the Department will be unable to meet its obligations as set out in the Revised Plan, you should contact the EPA to discuss the concerns or issues and, if necessary, negotiate new milestone schedules.

We look forward to working with you on these efforts and providing any technical assistance you might request. Again, we appreciate the time and resources you and your staff have devoted in developing nutrient criteria and look forward to your continued accomplishments. If you have any questions regarding this matter, please feel free to contact me at (404) 562-9273 or have a member of your staff contact Mrs. Lauren Petter at (404) 562-9272 or petter.lauren@epa.gov.

Sincerely,

Tony Able, Chief
Water Quality Planning Branch

cc: Brian Wrenn, NCDWR
Jim Gregson, NCDWR

North Carolina Nutrient Criteria Development Plan

v.2

May 16, 2019

Submitted to the

United States Environmental Protection Agency - Region 4

by the

North Carolina Department of Environmental Quality

Division of Water Resources

Raleigh, North Carolina

List of Acronyms

Acronym	Definition
APA	Administrative Procedure Act
APNEP	Albemarle-Pamlico National Estuary Partnership
CCMP	Comprehensive Conservation Management Plan
CGIA	Center for Geographic Information and Analysis
DO	Dissolved Oxygen
DWR	Division of Water Resources
EMC	Environmental Management Commission
EPA	Environmental Protection Agency
FTE	Full Time Equivalent
HRL	High Rock Lake
NC	North Carolina
NCDP	Nutrient Criteria Development Plan
NCIP	Nutrient Criteria Implementation Plan
NNC	Numeric Nutrient Criteria
NSW	Nutrient Sensitive Waters (a NC supplemental water quality classification)
SAC	Scientific Advisory Council (to be established as part of this NCDP)
STAC	Science and Technical Advisory Committee (an APNEP committee)
STORET	STOrage and RETrieval Data Warehouse
TAC	Technical Advisory Committee (HRL committee)
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WQC	Water Quality Committee (a subcommittee of the EMC)

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North Carolina Nutrient Criteria Development Plan

Introduction

Nutrient criteria management plans were strongly encouraged by the Environmental Protection Agency (EPA)[1] for all states through a Federal Register notice issued in 2001 and by subsequent EPA memoranda and actions. North Carolina (NC) developed a nutrient criteria plan, the Nutrient Criteria Implementation Plan (NCIP) in response to the 2001 register notice, which was mutually agreed upon in 2004. In order to re-establish mutual agreement with the EPA, the 2004 NCIP was updated and amended in June 2014 to reflect commitment and a schedule of progress toward the adoption of nutrient criteria for all state waters. The new plan, the Nutrient Criteria Development Plan (NCDP), established a Scientific Advisory Council (SAC) to develop scientifically-defensible criteria for three water body types, lakes and reservoirs, rivers and streams, and estuaries. For each water body type, a pilot water body was identified for nutrient criteria development along with a schedule for completion. These water bodies included High Rock Lake, the central portion of the Cape Fear River, and the Albemarle Sound. This North Carolina Nutrient Criteria Development Plan (NCDP) is a revision of the 2014 NCDP and revises the role of the SAC, recognizes the Criteria Implementation Committee (CIC), and provides updates to criteria development schedules.

Historically, North Carolina had established itself as a leader in the field of site-specific, flexible nutrient control strategies through the implementation of a chlorophyll-*a* standard and the development of a supplemental classification of 'Nutrient Sensitive Waters' (NSW). Although these strategies have been noteworthy, nutrients continue to affect water quality and have the potential of impacting aquatic life, the public's use of surface waters for recreation, and drinking water supplies. Therefore, additional nutrient management strategies, including water body specific numeric nutrient criteria as appropriate for protection of designated uses for all water body types, must be developed.

The North Carolina Division of Water Resources (DWR) developed its 2014 NCDP after holding a Nutrient Forum in 2012 and from input of stakeholders expressed during four public forums and written comments obtained from December 2012 through February 2014. Comments reflected the need for:

- Establishing a scientific advisory council (SAC).
- Flexible (i.e., site-specific or water body specific) nutrient criteria.
- Stakeholder involvement.
- Allowing all existing nutrient management rules and total maximum daily loads (TMDLs) to proceed as currently written.
- Establishing a balance between the best science on nutrient management and the cost-effectiveness of implementation.

Based upon that input, the 2014 plan:

- Outlined the creation of the SAC.
- Identified three areas for the development of nutrient criteria in the near future:
  - High Rock Lake
  - Albemarle Sound
  - Central portion of the Cape Fear River
- Identified a process through which the DWR will evaluate nutrients throughout NC.
- Affirmed the DWR commitment to implementing the NCDP.

[1] A table of acronyms is on page 18.

Numeric Nutrient Criteria

The focus of the 2014 strategy, to develop nutrient criteria based primarily on the linkage between nutrient related parameters and protection of designated uses, will be maintained. For the purposes of this document, "numeric nutrient criteria" and "nutrient criteria" are defined as either of the following:

- Causal and response variables expressed as numerical concentrations and/or mass quantities or loadings.
- Causal and response variables expressed as narrative statements with a scientifically defensible translator mechanism to derive or calculate numerical concentrations and/or mass quantities or loadings. Rule language will clarify that the translator will be used by the implementing programs.

Priority parameters for consideration are provided in Table 1.

Table 1. Response and causal variables for consideration. (Others may be considered.)

Response variables	Causal variables
Chlorophyll-*a*	Nitrogen
Phytoplankton	Phosphorus
Periphyton	
Macrophytes	
Diurnal dissolved oxygen (DO) range	
Minimum DO	
Diurnal pH range	
Water clarity	

When developing nutrient standards, we will consider all of the above nutrient criteria and causal and response variables as well as other nutrient related criteria and variables if appropriate. The use of biological confirmation will also be considered, in accordance with the EPA's Guiding Principles[2].

Evaluating Nutrients throughout North Carolina

The DWR will continue its commitment to evaluating nutrients and developing nutrient criteria throughout North Carolina on a site-specific basis. Nutrient criteria development efforts will be directed to the three specific water body types: 1) reservoirs/lakes, 2) rivers/streams and 3) estuaries. Our first priority will be to develop nutrient criteria on a specific water body within each water body type: 1) High Rock Lake, 2) the Central Portion of the Cape Fear River and 3) Albemarle Sound. Draft criteria for High Rock Lake have been completed. Following the development of criteria for these water bodies, the applicability of these criteria will be assessed for respective water body types through the state on a site-specific basis to ensure coverage of waters statewide.

Timeline:

We anticipate development and adoption of nutrient criteria for the three water bodies specified in this plan by 2025. Adoption of nutrient criteria statewide is anticipated by 2029.

[2] http://www2.epa.gov/sites/production/files/2013-09/documents/guiding-principles.pdf

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Timelines

Implementing this NCDP will require collaborative work among the DWR, EPA, SAC, other agencies, local governments and universities. The DWR considers this to be an interactive and adaptive plan and will continue to work with EPA Region 4. The estimated timelines may need to be modified in future revisions of the NCDP, given research, resource changes or unforeseen delays. The greatest challenge continues to be obtaining sufficient funding and personnel resources to support this endeavor. The DWR will keep the EPA informed of any delays and will negotiate new timelines as the need arises through annual Clean Water Act - Section 106 workplan development. All timelines are summarized in a Gantt chart in Appendix 1.

DWR Commitments in Implementing the NCDP

The DWR is committing four full time equivalents (FTEs) to the implementation of the NCDP. Staff resources will come from the Water Sciences Section and the Water Planning Section, with the following anticipated allocation between the sections:

- Water Sciences Section
  - Ecosystems Branch – 1.0 FTE
- Water Planning Section
  - Classifications & Standards/Rules Review Branch – 0.5 FTE
  - Modeling & Assessment Branch – 2.0 FTE
  - Nonpoint Source Planning Branch– 0.5 FTE

Input and participation from other DWR sections (e.g. Water Quality Permitting Section) and DWR Branches (e.g., Complex Permitting) will be necessary especially during the discussion of management strategies.

The DWR plans to maintain this level of commitment throughout the nutrient criteria development process. However, our greatest challenge is to maintain sufficient funding and trained personnel to complete the tasks outlined in this plan. Nothing in this plan obligates the DWR to a course of action in the absence of program resources.

NCDP Projects

The remainder of this document outlines seven projects discussed in chronological order regarding work efforts:

1. Review and amend as necessary the membership of the Scientific Advisory Council and the Criteria Implementation Committee
2. Complete nutrient criteria development for High Rock Lake
3. Nutrient criteria development for Chowan River/Albemarle Sound
4. Nutrient criteria development for the Central Portion of the Cape Fear River
5. Nutrient criteria development for estuaries statewide
6. Nutrient criteria development for reservoirs and lakes statewide
7. Nutrient criteria development for rivers and streams statewide

Each project has a task list with an anticipated completion date. A Gantt chart for all tasks is appended.

1. **Scientific Advisory Council**

The Scientific Advisory Council (SAC) was established in the 2014 NCDP to assist the DWR and stakeholder groups with the development of nutrient criteria. Members include individuals with expertise in areas related specifically to water quality, nutrient response variables, nutrient management, and point and non-point source nutrient abatement. The EPA was asked to participate on the SAC.

DWR recognizes that the composition of the SAC is essential to the successful development of nutrient criteria. DWR staff consulted with the EPA-Region 4 and the Albemarle Pamlico National Estuary Partnership (APNEP) regarding the creation of effective advisory groups such as a SAC. It may be necessary to periodically revise the membership of the SAC due to specific water body expertise and changing professional responsibilities. The DWR Director will select members based on the nominations and recommendations from staff. Each member will nominate an alternate to serve on the SAC in the event that the regular member is unable to attend. All alternates must be approved by the Director.

The SAC's duties may include:

- Reviewing the quality and relevance of nutrient data.
- Identifying data gaps in the scientific and technical information being used.
- Recommending measures to address data gaps (e.g., monitoring and data collection).
- Advising on criteria development approach for each waterbody type.
- Reviewing proposed causal and response variable criteria developed by DWR.
- Periodically assisting in the preparation of reports that present the progress of developing nutrient criteria.

Timeline:

A 12-member SAC was established in late 2014. DWR will continue to fill vacancies and revise membership as necessary to address expertise needs and facilitate criteria development.

2. **Criteria Implementation Committee**

The Criteria Implementation Committee (CIC) was established in 2015 to advise DWR on the social and fiscal impacts of proposed nutrient criteria. Members include persons with expertise in point and/or non-point source pollution, water quality/nutrient management economics, local government, and agriculture.

CIC members will accurately represent all stakeholder groups that are likely to be affected by nutrient criteria. Comments and analysis from this group will inform the development of any fiscal notes developed as part of DWR's rulemaking process. It may be necessary to periodically revise the membership of the CIC due to specific water body expertise and changing professional responsibilities. The DWR Director will select members based on the nominations and recommendations from staff.

The CIC's duties may include:

- Advising DWR on the potential social, economic, and environmental implications of adopting the proposed criteria to all stakeholders and the DWR.
- Assisting DWR with the development of fiscal documents as required by the Administrative Procedure Act (APA-Rulemaking) process.
- Periodically assisting in the preparation of reports that present the progress of developing nutrient criteria.
- Carrying out other relevant duties identified by the DWR.

Timeline:

An 8-member CIC was established in mid-2015. DWR will continue to fill vacancies and revise membership as necessary to address expertise needs and facilitate criteria development.

3. **Reservoirs/Lakes - High Rock Lake**

North Carolina has approximately 250,000 acres of freshwater lakes and reservoirs. High Rock Lake is a 15,180-acre reservoir with a 3,974 mi^2 drainage area located on the Yadkin River (Figure 1).

Nutrient impact concerns have been documented in High Rock Lake since the mid-1970s when the EPA conducted the National Eutrophication Survey. High Rock Lake was the most eutrophic of the 16 North Carolina lakes studied. Since 2005, the DWR has been working with a Technical Advisory Committee (TAC) to develop tools to evaluate sources of nutrient loading to High Rock Lake and resulting chlorophyll-*a* concentrations. The TAC is comprised of local stakeholders and DWR staff is charged with developing the tools that will be used to develop the Nutrient Management Strategy. Table 2 provides a summary of past nutrient management efforts (Tasks 1-7) and future steps (Tasks 8-12). New tasks and their schedules will be modified based upon a stakeholder process.

Impairments: High Rock Lake is currently on NC's list of impaired or threatened waters as required under Section 303(d) of the Clean Water Act. The entire lake is impaired for chlorophyll-*a* and parts of the lake are impaired for pH and turbidity.

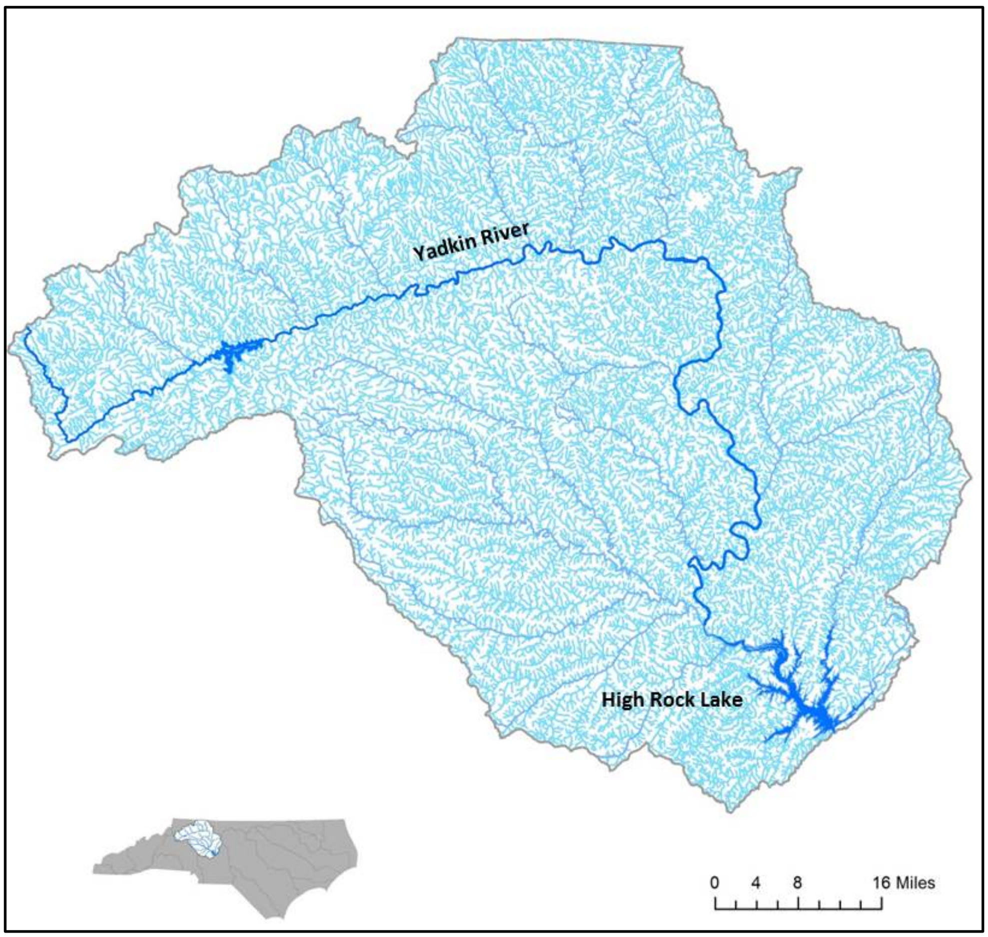

Figure 1. High Rock Lake watershed.

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Tasks and Timelines:

Table 2. Brief summary of past events and future efforts in High Rock Lake.

Task No.[1]	**Task**	**Anticipated Completion Date**
1	High Rock Lake – Impaired for chlorophyll-*a.* Ongoing eutrophication concerns led to recommendations for a nutrient management strategy for High Rock Lake (HRL) in the early 1990s. HRL was first listed as impaired for chlorophyll-*a* in 2004.	Not applicable
2	Technical Advisory Committee. The TAC was established in 2005 and continues to meet. The TAC is comprised of local stakeholders and DWR staff.	Completed 2005
3	319 Project - *Updated Land Cover.* Contract awarded to the NC Center for Geographic Information and Analysis (CGIA) to update land cover for the HRL watershed.	Completed 2007
4	319 Project - *Intensive Monitoring.* Contract awarded to Yadkin Pee Dee River Basin Association. Data collection was conducted from April 2008-April 2010. Samples were collected in the lake and watershed on a routine basis, as well as in response to high flow events in the watershed. Data were used to characterize both the lake and watershed responses to various stimuli, including seasonal weather changes.	Completed 2008
5	Intensive Monitoring Report - Final Report on intensive monitoring completed.	Completed 2009
6	HRL Watershed Model Development. The watershed model links conditions and activities on the land surface to responses in the streams and delivery to the lake.	Completed 2012
7	HRL Watershed Model Report. Final report issued August 12, 2012.	Completed 2012
8	Initiate discussions with the EPA regarding the current status of the efforts in developing nutrient criteria for HRL. These discussions will include the results and conclusions of the HRL Watershed Model Report, potential approaches for numeric nutrient criteria development, and the roles and responsibilities of the established SAC.	Completed June 2014
9	HRL Nutrient Response Model Development. TAC provides comments on HRL Nutrient Response Model The nutrient response model provides information on the responses of the receiving water body (i.e. High Rock Lake) to nutrient loading.	Completed November 2014

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Task No.[1]	Task	Anticipated Completion Date
10	HRL Nutrient Response Model Report	Completed October 2016
11	NNC development began after the nutrient response model was completed. Every other month meetings began in May 2015. Consultations with the SAC included a potential approach to be used in developing statewide nutrient criteria for lakes and reservoirs based on the modeling results.	
	a. Began consultation with the SAC — May 2015	
	b. HRL Stakeholder Meetings (All Completed):	
	1. HRL Stakeholder Mtg. 1 — January 2015	
	2. HRL Stakeholder Mtg. 2 — April 2015	
	3. HRL Stakeholder Mtg. 3 — July 2015	
	4. HRL Stakeholder Mtg. 4 — October 2015	
	5. HRL Stakeholder Mtg. 5 — January 2016	
	c. Present draft criteria to CIC	October 2019
	d. Receive CIC's comments	January 2020
	e. Present proposed NNC to WQC	March 2020
	f. Present proposed NNC to EMC	July 2020
12	Adoption of nutrient criteria for HRL per NC APA	January 2022

[1] Only tasks 11c-12 are depicted in the Gantt chart (Appendix 1).

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4. **Estuaries – Chowan River/Albemarle Sound**

North Carolina has approximately 2,130,000 acres of estuaries. The Albemarle Sound (Fig. 2) is part of the Albemarle-Pamlico Estuarine System, one of the largest and most important estuarine systems in the United States. The sound and a significant portion of its basin are within the programmatic areas of the Albemarle-Pamlico National Estuary Partnership (APNEP). As is required for all units of EPA's National Estuary Program, APNEP's activities are guided by a Comprehensive Conservation Management Plan (CCMP). One of the three goals within APNEP's 2012-2022 CCMP is "*a region where water quantity and quality maintain ecological integrity*" with one of this goal's outcomes being "*nutrients and pathogens do not harm species that depend on the waters*" as a priority for the next 18 years.

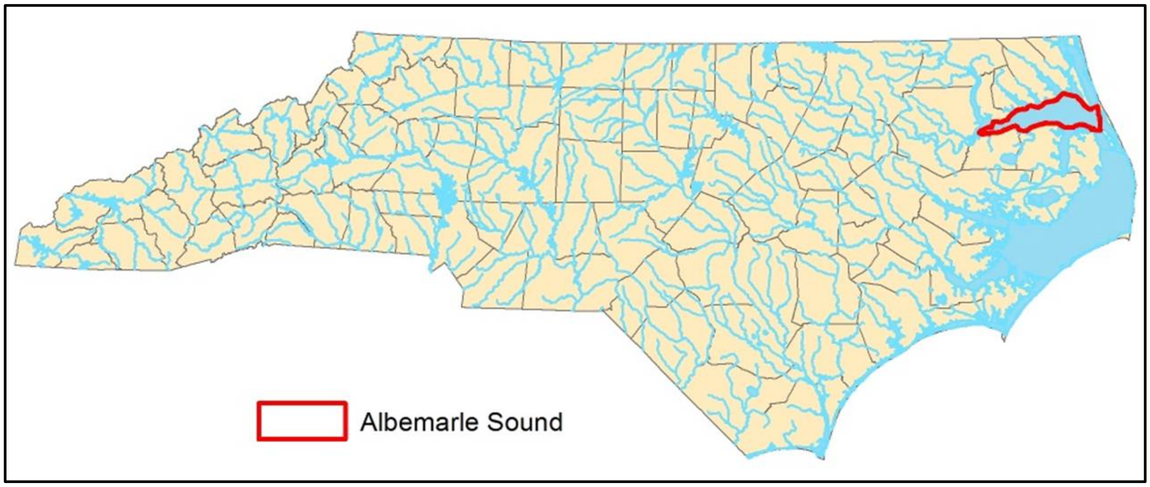

Figure 2. General location of the Albemarle Sound

Stakeholder interest is high in this area based on APNEP's work and associated activities in the region. The United States Geological Survey (USGS) has conducted monitoring projects in the Albemarle Sound and collecting a variety of environmental data, including nutrients and phytoplankton. In addition, the DWR is working with APNEP and EPA Region 4 to obtain funding for the development of nutrient criteria for the Albemarle Sound.

Data reviewed as part of APNEP's Ecosystem Assessment[3] indicated that chlorophyll-*a* concentrations, as reported by the DWR in STORET, do not show trends in the Albemarle Sound between 1980 and 2010. However, sampling data collected by the USGS during 2012 and 2013 indicate the presence of algal blooms throughout the growing season and academic researchers have noted continued increases in nutrient and chlorophyll *a* concentrations. Furthermore, episodic cyanobacteria algae blooms in the Chowan River have been regular occurrences since 2015 with some blooms producing cyanotoxins at levels that may impact human health. Local stakeholder groups, academic researchers, and local government representatives have joined together to advocate for further research in the Chowan River/Albemarle Sound in an effort to find the cause(s) of the algal blooms.

[3] APNEP. 2012. 2012 Albemarle-Pamlico Ecosystem Assessment. Albemarle-Pamlico National Estuary Partnership. www.apnep.org

Due to the high interest in the Albemarle Sound and continued algal blooms in the Chowan River, DWR will pair these two water bodies for development of numeric nutrient criteria. This will allow for a more holistic nutrient criteria development strategy for the watershed.

Impairments: Parts of the sound are impaired for pH and copper. The Chowan River is classified as a Nutrient Sensitive Waters [15A NCAC 02B .0202(49) - Nutrient sensitive waters mean those waters which are so designated in the classification schedule in order to limit the discharge of nutrients (usually nitrogen and phosphorus). They are designated by "NSW" following the water classification.].

Tasks and Timelines:

Table 3. Task list for the Chowan River/Albemarle Sound.

Task No. [1]	Task	**Anticipated Completion Date**
1	DWR initiates discussions with APNEP's Science & Technical Advisory Committee (STAC) and Policy Board regarding the Nutrient Criteria Development Plan.	Completed August 2014
2	APNEP convenes an Albemarle Sound workgroup of water quality specialists, interdisciplinary scientists, and local stakeholders to advance Albemarle Sound portions of the NCDP in support of its Comprehensive Conservation and Management Plan. Work on Task 5 begins.	Completed August 2014
3	APNEP, DWR and EPA representatives discuss the necessity and availability of additional federal resources for initial project tasks, including technical support for the Albemarle Sound workgroup, facilitation support for the SAC, and support for SAC members. (Note: external funding is crucial for progress on further NCDP development).	Completed June 2015
4	Albemarle Sound workgroup recommends focus area of study for the Albemarle Sound criteria development.	Completed October 2014
5	Albemarle Sound workgroup meets quarterly (or more often as necessary) to develop its Preliminary Phase I report. Meeting No. 1 August 2014 Meeting No. 2 October 2014 Meeting No. 3 April 2015 Meeting No. 4 November 2015 Meeting No. 5 January 2016 Meeting No. 6 March 2016 Meeting No. 7 May 2016 Meeting No. 8 July 2016 Meeting No. 9 September 2016	Completed September 2016

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Task No. [1]	Task	Anticipated Completion Date
6	Preliminary Phase I report completed. Report includes: • A bibliography and a summary of relevant findings that will inform the development of estuarine nutrient criteria in North Carolina's estuarine waters. • An analysis and summary of available water quality data for causal (N and P) and response variables (Table 1) in Albemarle Sound. The report will discuss the quality of the data available for Albemarle Sound and identify any spatial and temporal patterns. • If necessary, identification of research or monitoring needs for establishing scientifically defensible NNC. • Appropriate numeric thresholds will be reported for all variables that have scientifically defensible information supporting them, and recommendations regarding their use as NNC will be provided to DWR.	Completed January 2018
7	With consultation from the Albemarle Sound workgroup, U.S. Geological Survey completes the Albemarle Sound pilot study of the National Monitoring Network for U.S. Coastal Waters and their Tributaries. Workgroup recommendations and report will be revised, if necessary.	Completed January 2017
8	Present preliminary workgroup phase I report to the SAC and APNEP's STAC for review and comment.	Completed January 2018
9	Provide a formal status update to the EPA.	Completed February 2018
10	The Albemarle Sound workgroup adopts its final phase I report.	Completed February 2018
11	Based on final report recommendations and subject to available resources, perform additional monitoring, research and/or modeling to inform criteria development. The timeline for this step may be revised or accelerated depending on research, monitoring and/or modeling timelines proposed in the phase I report.	September 2019
12	The SAC, CIC, and DWR evaluate new monitoring, research and modeling information in addition to findings from the Phase I report. Nutrient criteria recommendations are developed and documented in a phase II report. *Upon completion of the phase II report, the SAC and CIC will have advised DWR all causal and response variables in Table 1 for use as nutrient criteria.*	April 2022

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Task No. [1]	Task	**Anticipated Completion Date**
13	Adoption of nutrient criteria for the Chowan River/Albemarle Sound per NC APA.	January 2024

[1] Only tasks 11-13 are depicted in the Gantt chart (Appendix 1).

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5. **Rivers/Streams - Central portion of Cape Fear River Basin**

North Carolina has approximately 63,000 miles of rivers and streams. The central portion of the Cape Fear River basin contains approximately 6,050 miles of rivers and streams and is defined from below the B. Everett Jordan Reservoir dam along the Haw River, and below the Randleman Lake dam along the Deep River to Lock and Dam #1 (Figure 3). This area has been identified as a priority for nutrient management since the early 2000s. This is one of the fastest growing regions of the state, and there will be a need to determine allocations for waste assimilation, assess the effects and management of nutrients discharged from point and non-point sources, and develop new drinking water sources in this region.

The central portion of the Cape Fear River has a history of high nutrients. Algal blooms and high chlorophyll-*a* concentrations occur behind Buckhorn Dam and Lock and Dams 1, 2 and 3, particularly during years with low precipitation. Nutrients have been an item of discussion within each of the three monitoring coalitions in the Cape Fear basin: the Upper Cape Fear River Basin Association, the Middle Cape Fear Basin Association and the Lower Cape Fear River Program. Additionally, the Rocky River Heritage Foundation[4,5], The Nature Conservancy, North Carolina State University and the University of North Carolina – Wilmington have expressed interest in nutrients.

Several municipalities have water supply intakes on this portion of the river. Algal blooms have increased drinking water treatment costs for the City of Wilmington; hence, there is a high level of stakeholder interest in this region. The Nature Conservancy is trying to start a process for addressing nutrients; additionally, the Middle Cape Fear Basin Association has expressed interest in working with the DWR on nutrient issues. Researchers from the University of North Carolina – Wilmington have also been studying the algal blooms and algal toxins along portions of the middle and lower Cape Fear River[6]. These events have stimulated considerable stakeholder interest regarding the effects of nutrients and nutrient management.

Impairments: Portions of the Rocky River are listed as impaired for chlorophyll-*a.*

[4] http://www.rockyriverchatham.org

[5] http://www.rockyriverchatham.org/files/RRPost_Mar3_2013-2.pdf

[6] Isaacs, J.D. et al. 2014. Microcystins and two new micropeptin cyanopeptides produced by unprecedented *Microcystis aeruginosa* blooms in North Carolina's Cape Fear River. Harmful Algae 31:82-86 http://www.sciencedirect.com/science/article/pii/S156898831300139X

Figure 3. Cape Fear River Basin. (Areas in color represent the Central portion of the Cape Fear River Basin for which nutrient criteria are proposed. L&D = Lock and Dam)

Notes: The subwatersheds in gray either have nutrient management plans (i.e., Jordan Lake and Randleman Lake) or are areas that have streams draining to the portion of the Cape Fear River downstream of Lock and Dam 1 (i.e., Lower Cape Fear). Thus, the areas in gray are not in the area designated as the Central portion of the Cape Fear River Basin. The subwatersheds in color are either listed as impaired for chlorophyll-*a,* or are of concern for nutrient over enrichment and comprise the "Central Portion of the Cape Fear River Basin."

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Tasks and Timelines:

Table 4. Task list for the central portion of the Cape Fear River Basin.

Task No.	**Task**	**Anticipated Completion Date**
1	Collect, compile, and review water quality data for causal (N and P) and response variables (Table 1). An initial review will focus on data quality, determining spatial and temporal patterns, and data gaps.	Completed December 2014
2	Present results of the data review to the SAC.	Completed January 2015
3	The SAC identifies additional data needs.	Completed March 2015
4	Additional monitoring to support modeling (January 2019 – December 2020).	December 2020
5	Nutrient response model development and report.	July 2021
6	Discuss with the EPA the results of the nutrient response model development and report.	July 2021
7	Establish stakeholder group. Quarterly meetings are planned, to begin July 2021. Nutrient criteria development with the SAC and stakeholder input. Consultation with the SAC will include the potential approach used in developing statewide rivers and streams based on the modeling results. a. Begin consultation with the SAC — July 2021 b. Present tentative NNC to SAC — June 2022 c. Present refined NNC to SAC — October 2022 d. Present proposed NNC to WQC — January 2023 e. Present proposed NNC to EMC — April 2023	April 2023
8	Adoption of nutrient criteria for the central portion of the Cape Fear River Basin per NC APA.	October 2024

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6. Activities proposed to prioritize estuaries statewide

The DWR will review any monitoring data that are available to develop priorities for nutrient criteria development. These tasks (Table 5) will be conducted concurrently with those activities in the Albemarle Sound.

Table 5. Tasks for estuaries criteria prioritization.

Task No.	Task	Anticipated Completion Date.
1	Data review and summary for estuaries. Collect, compile and review water quality data for causal (N and P) and response variables (Table 1). An initial review will focus on data quality, determining any spatial and temporal patterns and if there are any data gaps.	April 2020
2	Based upon the water quality data review estuaries will be summarized by watershed characteristics with SAC input.	October 2020
3	Present findings to the SAC.	November 2020
4	Prioritize specific estuaries for nutrient criteria and confirm approaches proposed in the Albemarle Sound nutrient criteria development process with SAC involvement.	October 2021
5	Review progress to date and make revisions to the NCDP if necessary.	November 2021
6	Develop nutrient criteria with SAC involvement using the confirmed approaches: a. Begin consultation with the SAC — November 2021 b. Present tentative NNC to SAC — January 2023 c. Present refined NNC to SAC — July 2023 d. Present proposed NNC to WQC — September 2023 e. Present proposed NNC to EMC — November 2023	November 2023
7	Adopt nutrient criteria per NC APA.	April 2025

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7. Activities proposed to prioritize reservoirs/lakes statewide

The DWR will review any monitoring data that are available to develop priorities for nutrient criteria development.

Table 6. Tasks for statewide reservoirs/lakes nutrient criteria prioritization.

Task No.	Task	Anticipated Completion Date.
1	Data review and summary for reservoirs and lakes. Collect, compile and review water quality data for causal (N and P) and response variables (Table 1). An initial review will focus on data quality, determining spatial and temporal patterns, and data gaps.	June 2023
2	Based upon the water quality data review, reservoirs and lakes will be summarized by size, morphological and other characteristics with SAC input.	December 2023
3	Present findings to the SAC.	January 2024
4	Prioritize specific reservoirs/lakes for nutrient criteria, and confirm the approaches proposed during adoption of the nutrient criteria in HRL with the SAC involvement.	December 2024
5	Review progress to date and make revisions to the NCDP if necessary.	January 2025
6	Develop nutrient criteria with the SAC's involvement using confirmed approaches: a. Begin consultation with the SAC — January 2025 b. Present tentative NNC to SAC — March 2026 c. Present refined NNC to SAC — May 2026 d. Present proposed NNC to WQC — October 2026 e. Present proposed NNC to EMC — December 2026	December 2026
7	Adoption of nutrient criteria per NC APA.	May 2028

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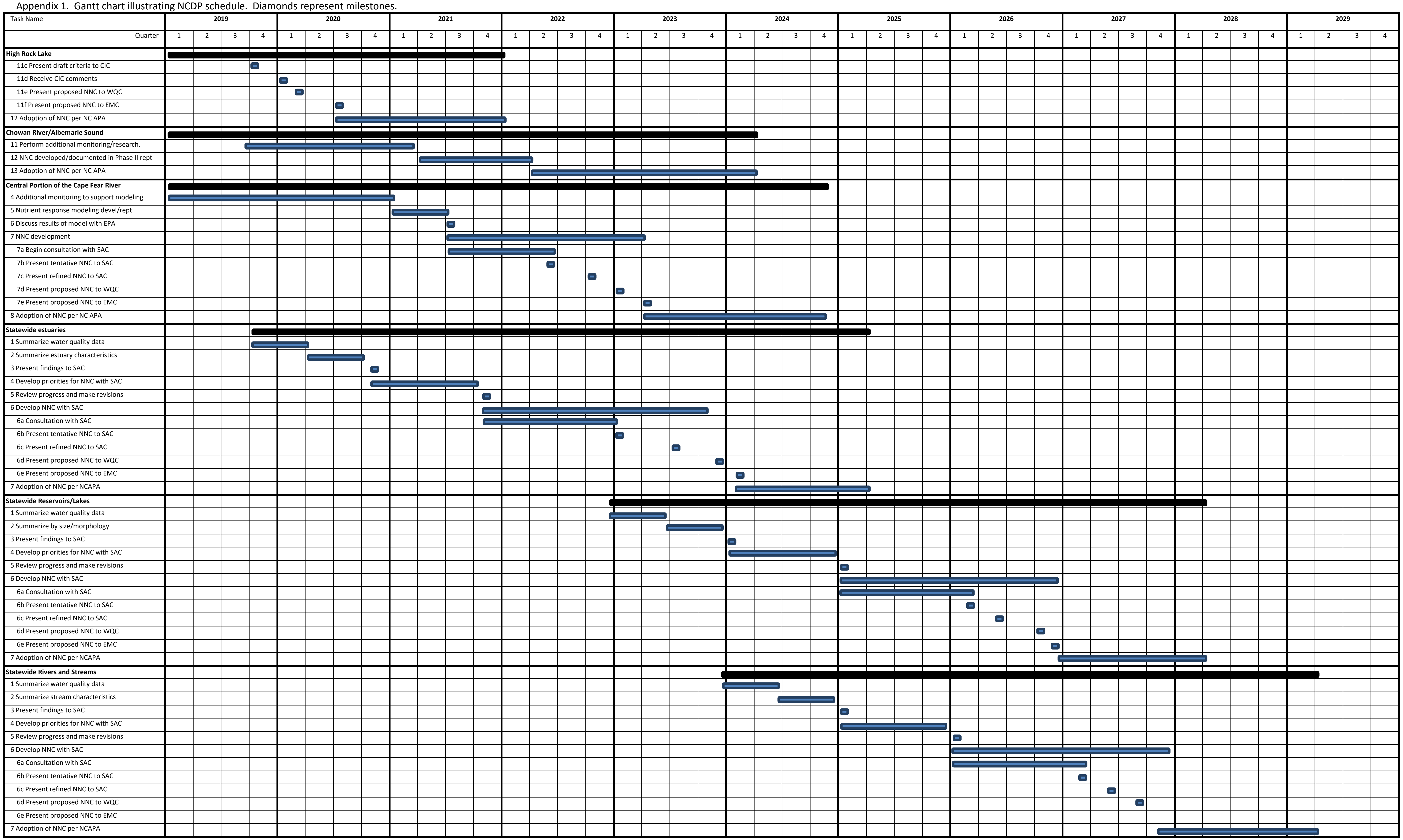
8. Activities proposed to prioritize rivers/streams statewide

The DWR will review any monitoring data that are available to develop priorities for nutrient criteria development.

Table 7. Tasks for statewide river/stream criteria prioritization.

Task No.	Task	Anticipated Completion Date.
1	Data review and summary for rivers and streams. Collect, compile and review water quality data for causal (N and P) and response variables (Table 1). An initial review will focus on data quality, determining spatial and temporal patterns, and data gaps.	June 2024
2	Based upon the water quality data review river and stream will be summarized by stream order, watershed size and other characteristics with SAC input.	December 2024
3	Present findings to the SAC.	January 2025
4	Prioritize specific rivers/streams for nutrient criteria with the SAC's involvement and confirm the approaches proposed during adoption of the nutrient criteria in the Cape Fear Basin.	December 2025
5	Review progress to date and make revisions to the NCDP if necessary.	January 2026
6	Develop nutrient criteria with the SAC involvement using the confirmed approaches: a. Begin consultation with the SAC — January 2026 b. Present tentative NNC to SAC — March 2027 c. Present refined NNC to SAC — May 2027 d. Present proposed NNC to WQC — September 2027 e. Present proposed NNC to EMC — November 2023	November 2023
7	Adoption of nutrient criteria per NC APA	June 2029

Appendix 1. Gantt chart illustrating NCDP schedule. Diamonds represent milestones.



EPA Final Cyanotoxin Criteria/Swimming Advisory

History

- Draft released December 2016
- Revisions made per public comments
- Finalized May 2019

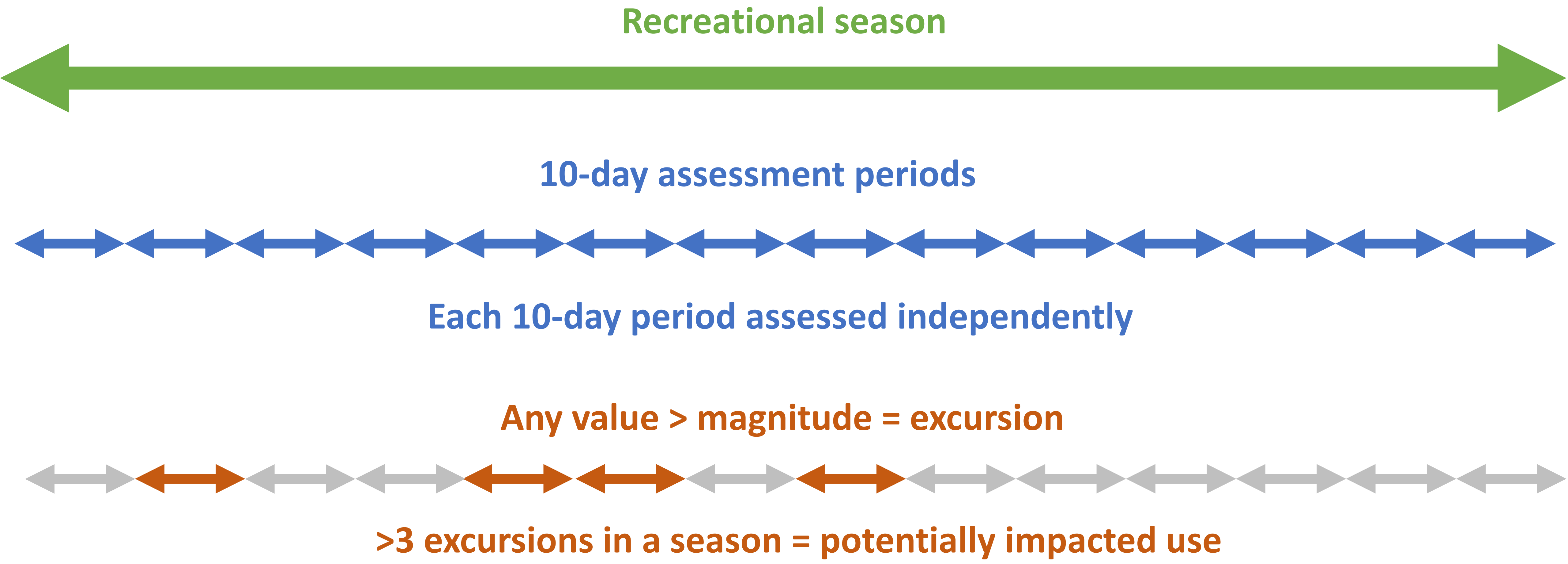
Quick summary

- Options for CWA criteria and swimming advisories (SA)
- Magnitude for microcystin and cylindrospermopsin
- Frequency and duration components for criteria & SA
- Protection for Incidental ingestion exposure (10 days, child 6 to 10)

Application	Microcystins			Cylindrospermopsin		
	Magnitude (ug/L)	Duration	Frequency	Magnitude (ug/L)	Duration	Frequency
Swimming Advisory	8	One day	Not to be exceeded	15	One day	Not to be exceeded
Recreational Ambient Water Quality Criteria		Multiple 10-day assessment periods across a recreational season	More than 3 excursions in a recreational season; not to be exceeded in more than one year in "*" years		1 in 10-day assessment period across a recreational season	More than 3 excursions in a recreational season, not to be exceeded in more than one year in "*" years

Excursion = a 10-day assessment period with any toxin concentration higher than the criteria magnitude.

The upper bound of the frequency is a risk management decision to be determined by states.



If >3 excursions/season occur more than <u>one year in "x" years, the use is impaired</u>

<u>"x" = states are to determine appropriate frequency of exceedance</u>

Application	Microcystins			Cylindrospermopsin		
	Magnitude (ug/L)	Duration	Frequency	Magnitude (ug/L)	Duration	Frequency
Swimming Advisory	8	One day	Not to be exceeded	15	One day	Not to be exceeded
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Excursion = a 10-day assessment period with any toxin concentration higher than the criteria magnitude.

The upper bound of the frequency is a risk management decision to be determined by states.

Microcystins Magnitude

$$\text{Recreational value (ug/L)} = RfD\ x\ \frac{BW}{IR}$$

Where:

RfD (ug/kg/day)	=	0.05	liver effects
BW (kg)	=	31.8	mean body weight of children 6 to 10 years
IR (L/day)	=	0.21	90^{th} percentile daily recreational water incidental ingestion rate children 6 to 10 years

Cylindrospermopsin Magnitude

Recreational value (ug/L) = $RfD \ x \frac{BW}{IR}$

Where:

RfD (ug/kg/day)	=	0.1	kidney effects
BW (kg)	=	31.8	mean body weight of children 6 to 10 years
IR (L/day)	=	0.21	90^{th} percentile daily recreational water incidental ingestion rate children 6 to 10 years

Children 6 to 10 years ingestion rate

- Draft = 0.33 L/day (11 ounces/d)
- Revised = 0.21 L/day (7 ounces/d)
- Final = 0.21 L/day (7 ounces/d)

Relative Source Contribution (RSC)

- Draft = 0.8
- Revised = no RSC
- Final = no RSC

Criteria duration & frequency

- Revised duration aligned to the drinking water HA (10-day exposure)
- Revised frequency provides flexibility to states

Estimated toxigenic cell density/toxin production (microcystin)

- Supports management of recreational waters
- Draft = toxigenic cell density of 20,000 cells/mL (4 ug/L toxin)
- Revised = toxigenic cell density of 40,000 cells/mL (8 ug/L toxin)
- Final = toxigenic cell density of 40,000 cells/mL (8 ug/L toxin)