Proceedings of the Albemarle Sound Nutrient Criteria Development Workgroup: Phase I

Prepared pursuant to the 2014 North Carolina Nutrient Criteria Development Plan

February 8, 2018

Water Resources
ENVIRONMENTAL QUALITY

Albemarle - Pamlico
National Estuary Partnership

Contents

Introduction and Executive Summary

In 2014, the state of North Carolina and the U.S. Environmental Protection Agency mutually agreed upon a plan to revisit and reevaluate the state's nutrient-related water quality criteria. North Carolina's Nutrient Criteria Development Plan (NCDP) described an approach to evaluate nutrient-related criteria in three pilot waterbodies: Albemarle Sound, High Rock Lake, and the Central Cape Fear River System. Lessons learned are intended to inform updated criteria for North Carolina's estuaries, lakes, and rivers, respectively.

Soon after the implementation of the NCDP, the Albemarle-Pamlico National Estuary Partnership (APNEP) convened an open group of scientists, interested stakeholders and agency staff to evaluate nutrient-related criteria in Albemarle Sound. The group met nine times between August 2014 and September 2016. In addition to considering all available information at its disposal, the group successfully secured resources for several targeted initiatives during its tenure.

At its final two meetings, workgroup members were invited to develop criteria proposals for parameters including pH, DO, chlorophyll-*a*, nitrogen, and phosphorus. Members were also invited to identify additional research or tasks if they determined that critical information needs remained unmet.

Efforts to generate consensus regarding appropriate nutrient criteria parameters were both rigorous and collegial, but ultimately no criteria recommendations emerged from the group. After its final meeting, workgroup members coordinated with DWR staff to prioritize additional research recommendations to further criteria development for Albemarle Sound.

In the NCDP, the pilot Albemarle Sound criteria evaluation effort was designed as a two-phase process with an intervening period for research support. Phase I has been completed since September 2016, and since that time DWR staff and workgroup members have been pursuing the research initiatives prioritized by the workgroup. Phase II criteria deliberations will be undertaken by the Scientific Advisory Council and the Criteria Implementation Committee.

Overview of Workgroup Proceedings

During its two-year tenure, the APNEP Nutrients Workgroup met nine times. Between meetings, workgroup members, agency staff, and subcontractors completed several initiatives designed to inform the criteria development process. A detailed summary of workgroup proceedings can be reviewed pursuant to the meeting notes, which are attached as appendices. Below, a summary of key events and timelines is provided.

August 2014. APNEP workgroup convenes in Kinston, NC for its first meeting. An overview of the NCDP and the group's charge was provided by APNEP staff. Attendees discussed desirable next steps.

October 2014. Workgroup members discussed appropriate ecological endpoints that should be protected by nutrient-related criteria (generally, designated uses). Workgroup members also discussed available data and desirable projects that might help the workgroup evaluate nutrient-related criteria during phase I. Workgroup members volunteered to pursue projects. The geographic scope of criteria recommendations was discussed and agreed upon.

April 2015. Project updates were provided. Projects topics included remote sensing for nutrient-related parameters, a grant proposal studying nutrient dynamics in the region (later put on hold), various analyses of historical data sets in Albemarle Sound, a literature review, and an analysis of legal and policy issues associated with nutrient-related criteria development.

November 2015. This meeting was facilitated remotely and was primarily administrative in nature. Status updates were provided on workgroup-related projects. Workgroup members volunteered to develop case studies to evaluate how other national jurisdictions have been approaching the nutrient criteria development process for estuaries.

January 2016. Representatives from the N.C. Coastal Resources Law, Planning, and Policy Center summarized their report to the group, which evaluated nutrient criteria-related litigation in the United States. Workgroup members presented their findings from the 11 estuarine criteria development efforts throughout the nation.

March 2016. Tetra Tech presented their findings regarding the classification and analysis of waters in and around Albemarle Sound with respect to their sensitivity to nutrient inputs. Differences between estuarine embayments and open sound sites were noted. DWR staff provided presentations and answered questions regarding its water quality assessment methods and its estuarine monitoring methods. The workgroup revisited the geographic area for which criteria recommendations would be considered and prioritized response criteria parameters for further evaluation.

May 2016. Workgroup members met in Edenton (on Albemarle Sound) for a series of scientific presentations regarding key aquatic species and habitats, as well as a summary of water quality studies conducted in Albemarle Sound by the U.S. Geological Survey. Limitations for developing an Albemarle Sound water quality model were also discussed.

July 2016. Relying on all prior information developed, workgroup members proposed and peer-evaluated nutrient-related response criteria proposals for pH, dissolved oxygen, clarity, TSS and turbidity. Additional research needs were identified in these areas.

September 2016. Relying on all prior information developed, workgroup members proposed and peer-evaluated nutrient-related response and causal criteria proposals for phytoplankton, cyanotoxins, chlorophyll-*a*, nitrogen, and phosphorus. Additional research needs were identified in these areas.

Supporting Materials from Phase I

The following products and reports were used to inform the criteria evaluation process during Phase I and are available for review during Phase II. At the time of this report's publication, these materials and others can also be accessed through the APNEP website at http://apnep.org/web/apnep/nutrientswkgrp.

Albemarle Sound Classification and Analysis. Tetra Tech, Inc. March 2016. This report was commissioned by the workgroup and financially supported through EPA's Nutrient Scientific Technical Exchange Partnership (NSTEPS). In this report, various monitoring stations throughout the Albemarle Sound study area were classified according to statistical similarities. Two general classes were identified: estuarine embayments and open sound sites. Various statistical and correlational analyses were then performed for nutrient-related data collected in each class. The full report may be reviewed in Appendix III.

Estuarine Criteria and Research Proposals. Phase I culminated with workgroup members proposing estuarine nutrient-related criteria and, if deemed necessary, further research initiatives. Proposals from workgroup members are available upon request from DWR staff.

Estuarine Criteria Development Case Studies. Workgroup members independently researched the criteria development process for nationally significant estuarine and marine jurisdictions. Abbreviated case studies were shared and discussed among the group. The 11 jurisdictions studied were Delaware Inland Bays, Great Bay (NH), Hawaii, Maine, Massachusetts Back Bays, Puget Sound, Rhode Island, San Francisco Bay, Chesapeake Bay, and Florida. Case studies are available upon request from DWR staff.

A Legal Analysis of Developing Numeric Nutrient Criteria in North Carolina's Estuaries. North Carolina Coastal Resources Law, Planning, and Policy Center. January 2016. This report, commissioned by the workgroup, summarizes the legal basis and relevant sources of authority pertaining to the establishment of nutrient-related criteria. A review of case law indicated that litigation on this topic is rare nationwide. The report summarizes the key issues and findings from Florida Wildlife Federation, Inc. v. Jackson, 853 F. Supp. 2d 1138. The full report may be reviewed in Appendix IV.

Literature Review. A literature review was commissioned by the workgroup and financially supported through EPA's Nutrient Scientific Technical Exchange Partnership (NSTEPS). Tetra Tech identified literature relevant to the development of nutrient criteria for estuaries in North Carolina, specifically the Albemarle Sound. Citations were provided in a digital database (EndNote), and they were organized based on several major themes including conceptual nutrient effect pathways, assessment endpoints, and methods applied to derive nutrient criteria. A version of this database is also available in Microsoft Excel. A memo describing the review in further detail can be found in Appendix V, and the database is available upon request from DWR staff.

Moorman, M.C., Kolb, K.R., Supak, Stacy, 2014, Estuarine monitoring programs in the Albemarle Sound study area, North Carolina: U.S. Geological Survey Open-File Report 2014–1110. Several USGS efforts complemented and supported the evaluation of estuarine nutrient criteria during Phase I. This 2014 report and associated supplements comprehensively characterized estuarine monitoring programs in Albemarle Sound. The report may be found online at https://pubs.usgs.gov/of/2014/1110/.

Moorman, M.C., Fitzgerald, S.A., Gurley, L.N., Rhoni-Aref, Ahmed, and Loftin, K.A., 2017, Water quality and bed sediment quality in the Albemarle Sound, North Carolina, 2012–14: U.S. Geological Survey Open-File Report 2016–1171. This report, published in 2016, evaluated USGS data collected on several nutrient-

related parameters between 2012-2014, including cyanotoxins. The report may be found online at https://pubs.er.usgs.gov/publication/ofr20161171.

North Carolina Water Resources: Utilizing NASA Earth Observations to Monitor Harmful Algal Blooms in the Albemarle Sound of North Carolina. National Aeronautics and Space Administration. April 2015. Upon request by the workgroup, a team with the NASA DEVELOP Program evaluated the feasibility of using remote sensing images to monitor algal blooms in Albemarle Sound. MODIS satellite color imagery was paired with historical water quality information. For this project, a poor correlation was found between the two data sets, indicating that further work would be required to utilize satellite imagery to inform or supplement existing water quality monitoring efforts. The full report may be reviewed in Appendix VI.

Prioritized Research Recommendations from Phase I

The process of developing and evaluating estuarine nutrient-related criteria helped identify data gaps that, if filled, may be helpful to the criteria evaluation process. Individual workgroup members independently identified 18 potential research projects that, if completed, may better inform Phase II proceedings. Several research proposals overlapped considerably, and they ranged in scope from relatively minor agency support requests to multi-year research endeavors.

After the final workgroup meeting, all workgroup members were provided with a list of the research proposals and a method for ranking them. Each member was invited to rank the proposals in priority order and to describe whether each proposal was necessary to support nutrient criteria development.

The summarized proposals below were deemed "necessary" by at least half of the workgroup respondents and they also ranked relatively well. A full list of ranked proposals is provided in Appendix VII. A status update is also provided as of the publication date of this report.

Proposal: Develop a clarity optical model. Submerged aquatic vegetation (SAV) in Albemarle Sound is an important fish habitat but can be degraded when conditions are light-limited. An optical model can help differentiate the cause of light limitation, which can include nutrient inputs (algal cover) but also dissolved organic matter or sediment. Several workgroup members expressed an interest in clarity criteria, with the development of an optical model being integral to that effort.

Status: In a change from past monitoring protocols, TSS data is now being collected in Albemarle Sound, which will assist with the calibration of an optical model for the area. DWR staff has contacted academic researchers with expertise in this field, but to date this project is not actively under development.

Proposal: Bioassays. The purpose of proposed bioassay studies is to determine which nutrients are controlling (limiting) algal growth, especially during periods favorable for algal bloom formation.

Status: A grant proposal was submitted in 2017 but not funded.

Proposal: Quantify and evaluate historical SAV coverage. Workgroup members indicated an interest in reviewing as much historical SAV coverage information as possible. Interest was also expressed in delineating locations that potentially support SAV based on other physical and chemical characteristics.

Status: APNEP has mapped SAV coverage from 2006-2008 coverage and will soon finalize 2012-2014 coverage. The Division of Marine Fisheries also retains historical SAV information for permitting purposes and has documented SAV during various habitat surveys. DWR staff is aware of external interest to perform potential habitat analysis of the type described but is not aware of a concrete project underway.

Proposal: Mapping the seasonal distribution of oxygen-sensitive estuarine fish species. Surveys from the Division of Marine Fisheries contain a wealth of information that can be used to ensure oxygen criteria are sufficient to protect fish species of all developmental levels. Conversely, it may also demonstrate where enhanced DO criteria might be best applied on a seasonal basis

Status: Upon further review by DWR staff, a great deal of this work has been performed by NOAA to prepare for oil spill responses. Some oxygen-sensitive species were omitted from the analysis and may be of interest.

Proposal: Continue sampling for algal toxins. Additional data was sought regarding the presence of algal toxins, which would be used to further examine its empirical relationship with chlorophyll-*a*.

Status: Additional algal toxin data is presently being collected in Albemarle Sound by independent researchers.

Proposal: Summarize historical clarity data. An evaluation of historical clarity data could provide reference condition information for this parameter, and estimates of historical monitoring intensity by all involved agencies (DWR, DMF, USGS and others) may help hone duration, frequency, and spatial extent recommendations for a clarity criterion.

Status: DWR has a large repository of clarity data from its monitoring program. This data has been reviewed preliminarily by staff. Some quality assurance concerns were identified.

Next Steps

Further review of nutrient-related criteria for Albemarle Sound will be conducted by the Scientific Advisory Committee and the Criteria Implementation Committee. Members serving with these groups are encouraged to familiarize themselves with the proceedings of the Phase I effort. If additional information or research is sought, SAC and CIC members are encouraged to raise these issues in subsequent meetings and/or discuss their interests with DWR staff.

Appendix I: Workgroup contributors

The APNEP Nutrients Workgroup was convened with no formal membership requirements, and all were invited to participate during this process. Whether as observers, subject matter experts or routine contributors to the workgroup, the following individuals and organizations participated in Phase I of the Albemarle Sound nutrient criteria development effort. Their effort, expertise and perspective are gratefully acknowledged.

Marcelo Ardon, East Carolina University
Tom Augspurger, U.S. Fish and Wildlife Service
Vince Bacalan, U.S. Environmental Protection Agency
Clifton Bell, Brown & Caldwell
Pam Behm, N.C. Division of Water Resources
Connie Brower, N.C. Division of Water Resources
David Carpenter, Albemarle-Pamlico National Estuary Partnership (APNEP)
Dean Carpenter, Albemarle-Pamlico National Estuary Partnership
Anne Coan, North Carolina Farm Bureau
Maya Cough-Schultze, N.C. Division of Water Resources
Sarah Collins, N.C. League of Municipalities
Greg Cope, North Carolina State University
Anna Cornelius, U.S. Environmental Protection Agency
Tiffany Crawford, U.S. Environmental Protection Agency
Bill Crowell, Albemarle-Pamlico National Estuary Partnership
Matthew Davis, Albemarle-Pamlico National Estuary Partnership
Nora Deamer, N.C. Division of Water Resources
Anne Deaton, N.C. Division of Marine Fisheries
Heather Deck, Pamlico-Tar River Foundation (Sound Rivers)
Marie English, Albemarle-Pamlico National Estuary Partnership
Rhonda Evans, U.S. Environmental Protection Agency
Stacey Feken, Albemarle-Pamlico National Estuary Partnership
Elizabeth Fensin, N.C. Division of Water Resources
Sharon Fitzgerald, U.S. Geological Survey
Laura Gurley, U.S. Geological Survey
Jim Hawhee, APNEP and N.C. Division of Water Resources
Coley Hughes, Albemarle-Pamlico National Estuary Partnership
Darryl Keith, U.S. Environmental Protection Agency
Jud Kenworthy, National Oceanic and Atmospheric Administration-retired
Marygrace Knight, Albemarle-Pamlico National Estuary Partnership
Steve Kroeger, N.C. Division of Water Resources
Keith Larick, North Carolina Farm Bureau
Martin Lebo, AquAeTer
Jing Lin, N.C. Division of Water Resources
Sarah Ludwig, Pamlico-Tar River Foundation (Sound Rivers)
Jamie McNees, N.C. Division of Water Resources
Cam McNutt, N.C. Division of Water Resources

Sid Mitra, East Carolina University
Michelle Moorman, U.S. Geological Survey and U.S. Fish and Wildlife Service
Sandy Mort, N.C. Department of Health and Human Services
Tyler O'Hara, N.C. Coastal Resources Law, Planning, and Policy Center
Nathan Owen, National Aeronautics and Space Administration
Hans Paerl, University of North Carolina-Chapel Hill
Heather Patt, N.C. Division of Water Resources
Mike Paul, Tetra Tech
Lauren Petter, U.S. Environmental Protection Agency
Mike Piehler, University of North Carolina-Chapel Hill
Jason Poe, U.S. Environmental Protection Agency
Brian Pointer, N.C. Division of Water Resources
Dianne Reid, N.C. Division of Water Resources
Amy Ringwood, University of North Carolina, Charlotte
Carrie Ruhlman, N.C. Division of Water Resources
Lisa Schiavinato, N.C. Coastal Resources Law, Planning, and Policy Center
Jen Schmitz, N.C. Division of Water Resources
Astrid Schnetzer, North Carolina State University
David Springer, Greenville Utilities Commission
Tim Spruill, U.S. Geological Survey-retired
Kathy Stecker, N.C. Division of Water Resources
Chris Ventaloro, N.C. Division of Water Resources
Hilde Zenil, East Carolina University

Appendix II: Workgroup minutes

APNEP Contaminants Management Workgroup Meeting Notes

August 5, 2014

Kinston-Lenoir Public Library
510 Queen Street, Kinston, NC

Attendees: Bill Crowell, APNEP; Anne Coan, NCFB; Matthew Davis, NCSU/APNEP; Jim Hawhee, APNEP; Dean Carpenter, APNEP; Sarah Collins, NCLM; Steve Kroeger, NCDWR; Michelle Moorman, USGS; Sid Mitra, ECU; Mike Piehler, UNC; Tom Augspurger, USFWS; Kathy Stecker, NCDWR; Dianne Reid, NCDWR; Heather Deck, PTRF; Sarah Ludwig, Duke/PTRF.

Jim Hawhee called the meeting to order at 10:07 AM. Jim asked each attendee to introduce themselves, their agencies, and what they are interested in hearing from the meeting.

Bill Crowell provided a presentation to describe APNEP's mission, history, workgroup structure, granting process and the CCMP.

Dean Carpenter presented an overview of the workgroup's CCMP actions and described the development of management and environmental indicators. These actions are linked to the goals and outcomes detailed in the CCMP.

- There are 58 CCMP actions that are aggregated into five components (Identify, Protect, Restore, Engage, and Monitor).
- APNEP's Ecosystem-Based Management (EBM) transition team consists of representatives from the APNEP Policy Board, APNEP Science and Technical Advisory Committee, Citizens Advisory Committee, state and federal representatives, EBM technology transfer consultants, and staff.
- Four of the CCMP actions are designated for the Contaminants Management workgroup (A2.4, A2.5, C1.1, and C1.2). All of the actions are described in the APNEP CCMP.
- The Implementation Committee has not been formed, but will be created pursuant to APNEP's most recent executive order. STAC members will be assigned to each workgroup for technical support.

Jim Hawhee presented an overview of North Carolina's estuarine nutrient criteria.

- Jim described the history of estuarine nutrient criteria for our state estuaries, approaches for setting criteria, and tasks and timelines for the workgroups.
- The nutrient criteria development plan was mutually agreed upon between DENR and the U.S. EPA, with APNEP taking a supporting role for development of estuarine nutrient criteria in Albemarle Sound.
- Diane Reid noted that "Numeric Nutrient Criteria" is defined in the Nutrient Criteria Development Plan. Jim agreed to change the definition in the presentation to that in the NCDP.
- Question: What is the implementation committee supposed to do?
- Answer: The implementation committee is to guide implementation of plans and actions within the CCMP. If a workgroup needs the implementation committee to fund items, then the workgroup would go to the implementation committee to ask for funding.

The group broke for lunch 12:05 PM and reconvened at 1:21 PM for discussion.

Jim provided some ground rules for discussion and sought input regarding additional rules.

Input was sought regarding the four CCMP actions assigned to the workgroup, aside from the nutrient criteria process. Jim asked which attendees were primarily interested in working with pharmaceuticals and metals. Sid Metra and Tom Augspurger expressed an interest in these topics, and Dean Carpenter agreed to facilitate a discussion to frame next steps for these two related actions (A2.4, A2.5). With the exception of estuarine nutrient criteria, further discussion regarding actions C1.1 and C1.2 was tabled.

Jim sought input regarding other people who might serve on the workgroup. He also noted the absence of workgroup members from the Albemarle Sound area and sought support from the workgroup in recruiting these members. Recommendations given were:

- Keith Larick- NCDA&CS
- Greg Cope, NCSU for toxicology and risk assessment advising.
- David Spring, Greenville Utilities for nutrient implications impacting WWTP.
- Bob Christian. Dean noted his participation on another workgroup.
- Carl Crozier, NCSU
- Deanna Osmond, NCSU
- Diane Hardison, Domtar
- Martin Lebo, Weyerhaeuser
- Ana Zivanovic-Nenadovic, NCCF

Discussion turned toward approaching the nutrient criteria for Albemarle Sound. Jim asked the group what types of resources they might be able to provide, and resources they might seek. Attendees noted that this might be premature, as identification of the uses and ecosystem attributes to be protected through nutrient criteria had not yet been discussed. Other items of note included:

- There may be biosolids risk assessment documents from employees in DENR. Also, there are several soil scientists from NCSU that have the ability to provide insight into biosolid nutrient impacts.
- It was agreed by several attendees that it would be helpful to determine what data is available now for the Albemarle Sound, and what data is not available. The creation of a general Excel parameter table of where known data was measured, why it was measured and how long it was measured was recommended by several attendees. (Chlorophyll, DO, Turbidity, TSS, SAV etc…) We may be able to create preliminary tables from the USGS datasets.
- There are regional models and models for the Albemarle Sound that the USGS may have. If necessary, we should adapt the model that already exists and modify it. What questions do we hope to answer with the models? We may not have enough data to complete model simulations for future events.
- Regression analyses with current data may be useful for correlating nutrient inputs and resulting environmental changes.
- Several members offered to provide publications and data sources to assess changes (if any).
- It can be difficult to reference nutrient levels without knowing residence times (Jim's note- residence time for water in Albemarle Sound is approximately 45 days.)

- Depending on the workload, it appears it may be necessary for a contractor, graduate student or some other source to assist in assimilating relevant data for this project.
- It was suggested that the workgroup should focus on a smaller set of promising nutrient criteria further in-depth, rather than assessing each causal and response variable individually. Chlorophyll a and turbidity were suggested as promising candidates.
- How important is phosphorus in controlling primary production? There are some organisms that can fix their own nitrogen but bloom with excess phosphorus.
- General consensus appeared to suggest support for the water body use designations in and around Albemarle Sound (SB, primarily). Differentiation in these uses primarily relates to bacteria and pathogen issues rather than nutrient inputs.

An in-person meeting was recommended in approximately two months (October).

Support for file sharing and a listserv was requested, which Jim agreed to investigate.

The Contaminants Management Workgroup Meeting concluded at 2:59PM

APNEP Contaminants Management Workgroup Meeting Notes

October 21, 2014

Library, USGS NC Water Science Center

3916 Sunset Ridge Rd

Raleigh, NC 27607

Attendees: Tom Augspurger, USFWS; Tim Spruill, USGS (retired); Martin Lebo, Weyerhaeuser Co.; Anne Coan, Farm Bureau; Sharon Fitzgerald, USGS; Laura Gurley, USGS; Sarah Collins, NCLM; Steve Kroeger, NCDWR; Kathy Stecker, NCDWR; Michelle Moorman, USGS; Marie English, APNEP; Dean Carpenter, APNEP; Jim Hawhee, APNEP

On phone: Hans Pearl, UNC IMS; Sid Mitra, ECU; Rhonda Evans, US EPA; Lauren Petter, US EPA; Anna Cornelius, US EPA; Greg Cope, NCSU; Darryl Keith, US EPA; Bill Crowell, APNEP

Jim Hawhee called the meeting to order at 10:07

Chad Wagner of USGS gave an introduction to organizational changes at USGS.

Starting Oct.1 the North Carolina, South Carolina and Georgia water science centers merged in order to do science across watersheds without the confines of state boundaries. This merging is being done across the US. The Albemarle-Pamlico has had quite a bit of collaborative science over the past 20-30 yrs.

Jim asked each attendee to introduce themselves and their agencies.

Jim described the Google Drive folders and provided an overview of APNEP's forming Implementation Committee. He noted the opportunity for a member of the Contaminants Workgroup to serve on this committee and asked if there was interest in serving. No one volunteered.

Tom Augspurger presented an overview of risk assessments and their use for metals in sediments and contaminants of emerging concern. Tom distributed a 1-page memo to support his presentation, which can be found on Google Drive. Points noted during the presentation include:

- The group needs to make decisions on when and at what pace to tackle risk assessment tasks.
- The job of a risk assessment is to put together information to answer a specific question.
- The first step is problem formulation and applying this to the contaminants group. The group needs to define an assessment endpoint.
- The second step is analysis, which involves an exposure assessment and effects assessment.
- For APNEP action A 2.5, important questions to be answered include endpoint, geography, timescale, and effects of interest to the workgroup.
- Scientists can provide a menu of study options; managers need to decide what they want from a risk assessment.
- There are currently no sediment metal standards.
- In recent literature, dissolved metals are being connected to harmful algal blooms.
- There was discussion about previous studies found on the information memo.
- The Hyland paper is a risk assessment and the estuarine work was included in the US EPA National Coastal Condition Assessment. This 2012 data may be available by phone call.

- The USGS samples collected in 2012 in the Albemarle are more current and more resolved than the EPA data.
- There was an inquiry regarding opportunities to influence EPA's 2015 sampling plans. Rhonda noted that if the state has an interest, EPA may be able to do this but 2015 is a quick turn around and strong support from the state is needed.
- Tim asked what are the baselines when they are looking at toxicity effects? Tom answered that they look for correlations between biodiversity scores and concentrations. Tim noted the difference between making comparisons with regional average biodiversity scores vs. changes in scores over time.
- Martin brought up the effects of hurricanes on sediment and subsequent contaminant fluxes and questioned if this had been studied.
- Dean noted that for the A2.4 and A 2.5 actions (metals and contaminants of emerging concern (CECs) the group is not restricted to the Albemarle Sound.

Sid Mitra discussed the preliminary findings of local research on CECs. Sid also distributed a 1-page memo to support his presentation, which can be found on Google Drive. Points noted during the presentation include:

- In terms of risk assessment, we are at the same place as metals but further back in the trajectory because there are so many unknowns about how to effectively manage this broad group of chemicals. Septic tanks and the level of wastewater treatment give various magnitudes of input with effects ranging from no effects to community level impairment.
- North Carolina is a state where we rely on a lot of septic systems so CECs have the potential to be quite a concern in NC coastal systems.
- Only a couple of states have attempted to study CECs and they are listed on the A2.4 handout. The approaches varied with some stopping at monitoring and others conducting risk assessments based on literature reviews.
- The first step in North Carolina is to determine levels of CECs. Studies have been done on CEC levels in tributaries and sediments but no studies in the estuary proper. Not knowing the levels means we don't have an idea of which compounds to target yet.

Tom asked if the group wants to go forward with conducting risk assessments in our sounds.

Dean said APNEP's mission primarily concerns ecological health, with human health as a secondary concern. The technical community could make a proposal on the problem formulation and then present it to the Policy Board as a preliminary step to a risk assessment. There may also be an opportunity to interact with the policy and economics workgroup on these assessments.

Anne mentioned that we might not be far enough along for a risk assessment and that a trend analysis might be the place to start.

Tom recommended meeting with the Policy Board to show them the work that EPA and USGS are currently doing and ask what it is they want to have done for our system. This would give a sense of if it is better to focus on things where NC is data poor like organic contaminants.

Sharon noted USGS's capabilities of doing these analyses with appropriate funding.

Dean asked that while Tom and Sid took on the initial steps for the workgroup, if others are interested, they are welcome to contribute. Whether to break the working group into specific subgroups was discussed. Is it best to break off into two sub-groups or as Michelle mentioned, there are impacts from both so is it better to coordinate nutrients with metals and CECs? Jim noted some concerns with APNEP having the resources to staff two groups.

Jim discussed building up the community of interest on CECs and metals, doing some problem scoping through the winter months and touching base via telephone.

Sid asked if we should tell others that we are doing a risk assessment or what should we set forth as the objective? Rhonda said that this has been an issue in other National Estuary Programs (NEPs) and one helpful step in this process might be to do a quick survey of NEPs and see how they have addressed it. She offered to help with this.

Sid said that using CCMP actions as a focus point might be a good place to start and then refine them as gaps in data are discovered.

Tom said that a briefing should be put together for the policy board on what has been done and where there are gaps.

Michelle mentioned that Hyland has a Roanoke River site with long-term toxicity data on benthic invertebrates that includes tissue sample data.

Dean commented that Hyland and Balthis are both on the resources monitoring assessment team so they might be able to provide some insight and would be willing to help.

Martin said that as we go toward a briefing it is important to get a sense of relevance. What is nice to know information vs. relevant? What can you learn from what has already been done?

Tim brought up the fact that standards are very difficult to come up with because you have to understand all of the processes. It could be worthwhile to see what other states have done to look for practical approaches.

Tom also posed the question of whether data should be site specific or if it is better to come up with a number that is generally harmful to benthic community?

Michelle introduced the NOAA SQuiRTs (Screening Quick Reference Tables) which synthesize a lot of data on contaminants. It is a helpful resource for starting this process because it has identified some priority contaminants.

Jim asked if anyone else would like to be looped in on the CEC calls. Michelle and Sharon would like to be included.

Break for lunch at 11:33 PM. Reconvene at 12:30 PM.

Michelle passed around copies of the NOAA SQuiRT tables.

Jim laid out the goals for the afternoon on nutrient criteria as discussing environmental endpoints for nutrient criteria development, reviewing a list of potential tasks, introducing relevant projects and setting the boundary for the Albemarle Sound pilot study area.

Jim asked what things do we want to protect, what are our endpoints?

Kathy suggested using the current designations based on specific uses. There is the option to protect the most sensitive and thereby protect all uses. Tim suggested searching for examples of “healthy estuaries.” Are there efforts where they identified characteristics for particular purposes? How do you want the system to be functioning? Are there dead zones? Is there an intermediate part of what is healthy where everyone agrees? Anne agreed that we should start with designated uses because this is why criteria are being developed.

Michelle mentioned NOAA’s National Estuarine Eutrophication

Assessment (NEEA) report which has several methods of assessment for estuaries around the world and it provides a score for each estuary. SPARROW modeling data feeds into the NEEA assessment. North Carolina's sounds were rated unknown based on insufficient data. She offered to send this paper around.

Tim said that this seemed like a good way to go because if something is judged as healthy then it should be supportive of most uses. A general health report is a good place to start but it does not answer the question of what you are managing for.

Kathy said North Carolina currently has chlorophyll-a standards for everything but trout waters. Is chlorophyll-a adequately protective or do we need other variables that would be more appropriate?

Jim reminded the group of the scope of the workgroup's purview through the NCDP. The group should identify what constitutes sufficiently protective nutrient criteria rather than determining an optimal level of nutrient inputs. The group should facilitate the best recommendations and develop good information to make these decisions. APNEP is concerned with a broader suite of approaches beyond regulatory tools for estuarine protection and restoration, but for the purposes of criteria development the scope of the workgroup's charge is narrower and its approach should align with regulatory processes.

Martin suggested having a biological health context beyond just a nutrient number and said other states do this. If you optimize to protect grasses, you reduce nutrient levels which can reduce the food base so you have to keep in mind that you are managing for multiple objectives. Anne also mentioned the importance of being able to adjust for naturally occurring sources like phosphate mines.

Jim asked about managing to protect against algal blooms. While discussions indicated that eliminating all blooms might not be the best approach, the group agreed that large and frequent blooms are a problem and an endpoint to be concerned with in the nutrient criteria development process.

Kathy reminded everyone that the standards are not concerned only with fish and that all trophic levels of aquatic life including primary producers are included. Martin asked about researching species assemblages and commented that this should be considered.

Tim asked if we are interested in the concentration of certain parameters or the nutrient loads because focusing on all tributaries that are loading could be another approach. Martin identified criteria and concentration as what we are looking at while nutrient load is the cause/problem.

Tim said the only way to control something is through loading and it is necessary to work back up the watershed in order to maintain concentrations.

Michelle said we have estimates of loads coming in from tributaries and lands adjacent to estuaries but there are a lot of missing sources.

Sarah mentioned that nutrient criteria should not go too far up the watershed and reminded the group of its charge to evaluate estuarine waters using Albemarle Sound as a pilot. Other groups are working on riverine standards.

Jim reminded the group that setting criteria is the primary focus of the workgroup and setting strategies to reduce nutrients comes later if it is necessary.

Kathy read the definition of biological integrity from the red book and said that finding a balance that is least impacted is important and that it must be similar to reference conditions.

Tim asked about setting reference conditions. Jim said that reference conditions are one approach to setting criteria. It was then asked whether setting criteria that are protective for aquatic life uses is sufficiently protective regarding other uses because aquatic life are typically the most sensitive to nutrient inputs.

Lauren suggested using maintenance of biological integrity as a starting point because it narrows the focus. Some states use a weight of evidence approach. Depending on scope, different parts of an estuary might have different things that should be protected.

Martin brought up the importance of how the criteria are to be averaged. The averaging period is as important as the number. Kathy mentioned how the current criteria being written as "not to exceed" is confusing and that people need to understand more about magnitude, duration and frequency.

Jim asked if there were any other endpoints the group is interested in examining other than: fish kills, anoxia, submerged aquatic vegetation or drinking water. It was noted that Albemarle Sound is not a current source of drinking water. Tim mentioned influence of turbidity on Albemarle.

Jim moved on to a discussion of the proposed task list for the Albemarle Sound. The idea is to work in two phases. Tasks 1,2, and almost 3 have been completed. Today we want to accomplish task 4 (workgroup recommends focus area of study for the Albemarle sound criteria development). There are no deliverables between now and Nov. 2015 except for routine meetings, but the final phase I report is due in March 2016. In the plan we committed to evaluate both causal and response variables. What is a good indicator and what are the reasonable thresholds? Are there comments on the approach outlined in the plan?

Jim asked where investigatory resources should be focused in phase I. One approach is to spend equal time and resources vetting all proposed indicators in the Nutrient Criteria Development Plan. Alternatively, some discussion at the last meeting indicated that the group might prefer to invest more time and resources examining select indicators based on expert knowledge. After some discussion, the group agreed that a broad review of all proposed indicators was the preferred approach, which aligns with the approach outlined in the Albemarle Sound section of the Nutrient Criteria Development Plan.

It was clarified that the "numeric thresholds" reported in the phase I report for November 2015 can potentially be a range and something can be refined later based on additional research. The workgroup is not proposing the final nutrient criteria but is instead recommending criteria to DWR.

Tim reminded the group of the EPA research in the 1970s that was based on 20 years of good research. He indicated that looking at these ecoregional numbers might be the cheapest, most effective way to evaluate criteria.

Martin said that phase one should end with revised information on the next steps to take. By the end of phase I you should know what you want to do for phase II. The report has to be written carefully so numbers are not lifted and misused.

Jim provided an overview of several potential projects that would begin to help the group gather relevant information for consideration in the nutrient criteria development process.

Michelle explained a few of the proposed projects that related to USGS.

- The Albemarle Sound pilot project she is working on is part of the National Monitoring Network for U.S. Coastal Waters and their Tributaries. In the early 2000s a plan was developed to integratively monitor our coastal waters. This provided money for a 4-year demonstration

project in the Albemarle Sound to be completed in September 2015. On the website there is a report of all of the monitoring activities currently underway around Albemarle Sound. This effort provides a ready source of information to examine historical monitoring data to facilitate the nutrient criteria development.

- The NASA DEVELOP program has a project underway to examine the spatial extent of HABs in the Albemarle using remote sensing data. NASA is providing in-kind support for this project. There have already been toxic blooms reported in embayments in the Albemarle Sound.
- Grant with ECU: Through this grant there are some data sets that were previously inaccessible that are now being added to STORET.
- A proposal is underway by several partners in the workgroup to the NOAA ECOHAB program to examine processes and sources driving HABs in the Albemarle Sound for three years. This grant has stiff competition, but if not funded by NOAA the proposal may be suitable for other opportunities.
- Historic data was collected and reported by Duke students who developed an ArcGIS toolbox using STORET data from the state to look at data spatially and temporally. The R script can be adapted for use on this project. The project was completed in March 2014 with USGS as a client and the report is available online.

Kathy asked if the statewide trend analysis for 2000-2012 could be shared on Google drive. Jim indicated that he would add it.

Jim said to let him know if there are any analyses the group would like to see that would help inform decisions on nutrient criteria development.

There is a broader discussion about EEP, DWR, USGS, and APNEP developing a SPARROW model to inform N and P inputs into the sounds because the current ones are dated. SPARROW is not a tool for modeling nutrient criteria per se but can serve as a screening tool to determine areas of potentially high nutrient inputs. Funding prospects for the project are uncertain.

Kathy led a brief discussion on modeling and purposes. SPARROW models will give relative contributions of loading from different areas. Other models in other parts of the state are deterministic models to represent the system and then run scenarios to see if a target can be met.

Michelle passed around a fact sheet on SPARROW.

Jim suggested going through phase I without sophisticated modeling and then determining the necessity of further modeling as part of the phase I report.

Jim noted that literature reviews tailored for this workgroup's purposes would be useful and several have been done across the country. Jim proposed seeking a tailored effort for this workgroup's purposes that might be done through EPA's NSTEPS (Nutrient Scientific Technical Exchange Partnership and Support) process.

Jim also expressed interest in a legal and policy analysis, specifically analyzing case studies regarding estuarine criteria development. This might be good for Duke students to study various cases and report back in Feb. or March of 2016. It can help identify best practices while also identifying the legal and practical challenges that criteria development efforts have encountered.

Hans asked about the most effective mechanism for pulling together papers that are applicable to this work like Martin Lebo's paper on the Neuse, Bob Christian's work and Don Stanley's work. Tim also asked who is

doing the lit review. Jim answered that graduate students or the contractors available through the NSTEPS program are the best options for the literature reviews depending on resources and availability.

Jim asked if there were any objections to moving forward with these initiatives as described. There were no objections.

Jim introduced boundary options for the study area. Setting boundaries for the Albemarle Sound effort is one of the tasks delineated in the NCDP. These included various jurisdictional approaches like the study area, ranging in scope roughly from all of North Carolina's estuarine waters north and east of Roanoke Island to the smaller SB designated use boundary for Albemarle Sound. Many members of the workgroup preferred to use a broader study area for the purposes of nutrient criteria study during phase I of the report and coalesced around the area being examined by the USGS Albemarle Sound monitoring study.

Anne and Sarah suggested keeping the boundary to a narrow interpretation of the Albemarle Sound without going too far south or too far north into the Currituck Sound. Reviewers of the NCDP are on notice that criteria will be developed for an area commonly understood as Albemarle Sound.

Jim asked if the workgroup could move forward with a compromise position where the scope of study for the phase I reports included the broader USGS boundaries, but with the understanding that criteria recommendations from the workgroup should be limited to the SB designated use boundary around Albemarle Sound. No objections were made to this proposal.

Jim reminded members of an opportunity to serve on APNEP's implementation committee but there are no volunteers at this time.

The meeting concluded at 3:05 pm.

APNEP Contaminants Workgroup Meeting Notes

April 23, 2015

1:00pm

Via WebEx

Members Present: Anna Cornelius (EPA), Anne Coan (NCFB), Clifton Bell (Brown and Caldwell), David Springer (Greenville Utilities Commission), Jing Lin (DWR), Keith Larick (NCFB), Lauren Petter (EPA), Marty Lebo (AquAeTer), Nathan Owen (NASA), Rhonda Evans (EPA), Sandy Mort (DHHS), Sara Collins (NCLM), Sharon Fitzgerald (USGS), Steve Kroeger (DWR), Tim Spruill, Tom Augspurger (USFWS), Amy Ringwood (UNCC), Jim Hawhee (APNEP), Dean Carpenter (APNEP)

Welcome and Introductions: Jim Hawhee

Jim Hawhee convened the meeting and asked workgroup members to introduce themselves.

Jim noted that it has been six months since group has fully met. However, the Metals & Emerging Contaminants subgroup has met several times via telephone in the interim.

Workgroup Logistics: Jim Hawhee

Jim Hawhee noted the challenges in convening the workgroup given a divergence between nutrient-related and other contaminant-related initiatives. He also noted that many workgroup members seemed to have a primary interest in one topic or the other. He asked whether the group would be amenable to a split. No objections were made, with support indicated by Sara Collins, Anne Coan, and Amy Ringwood.

Jim Hawhee stated that, based on no objections, he will take steps to separate the workgroups and provide APNEP support for each.

Nutrient Criteria Plan Development Update: Steve Kroeger

Steve Kroeger noted that over last few months the Science Advisory Council (SAC) identified in the Nutrient Criteria Development Plan (NCDP) has been formed. The first meeting will be held in Raleigh, North Carolina on May 6 from 9:00am-3:00pm. Steve also informed the group that the Criteria Implementation Committee (CIC) nominations had been forwarded. Workgroup members that would like to remain informed about these proceedings were asked to send Steve an email to be added to the email distribution list. The High Rock Lake technical advisory committee (TAC) also planned to meet on April 29 from 1:00-4:00.

Jim Hawhee reminded the group that APNEP is working on the Albemarle Sound as one of the three pilot areas delineated in the N.C. Nutrient Criteria Development Plan. The other two pilot areas are High Rock Lake and the Cape Fear River.

NASA DEVELOP Project Summary and Findings: Nathan Owen

Nathan Owen presented a PowerPoint Presentation to the workgroup about the NASA Applied Sciences' DEVELOP National Program. He discussed the nine application areas for the program which includes agriculture, climate disasters, ecological forecasting, energy, health and air quality, oceans, water resources, and weather. He also discussed the dual-capacity building which accommodates both participants and end-user organizations. The APNEP project is a water resources project that consists of a five-person team who

has since dispersed. The project began as a USGS project with Michelle Moorman and APNEP joined later as a partner. The project sought to evaluate the use of remote sensing data to detect and measure chlorophyll a in Albemarle Sound as a proxy for algae. Nathan spoke about the MODIS sensor on the AQUA satellite as well as in situ water quality data. He then went on to describe the project methodology. SeaDAS was found to be generally is poor at sensing in shallow areas. He also noted that the algorithm used delivered poor correlation to water quality samples collected in the field (R^2 value = 0.0196). Nathan concluded by stating the benefits of the research which was that MODIS provides a larger picture, which could mean improvement of the algorithm. Nathan's interests for future work include DEVELOP partnering with other organizations to explore beta-test approaches for a 10-week project.

Anne Coan asked what the time-lapse video of MODIS data was in regards to what is depicted. Nathan Owen confirmed that MODIS is vastly overestimating Chlorophyll a.

Tim Spruill asked if there are any publications or summaries of this project. Nathan Owen informed Tim that a report will be available next week. Jim indicated he would share these with the group once they became available.

Jim Hawhee thanked Nathan on his nice first attempt. Nathan Owen mentioned that he is working with APNEP on a new wetland project as well.

Project Update: NOAA ECOHAB Proposal: Jim Hawhee

Jim Hawhee informed the group of the proposal status in regards to the opportunity to study nutrient bloom dynamics. Due to comments on the pre-proposal, workgroup members declined to submit a full proposal. For now the proposal is on hold.

Project Update: Analysis of Historical Data Sets: Sharon Fitzgerald

Sharon Fitzgerald is taking over the USGS Albemarle Sound monitoring study until its completion this year, as Michelle Moorman accepted a position with the U.S. Fish and Wildlife Service. In this study they repeatedly sampled 23 constituents at eight representative sites in 2013 and 2014. They also conducted a small quality assurance study.

Jim Hawhee asked that Sharon please talk about time frame of historical data analysis. Sharon replied that the data analysis time frame is only between 2012 and 2014. Jim Hawhee expressed that the need for historical data is important to support the reference method and indicated he would work with DWR to conduct these analyses.

Anne Coan asked about Sharon's use of the term "exceedance" for some nutrient-related parameters. Sharon stated these were derived from NOAA guidelines and are not exceedances as defined by the Division of Water Resources. Anne Coan noted that North Carolina does not have TP, TN standards.

Clifton Bell asked whether the study measured cyanobacteria biomass or count and whether or not it makes a difference. Sharon mentioned the World Health Organization guidelines for cyanobacteria.

Amy Ringwood asked if there was any empirical ability to measure toxins. Sharon replied that some calculations were made based on algal species' theoretical ability to provide toxins and but actual toxin measures were generally low during the study period.

The issue of the study boundary arose. Jim Hawhee reminded the group of its decision in the past meeting that, as a pilot effort, recommendations would be for the Albemarle Sound SB boundary. However, a broader area may be examined in the meantime to inform these recommendations.

Project Update: Correlational Statistics, NSTEPS Proposal: Jim Hawhee

Jim Hawhee worked with Steve Kroeger on the proposal and reviewers submitted positive feedback. Jim asked if there were any general impressions on the proposal.

Anne Coan expressed her concern in regards to the timeline as the September 30 deadline in the NCDP appears to leave a short time frame for completion. Lauren Petter pointed out that the EPA already has in-house contractors. It was also noted that the deadline has some flexibility and was set for planning purposes.

Jing Lin brought up that there is no table of parameters included. Lauren Petter stated that the response parameters are noted in the NCDP. The causal parameters are TN and TP.

Steve Kroeger suggested using the term “algal blooms” rather than “harmful algal blooms” unless demonstrated otherwise.

Jin Ling suggested that the literature review project (discussed below) might precede the data analysis project.

Anne Coan asked if there was EPA Region funding available. Lauren Petter answered that the sooner the proposal is in the queue, the better chance it is to get annual allocation.

Marty Lebo asked if the data analysis will expand beyond TN and TP to specific parameters such as total vs. particulate vs. dissolved. He suggested that to get at causality, you need to go beyond total measures. Sharon stated particulate vs. dissolved is a necessity. Steve Kroeger said that we don’t presently measure dissolved phosphorus. Marty Lebo: P just total? Steve Kroeger: Correct, just TP on a monthly basis.

Tim Spruill brought up that the state measures turbidity. Steve Kroeger confirmed that DWR measures turbidity. He brought up the issue with assuming biological response with additional nutrients, when it really depends on light-limitation. He also suggested that turbidity and secchi depth should be included in the analysis. Sharon asked if there was any evidence that the Albemarle-Pamlico estuary has ever been light limited. Tim Spruill suggested that major storms could cause light limitation. Thinking more upstream, in a watershed you may not impair water at the point but it’s added to the load downstream. Jing Lin agreed with Tim’s point. This is important for algal blooms as well as SAV. Marty Lebo stated that in Albemarle Sound, the light limitation concerns are not for algae but for SAV. Including turbidity and secchi depth is fine but this will make interpretation more challenging.

Amy Ringwood asked if diurnal highs and low had been collected. Steve Kroeger said data loggers will be used.

Project Update: Literature Review: Jim Hawhee

Jim Hawhee reported that the proposal was well received by the EPA. He opened the floor for feedback on whether the literature review should come before the analysis. Anne Coan suggested the literature review be in advance and Tim Spruill agreed. However, Steve Kroeger added that general causal relationships have been known for years. Anne Coan noted that there is not so much literature for the SE estuaries. Marty Lebo stated that both data sources are necessary and there is value in proceeding with both simultaneously. Steve Kroeger noted that the data provided are relatively clean. Jim Hawhee reported that currently funds are

available for both efforts. Anne Coan suggested that it may require a second round of analysis for filling data gaps and there could be a need for additional funding.

Jing Lin asked, assuming both projects move forward together, if it would be possible to extend the time period of correlational analysis to ensure exchange. Lauren suggested it's better to go forward with projects then apply for subsequent analysis.

After this discussion, the group ultimately agreed to continue moving forward with both literature review and data review projects concurrently.

Project Update: Legal/Policy Analysis: Jim Hawhee

Jim Hawhee updated the group that the proposal was put through to get Duke MEM student interest but there has been no luck. He spoke with Lisa Schiavinato on the possibility for her team to work on this topic this summer. Tim Spruill expressed his support for the initiative.

Jim Hawhee suggested it might be helpful to review work by other jurisdictions and Sharon Fitzgerald recommended the environmental law program. Lisa Schiavinato expressed her willingness to assist, said she will be discussing details with Jim Hawhee.

Anne Coan asked when to expect to hear about EPA proposals? Lauren stated there is no defined date from submission. Jim Hawhee stated he anticipates submitting by next week.

Jim noted that this was the conclusion of the nutrients portion of the agenda and gave people interested in these initiatives a few moments to disconnect from the call.

Metals and EC Initiatives

Metals and Emerging Contaminants Updates: Jim Hawhee

Jim Hawhee provided a recap of work on these initiatives to date. Tom Augspurger and Sid Mitra provided one-page summaries on metals and emerging contaminants, respectively. The subgroup has a couple of conference calls (mid-December and early March). Feedback: (1) good idea to follow-up with general literature review and synthesize a data analysis based on prior work. Also, field studies could help fill gaps. Jim asked for comments as to how the group might move forward and noted that APNEP had approximately $20,000 budgeted to support these efforts.

Jim Hawhee expressed interest in consolidating what we know and the field plan.

Tom Augspurger inquired about geographic areas of interests, contaminants of interest, time frame, and contaminant trends and other biota. Up from mouth, personal care products have generally not been evaluated.

Rhonda Evans suggested that the team might develop a white paper. Other National Estuary Programs (NEPs) have taken this course. Rhonda offered to research papers from other NEPs.

Anne Coan noted that there are over twenty municipalities on the Chowan River that do land applications of wastewater biosolids rather than discharge into waters. This began when Chowan started having issues in 1980s.

Sandy Moore stated that fish tissue analysis from estuaries is scarce and asked what the value of fish tissue data is in regards to human health. She also states that the NC Division of Public Health generally relies on freshwater fish consumption advisories.

Tom Augspurger inquired as to whether there are resources for mining databases to inform chemical use to make a list of compounds of concern? Potentially.

Anne Coan noted the Agricultural Health Study conducted in Iowa and NC and said there have been follow-up studies since data collection began around 12 years ago. Agricultural data and pesticide use data are difficult to derive from sales data.

Summary of Feedback Regarding Next Steps: Jim Hawhee

Jim Hawhee expressed interest in supporting a white paper to come up with a game plan. He noted that there is $20,000 available from APNEP to assist.

Rhonda Evans explained the upcoming Coastal Condition Assessment as a way to potentially collect additional field data in this area. However, at this time it appears unlikely that APNEP can supplement the effort or adjust monitoring protocols. Dean Carpenter noted that APNEP staff has requested these protocols for months.

Anne Coan explained that USGS NAWQA has been collecting contaminant data since 1991.

Tom Augspurger remarked that NOAA no longer has a regular survey. Chesapeake Bay Program contaminant of concern might be instructive. Look at toxics inventory by Toxics Release Inventory Program in the Albemarle-Pamlico estuarine system. He suggested taking $20K to display historical data in geospatially explicit form to help understand current coverages and identify a priority list of chemicals to study.

Jim agreed to work with the group to begin developing a scope of work for a synthesis of contaminants data.

Public Comments

There were no public comments.

Adjourn

The meeting adjourned at 4pm.

APNEP Nutrients Workgroup Notes

November 10, 2015

WebEx Meeting
10:00am-11:30am

Meeting Attendees: Jim Hawhee (DWR), Steve Kroeger (DWR), Jing Lin (DWR), Anne Coan (NCFB), Clifton Bell (Brown & Caldwell), Keith Larick (NCFB), Lauren Petter (EPA), Marty Lebo (AquAeTer), Rhonda Evans (EPA), Sharon Fitzgerald (USGS), Tim Spruill (USGS-retired), Jamie McNees (DWR)

Introductions

Jim Hawhee convened the meeting and welcomed everyone who joined via WebEx. He updated the workgroup on his position change from APNEP to DWR. Presently, he plans to continue facilitating the workgroup through Phase I of the Albemarle Sound portion of the N.C. Nutrient Criteria Development Plan (NCDP).

Summary of progress to date

Jim provided an update to the group regarding progress to date for the workgroup and for projects informing the development of Albemarle Sound nutrient criteria. A series of maps were reviewed, including maps indicating designated uses, salinity, and monitoring stations. Jim briefly reviewed potential nutrient impacts for the Albemarle Sound. He noted the importance of protecting its designated uses: fishable and swimmable, as well as aesthetic and toxic concerns. He also noted the presence of a bloom in the Chowan River this summer (distinguished from Albemarle Sound but draining to it) dominated by Anabaena and Microcystis. Microcystin toxins were also identified.

2016 timeline discussion

Jim showed a timeline for the NCDP in terms of Albemarle Sound Phase I. He reminded everyone that there was an original commitment to quarterly meetings and the hope was to have Phase I completed by March 2016. Steady progress has been made but phase I will likely extend until summer 2016. Jim noted that all workgroup projects are scheduled to conclude by December.

Jim showed another timeline for Phase II for Albemarle Sound in the NCDP. He noted that there are roughly two years reserved for future data acquisition or analysis if necessary, then in phase II the group would make final recommendations. Jim also reminded the group that in his new position, he doesn't presently have plans to lead the workgroup beyond Phase I.

Jim then mentioned EPA's three generally recognized nutrient criteria development approaches (reference condition, stressor-response, and modeling). Jim stated that the initial focus for Phase I recommendations would likely be based on reference condition or stressor-response approaches, as no model for Albemarle Sound presently exists.
Jim discussed the status of various projects underway to inform the workgroup. They were as follows:

NASA DEVELOP Project. Complete but inconclusive results. He said that although using remote sensing for Chlorophyll-*a* monitoring was interesting, nothing definitive could be determined from this approach because it correlated poorly with *in situ* monitoring.

USGS Albemarle Sound Initiatives. Jim noted that these projects are nearly complete and the Duke MEM project analysis on nutrient variables can be found on the Google Drive Share Site. Sharon added that the Currituck Sound project is in final review and the Albemarle Sound project is in data review that will go for approval soon. She also shared that the Currituck report should be out by the end of the month and Albemarle report might be out by the end of next month.

Jim asked Sharon if they will be finished by the end of the year. She could not say definitively but had high hopes the reports will be concluded before the proposed data workshop in February (based on the draft 2016 timeline sent prior to the meeting, which was adjusted during the meeting).

Literature Review. Jim informed the group that the literature review for Tetra Tech is complete. Jim said he went through and created a text document for each keyword. Mike Paul provided an Excel Spreadsheet that is searchable. This will be sent out after the meeting.

Data Review and Analysis. Jim stated that the second NSTEPS project is underway and that they have some preliminary results. The project is scheduled to conclude in December. He continued saying that there would be a couple months between the release of the report and the data workshop, where DWR staff can potentially assist in providing additional information if there are remaining data gaps.

Nutrient Criteria Law and Policy Review. Jim stated that this project is nearly complete and that he sent edits to the policy fellow at Sea Grant yesterday. He explained that the case study findings were a helpful starting point for future investigation. The project also provides an overview of national litigation relating to nutrient criteria development, primarily in Florida.
Jim then opened the floor for questions.

Anne expressed concern about the usability of the literature review. She stated that she was able to find titles of studies but not information on what the study accomplished. She also explained that there was a fee associated with accessing the articles online. Jim noted that due

to copyright considerations full access couldn't be provided, but that those with access might provide hard copies of specific citations if used as the basis for criteria.

Anne and Sharon both mentioned difficulties accessing the literature review. Jim suggested she try again using the Excel database, which will be sent out after the meeting.

Assignment of case study reviews for January meeting: Jim Hawhee

Jim then discussed the proposed timeline (sent to the group before the meeting) that consists of three workshops. Jim suggested each person adopt a case study and provide a written analysis and verbal presentation about the study to the rest of the workgroup. These overviews and presentations would not be discussed until the January meeting which gives the workgroup two months to complete the task. Things to highlight in the analysis might include likes and dislikes about the process and what local stakeholders thought. It would be a chance to highlight or strike out case studies and synthesize the information.

Jim continued on to the February data review meeting. He mentioned a presentation from Mike Paul might be helpful regarding analysis on parameters in Albemarle Sound. The Tetra Tech data report would be reviewed, and potentially other data from DWR if necessary.

Jim concluded with discussing the March meeting. He would like to see the group have the final meeting in Edenton to adopt a proposal or negotiate a compromise. He would like to see a draft Phase I report summarizing proceedings and recommendations in April for workgroup and NCDP Scientific Advisory Committee comment. The goal would be to finalize in May or June and DWR would then decide whether to take it to the rule making process.

Jim then asked for comments on the draft approach for concluding Phase I.

Anne thought proposing criteria by March was ambitious. She suggested looking at the High Rock Lake model and noted the utility of modeling for criteria development. She also expressed concern that the Albemarle Sound recommendations could potentially go to rulemaking rather than being solely used to inform statewide estuarine criteria development.

Jim responded that we don't have an Albemarle Sound model at this time and that Phase I was designed to provide recommendations (for criteria or further investigation) with the information we presently have. Modeling is one of three nutrient criteria development approaches that has been approved by EPA. However, a conclusion by the group that presently available information is insufficient to propose criteria at the end of Phase I is a reasonable possibility. With regard to rulemaking, he mentioned that recommendations would be provided to the department, but further review would likely take place before rulemaking commenced.

Sharon Fitzgerald inquired whether EPA would accept North Carolina's proposal. Jim noted that EPA is represented on the workgroup and can note concerns if warranted.

Lauren also noted that after the Tetra Tech report and USGS report it's worth seeing what data is available and determining whether it is sufficient to support criteria. She noted the utility of causal criteria in the permitting process.

Marty thought the goals for the January and February meetings were reasonable but was concerned that coming up with a recommendation in March was ambitious.

Keith reminded the group that the NCDP EPA signed off on is projecting criteria being set by 2019. He agreed that March seems ambitious, that there is still plenty of time left.

Jim responded noted the difference between adopting estuarine criteria and concluding Phase I. Phase I does not need to conclude with criteria recommendations, but could. Jim asked if there were objections to slowing down the decision making process for phase I. There were none.

Sharon Fitzgerald asked Jim when he would be stepping away. Jim noted that in his new role he has new duties but will try to facilitate through the end of Phase I.

Anne mentioned the January case study review and asked for more details on the responsibilities of the workgroup members. Jim asked workgroup members to volunteer to complete an approximately 2-page case study review. Anne noted that the holidays were coming up, which might pose a problem for some of the members.

Jim then showed a preliminary template using Hawaii's nutrient criteria as an example of the case study process. Clifton informed the group that he had worked in Hawaii on nutrient criteria and that is has since become problematic. The group had some preliminary discussion on the topic, and Jim noted that this is the purpose of the January meetings.

Anne suggested that instead of each member doing a case study, experts from various jurisdictions can discuss their experiences. Sharon also supported that suggestion.

Jim said links could be provided for presentations made in Florida and Chesapeake Bay. He agreed that it would helpful to hear from locals but it might also be helpful to have findings on paper. He asked the group if he should arrange speakers for the upcoming meetings.

Tim noted he would like to hear perspectives from the people involved in the workgroup.

Jim then suggested each person contact jurisdictional experts and then follow up with a presentation on what was discussed.

Marty noted he was hesitant to condense too much information into short summaries for discussion. We may need more than 1 meeting for case studies.

Clifton Bell added that in the James River Estuary in Virginia they were linking chlorophyll-*a* to harmful algal blooms. Jim agreed that the Virginia case study should be reviewed.

Anne asked if you had to support the case study you choose. Jim said no endorsement is implied. This process is to educate everyone on alternate criteria development approaches.

Jim then attempted to combine some of the considerations voiced by the workgroup to construct a final plan for the meetings. He suggested that the group take on case studies and prepare three to four page summaries for the January meeting, arrange speakers for the February meeting to further explore discussion points via WebEx, and push the data review to March. Then the group would discuss future steps at the March meeting.

There were no objections to this proposal among the workgroup.

Jim showed a list of examples of case studies and asked people to volunteer for a case study they would be interested in. Assignments were as follows:

- Clifton Bell, Brown and Caldwell: Chesapeake Bay/James River Estuary
- Lauren Petter, EPA: Florida
- Tim Spruill, USGS retired: Delaware Inland Bays, Chesapeake Bay
- Marty Lebo, AquAeTer: Massachusetts Back Bays and Great Bay (NH)
- Marygrace Knight, APNEP: Puget Sound
- Jim Hawhee, DWR: Hawaii and California

Anne asked if Jim could provide a template for the case study write-ups. Jim said he would do that.

Marty inquired about what questions to ask investigators and what questions need to be answered about the cases. Jim suggested that the workgroup members decide what information they would like to hear from the case studies and to let him know. Jim said he would send out a draft template for review by the group.

Anne asked when the meeting will be held in January. Jim stated it would be held later in the month but that he would send out a Doodle poll later with specific dates.

Conclusion

Jim informed the group that he would be sending out a follow-up soon. Anne asked if Jim could send the PowerPoint presentation to the workgroup. Jim said he would do that after the meeting. Jim asked for people to speak their names if they were present on the phone and did not contribute to the conversation. No one responded.

The meeting adjourned at 11:30am.

APNEP Nutrients Workgroup Meeting Notes

January 27, 2016

Attendees

Dean Carpenter, APNEP; Marygrace Knight, APNEP; Coley Hughes, APNEP; David Carpenter, APNEP; Lisa Schiavinato, N.C. Coastal Resources Law, Planning, and Policy Center; Tyler O'Hara, N.C. Coastal Resources Law, Planning, and Policy Center; Steve Kroeger, DWR; Jim Hawhee, DWR; Carrie Ruhlman, DWR; Jen Schmitz, DWR; Jing Lin, DWR; Keith Larick, N.C. Farm Bureau; Anne Coan, N.C. Farm Bureau; Rhonda Evans, USEPA; Clifton Bell, Brown and Caldwell; Tim Spruill; Martin Lebo, AquAeTer; Sharon Fitzgerald, USGS; Hans Paerl (remote), UNC Chapel Hill

Proceedings

Welcome, introduction and announcements

Jim Hawhee gives general introduction and opening and asked workgroup members to introduce themselves. He provided a recap of the current status of nutrient criteria development in North Carolina, including the three pilot areas: High Rock Lake, Middle Cape Fear River, and Albemarle Sound. Also, two advisory bodies the state have convened: the Scientific Advisory Committee (SAC) and the Criteria Implementation Committee (CIC). Therefore, some parties may be involved in one or more of each of these tracks concurrently.

Jim asked for comments or changes to last meeting's minutes. No objections were raised, so those minutes were approved. Moving on to this meeting, the James River Estuary was added to today's case study load, in addition to the others prepared for the meeting.

Steve Kroeger and Carrie Ruhlman provided an update on the SAC and CIC. As part of the Nutrient Criteria Development Plan (NCDP) with EPA, the SAC was formed to recommend scientifically sound criteria for NC waters. This year's SAC schedule depends on APNEP's involvement and production of data for SAC. The SAC is presently focused on evaluating High Rock Lake criteria. The SAC was briefed in December as to the progress of the APNEP Nutrients Workgroup (Albemarle Sound) and asked to participate as they see fit, but can work more closely if needed. Group members noted that they would need feedback from the SAC once criteria are recommended, so regular updates would be warranted.

The CIC has convened but is still evaluating its role in the criteria development process.

Relevant project updates were also shared among the group. Sharon Fitzgerald discussed the status of two USGS projects in the area. Currituck Sound monitoring is ongoing in anticipation of the Mid-Currituck bridge, with baseline water and sediment data being collected according to a four-year sampling plan. Also, the four-year project funded to monitor Albemarle Sound and assess baseline conditions of Albemarle Sound and its tributaries is concluding

Jim Hawhee also discussed the status of the data analysis project underway by Tetra Tech on behalf of the workgroup. That document is nearing publication. Preliminary findings suggest Albemarle Sound is ecologically distinct from other waters in the region, including Currituck, Roanoke, and Croatan Sounds. This supports the development of site-specific nutrient criteria for Albemarle Sound. Additionally, the law and policy analysis project is complete, with Tyler attending to present their conclusions.

Legal Overview of National Nutrient Criteria Development Efforts – Tyler O'Hara

Tyler O'Hara, a UNC law student working with the N.C. Coastal Resources Law, Planning, and Policy Center provided an overview of national nutrient criteria development litigation. To date, litigation at this stage appears to be rare, with a single major case involving the state of Florida. Tyler provided an overview of the Clean Water Act as it relates to criteria and then a procedural history of the case in Florida (Florida Wildlife Federation v. Jackson, 853 F. Supp. 2d 1138). Ultimately, site specific estuarine criteria were adopted throughout Florida utilizing a patchwork of methods (note: methods are well described in both the submitted NCCRLPP report and in the Florida case study document). Tyler discussed the application of the "arbitrary and capricious" standard in this case, notably the finding by the court that a failure to show a *harmful* change in flora and fauna as a basis for criteria was arbitrary and capricious.

Case Studies

(Case studies are on the shared Google Drive account. Efforts to recap them here are brief.)

Delaware Inland Bays– Tim Spruill

DE started with the 1998 requirement to establish standards. They were initially suggested by the Chesapeake Bay group, based on nitrogen and phosphorus. DE engaged in a TMDL analysis to try to attain those standards, which turned out to be extremely difficult; therefore, they still have not attained those standards today. The DE inland bay is significantly smaller than Albemarle Sound, only 7 feet deep across the Bay. Originally this ecosystem was thought to be very healthy; however, now dominated by algae without healthy oxygen levels and minimal aquatic life. Existing nutrient criteria were adopted from 1980/90's Chesapeake Bay studies. (DIN = 0.14 mg/L, DIP= 0.01mg/L). These criteria appear stringent and are frequently exceeded.

New Hampshire Case Study – Martin Lebo

New Hampshire analyzed data across the Great Bay system to attempt to predict appropriate levels of nutrients for the sustained health and protection of seagrass and benthos. In 2009 they proposed criteria based on this analysis with the input and review from EPA scientists. In 2013, these were re-evaluated and these criteria were not adopted. Simple regressions and relationships were evaluated, and nutrient levels were established that were different than the initial criteria, so they were retracted. Marty believes that the complicated ecological processes in an estuarine environment create opportunistic communities, which were not considered adequately in the regressions and analyses. Therefore, it is difficult to establish a clear linkage between nutrients and responses; this lack of proven cause/effect was the main question posed by the peer-review and the reason why they felt the criteria did not answer that question sufficiently.

Hawaii Case Study – Jim Hawhee

Hawaii's criteria and thresholds are very stringent and complicated, with geometric means and percent exceedances. Surprised to find that a little less than half of the marine waters on Hawaii are impaired for nutrients. Overall, the development of these criteria is very cryptic and unknown. Several UH researchers and private consultants came up with them in the 1970's. General perception, even among regulators, is that the criteria appear to be too stringent but it's unclear how to change them effectively (limited resources, EPA anti-degradation concerns, etc.).

Maine Case Study – Sharon Fitzgerald

Maine was slated to establish criteria by the end of 2015, but the deadline was missed and will continue to be missed for quite some time. The modeler is doing dilution modeling, which analyzes how much dilution is

required to meet a standard, which is an interesting approach. Sharon believes they are locked in a cycle of being unable to adequately model the impact of the criteria without first establishing them, but unable to establish without more data. Ultimately, the lack of data will be detrimental to establishing NNC. A rolling permit process will help bring in additional data points (RPA – Regional Potential Analysis).

Massachusetts Case Study – Martin Lebo

Process to address 89 estuaries. 2000 pilot estuaries, Data intensive, monitoring intensive, modeling intensive. TMDL done for each estuary. Coastal communities, stormwater runoff, salt marshes are nutrient sources. Each segment was modeled to determine nutrient responses. Modeling allowed evaluation of responses to modifications in loading to the system. Strong community engagement during the process from the beginning. Also notable for the early policy decision related to each estuary, as classifications relate to various desired trophic states. Modeling is an ongoing process, with a certain number of segments modeled per year.

12:00 – Break.

12:25 – Reconvene.

Puget Sound Case Study - Marygrace Knight and Jim Hawhee

Numeric criteria exist for DO and turbidity, as well as narrative criteria for aesthetics. Dissolved oxygen and turbidity have criteria based on a percent increase above background, implemented on a point-by-point basis. Washington's Nutrient Control Plan doesn't offer further marine system recommendations (most recommendations already implemented in prior years), but the Puget Sound DO study found human influences were reducing DO more than allowable under rule. Findings were based on statistical models rather than direct measurements. Nutrient TMDLs under consideration to address DO violations. This is a data rich system with sophisticated models, but DO is really the driver of nutrient controls. Not much discussion of HABs, though they can wash in from the ocean. DO issues are driven by salinity gradients and ocean nutrient imports as much as human influences. WWTP limits are 25 NTUs for turbidity. It was noted that limits are measured instantaneously, so even one violation over a 10-year period influences allocations.

Rhode Island Case Study – Jing Lin

Numeric nutrient criteria are presently being evaluated and are not in effect. Narragansett Bay is split between RI and MA. It is deeper than Albemarle Sound, with deepest points in the channel mouth. Very important fish and shellfish industries in the area. A majority of the nitrogen input is from wastewater. They have water quality standards for many endpoints, including aquatic life. What is interesting is that most of the biological conditions were evaluated using narrative criteria, by comparing the difference between reference or expected conditions and those found at a specific site.

The bay is not impaired for low pH, but is impaired for low DO. Narragansett Bay long-term studies have shown that climate (particularly increase in temps) have played a role in the delineation and extent of hypoxia in the Bay, due to 1) stronger stratification and 2) changes in phytoplankton assemblages. This is a complicating factor when looking at the trends in DO in the bay. A study in 2015 found that a 15% reduction in Total N in wastewater is improving water quality now. DO seems to be driven by physical factors as well as nutrients (stratification, etc.). Narragansett Bay was noted as a good example of the role of climate change can play in the establishment of nutrient criteria. Recent studies show that the thresholds are changing significantly with increased water temperatures and subsequent physical changes in the water column.

San Francisco Bay Case Study – Jim Hawhee

About $850,000-$1million per year from WWTP permits funds research and development related to nutrient criteria. Chose to go with a narrative response to parameters, including 4 criteria. These criteria are being developed using a very collaborative, scientifically rigorous approach; however, they still are not being implemented or adopted from a regulatory standpoint. It seems as if they are not interested in adopting NNC by themselves, but rather use them as a translation tool. Process to evaluate the suitability of various response parameters was notable. Top down pressures were notable in this system, including algal predation by invasive clams. Also, in contrast to Albemarle Sound, San Francisco Bay is a well-flushed system, with constant exchange with the ocean.

Chesapeake Bay Case Study – Clifton Bell

EPA likely considers this the flagship system for nutrient criteria development and it is one of the best-funded programs in the world. Extremely robust modeling framework. Most are numeric criteria, but chlorophyll-a is narrative. No N or P criteria. Though chlorophyll-a is an indicator of many other parameters, the committee did not feel bay-wide criteria would work for this system; however, it was recommended that numeric chlorophyll-a criteria be developed for areas where algae are a problem. The group discussed various modeling scenarios, including the "John Smith" predevelopment scenario as related to nutrient criteria, which indicates some potential hypoxia during those times. Distinctions between Chesapeake Bay chlorophyll recommendations and state-adopted criteria were noted. Some work has been done correlating aerial data with nutrients and chlorophyll. APNEP provide a comparative overview of its seagrass monitoring efforts. An aerial census is conducted every 5 years, with smaller stations sampled annually.

James River Case Study – Clifton Bell

The James River is an area in the Chesapeake Bay watershed where a site-specific chlorophyll-a criterion has been developed. Results of analyses were used to define defensible ranges of chlorophyll-a. High chlorophyll peak, 80-100, microcystins known to occur, mahogany tide/dinoflagellate blooms in more saline areas. 10-23 (seasonal average) was set as standard in 2005. 2010 EPA had a new baywide model which showed additional $1 billion in costs to achieve goal. In light of that potential investment, calibration of the model in the James River and more rigorous linkages were sought. Research scheduled for completion in 2016. Includes new monitoring efforts, enhanced modeling of chlorophyll a/algal density, and laboratory studies. *Microcystis* and *Cochlodinium* are among the genera of interest.

Florida Case Study – Rhonda Evans

Rhonda provided an additional overview of Florida's nutrient criteria development process, which was also covered somewhat in Tyler's presentation. The full list of standards is available online. There is also a link to the webpage at the end of the presentation. Seagrass recovery efforts were the main driver for criteria development in Tampa Bay, while other estuaries had criteria set based on a reference condition approach.

Wrap-up and Discussion

Jim informs the group that additional information from South Carolina/ Georgia may be relevant, which was posted to the Drive account. He requested that the group review all of the case study documents online. Based on prior discussions, the group indicated an interest in hearing from external experts in these various jurisdictions. Jim poses question to the group: from where would you like to seek expert opinions? After

some discussion, the consensus was to wait on consulting specific jurisdictional experts. Instead, the group will focus its March meeting on the analyses contained in the forthcoming Tetra Tech report.

Group members discussed some general process matters, including how criteria recommendations will be supported and documented. The group also noted impressions from the case studies. Workgroup members emphasized various points, including the desirability of defensible links to designated uses, concerns about unintended consequences of criteria, and the various methods by which other jurisdictions are moving forward with criteria.

3:00 Adjourn.

APNEP Nutrients Workgroup Meeting Notes[1]

March 23, 2016

Attendees:

1. Anne Coan (Farm Bureau)
2. Bill Crowell (APNEP via phone)
3. Brian Pointer (DWR)
4. Cam McNutt (DWR)
5. Carrie Ruhlman (DWR)
6. Clifton Bell (Brown and Caldwell)
7. Connie Brower (DWR)
8. Dean Carpenter (APNEP)
9. Heather Patt (DWR via phone)
10. Jamie McNees (DWR via phone)
11. Jim Hawhee (DWR)
12. Jing Lin (DWR)
13. Marcelo Ardon (ECU)
14. Martin Lebo (AquAeTer)
15. Michelle Moorman (USFWS)
16. Mike Paul (Tetra Tech)
17. Pam Behm (DWR)
18. Rhonda Evans (EPA Region 4)
19. Sharon Fitzgerald (USGS)
20. Stacey Feken (APNEP)
21. Steve Kroeger (DWR)
22. Tiffany Crawford (EPA Headquarters via phone)
23. Vince Bacalan (EPA Headquarters via phone)

Overview of Tetra Tech report "Albemarle Sound Classification and Analysis conducted under the Nutrient Scientific Technical Exchange Partnership Support (N-STEPS)"

Presentation by: Mike Paul, Tetra Tech

N-STEPS

- N-STEPS is an EPA program through which states can have their technical support documents reviewed, and support can be provided to states for data analysis, statistical analysis, water quality modeling, literature review, etc.
    - NSTEPS projects for North Carolina
        - First project was analysis of lakes data (2014)
        - Additional project was to look at data from Albemarle Sound to form background on classification

Classification

- Classification[2] - An important step in developing nutrient criteria
- Classification reduces natural variability due to land use, geology, hydrology, climate, etc.
- Classification also reduces variability in response of a system to nutrient enrichment.
    - Responses can vary in different systems due to cofactors such as turbidity, pH, fauna.

- Factors that influence classification include:
    - Water residence time

[1] Meeting notes complied by Steve Kroeger and Jim Hawhee. Numbers in parentheses correspond to hours, minutes and seconds on one of two recordings (Morning, Afternoon).

[2] Mike Paul makes reference to EPA's Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Waters, avialble here: https://www.epa.gov/nutrient-policy-data/nutrient-criteria-technical-guidance-manual-estuarine-and-coastal-waters

- Watershed area
- Vertical mixing
- Stratification
- Wave exposure, etc.

- A priori classification
  - EPA's guidance document (Chapter 3) uses the factors to suggest classifications on
    - Geomorphology
    - Hydrology
    - Habitat
  - A priori classifications are best applied when there are multiple water bodies being classified; not readily applied when there is a single estuary (i.e. Albemarle Sound)

Albemarle Sound - Sample Frame

- First step – define the area of interest
  - Class S waters
  - Originally included adjacent sounds, e.g. Currituck Sound, Roanoke Sound, Croatan Sound – later rejected since these areas were different based on phytoplankton, water chemistry.
- Water chemistry and phytoplankton data served as basis for classification. These data were provided by the NC Division of Water Resources.
  - 20 sites within the Albemarle Sound proper
  - 37 sites in adjacent SB and SC waters.
- "River sites" refer to the tributaries. "Rivers-sites" is a misnomer and not intended to imply the areas have a freshwater classification. They are the side embayments to Albemarle Sound (making reference to Alligator R., Perquimans R., Little R., North R., Yeopim R; see: Figure 2. Maps of Albemarle Sound Focus Area, page 46)

Statistical classification based on water chemistry and chlorophyll-a

- Descriptive statistics: univariate and multivariate
- TREED regression used to determine if there are functional differences
- Phytoplankton – multivariate analyses were used to see if biology can show any patterns

Multivariate Classification - Water chemistry differences

- Multivariate analyses are like a map.
  - Points close to one another have similar water chemistry
- Results color coded:
  - Open sound sites vs those in side embayments ("river sites")
  - < 1 meter vs . 1 < depth < 3 meter vs > 3 meter
- You look for spatial patterns in multivariate analyses

Questions and comments on the spatial scale.

- Sound sites have higher salinity, pH, lower total nitrogen (TN), lower total phosphorus (TP)
- Embayment sites have higher nutrients, lower salinity

Comments

- Dean Carpenter: The color (dark blue) of the sounds sites may be masking embayment sites under the sound sites. Dr.Paul agreed and commented that the embayment sites under the sound sites may be on the edge of the embayments.

- Jing Lin: comments on the x- and y-axes. The x-axis reflects a salinity nutrient gradient, whereas the y-axis reflects a turbidity gradient; is there more variation in salinity and nutrients for the river than the sound. Dr. Paul thought it was safe to interpret that river and sound sites have comparable variability in DO and turbidity, whereas the river sites have greater variability in salinity and nutrients.

TREED Regression

- TREED regressions is a child of classification and regression trees (CART)
- In traditional CART groups are determined by statistical similarities among the groups. One attempts to minimize differences between means, or deviations between two groups.
- TREED regression separates sites based upon functional differences.
- TREED regressions in the report are based on functional relationships between TN and chlorophyll and TP and chlorophyll a.
- Variables that separated similar nutrient-chlorophyll responses were salinity, temperature and maximum depth.

Steve Kroeger placed this graph in this meeting summary to illustrate a TREED regression:

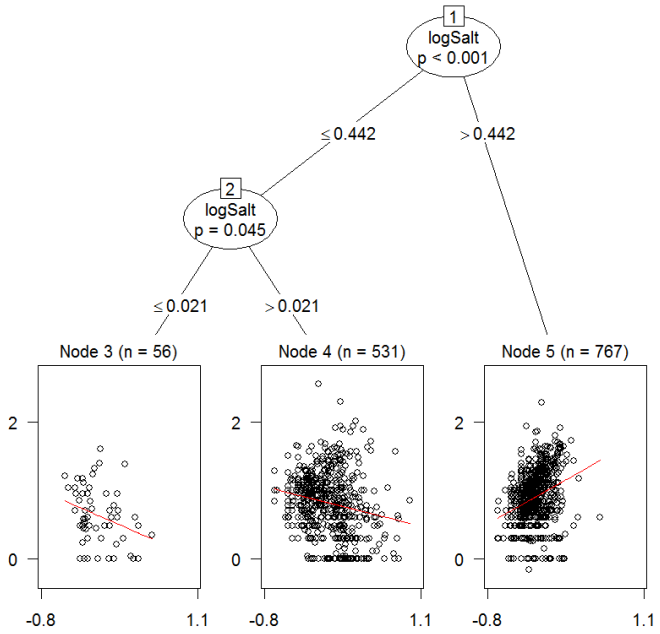


FIGURE 1. TREED REGRESSION OF CHLOROPHYLL-A AS A FUNCTION OF TN CONCENTRATION USING LOG-TRANSFORMED SALINITY (THIS IS FIGURE 4 IN THE TETRA TECH REPORT)

Note there are two major groups: Group 1 denotes (3 and 4) and Group 2 is Node 5. These two groups break when salinity is 2.8 ppt. ($2.8 \text{ ppt} = 10^{0.442}$ -note that salinity in the graph was log transformed). There is a positive relationship (slope of red regression line) between TN (x-axis) and chlorophyll-a (y-axis) when salinity is greater than 2.8 ppt.

Summary of TREED Regressions:

- Salinity: Positive relationship between chlorophyll-a and TN in higher salinity waters. No or perhaps negative relationship between chlorophyll-a and TN in lower salinity waters. Steepest (positive) relationship between chlorophyll-a and TP in higher salinity waters, but lower salinity sites also have positive relationships between chlorophyll-a and TP.
- Temperature: Warmer waters (or seasons) have steeper relationships between chlorophyll-a and nutrients (TN and TP). This is likely a seasonal classification, not spatial.
- Water depths: Samples from the medium depths were associated with the strongest chlorophyll responses to TN and TP than the shallowest (<0.2m) and the deepest areas.
- When samples were coded as either river or sound, Sound samples had a steeper, positive response to TN and a negative response to TN, whereas the River samples had a steeper, positive response to TP than the Sound sites.

Question –

- Marcelo Ardon – *What are the salinity units in ppt?*
  Answer – units were ppt, and log-transformed.

  Why were the breaks in salinity in the TREED regressions different for TN and TP? For TN the first break was 0.4, whereas for TP the breaks was 0.29 (not a big difference).

  Answer – Dr. Paul does not know why there were differences in the salinity breaks between TN and TP, but these breaks are subtle, and were based on statistics, not ecology.

Analysis of Phytoplankton Data

- Used Nonmetric Multidimensional Scaling (NMS- an ordination method used to make a "map". Results close to one another have similar species composition).
- NMS of the samples revealed changes in algal species composition between the sound proper and side embayments. These may be due to changes in salinity and pH.

Summary of Classifications

- The classifications support an open sound and embayment (river) separation. This is due to differences in water chemistry, phytoplankton and some functional differences in nutrient-chlorophyll relationships.

Descriptive statistics on classifications (sound vs. embayment).

- Frequency distributions were summarized using cumulative distribution functions and box and whisker plots.
    - Results:
        - Nutrients higher in rivers than sound
        - Chl-a concentrations are similar
        - Secchi depths slightly higher in sound
        - DO higher in sound
        - Turbidity similar

Exploratory Analysis - Stressor-Response (nutrient vs chlorophyll-a)

- Exploratory stressor-response relationships were examined using linear regression between log transformed data for TN, TP, chlorophyll-a. Dissolved oxygen values were not log transformed.
- Two averaging techniques were used: 1) long term averages of all samples for a site (Figures 15 and 16 in the report) and 2) annual averages of samples for each site (Figures 17 and 18 in the report).
- Grab sample pairs were not used in the regressions because that would overweight sites that have more samples. Dan Conley[3] has looked at various averaging methods and how those affect relationships between causal and response variables. Site year averages work well.
- Jing Lin asks a question on the differences between TREED analysis and stressor-response graphs. Subsequent discussion addressed that each approach used different summaries of the data: TREED analyses used data-pairs whereas the regressions used two averaging approaches: 1 - long-term site averages and 2 - site-year averages. A summary of the results from these approaches is in the table below:

	Chl-a and TN	Chl-a and TP	DO and TN	DO and TP
Regressions				
Long term avg.				
All sites	0	0	—	—
Sound sites	0	0	0	0
River sites	0	+	—	0
Site year avg.				
All sites	0	0	—	—
Sound sites	+	0	—	—
River sites	0	+	+	+
TREED			No TREED analyses were completed with dissolved oxygen	
Salinity > 2.8	+	+		
Salinity < 2.8	—	+		

[3] http://lucci.lu.se/people_conley.html

0 = no relationship; + = positive; — negative; Chl-a and DO were response variables.

TN and TP were causal variables.

Albemarle NSTEPS Report - Summary

- Sound vs. adjacent embayment classification seems defensible based on water chemistry and biology (phytoplankton).
- Nutrient concentrations vary by these two classes (sound vs. embayment) but chlorophyll-a does not.
- Functional differences exist in terms of preliminary stressor-response relationships
    - Chla increases to TP in adjacent embayments (rivers).
    - DO declines to both TN and TP in adjacent embayments, increases in sound

Questions and Discussion

- Clifton Bell: - Results showed increasing DO with increasing salinity – why?; MP not sure why. Perhaps organic loads being different between embayments and sound; BOD and SOD may be factors as well. Jing Lin -- asks about oxygen saturation, and Dr. Paul thought doing an analysis by saturation is a good idea.
- Jim Hawhee – Correlation is something to be considered. What are the rho values on the linear regression plots? What do these mean? Dr. Paul – rho values describe the spread of data along the regression line. Rho values range from -1 to 1. Zero represents no correlation.
- Clifton Bell - Correlations do not imply cause and effect. Dr. Paul field data will never confirm cause and effect.
- Sharon Fitzgerald - One way to reduce variability is to include seasonality.
- Martin Lebo - One pathway not shown are internal sources. The embayments receives freshwater with drainages with low DO, colored waters, and small cities in the watersheds. You would expect low DO and higher nutrients from these sources.
- Marcelo Ardon - taking a step back, results are consistent with the literature
- Sharon Fitzgerald --- Discusses the Redfield ratio and identifying limiting nutrients. Dr. Paul mentions a paper[4] by Bill Lewis and Wayne Wurtsbaugh.

Housekeeping

Jim Hawhee asked the group members to introduce themselves. He then covered a number of housekeeping items, including revisitation of the ground rules agreed upon by the group during 2014.

North Carolina's assessment methods

Cam McNutt, DWR Modeling and TMDL Unit

- Water quality assessment methods are used to determine whether or not surface water bodies are meeting water quality standards.

[4] Control of Lacustrine Phytoplankton by Nutrients: Erosion of the Phosphorus Paradigm: http://onlinelibrary.wiley.com/doi/10.1002/iroh.200811065/abstract

- Assessment methods are approved by the Environmental Management Commission (EMC), not the U.S. Environmental Protection Agency (EPA).
- Standards are approved by the EMC, not the EPA.
- EPA can add sites to 303(d) list
- There are five assessment categories: 1 through 5. Category 5 is where sites are placed that are not meeting water quality standards, and is referred to as the 303(d) list or impaired water body list.
- Five 303(d) assessment methods:
    1. Numeric (physical/chemical parameters such as chlorophyll-a)
    2. Biological (communities of benthos or fish)
    3. Pathogen
    4. Shellfish harvesting
    5. Fish consumption
- Numeric
    - Written as for results "not to exceed" a numeric standard
    - EPA allows for some exceedances (10%)
    - 10% exceedance with 90% confidence is the standard North Carolina uses.
    - The 2016 Category 5 list contains sites not meeting standards for copper, DO, turbidity, Ph (low and high), and chlorophyll a.
- Biological Assessment Methods
    - Fair, Poor or Severe biological rating -- Cat 5
    - 339 benthic impairments
- Pathogen
    - 5 samples in 30 data (geomean >200; or more that 20% exceeding 400)
- Shellfish
    - Based on Division of Marine Fisheries growing area
    - 565 areas exceeding shellfish harvesting criteria
- Fish consumption
    - Advisory by Department of Health and Human Services (DHHS)
    - Fish tissue data present
- Changes from 2014 include new additions like 21 benthic sites (many are from RAMS)

During the discussion, Cam clarified how clarity and turbidity assessments were conducted (just turbidity/TSS, no use of light meters). It was asked whether EPA accepts TMDLs when exceedance criteria are not written into code, i.e., duration and frequency components that are part of the assessment methodology. They do. Also asked was whether any temporal or spatial averaging was done for the parameters for which we have standards (chlorophyll a, pH, turbidity…)? Not presently. Vertical averaging also asked about. Calculations based on surface sampling.

North Carolina's estuarine monitoring methods

Brian Pointer, DWR Water Sciences

- Statewide the ambient monitoring systems has 318 stations. These are mostly streams with monthly monitoring, most sites have a long period of record.
- 110 sites have data since 1968
- Albemarle Sound monitoring conducted by Washington Regional Office (WARO). At one time there were 8 people conducting monitoring; now there are 3.

- Sample collection methods include road crossings for streams and estuarine stations sampled via boats. Photic parameters: integrated sampling 2x Secchi depth
- 61 sites are sampled by WARO

During discussion, it was asked to what level phytoplankton are classified. Generally, as specific as possible, often to the genus level. The history of the phytoplankton monitoring program, beginning in the Chowan River basin, was discussed. It's becoming more important to understand species composition in relation to chlorophyll a, including its spatial extent.

LUNCH

Spatial Extent of Albemarle Sound

Jim Hawhee; **See *Figure 2*; page 46**

Jim discussed the need for clarity regarding the spatial area to which recommendations would apply. Handouts for this meeting include a map ("Albemarle Sound: Designated Uses") which was developed as part of discussions in 2014. The 2014 map differs from the map on page 5 in the Tetra Tech report "Albemarle Sound Classification and Analysis conducted under the Nutrient Scientific Technical Exchange Partnership Support (N-STEPS)" (March 14, 2015). There are two noteworthy differences between the maps. The 2014 map does not distinguish waters classified as SB between "rivers" and Albemarle Sound proper. Additionally, the western boundary in the Tetra Tech report is a few miles east from the boundary in the 2014 map. Jim states the map in the Tetra Tech report is the one to use as a common reference for the development of nutrient criteria.

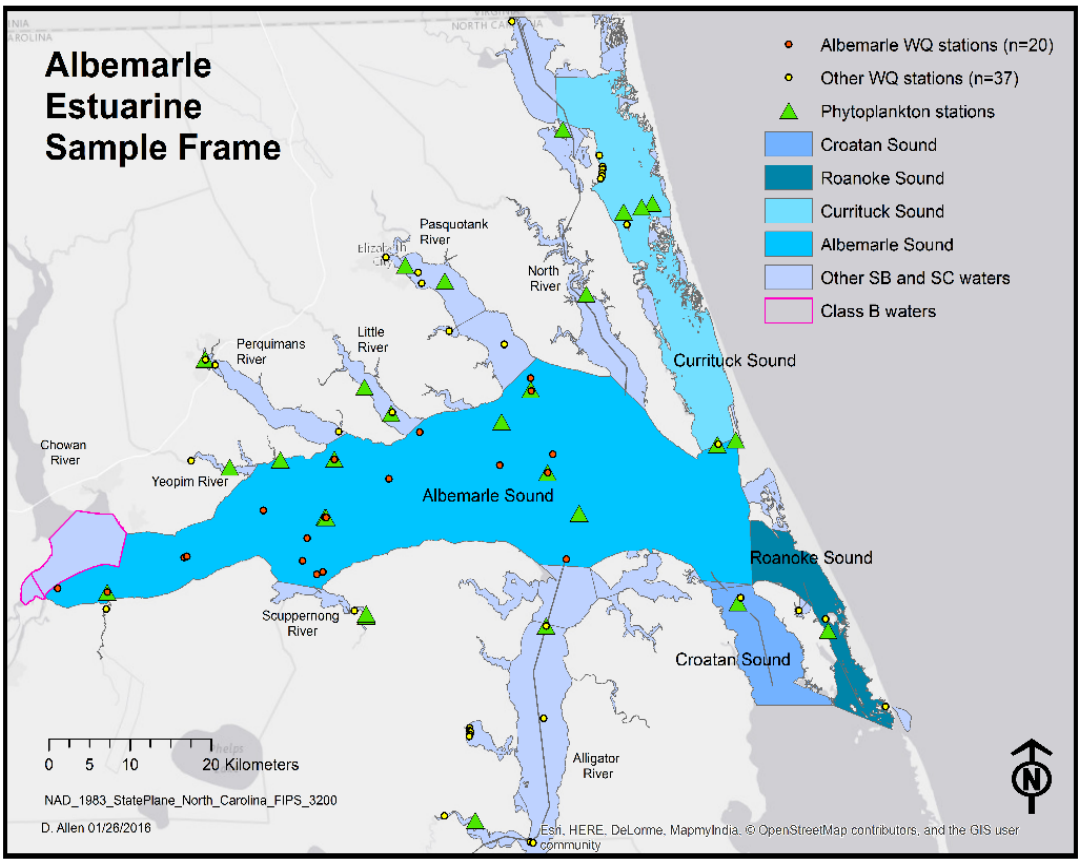


FIGURE 2. MAPS OF ALBEMARLE SOUND FOCUS AREA
TOP: 2014 MAP. BOTTOM: MAP IN TETRA TECH REPORT

Discussion focused on three items:

1. SB is a primary recreation classification: Connie Brower noted that the SB classification is for primary recreation; Jim Hawhee replies that the workgroup, in its initial discussions, focused on the extent of the waters delineated by the SB classification and not on its use as primary recreation.
2. Does the study area include the tributaries/embayments? Various workgroup members discuss whether or not the study area extends into the tributaries or whether the focus is on Albemarle Sound proper. Anne Coan, Martin Lebo and Jing Lin note that there will be differences in water quality in the tributaries than the sound (e.g. fresher water). Jim replies that whether or not to include the tributaries/embayments in their recommendations is up to the workgroup.
3. Does the study area include other sounds, e.g. Currituck Sound, Roanoke Sound, Croatan Sound? No.

Proposal and discussion of path forward to conclude Phase I.

Jim asked the group to take about 5 minutes and look through 3 pages that were provided: 1) timeline, 2) suite of information that can be provided by the DWR dataset, 3) individual recommendation worksheet (strawman proposal) proposed for use to recommend appropriate response parameters and causal criteria.

After reviewing the materials provided, workgroup members offered a number of observations. Concerns were expressed in proposing both response and casual parameters simultaneously, as casual recommendations might hinge on a consensus recommendation for response parameters. Also, group members discussed a preference to discuss ecological goals, targets, and the current condition of Albemarle Sound before proceeding with recommendations. A plan for proceeding was discussed, with separate meetings planned to discuss Albemarle Sound ecology, response criteria recommendations, and causal criteria recommendations. Amendments to the draft criteria recommendation worksheet were also discussed. SAV ecology and extent, fisheries, and algal species information were among the detailed information requested by the workgroup.

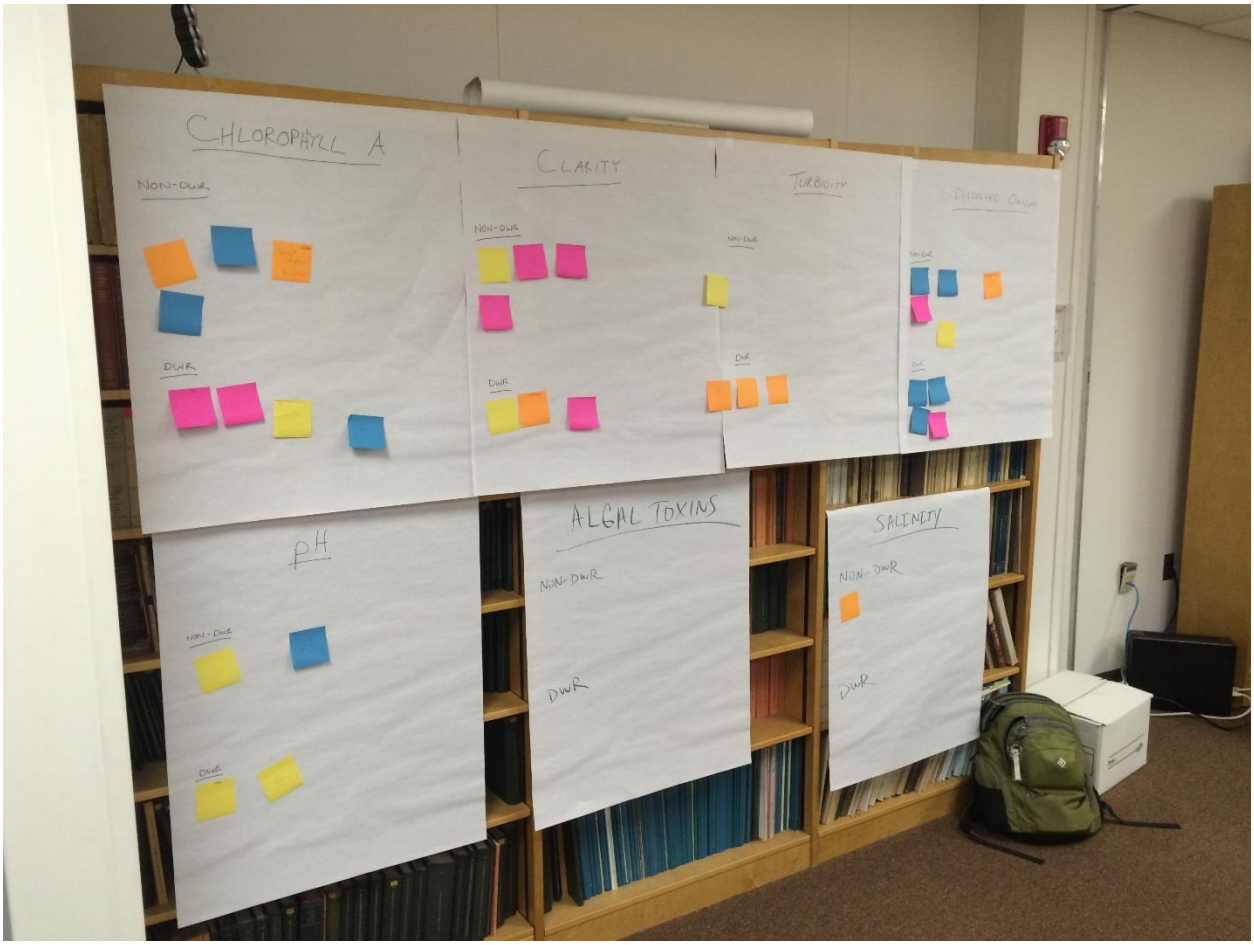
Discussion and prioritization of response parameter for further investigation

(Prior to the meeting, workgroup members were asked to complete a worksheet on which they were instructed to "preliminarily rank which response parameters you think have the best potential for criteria development in Albemarle Sound." Responses were compiled, organized by rank, and provided to the group to facilitate discussion during this exercise.)

Before the nonbinding ranking exercise, workgroup members were asked to review all responses and offer comment to the group. The ranking and relative values of various response parameters were discussed. Dissolved oxygen was discussed as it relates to fish survival and the oxygen requirements of various organisms. It was also noted that Albemarle Sound is less stratified than other systems and that wind mixing and temperature appear to have a large influence on oxygen levels.

After some further discussion, workgroup members were asked to place sticky notes on hanging sheets of paper to indicate their prioritization of response parameters. Blue sticky notes indicated the first priority (blue ribbon), pink indicated second priority (red ribbon), yellow indicated third priority (bronze

medal), and orange indicates other parameters of interest (honorable mention). Prioritization was also noted between DWR and non-DWR staff.



In roughly descending order of priority, the compiled results were as follows:

Dissolved Oxygen
Non-DWR: 2 first place, 1 second place, 1 third place, 1 honorable mention
DWR: 3 first place, 1 second place

Chlorophyll a
Non-DWR: 2 first place, 2 honorable mentions
DWR: 1 first place, 2 second place, 1 third place

Clarity
Non-DWR: 3 second place votes, 1 third place vote
DWR: 1 second place, 1 third place, 1 honorable mention

pH
Non-DWR: 1 first place, 1 third place

DWR: 2 third place

Clarity/Turbidity (on the line)
Non-DWR: 1 third place
DWR: 1 honorable mention

Turbidity
DWR: 2 honorable mention

Salinity
Non-DWR: 1 honorable mention

Algal toxins
No votes

Housekeeping and adjournment

Jim asked for follow-ups regarding workgroup members interested in a field trip on Albemarle Sound coordinated by APNEP, with some members indicating an interest.

APNEP Nutrients Workgroup Meeting Notes

May 25, 2016

Attendees

Clifton Bell, Brown and Caldwell; Tim Spruill; Martin Lebo, Aquater; Hans Paerl, UNC Chapel Hill, Michelle Moorman, USFWS; Jud Kenworthy; Hilde Zenil, ECU; Anne Deaton, DMF; Connie Brower, DWR; Elizabeth Fensin, DWR; Chris Ventaloro, DWR; Dean Carpenter, APNEP; Steve Kroeger, DWR; Jim Hawhee, DWR; Jing Lin, DWR; Stacey Feken, APNEP.

Proceedings

Jim Hawhee, Division of Water Resources (DWR) gave an introduction, explaining we had 20 minute presentations with 45 minutes of time slotted for each, so hoped there would be ample time for discussion. He envisions this meeting as a process to get some ecological grounding before the group gets into developing criteria recommendations. This can relate to specific parameter recommendations which include frequency, duration, spatial extent, or can relate to research recommendations.

Jim reviewed a few housekeeping items, including a new policy that might limit the ability to provide working lunches in the future. He shared regrets from a few members unable to attend, including Lauren Petter, Sara Collins, and Anne Coan. He promised to distribute the notes from the past few meetings to the group soon and give everyone time to review and correct as needed. Tammy Hill of the DEQ Water Sciences Section sent a draft of the data compilation discussed at the last meeting, he hopes to send out by the end of the week.

He and Steve Kroeger informed the group of staffing issues associated with the section leading the statewide Nutrient Criteria Development Plan (NCDP)—Carrie Ruhlman has left DWR to join the N.C. Wildlife Resources Commission as a policy analyst. Steve Kroeger will be retiring in September. The Water Sciences section has been leading the NCDP process, and there are ongoing discussions about potentially moving the effort to the Planning Section, however decisions have not been made. Though Jim has also moved from APNEP to a new position, he has committed to continue leading the Albemarle Nutrient Workgroup through the end of Phase I, and APNEP may be assisting with some administrative support.

Jim noted there are two additional meeting scheduled in July & September. He hopes the group can wrap up its recommendations by the end of the year and have those be the final meetings of Phase I. There is additional time built in to the NCDP process for a Phase II if needed.

Workgroup members and participants introduced themselves. Jim turned the meeting over to the first presenter.

Please access the presentations here or visit the Nutrient Workgroup website to access the meeting materials.

Submerged Aquatic Vegetation (SAV) Ecology and Water Quality—Dr. Jud Kenworthy

Dr. Jud Kenworthy, National Oceanic and Atmospheric Administration (NOAA) (*retired)*, mentioned that his talk would focus on the relationship between light and submerged aquatic vegetation (SAV) since the workgroup is interested in developing criteria and standards, but cautioned that many of the parameters that have criteria associated with them interact with light. You might be managing for light then realize it is something else.

He's excited to see an interdisciplinary group working on these issues. He believes the awareness of the link between SAV and water quality exists, but the action associated with implementing a plan to tackle the issues is lacking. Bringing together all of the different agencies and interest groups together is a positive step forward. He encouraged the group to look to the work done in Virginia and Chesapeake Bay for guidance and lessons learned, since they have covered this turf ad naseum for decades and have tons of experience dealing with similar systems & species. He is happy to help guide anyone in the room towards the relevant literature. He will not necessarily be presenting anything new, and noted there is no need for North Carolina to reinvent the wheel. We are however behind the curve, but it won't take long for us to catch up and push through the resistance and dragging of feet and make progress in Albemarle Sound.

Dr. Kenworthy covered all of the factors that affect SAV growth and health—light, oxygen, nutrients, organic sediment loading. SAV is a complex community, one of our most important primary producers, but it's important to note they are rooted in the sediment unlike plankton or drift algae. They can move slowly through vegetative growth and flowering and seed production, but not far, so light and any aspect that interferes with light is important. Typically, plants grow on the bottom, but there are canopy forming species that grow vertically in the water column and across the surface. There are factors that influence growth including epiphytes, or macroscopic algal species, an important component of primary productivity in the system. It's one of the main pathways in the food web, as many invertebrates feed on epiphytes. An important component is the balance between grazers and algal growth in the system—too many epiphytes can shade plants and limit SAV growth.

When you think of a nutrient standard, you have to recognize the need for sufficient oxygen for the system to function properly. Low oxygen concentrations can also slow grazer metabolism, epiphytes can accumulate on the leaves and block light. Rooted plants take up nutrients in the sediment and in the water column so you have to think about both. Too much nutrient loading can be detrimental. Hydrogen sulfide is one of the most toxic substances for these plants, they need to be able to oxygenate the rhizosphere to conduct biogeochemical process to deal with the organic matter. Increasing the organic load can increase biological oxygen demand (BOD) and stress the system. They are clonal plants interconnected by rhizomes, shoots are supporting other shoots. They can resist stress up to a certain point, but the impact can be slow and insidious. Degradation can first occur underground, causing plant death from the bottom up. The plants may look healthy from above, so it may take awhile for the impact to be seen, ultimately the community cannot support itself and dies off. Organic matter loading is a contributor, but the die off of plants also contributes to a self-perpetuating cascade and factors such as an algae or plankton bloom can make matters even worse. We refer to these plants as bioengineers, they can create their own water quality, but if you knock something out of balance it can tip the scale.

Dr. Paerl noted that the interaction with light was important, if you increase the organic matter you decrease the transparency. The ability of the plants to photosynthesize and keep up can be a problem. Dr. Kenworthy noted that the resuspension of organic matter from the sediments can also contribute and things can happen fast. The system can be knocked out of balance through an algal bloom, and if you add a stochastic event such

as a storm, or a big pulse of freshwater, things happen quickly. He showed this general paradigm in his slides and photos of healthy system compared to a system on the verge of decline.

Dr. Kenworthy said the good news is that we have a number of case studies from around the country, that if we do reduce nutrient loading, we can reverse the process, however it doesn't happen fast and is hard to manage. One of the reasons is the legacy of organic matter loaded in the sediments, you have to wait out the time period it takes to process that organic matter in the system.

One of the important thing to recognize is the light requirements are different for healthy vs. degraded plants, and different for plants in different parts of the system—e.g., at different depths. If we fix a criterion in the optimal condition, it may not be suitable to bring a system back if it's been severely degraded. A key point is that the conditions needed to bring back good water quality might be more stringent than what would be needed to maintain a healthy system. It's important to know where you are along the gradient. In terms of developing a management strategy, it is important to note that it may be a long time to see results. Steve Kroeger noted that it's important to know from a management perspective how long it takes a system to recover, so many questions are asked from stakeholders about nutrient management strategies and whether or not there are measurable results, when it could be there may not have been enough time for the system to recover.

Dr. Paerl noted that the tidal regime and residence time is also important. Nutrients can become trapped, relative to Tampa Bay where there is a success story with SAV recovery, it's easier for things to be flushed out in that type of system vs. in Albemarle Sound.

Dr. Kenworthy said they clonal, but they also reproduce sexually and some behave like annuals such as *Ruppia,* a common species in Albemarle Sound. For another common species, *Valsineria,* seed production requires a great deal of energy and is highly dependent on salinity, so it's another example of how you need to consider other parameters even if you're managing for light.

The bottom line is that SAV has really high light requirements, ranging from about 5-35% of the incident light, whereas the other competitors have at least an order of magnitude lower light requirements. We can monitor the SAV beds and see responses to the conditions as water quality changes in the water column above them.

It's important to manage light for SAV because all of its competitors have a great advantage over SAV. Most species have high minimum light requirements, and there are differing light requirements depending on the location…deep edge vs. shallow edge. It is important to know the state of the system. The light requirements increase as impairment of the system increases. There is an optimum balance between the percent organic matter and light requirements. Dr. Michelle Moorman noted that she has data for the percent organic matter in Albemarle Sound, she will discuss later during her presentation.

Dr. Kenworthy then talked about a metric for light. The most common measurement is secchi disc. There are limitations however, since your eye is used to measure secchi, and your eyes have a peak sensitivity which can be an issue in high salinity or high color dissolved organic matter (CDOM) waters. For research sensors that measure light electronically are used more commonly. It's important to note that they all measure apparent optical properties of light, which are all changing constantly and subject to many different factors including the angle of the sun, time of day, day of the year, surface disturbance, refraction, etc. However, it doesn't tell you anything about the characteristics substances in the water that are affecting light. We do know there are 4

main optical components of water quality that can affect SAV growth and survival: water itself, CDOM, chlorophyll, and total suspended solids (TSS) often measured as turbidity (NTUs). You need to measure them or use a biooptical models to calculate an attenuation coefficient to measure the amount of light reaching the bottom and parse out which component are affecting the system. He believes CDOM will be very important in Albemarle Sound considerations. A biooptical model can be an important management tool vs. using secchi or a PAR light sensor.

Jing Lin asked about accounting for epiphytes: Mike Kemp's group has adjusted for epiphyte chlorophyll *a* values and have come up with a term light at the leaf vs. light at the bottom.

Clifton Bell asked whether turbidity is better statistically than TSS for the bipoptical model as some suggest in the literature. Most of the time you can calibrate turbidity but you have to look at TSS, since most of the variability is in the color/size/source. You can relate NTU to TSS and come up with a relationship, so you can go either way.

Dr. Moorman asked if dissolved organic carbon (DOC) could be used as a surrogate for CDOM, he replied he hasn't done since CDOM is easy to measure. She used DOC but mentioned there were papers. He mentioned there was a great deal of data in the Tetra Tech report. Jing Lin asked if CDOM values were conservative. Dr. Paerl thinks in some cases it is and some not, it depends on the precipitation that occurs at the turbidity maxima that goes on in estuaries. It appears to be in the Neuse but perhaps not in other areas.

Dr. Kenworthy has been working with a model from Chuck DeLagos [correction 1/9/2018 : Gallegos] developed for farm ponds in Oklahoma and now used in estuaries including Chesapeake Bay. It runs on an excel spreadsheet, and uses chlorophyll, TSS & CDOM, which are routinely measured, you just need the stations. It takes about 30 samples to calibrate. Martin Lebo asked about properly accounting for the variation in a system as large as Albemarle Sound in calibrating the model. Dr. Kenworthy replied that you have to be strategic about the samples/stations used, particularly with TSS. Mr. Lebo pointed out that it also depends whether you are on the eastern or western side of the sound with different riverine sources and length to settle out some of the suspended particles. Dr. Kenworthy showed how you can use the model as a tool to go through the what if scenarios.

Tim Spruill asked for clarification for chlorophyll *a* dry weight, that typically in literature 15 ug/L is used as a point of departure, is that always or often associated with a lack of SAV. Dr. Kenworthy replied that was not always true, you could have a system impaired by TSS. Jim Hawhee noted the point has been made that the optical properties are complex and based on multiple things, the way we go about resolving an impairment may be very different if it's chlorophyll vs. TSS and may require different management strategies. Mr. Lebo made the point that you need to know the status of the system, it may not be that there actually is an impairment that results in the need for reductions.

Anne Deaton stated that since there is a combination of factors that contribute to light availability, how do you implement from a management perspective—where has it been done practically and how? Dr. Kenworthy replied in Virginia, water clarity criteria are expressed a percent light through the water column, and they consider salinity regime, and have secchi depth. They have different numbers for the tidal segments and tributaries in their standards. He mentioned that just a few years ago we didn't have enough information about where SAV is present, and thanks to Coastal and Recreational Fishing License (CRFL) grant funding from DMF we've come a long way. We now have a PhD student mapping and establishing sentinel stations to

monitor as we'll see in Hilde's talk. We didn't even know where to apply the standard but are moving in the right direction.

Dr. Moorman noted that though data is limited in Albemarle, monitoring data / secchi exists, DMF has a ton of data, so if we have the science to support water clarity criteria, it's easily measured and captured with our existing ambient monitoring stations. Clifton Bell noted there is a relationship between secchi and PAR. Dr. Moorman measured both in her study and not sure if it will be in the USGS report, she'd say it was a starting point and additional research would be needed.

Connie Brower asked if these were adopted in Virginia's water quality standards or in some other location in VA's water quality program. Clifton Bell who is from Virginia said yes, it's for all of the tidal segments in the bay and the tidal tributaries, and is also implemented through the Chesapeake Bay TMDL. There is an aerial application as well where they look at SAV coverage, you can meet standard by either meeting the SAV coverage or the light standard:

9VAC25-260-185. Criteria to Protect Designated Uses from the Impacts of Nutrients and Suspended Sediment in the Chesapeake Bay and Its Tidal Tributaries.

Submerged Aquatic Vegetation status and trends—Hilde Zenil, ECU

Hilde Zenil, of East Carolina University (ECU) opened up her presentation by discussing the importance of SAV and the ecosystem services it provides: shoreline protection, protection of fish and invertebrates (including blue crab, a $35 million industry in NC) and carbon sequestration. She explained that seagrass decline is a global phenomenon, where declines have been observed over the past 8 decades.

She then turned to what's happening in North Carolina. Her advisor, Dr. Joe Luscovicsh [correction 1/9/2018: Luczkovich], observed a decline in Bachelor Bay from 2011-2014 during studies. Though it could be normal variation, they are not sure. This is why it is important to monitor and see what happens. Looking back at the historical distribution of seagrass over 10 years from various sources, it appears there is not as much SAV on the south shore of Albemarle Sound as the north. They have done studies near Edenton, Alligator River, Kitty Hawk Bay monitoring SAV with multiple methods: aerial, sonar, underwater video. North Carolina has the 3rd largest area of SAV in the continental United States based on aerial imagery. They believe this may be an underestimate due to lower salinity, more turbid conditions. You can also miss SAV if you just use aerial imagery.

The sound was divided into 5 regions, and rapid assessment of sentinel sites was conducted. They hope to observe trends over time so have been applying for grants to allow them to continue research. She explained the sampling method. There are two types of sites in Albemarle Sound parallel to the shore at 1-meter depth. In 2014, they conducted rapid assessments in units 10 kilometers apart, with 660 transects in Edenton, Kitty Hawk Bay, and the Alligator River. The selection criteria for sentinel sites for long term monitoring included historical presence of SAV and the presence in both sonar and video from the 2014 assessment. Of 600 sites, 220 historically contained SAV, 88 met the selection criteria, and 10 sentinel sites were selected. Sampling is conducted spring and fall and a great deal of variability has been seen seasonally. Temporal changes in species and abundance have been observed.

They also evaluated land use around Kitty Hawk Bay and Edenton. She explained that nutrients were not a focus of her work, and they have not measured nutrients, though she has evaluated land use in the area where

she is conducting research. So far they have observed more SAV near agricultural and developed areas, and they are not sure why, it would be an interesting area for additional research.

She will continue the sentinel sampling and evaluation of species composition and SAV distribution. She expressed the need for continued monitoring and noted that it might be valuable for another group to measure nutrients at their sites since they plan to continue monitoring SAV for multiple years.

Martin Lebo asked if she had gathered salinity measurements for her sampling years. She has not done for her sites, and asked if someone has a dataset. He noted that the state monitors water quality, and it may help to explain if they note a change in seagrass that it may be due to salinity and not nutrients. Dr. Moorman mentioned that DMF collects secchi and salinity when they are monitoring fish, which may be a larger database. Anne Deaton replied they collect salinity, temperature, and qualitative measurements of sediment and bottom composition. Jim mentioned a team at UNC-IMS maintains a historical database. Dr. Tom Allen has compiled historical salinity back to the 1980s in the NC Coastal Atlas with Dr. Lindquist, it includes Mark Renson's data from the 1970s for low salinity systems.

Dr. Kenworthy mentioned the species composition results would be very interesting. Before the meeting, he sent a study to the group that showed that non-native species made up a dominant portion. In Kitty Hawk there is milfoil and hydrilla. You could interpret this that these areas have been disturbed and the non-native species are more successful, you may want to be careful with the graph shown until you know more. Dr. Moorman suggested looking at the percentage for each land use in the study area, and the methodology for deriving percent land use. Hilde explained she had put the graph together for the group to spark discussion but it was not meant to be conclusive. Anne Deaton mentioned talking to the aquatic weed control program, as areas in Kitty Hawk Bay are being treated for milfoil which could impact the sentinel sites. Hilde mentioned a site in Bachelor Bay where a girl shared that her parents had used herbicide to remove the SAV. Hilde noted that many people see SAV as a nuisance and mentioned the social science aspect and the importance of raising awareness about the value of SAV.

Steve Kroeger mentioned that sediment type is important and asked if you can evaluate with sonar. Hilde said you can determine hardness from the sonar. Dr. Kenworthy mentioned there are issues, that in some places the soft bottom creates a false echo. Hilde explained this is why they were ground-truthing with the underwater video. Dr. Paerl noted there is a depth contour in Albemarle Sound and asked if she had data, in the southern end typically has less SAV than the north. Hilde stated they stay at 1 m depth. Anne Deaton mentioned that she has heard from people that work there that it is the wind; the area is so much more exposed. Hilde showed a wind shear model she is working on based on a single storm. Martin Lebo noted it would also be good to look at the blooms that occurred along the Chowan, if you can separate the herbicide applications you could also look at recovery and how long it takes to come back. Dr. Paerl mentioned there are allopathic interactions associated with algal blooms, but the literature was all over the place, but that most was in freshwater. Dr. Dean Carpenter mentioned Joe's hypothesis that the CDOM / blackwater is higher there which can have an impact. Hilde mentioned they have observed cypress trees and blackwater near their sites.

WORKING LUNCH

Algae in Albemarle Sound—Elizabeth Fensin, DWR

Elizabeth Fensin, an algal ecologist with the Water Sciences Section of DWR, gave an overview of the types and diversity of algal species in Albemarle Sound based on sampling conducted from 2000-2015. She mentioned that blooms had only occurred occasionally since 2006, with 1 or 2 cyanobacteria blooms in the summer. Of the chlorophyte taxa, green algae are more common in freshwater. Various types of diatoms are common in both fresh and saline waters. Dinoflagellates often bloom in brackish water. Cyanobacteria are very common and often bloom in summer—common species are referred to as "Annie, Beny, Mike & Cindy": *Anabena, Microcystis, Cylindrospermopsis.* [Correction 1/9/2018, pers. comm. From Elizabeth Fensin: "The four cyanobacteria most likely to cause problem blooms—"Annie, Phannie, Mike, and Cyndy or Anabaena, Aphanizomenon, Microcystis, and Cylindrospermopsis."]

She explained that "algal bloom" is a state of mind and a relative term which depends on how the bloom is measured (units or counts of algal cells vs. biomass or biovolume, in the field dissolved oxygen level/pH can be measured). DWR has established definitions to provide a quantitative approach to describing a bloom, which were adopted by USGS for the recent Albemarle survey. She explained that chlorophyll *a* measurements are an "after the fact" indicator of a bloom, algal densities are used to determine whether a bloom actually occurred. You have to look at the species and can not necessarily attribute a bloom to a single species. She illustrated by reviewing recent blooms and identifying the species observed. The ongoing cyanobacteria blooms in the Chowan River and Albemarle Sound were a surprise.

She mentioned that no one was currently taking algal samples in Albemarle Sound. It was noted that sampling was difficult due to the size of Albemarle Sound and resulting logistical challenges associated with access, boat travel, etc. Dr. Hans Paerl noted there were no ferries in Albemarle Sound as in Pamlico, where they are collecting data via FerryMon. He mentioned that Dr. Nathan Hall of UNC-CH is doing work on *Microcystis* in the Cape Fear basin.

Dr. Michelle Moorman mentioned that DMF conducts routine fish sampling and suggested there may be an opportunity to incorporate algal sampling into their protocol. Anne Deaton suggested coordinating with Charton Godwin and Katie West to see if it would be feasible. The group agreed it would be a good opportunity for interagency collaboration and sharing.

Albemarle Sound Fish and Fisheries—Anne Deaton, DMF

Anne Deaton of the Division of Marine Fisheries gave an overview of fish and fisheries in Albemarle Sound. She emphasized that habitat was important, and explained that the Coastal Habitat Protection Plan (CHPP) had recently been updated and was undergoing final review. She explained that Albemarle Sound was a drowned river system with a great deal of riverine input. It is a low salinity system—greater than 80 percent is less than 5 ppt salinity, with Oregon Inlet being the only opening to the ocean.

She gave an overview of the different types of common fisheries species and fish guilds. Freshwater species include catfish, perch, bass, bluegill. Diadromous species include river herring, striped bass, sturgeon, shad, and the American eel. Marine spawning/low salinity nursery species include Atlantic croaker, spot mullet, and flounder. Marine spawning/high salinity nursery species include: bluefish and sheepshead. Inlet/estuarine spawning species include oyster, blue crab, red drum, and spotted seatrout. She reviewed the commercial landings from 2014, noting that blue crabs, southern flounder, and catfish are the top three species in Albemarle Sound.

She reviewed spawning, egg, larval, and juvenile requirements for various species based on dissolved oxygen, temperature, salinity, and flow. She noted that the diadromous fish have very specific water quality needs and

would be a good group to focus on. Menhaden for example are sensitive to low dissolved oxygen. She provided an overview of the ambient stations where DWR collects water quality data showing trends for TP, TN, DO, and turbidity.

She then talked about the findings from the CHPP, focusing on the recommendations for the most important areas of Albemarle Sound to protect based on reproductive and survival requirements, as illustrated in the maps in her presentation. The Chowan and Roanoke are important spawning areas.

She also shared the results of work done by Tim Ellis under a Sea Grant fellowship. He used juvenile trawl data to evaluate the abundance and distribution of fish including striped bass, herring, white perch, spot & croaker. He evaluated species richness and diversity, and found that out of 64 species, there were only 11 that occurred in at least 10 percent of the samples, all estuarine species (spot, croaker, bay anchovy). He evaluated temperature, salinity, DO, wetland edge, SAV, substrate type, habitat alteration score, and shallow water (<6ft). He observed that as the amount of habitat alteration increased there was a decrease in diversity. He found juvenile striped bass widely distributed but more concentrated in western Albemarle Sound; blueback herring almost absent from eastern sound; white perch most concentrated in the Chowan River; spot most concentrated in northern tributaries, and croaker in eastern sound. Blueback herring, white perch distribution, species richness and diversity declined DO < 4 mg/l. Striped bass and spot distribution declined DO < 6 mg/l. Blueback herring, striped bass, croaker abundance declined with increasing alteration scores. There was no positive correlation with SAV coverage or wetland shoreline.

In general, water quality concerns include the following: Reports of blue crabs dying in crab pots due to low DO events, algal blooms in Chowan River reported in 2015, anadromous fish more sensitive to water quality. Anadromous fish spawning areas are designated by Marine Fisheries Commission, but there are no water quality protections. Water quality standards not targeted for SAV, yet SAV critical for many Albemarle fish species. The CHPP recommends modifying water quality standards to sustain SAV, as it provides umbrella protection for many fish species and estuarine communities. She recommends correlating work with the fish habitat protection areas established for fish.

Download the CHPP here: http://portal.ncdenr.org/web/mf/habitat/chpp/downloads

USGS Water Quality Studies and Data—Dr. Michelle Moorman, USFWS

Dr. Michelle Moorman, United States Fish and Wildlife Service (USFWS), gave an overview of the Albemarle Demonstration Project she conducted while with the United States Geological Survey (USGS). She noted that she had contacted Jill Paxton after the other presentations, who said she would be happy to collect phytoplankton data at a subset of existing ambient monitoring sites, and Elizabeth Fensin will be happy to analyze them but asked that we make the sites count. Dr. Moorman charged the group with thinking about the best sites to collect phytoplankton data during her presentation.

The study was conducted for the National Monitoring Network for US Coastal Waters and their tributaries. She noted that the study was not developed with nutrient criteria development for Albemarle Sound in mind. The goal was to fulfill the criteria for a national monitoring network as a pilot for US coastal waters. There were two objectives: assess current monitoring network in the Albemarle Sound and assess against a landscape conservation design, a plan for every estuary in the US to be monitored to this minimum, and do estuaries meet the estuarine design. The report assesses the existing monitoring network in Albemarle Sound and can be found online: http://nc.water.usgs.gov/projects/asnmn/reports.html

The second was to identify monitoring gaps and conduct actual monitoring, which will be discussed today. The study area was limited to the estuarine environment and direct inputs. In general, the data is very limited for Albemarle Sound. There is new data from USGS that evaluates trends in water quality up to 2012, which is part of a new USGS national trends assessment that has not yet been published. Trends are analyzed by using non-parametric methods to look at data through time. In general, though total nitrogen (TN) has been decreasing in other areas, it has been increasing in southeastern estuaries. There is an increase in the south Atlantic for total phosphorus (TP). There is also a report done by Duke that is on the shared drive worth reading, they synthesize data in a different way than the Tetra Tech report.

Another report summarizes SPARROW model results up to 2002. The approach uses trends data and modeling to predict nutrient loads in unmonitored watersheds. Whereas a statistical model analyzes trends in real data, SPARROW modeling relates in-stream water-quality measurements to spatially referenced characteristics of watersheds, including contaminant sources and factors influencing terrestrial and aquatic transport. SPARROW empirically estimates the origin and fate of contaminants in river networks and quantifies uncertainties in model predictions. This approach has been used to evaluate TN/TP loads for the whole Atlantic. It includes estimated total loads from coastal watersheds that drain into estuaries, not just the riverine input. Nutrient sources are mixed agricultural, urban, atmospheric with a great deal of background phosphorus. The report can be accessed here: https://pubs.usgs.gov/ds/0820/pdf/ds820_text-only.pdf

The model considers load sources, land use/land cover. Dr. Moorman noted that there has been a great deal of ditching and draining in the area around Albemarle sound. A former USGS colleague wrote a report in 1975 that talked about the impacts. She currently works in the Hyde County watershed and thinks it needs to be considered. She currently works at Lake Mattamuskeet National Wildlife Refuge, a 40,000 acre lake in a small coastal environment. The land use is mostly agriculture and waterfowl impoundments which drain directly to the lake with no other riverine input. Their technical working group has adopted SAV as the response indicator for their lake model. They have observed that TN, TP, suspended sediments, pH and chlorophyll a have all increased significantly since the 1980's. SAV has declined significantly. Since the land use in the watershed is very similar to other small coastal watersheds, they wonder why eutrophication is so pronounced at Lake Mattamuskeet. It is possible that longer lake residence times as a result of rising sea levels could be part of the problem. She noted it was something to think about in terms of management strategies/Best Management Practices. Dr. Paerl asked about herbicide use, she replied they do not believe it is a factor based on pilot data (not detected in samples taken for the NAQWA study) and the way that SAV has declined, but they cannot say with complete certainty that pesticides are not a factor. Hilde asked how they are monitoring SAV—she replied they use a quadrat and visual observations.

She turned back to their sound-wide study. They looked at phytoplankton composition, nutrients, DOC, silica, cyanotoxins, TSS, DO, chla, temperature, pH, conductivity, PAR, secchi, alkalinity, dissolved metals, and pesticides at around 35 sites in 2012 and resampled 10 of the sites in 2013 to fill in data gaps. The idea was to combine data sets with DWR, which has not been done if someone is interested.

She then went over the results, most of the chlorophyll *a* concentrations were under 40 ug/L, some were above. She discussed cyanobacteria and mentioned that the World Health Organization (WHO) Standards, which are based on cell count/recreational risk, were often exceeded in Albemarle Sound (see paragraph and table below). The species present in the Albemarle are often associated with freshwater. They observed that cyanobacteria are concentrated in Albemarle Sound "proper" and Currituck. When they had high cell counts of algae the samples were dominated by cyanobacteria. They also looked at the percentage of species capable

of producing toxin. Elizabeth Fensin noted that just because you have a species capable of producing a toxin, does not mean that they are producing the toxin.

They tested for the following cyanotoxins: microcystin, cylindrospermopsin, and saxitoxin. Microcystin and cylindrospermopsin were occasionally present at a low levels. The peak value for cylindrospermopsin was around 1.5 ug/L. Recreational guidelines are typically around 5 ug/L which is exceeded at Mattamuskeet routinely. It is rare that cylindrospermopsin is present at both these location, a recent EPA survey showed cylindrospermopsin present in only 5% of the waterbodies sampled. Microcystin was also present at very low levels except during a bloom in August of 2013 when samples were 69 ppd, exceeding the WHO's guideline of 20 ppb. They looked at the trend between chlorophyll a and microcystin and cylindrospermopsin, which had no strong relationship. In general, they did not see a great deal of toxin below 15 ug/L chlorophyll a. If we consider a toxin standard we might want to think about it in response to a threshold being exceeded for phytoplankton/ chla. Clifton Bell noted the WHO standard for microcystin is around 20 ug/L (high relative probability for acute health effects) and if you look at the different states the lowest is 6 ug/L. An excerpt from WHO guidelines is provided below:

> *For recreational waters, the WHO concludes that a single guideline value for cyanobacteria or cyanotoxins is not appropriate. Due to the variety of possible exposures through recreational activities (contact, ingestion and inhalation) it is necessary to differentiate between the chiefly irritative symptoms caused by unknown cyanobacterial substances and the more severe health effects due to exposure to high concentrations of known cyanotoxins, particularly microcystins. The WHO guidance values for the relative probability of acute health effects during recreational exposure to cyanobacteria and microcystins are:*

Relative Probability of Acute Health Effects	***Cyanobacteria (cells/mL)***	***Microcystin-LR (µg/L)***	***Chlorophyll-a (µg/L)***
Low	*< 20,000*	*<10*	*<10*
Moderate	*20,000-100,000*	*10-20*	*10-50*
High	*100,000-10,000,000*	*20-2,000*	*50-5,000*
Very High	*> 10,000,000*	*>2,000*	*>5,000*

The take home is that the Albemarle Sound is a big system and variables are different depending on where you are—phytoplankton communities, salinity regime, etc.

She also looked at the relationship between TN and chlorophyll, but noted were issues with the chlorophyll data that need to be addressed. She suggested not developing a mathematical model from the data by providing a 6 microgram per/liter correction due to potential QA/QC issues with the lab. Though she believes the trend is valid, she cautions using the data to develop criteria. Dr. Spruill noted no matter what analytical issues exist, he has seen strong correlations in his research and it is generally seen in the literature. Clifton Bell noted there was a compelling relationship with nitrogen, if there is a nitrogen limitation in Albemarle it would be good rather than being replete of nitrogen. The numbers are above what you would normally consider being a physiologically limiting concentration, could it be representative of something else, such as luxury uptake and storage of nitrogen in the cell. She replied it could be since most was organic nitrogen. Dr. Paerl

noted that the chlorophyll accounts for most of the TN out there. Dr. Paerl noted it is a shallow system with resuspension, that the only way to find out what is limiting is to take samples and do bioassays, and that he has grown more cynical of N:P ratios over time particularly in a shallow system.

They evaluated the biological parameters seasonally and saw peaks in summer and fall. There is also data collected by citizen scientists during the blooms.

She encouraged the group to think about how they could collaborate moving forward. She would be very interested in working together to identify and fill data gaps, possibly include or follow up on the work done by Michael Paul with Tetra Tech.

Dr. Moorman explained the study was still undergoing review internally within USGS and has not yet been published.

Albemarle Sound modeling gaps—Jing Lin, DWR

Jing Lin, DWR, gave an overview of water quality modeling challenges for Albemarle Sound. She explained there was currently no plan to construct a model for Albemarle Sound. She gave an overview of the types of models designed to do multiple things, they all have different data needs and challenges. There are process based models—watershed models, receiving water models: hydrodynamic models, water quality models, and various types of statistical models.

She gave an overview of major estuarine processes to be represented with a process based model: estuarine hydrodynamic processes including freshwater flow, thermohaline circulation, harmonic tides, wind-driven circulation, vertical stratification, turbulence. Biogeochemical processes include algal growth, respiration, nutrient limitation, nitrification, denitrification, benthic flux, phosphorus sediment adsorption, hypoxia, DO reaeration.

For Albemarle Sound, the following major processes would have to be represented, at a minimum: estuarine hydrodynamic processes: micro-tidal, wind-driven, well-mixed; biogeochemical processes: different algal groups, different nutrient limitation pattern river vs. sound, sediment nutrient flux, and SAV.

There are challenges associated with model development for Albemarle Sound. Many sites do not have the necessary data to construct a model. The bathymetry and shoreline are very complex, there are questions of where the river boundary ends and sound begins, issues with the surface and bottom boundaries, nutrient flux, surface elevation and water quality. Dr. Moorman noted that in general there is a lack of hydrologic data based on her experience.

Jing gave an overview of the process associated with model development with examples from other areas including Chesapeake Bay, Delaware Bay, and Gulf of Mexico hypoxia modeling. Typically, there is an advisory committee that assists with monitoring, data production, model selection, calibration and review. In general, there is a great deal of work needed to develop a model, more data is needed, and it takes staff time and resources to develop.

Recommendation process and discussion—Jim Hawhee, DWR

Jim noted that his role would be coming to an end but that the statewide NCDP process would take several years. He asked the group to think about where we currently are in the process…is everyone comfortable, do we need more data in order to make recommendations? He noted that some may be ready to recommend specific parameters including timing frequency duration, spatial extent, but that others may want to see

additional information and studies. He would like to attempt to move forward and get as far down the criteria recommendation process as we can by September. That means the group would focus on response parameters for the July meeting, and if needed, a meeting in September to focus on causal parameters.

Hans Paerl said he would like to hear from the group what the key questions are that need to be asked. For example, what nutrients are limiting, we do not know much about that in the system. Are there seasonal or geographic patterns? Can we go with the standard paradigm that phosphorus is limiting in freshwater and nitrogen in marine that may not apply since the system is brackish and low salinity? They are important to ask before going too far down the road of developing criteria.

Tim Spruill noted that based on the data, the river systems may be nitrogen limited, but it could switch. He thinks you need to ask when the major problems are occurring, what conditions have been produced that cause the most problems. He thinks summer and fall when you see oxygen depletion, algal blooms, so that is the critical time. The ones that cause the most troubling issues for fisheries, recreational use, drinking water supply typically occurs during this time.

Jim stated he envisions the process that if Dr. Paerl thinks there are data gaps, those become research recommendations, whereas Dr. Spruill may have the information needed to move forward. He provided a sheet and asked the group to propose recommendations they feel comfortable with whether it's research or criteria recommendations by July 1 along with the rationale so they can convince each other.

Martin Lebo encouraged the group to think about the overall health of the system and the body of knowledge presented to date, including where there are information gaps. Are we maintaining a relatively healthy ecological system, or are we trying a solve a problem or improve an existing condition? How does that affect the decision?

Dr. Paerl stated that it would be helpful to get a copy of the USGS report. Jim will follow up and request the report.

Dr. Kenworthy encouraged the group about prioritizing and thinking about the low hanging fruit—Are there one or two metrics to focus on. Are the uses being attained?

Jim encouraged the group to work together and share data. He promised to follow up with the data from Tammy and notes from previous meetings. He thanked everyone for attending and adjourned the meeting.

APNEP Nutrients Workgroup Meeting Notes

July 20, 2016

Attendees

Dean Carpenter - APNEP

Anne Coan – NC Farm Bureau

Lauren Petter – USEPA

Jason Poe - USEPA

Clifton Bell – Brown and Caldwell

Tim Spruill – Independent

Martin Lebo – AquAeTer

Jim Hawhee - DWR

Jen Schmitz - DWR

Nora Deamer – DWR

Jing Lin – DWR

Connie Brower – DWR

Michelle Moorman – USFWS – on phone

Stacey Feken – APNEP – on phone

Proceedings

1. **10:00 -Convene.**
    a. Jim Hawhee gives general introduction and opening. Introductions and roundtable.
    b. Jim calls for comments or changes to the January, February, and March meeting's minutes. He asked workgroup members to review notes and provide edits within 2 weeks (Friday August 5).
    c. Overview of staff changes at DWR – Steve Kroeger retirement; cancellation of August SAC meeting.
2. **Parameter Discussion- pH**
    a. Michelle – recommend keeping current standard and use it as an indicator of phytoplankton blooms.
    b. Martin – agrees, no reason to change the current standard.
    c. Clifton – do not recommend that this is an instantaneous standard; however, no duration specified. He suggests 90th percentile.
    d. Nora – agree, maintain current standards.
    e. There was some discussion about whether to include 10% exceedance language in the criteria, retain it in the assessment method, or have it in both places. Lauren clarifies that

EPA would prefer a standard written with a narrative frequency component to cover all the bases.

f. Growing season considerations were also discussed. DWR uses all available data (year-round) in assessment. Some concerns were expressed that the pH standard should include the growing season only, while others disagree and note that pH could potentially be an issue all year.
g. Jim summarizes:
    i. There is conceptual consensus of retaining the present magnitude and applying a 'no more than 10% exceedance' frequency. Aka, 'not outside the prescribed range more than 10% of the time'.
h. The group also discussed whether support should be expressed for the current assessment methodology, which allows for a 10% exceedance with confidence intervals. Group decides to abstain from commenting about assessment methodology due to lack of consensus.
    i. Discussing assessment methodology in general (not specific to pH) may be an agenda item for next meeting. Will focus on response criteria only for this meeting.
i. Propose a *research* recommendation to determine which parameters require a seasonality approach moving forward.

3. Parameter Discussion – Dissolved Oxygen

a. Michelle recommends keeping current standards
b. Martin agrees
c. Clifton current standard is sufficient but may be slightly overprotective. Should be expressed as having a one-hour average duration.
d. Tim – recommends 5 µg/L floor, using bottom values. Recommends specific sampling frequency.
e. Jing – possibly increase standard to 6 µg/L. Would like to add a subsurface component as well, possibly with different criteria. Also need to clarify what the 10% exceedance is hoping to cover.
f. Michelle recommends additional *research* into what is a true impairment to biota based on instantaneous DO values. Some discussion on biota being able to 'escape' low DO pockets – disagreements on what bottom fauna/benthos who may not be able to escape need in terms of a minimum DO. Further *research* needed into what lives where in AS.
g. General discussion regarding the implementation of this standard and whether Albemarle in particular would fail based on natural conditions.
h. Jim asks if there is consensus to maintain the 5 µg/L standard, but also incorporating the 10% exceedance frequency language. Many did, but Clifton and Connie raised some outstanding concerns about including frequency language into the standard. Concerns were expressed that the standard may not be approved with that language. Also, there was discussion of how the criteria would account for new monitoring approaches. The question was also raised as to whether assessment methods could be considered in the development of a TMDL.
i. Lauren expressed caution about North Carolina's assessment methods in relation to waters with insufficient data. She distinguished between confidence in the assessment method and in the criteria itself.
j. Clifton indicates there are examples of TMDLs being set very low to bring waterbodies into attainment, with associated assessment methods that are EPA approved. This would impact our development of standards; whether or not we need allowable exceedance

language included. Connie/Lauren request examples be sent to them (*research* need), including the specific parameters at issue. Further investigation also needed into evaluation of a subsurface standard (*research* need).

4. **Parameter Discussion – Clarity**
    a. Michelle – proposing a 'step-down' approach, but hinges on increased monitoring. Clarity issues would suggest the presence of harmful algal blooms, which would provoke additional monitoring in those areas. Need to assess clarity data and trends over time (*research* recommendation). Jim cautions that there are some QA/QC issues with Secchi depth readings in the past.
    b. Chris/Jim – recommend criterion of 13% light through water (PAR or Secchi), April 1-October 31, in waters less than 3m deep, predicated on Chesapeake Bay research. Spatial extent of criteria may be informed by data density collected by DWR and partners, requiring some *research.*
    c. Marty/Clifton – *Research* recommendation regarding nature and extent of historic SAV populations. Dean indicates a new map with the 2012 flyover data will hopefully be out this year.
    d. Clifton – *Research* recommendation regarding relationship between clarity and chlorophyll-a using bio-optical model; perhaps alter criteria based on this historic relationship. Michelle suggests some USFWS reports coming out in September may offer guidance on these models.
    e. Tim brings up the issue of determining which SAV are desirable vs invasive, and if we want to be protective of some or all. It was noted that it is impossible to determine species distribution from aerial photographs.
    f. Discussion regarding evaluation of known SAV coverage vs historic coverage, and the viability of using this information for criteria establishment purposes. Implementation will also be an issue. Lauren suggests using known SAV coverage to set the standard to be protective of what exists.
    g. Jim asks for consensus on whether we should move forward with clarity as a parameter. Mostly group consensus, some abstentions.
    h. Jim asks for opinions on using the Chesapeake Bay as a potential model for this parameter so as not to reinvent the wheel. Clifton gives the caveat that they had good information regarding historical SAV coverage which drove their recommendations – we need to do the *research* to come up with the same if we can. Marty wants to clarify that it's a good starting point, but it is not the exact same system and should be individualized. Tim suggested that protecting for optimal habitat now will allow SAV to grow wherever possible, and not necessary to flesh out historic SAV coverage. Others disagree.
    i. Marty reminds the group that the process we are using to develop these criteria is equally as important as the standards themselves.
    j. Marty would like to see the range and distribution of historic Secchi depth readings across the Sound to see where 13% falls. (DWR work needed to sort out data).

5. **Parameter Discussion – TSS**
    a. Jen/Jim – recommend this TSS standard in addition to or potentially replacing the existing turbidity standard. This is due to the difficulty using turbidity in relation to the clarity standard if we move forward with it. TSS analysis accounts for the settleable solids, which contribute to clarity issues, while turbidity would not. Need to harmonize the clarity/turbidity/TSS relationship.
    b. Michelle brings up the issue of hold time for turbidity, which is not as much of an issue with TSS, as well as representativeness of field conditions.

c. Marty says if we use Secchi depth to protect the designated use for clarity, and determining what comprises that issue will be done using the biooptical method.
d. Connie – *research* needed to justify why other states use TSS instead of turbidity, and which have repealed turbidity in favor of TSS, and why.
e. Jim asks if collection of TSS as a *research* recommendation would be helpful – group consensus is yes. Predicated based on existing model.
f. Jim wants to investigate aquatic life impacts of TSS and sedimentation, perhaps informed by an ongoing DMF-funded study (*research* need).

6. **Parameter Discussion – Turbidity**
    a. Marty suggests tabling this (no recommendation this phase), but explore the relationship between clarity/TSS/turbidity for phase 2. Group consensus.
7. **Other Recommendations**
    a. Would like to prioritize parameters that have been discussed so far. Marty recommends sending out the parameters from today's meeting to be ranked by participants.
    b. There are often linkages between multiple parameters – these need to be considered during prioritization.
    c. More data is better! Connie clarifies that we have data, but aren't able to use them necessarily due to poor QA/QC issues. Michelle suggests that all water quality data collected needs to go into STORET.
    d. Bioconfirmation – institutional knowledge is lost from DWR. Will need to brush up on this as a group. Homework – read EPA document on bioconfirmation.
8. **Parameter Discussion – Phytoplankton/Cyanotoxins – tabled for next meeting**
9. **Parameter Discussion – Chlorophyll-a – tabled for next meeting**
10. **3:00 - Adjourn**

APNEP Nutrients Workgroup DRAFT Meeting Notes*

September 21, 2016

http://www.apnep.org/web/apnep/nutrients

*****These notes document the final meeting of the workgroup. Unlike for prior meetings, notes from this meeting were not reviewed or approved by workgroup members. Therefore, they only represent the notetaker's account. These discussions were technically difficult in nature and documenting them in real time was challenging. Due to the lack of workgroup review, the summary of workgroup members' input may be imperfect and due caution is advised.

Attendees

Lauren Petter, Environmental Protection Agency (EPA), Astrid Schnetzer, North Carolina State University, Anne Coan, N.C. Farm Bureau, Clifton Bell, Brown and Caldwell; Tim Spruill; Martin Lebo, Aquater; Hans Paerl, UNC Chapel Hill, Michelle Moorman, USFWS; Connie Brower, DWR; Elizabeth Fensin, DWR; Chris Ventaloro, DWR; Dean Carpenter, APNEP; Steve Kroeger, DWR; Jim Hawhee, DWR; Maya Cough-Schultz, DWR; Jing Lin, DWR; Heather Patt, DWR, Jamie Mcnees, DWR, Nora Deamer, DWR; Stacey Feken, APNEP.

Proceedings

Jim Hawhee, Division of Water Resources (DWR) welcomed attendees and everyone introduced themselves.

Michelle Moorman, USFWS, announced that the USGS report will be available in two weeks.

Jim announced that Steve Kroeger will be retiring at the end of September and he will now be coordinating the statewide Nutrient Criteria Development Plan (NCDP) process. This will be the last meeting of Phase I of the Albemarle Nutrient Criteria Workgroup. We may need to revisit Albemarle Sound at a later date. The goal of the meeting is to find consensus on criteria proposals where we can find it, document concerns and discussions, and continue to identify potential research items. He doesn't anticipate that this group will meet again, but he would like to follow up and prioritize research endeavors. He will be working on the Phase I report in October.

Jim asked for approval of the meeting minutes back through January. Anne Coan asked to have her name changed on the March meeting minutes, the minutes were approved pending these changes. The January and May minutes were approved. Lauren Petter, EPA, noted that comments regarding "EPA's concerns" on insufficient data or confidence intervals were stronger than she had intended, and suggested the notes be changed to "caution" instead. The July minutes were approved pending these changes. Jim will send out the notes for the September meeting and likely ask for approval via email.

Please visit the Nutrient Workgroup meeting materials folder to access written summaries of the proposals.

CRITERIA PROPOSALS

Phytoplankton and Cyanotoxins

1. Phytoplankton and Cyanotoxins Criteria Proposal 1, Michelle Moorman and Jill Paxton

Michelle Moorman worked with Jill Paxton, who runs the DWR estuarine monitoring team, on her proposal. She noted there is the issue of developing standards, and the other issue of rapid response when blooms occur. She wondered if it was addressed in standards and whether or not this was the appropriate venue, but noted it was something that needed to be considered. Sometimes it takes a great deal of time to get information out to the public. From a standards perspective they proposed a step down method of rapidly detecting Harmful Algal Blooms (HABs), starting with an immediate field assessment measuring pH, secchi, and a grab sample using existing standards for pH and chlorophyll to determine if there is an algal bloom or impairment, then find out if toxins are being produced. She does think there is a need to develop rapid response procedures to quickly sample and assess HABs, determine if waters are not safe for swimming and recreation, and get that information out rapidly to the public. There is a question though of whether or not this method could be used as a guideline or a standard. Regardless, there is a lack of public knowledge and people have been observed swimming and recreating in waters when recent blooms have happened on the Chowan and elsewhere. We should also consider what should our cyanotoxin standards be given the human health risk. Current guidelines in other states are pretty conservative, there is a need for additional research.

Tim Spruill asked what other states do along the coast. Michelle referred to the World Health Organization guideline of 20 ppb for microcystin. Generally, there is not a good correlation between chlorophyll *a* and toxin production. Tim mentioned that you would not necessarily expect to see a relationship, the organisms producing the toxin do not necessarily have a great deal of chlorophyll. Michelle mentioned that EPA has done research at Research Triangle Park and has produced guidelines.

Hans Paerl said he had a student that did his master's project in Currituck Sound, and noted it was very fresh and potentially very susceptible to the presence of cyanotoxins such as cylindrospermopsin, stimulated by nitrogen. Currituck is ripe for blooms, it is fresh and there is good interchange with sediments.

Hans noted that there are states with criteria such as Oregon, Washington, California and perhaps the decision for the state was to determine whether or not those are appropriate for Albemarle Sound. Astrid Schnetzer and Michelle said Ohio and Nebraska have them as well. Hans noted it was a state by state thing that depends on the problems they have and the uses of the water. Connie Brower commented that there are a number of published criteria, and other states use them to judge whether or not things are right or wrong, but not all states have adopted them as standards. EPA is working on recreational numbers; drinking water standards have been published. It is much easier once they are published and vetted to get them through the rulemaking process and adopt the criteria into state standards. Chris Ventaloro recently attended a conference on recreational standards and learned that toxin standards may be published before the end of the year.

Connie commented on the issue of getting information to the public. Elizabeth Fensin and Mark Vander Borgh are working with the Department of Health and Human Services (DHHS) on a crossover to determine toxins. Elizabeth noted that they have to go back to square one each time, there is limited capacity to test for toxins in time. DWR does not have authority to close the waters for recreational uses or public health concerns, and DHHS says it is the counties' responsibility. Some counties have been proactive, while others have not, each county is looking for their own methods, but there is not an official statewide process yet. DWR staff does communicate with the DEQ Public Information Officers, who may issue a press release.

Jim noted that Michelle had an interesting proposal and wondered if toxins were the way to go. Michelle mentioned that cyanobacteria could also be used, but toxins would be more rapid, it's a chemical, more

repeatable versus data that may be more variable and not necessarily tell you if there is a human health risk. Connie noted that her proposal could be used for something different such as testing. Connie believes Michelle's proposal could be used for something different, and explained they need as much support as they can to do the testing for Elizabeth and Mark. The more they hear from the group, the more likely they that the Water Sciences section is to get the support needed for this type of testing to be done at the lab. Elizabeth said they are starting to use the abraxis test strips, but even if you get a hit, it's still not clear what the agency can do with the information. Steve Kroeger said that Secretary van der Vaart had tasked Mark Vander Borgh with getting a HAB response plan in place, and that part of that includes bringing some of the algal toxin testing into their arena. Connie noted that if that happens it will be easier for them to have better notification and a timelier response in place. Elizabeth noted that there is still the issue of deciding who has the responsibility to be the first to issue the notices. She said we may get more money for testing but are not sure they will get additional money for staff, so it remains a grey area. Nora Deamer suggested that Michelle's proposal using secchi, pH, and DO be written into a QA protocol which could provide a trigger for the next steps where you take phytoplankton, chlorophyll samples etc. Michelle said the other thought behind their proposal was that you could expand monitoring beyond the current groups such as the estuarine monitoring team, which is way overstretched, that this could be an approach that was potentially robust enough to be included in any standard if the right training was provided. In the Gulf of Mexico, they have round robins with multiple groups such as Marine Fisheries, Riverkeepers, etc. participating. We know there is not enough data compared to the size of the estuary, so this is another way to make the date set more robust.

Tim Spruill asked whether Michelle was proposing a standard. She clarified they were proposing to keep the pH standard we already have, but that she was not proposing cyanotoxin standards since she was not an expert in that area. She agrees on waiting for EPA's proposal since they have some of the best cyanotoxin minds in the country. Tim noted that other states do have standards. He believes that protection of the environment and population should be the priority for the state and we should adopt something, he doesn't understand how states can get by without adopting anything. Elizabeth mentioned that in the Midwest, there were anecdotal reports of dogs getting sick in the Midwest and people's stomachs hurting, and though it sounds bad, if there were more incidents here we'd likely see more of a statewide response, she wished that people would report these anecdotal incidents more often. Tim noted that with red tide for instance, the effects are not just aqueous issues, that air/breathing is an issue as well. Hans said that was due to red tide in coastal waters and was a separate issues occurring in a different place. Tim acknowledged this but noted those issues could occur further in the inner estuary as temperatures change, and that is was not just the chemical effects that we should be looking at. He feels like we should be looking at all the different ways that human and environmental health can be impacted. He believes it's a good idea to be conservative and go with numbers that have been published, since we should protect the resources owned by the people of the state.

Jim said it did not appear that we would be able to agree on a toxin parameter today, suggested waiting for the EPA proposals, and asked if there was interest in pursuing these parameters for Phase II. Hans said we might not be able to make recommendations on set levels of toxins, but asked if there were states that have well-defined standards, that the recommendation could be that DEQ should look at those and evaluate whether or not they were appropriate for inland waters with cyanotoxins in North Carolina. He reiterated that he did not think we should confuse the red tide issue with what's going on in inland estuarine waters, inside the Outer Banks. Hans likes Nora's suggestion of using triggers to get the agency to focus on the potential for toxins and respond. He thinks chlorophyll is ok, even though it does not always encode for cyanobacteria, but that it certainly encodes for blooms. As an initial warning, green light, whatever you call it, it's easy get results

quickly, can be measured in the field, using test strips for example, and is a quick way to assess whether or not there is a problem. If there is one, you have to get into more of a sophisticated analysis to get the real numbers.

Lauren Petter believes it would be wise to wait for EPA to finalize their recommendations. Tim asked how many states have standards vs. guidance. She will send a link, there a 20 states that have standards. She noted there is a difference between recreation and action level. Connie noted that many are advisory levels, since it is a challenge to set a standard, but they do hope they will continue to work on it. She noted that even with drinking water, EPA had set guidance rather than criteria in light of the challenges. She reiterated Steve's comment earlier that the Secretary has asked Mark to look into this further, that we have agency buy in. How long that may take and whether or not they get the staff or budget to implement is another issue, but at least it has been recognized as a significant issue by upper management. She's been in the meetings between DEQ and DHHS, and noted that is really is a challenge to determine who should play what role. She noted that these comments will help support this recognition that other people are concerned, and there is a need to address the issues further.

Tim asked for clarification on whether these were just guidance for cyanotoxins for the other states. Connie mentioned that she was not certain for every single state. Lauren said some have action and some have advisory levels, that she would have to look more closely, that some states may deal with it on a case by case basis. Tim said it seems odd we do not have standards after years of research and millions spent, we know that an increase in nutrients results in an increase in algal blooms, the issue is not going away. He believes it would make sense to establish preliminary standards so we have some protection. Michelle noted there were relationships for parameters that we do have standards for such as pH. She is supportive of the idea of developing advisory guidelines.

[Link to EPA webpage regarding the regulatory status of HABs, cyanobacteria and cyanotoxins in the U.S.]
Tim noted that cyanobacteria in the top of the water column utilize nitrogen, but do not necessarily correlate with chlorophyll, as they are not nitrogen limited, you can reason that you have an occurrence without necessarily having high chlorophyll. He noted that in highly colored waters you may not see an algal response. Hans said there is a great deal of variability in chlorophyll related to cellular biomass, but a bloom is a bloom. Chlorophyll concentrations are elevated regardless, if see 40, indicator that you need to be concerned, extra vigilant. Not all cyanobacteria fix nitrogen, most problems in lakes, do no assume the old paradigm that nitrogen fixation is the issue. He noted that other things correlate which have nothing to do with nitrogen fixation and recommended keeping things simple and sticking to chlorophyll. Elizabeth said to keep in mind there is a lag time with chlorophyll and phytoplankton results of about a month. If want rapid advisory, it may not be best to rely on chlorophyll. You could use cell counts, etc. Michelle stated that is why they proposed using a rapid indicator in the field, use test strips for pH, it is a nice way to collect data without having to send a sample to the lab. There is a nice relationship between pH and chlorophyll and dissolved oxygen.

2. Phytoplankton and Cyanotoxins Research Proposal 1, Martin Lebo

Martin Lebo said his approach was simple and involved looking the available data to determine whether there were really concerns in the sounds vs. problems in the watershed. Are there really problems with the community in the sound, or are there issues in the margins such as embayments or river mouths that are really more a watershed problem coming down. Research should be augmented with additional testing such as

toxins or taxonomic assessments so we can understand what and where things are going on. We need to take bottle samples when blooms are happening to get a better understanding. Elizabeth mentioned that it takes 20-24 hours, do cell counts, still more rapid than waiting on chlorophyll results. Nora stated that she did not think phytoplankton is being collected at all stations. Elizabeth mentioned that Jill's group started collecting back in June so we should have a few months' worth of data. She noted that the Chowan-Edenton Environmental group is also collecting data.

3. Phytoplankton and Cyanotoxins Research Proposal 2, Clifton Bell [discussed after lunch]
4. Phytoplankton and Cyanotoxins Research Proposal 3, Clifton Bell [discussed after lunch]
5. Phytoplankton and Cyanotoxins Research Proposal 4, Hans Paerl

Hans noted his first proposal was similar to Clifton Bell, whose proposal will be discussed after lunch. He believes it is good, but only relevant in the summer when the bloom exists. All agree the relationship between chlorophyll is squishy, unless you have a mono bloom of species, you will not get a good regression. His 2nd proposal related to algal bioassays, important use of data collected in Chowan and in the sound itself. See how much the system has changed, look at the data more thoroughly to see if there are trends, other issue is what is limiting or controls nutrients. He and Clifton both propose the use of bioassays to get a short term snapshot of which nutrients are controlling growth, and when on a seasonal basis, it is not likely to be an issue in the winter. There is a great deal of phosphorus stored in the sediments, and there may be a limit to how much phosphorus can be controlled beyond what is already being done. It is more likely that nitrogen is limiting. We need to know what the nutrient limitation dynamics are in the sound. Tim Spruill asked if we have any numbers already, as a ton of research has been done over the years, surely there is something that can be used for management proposes. At what point do you use the numbers from bioassays. Hans replied that there were two kinds of bioassays, 1) determine which nutrients are limiting at the time the sample is collected. 2) Distill water for major ions, see growth response from algae. You dilute, see growth potential reduced from algae. This was used in the Neuse for TMDL development. The nitrogen concentration varies, and phosphorus did not play a role in the lower Neuse.

Tim said he was still not clear how this could be used for management purposes. Astrid Schnetzer noted that the bioassay is the only what to see species composition shifts based on what is actually happening in the environment. Anne Coan said the beginning of the group, it was recognized that the Albemarle system is different. We can't us the numbers from the Neuse since it is a more mixed system, there may be different limitations. Hans noted that for the TMDL, the methods looked at historical trends, increase in loading, how much nitrogen is reduced, concentration at any time of year. Using dilution bioassays, if reduce by 30 percent, will control algal populations. Tim again noted that we would never understand everything about the system and expressed frustration that nutrient criteria was not being proposed. He referenced the publication from 1982. Astrid noted that we have better methodologies now, recent detections use tools/ develop empirical relationships / fit system / and mentioned that we are flying half blind if we do not take advantage of these tools.

Hans mentioned that for loading you look at all seasons. Anne Coan mentioned that with data mining exercise, she is not sure how you tease out the legacy loading, which is a big issue when it comes to implementation. Hans noted there is internal loading, even if you cut off external loads, how long does it take the system to sustain. Martin noted that Clifton's proposal included triggers, and thinks it warrants further discussion. He thinks the bioassays fits in with Hans proposal.

6. Phytoplankton and Cyanotoxins Research Proposal 4, Hans Paerl
7. Chlorophyll Criteria Proposal, Martin Lebo

Martin noted that the chlorophyll concepts are well established, it is the details where states get caught up in individual needs and relationship to uses. He thinks 25 is a good starting point, it is the same range referenced in other systems.

8. Chlorophyll Criteria Proposal, Clifton Bell [discussed after lunch]
9. Chlorophyll Criteria Proposal, Tim Spruill

Tim said in looking at the data and information that has been around the past 50 years worldwide for coastal, reservoirs, lakes, almost always there is a relationship with phosphorus. He mentioned thought that he had trouble coming up with this relationship using DENR data, there was a weak relationship with TT data too. Trophic studies in the 60's/70's the numbers come out the same. Phosphorus is important in marine systems, not just nitrogen. His data shows phosphorus is limiting as well in Albemarle Sound. Casual relate to response, should collect data. You start to see eutrophication between 20-30 ug/L in all of the old datasets, that there is good support to show how it related to causal factors. He recommends continuing the current stand of 40 ug/L, with a violation occurrence of 40 ug/L or higher at the 90th percentile at any station or a growing season mean of 20 ug/L or above at a single station.

10. Chlorophyll Criteria Proposal, Lauren Petter

Based on the recommendations from the 2003 Bricker report, she recommends a criterion concentration between 5-20 ug/L. This should be tied to submerged aquatic vegetation, considering criteria adopted in comparable systems in Chesapeake Bay and in Florida. She noted you would need to be mindful of the spatial extent and may need to split different regions of the sounds. Martin asked about other states, no instantaneous, averages, lover seasonal averages. Anne mentioned that salinity and spatial extent were important. Martin noted that the salinity could be similar but the physical conditions could be completely different. Lauren noted relevant as bounds for discussion to consider, help bound the numbers. Martin asked with SAV if you would rely on historical presence, said you would probably need bioptical models to translated. Anne said 20 was Tim's proposal, mid sound stations, you may not have SAV. Is 20 relevant mid sound where you may not have SAV?

Tim said to remember 20 ug/L was a mean, not matter limit mid system vs. the edge. North Carolina is not unique, the values are relevant. Look at the trends, range, can't segregate spatially. Anne asked is could relate to salinity mid-channel vs. freshwater entry points, is there a way to define presence/absence of SAV. Hans said Chuck Gallegos worked in Chesapeake Bay on issues related to turbidity, color, and chlorophyll. If you know 2 of the 3, you can use an equation to figure out where the SAV is. This method was used by Jud Kenworthy and a post doc in Currituck and North River. Martin said you can use a bioptical model and get standard manage relationship to chlorophyll. Tim noted that conditions change, why use models, have enough data in the literature. Jim said this has implications for the Nonpoint Source group, prefer not to develop a nutrient strategy if light limitation results from a sediment issue. Tim suggested using indicators, try to find one or two things to see i8ft there is a problem. He feels as though the use of models is employing many

consultant and universities. 20 seems good, it protects SAV and habitat, it's simple. Break up into pieces not happen logistically.

Jim noted that all proposals include the top 90th percentile vs. median. If you look at all, is one better than the other? Various workgroup members discussed their views. Astrid Schnetzer pointed out that Albemarle Sound is a complex system and we cannot measure everything, but however we do not want to choose an approach that is too simple either. Different critters respond differently, temporal succession matters. We do not want to miss an opportunity to look at different triggers and see how the algal community responds. Tim noted that from an environmental management standpoint the reality of implementation is that you have to generalize. Astrid believes we can do both, and recommends a compromise that builds on what we do know and have learned tied to additional research.

11. Chlorophyll Research Proposal, Tim Spruill

Tim talked about the nearly complete USGS study and that it tied to his research proposal for chlorophyll a. He was able to see the same relationship as in the literature, but did not see the same with the state data. Jim Hawhee reminded him the USGS data was flagged. Michelle Moorman noted that the difference could have been that the state dataset is year round data, whereas hers was summer. Tim said even with a seasonal mean you should get a good relationship. He said you could verify with an outside lab such as NOAA or one that is NELAC certified. Clifton Bell asked for clarification on what is wrong and worried we were not comparing apples to apples. Seasonal and temporal variability with different datasets exists. Tim said he was analyzing station means for TN & chlorophyll. Clifton noted that chlorophyll was a different animal. Martin Lebo asked whether or not the state lab participated in the verification and round robins in the past? Clifton said yes, and Elizabeth said they've done it with phytoplankton data the past two years. Michele said there was one in 2013, which is how they knew they had issues with their data, Magdi helped them flag it. It's not that the data is not good, just there may be some bias due to imprecision in the data, which Meritech is unable to quantify. The state data set should be tighter. There could be spatial variability, eastern Albemarle Sound, Currituck noted that highest variability. The embayments are different than the sound. The round robin included all certified labs in the program in the Albemarle Sound proper. Michelle said they did replicate sampling for the state with Jill Paxton's ground, they took sample concurrently twice for nutrients and chlorophyll a. Theirs were 6-7 ug/L less than the state which raised a flag. There was a concern with Meritech's lab practices. They are unable to apply a correction to the data so she cautions about using the data for regulatory purposes or creating a regression. Jing Lin stated that the data to be used for assessment should consistent with the data used to develop criteria and Michelle agreed.

[Working Lunch]

12. Phytoplankton and Cyanotoxins Research Proposal 2, Clifton Bell

Clifton's proposal for chlorophyll is to stick with the 40 that we have now assessed as North Carolina currently does as a placeholder until we can improve it and more closely tie to the designated uses of Albemarle Sound. It appears there is a great potential to do that in looking at water clarity and SAV protection. We've heard about tools to do that in previous meetings such as a biooptical model, so that was a research recommendation to refine those relationships between TSS and chlorophyll *a*. In looking at empirical relations with cyanotoxins, it might not be the biggest issue in the sound but perhaps more with the rivers coming in. We may want to apply the thought process elsewhere, incorporating the data from the adjacent rivers. We may want to look

at using a geometric mean for a criterion and looking at temporal averaging, which he understands was discussed in the morning session. For a number of things we may want to get at with chlorophyll like SAV we are not really wanting to look at instantaneous effects but rather seasonal conditions. There is also precedent for translating back and forth between the two, such as algal blooms that occur over a short duration, empirically relating back to a geometric mean, so there is an acceptable frequency of high end events, and you can translate empirically back and forth, hopefully getting at a target distribution. Wouldn't want to take a value derived as a seasonal mean and apply it as not to exceed value or vice versa, as that would be mixing and matching statistics. Also suggest spatial averaging, making sure we're not drawing segments around a particular station, there might be some geographic delineations we could make using spatial averaging. The 1 in 3 allowance is another frequency consideration.

Jing Lin asked if there was a reason he proposed a geometric mean vs. and arithmetic mean. Clifton noted that for a log normally distributed variable like chlorophyll a, the geometric mean is a better indication of central tendency, EPA has written this up. In the James River just north of Albemarle Sound, they found the arithmetic mean was more indicative of effects like the high end events, which makes sense because the arithmetic mean is more sensitive to the upper end of the distribution. There they were deriving criteria to prevent the effects based at the high end, and going back to a seasonal average, the arithmetic mean was a better predictor. It depends if you are interested in the high-end effects or a long term average for SAV. The state wanted a geometric mean so they developed a method to translate. Tim clarified it was like a median and a way to avoid higher end effects. Jing said that modelers do not like geometric means, takes a lot of data and memory, you might get model results every minute. Martin asked if that was a post-processing issue. Connie said post-processing was a big issue for them, we want to write something so there is no question of how you are going to assess it. Nora tried to run some geometric means and excel could not handle since she had too many data points.

13. Phosphorus Criteria Proposal, Tim Spruill

Tim believes we have enough data to establish standards. For phosphorus in particular, it's been shown over and over both qualitatively and quantitatively there are well-established relationships between phosphorus and chlorophyll a. There are well over 50 studies between the 1960s and 2000. The more important issue is at what point you see problems. Over and over 0.01 mg/L comes up and he recognizes some do not agree with it, but there are many that do agree. Many researchers evaluated tropic conditions and came up with the same concentrations around the world. When Vollenweider did his model, it was about 0.01 for dissolved P, and 0.025 for Total P, he developed a regression model which showed that when you get above this concentration you see problems and algal growth. So then he doubled the number to 0.05 as a safety factor. Around 200 biologists came up with consistent qualitative evaluations of when lakes were considered eutrophic, Vollenweider incorporated this into his model. He accounts for lake depth and residence time of the water. If something flushes out more quickly you can sustain more load.

Tim believes these are well established relationships that are applicable to Albemarle Sound and that for open water you should not exceed 0.05 annual mean based on 12 samples with no single monthly sample above 0.07 mg/L during the summer growing season. These are also based on numbers published in an EPA paper from 1987. When you get above these numbers, you see oxygen depletion, stratification, and other issues associated with eutrophic lakes.

Hans clarified that his proposal was that the upper limit should be 0.05 mg/L Total P. Tim said yes, but that it could be 0.05-0.08, but he was trying to be conservative. Hans went back to Anne's point about legacy phosphorus and that our coastal sounds were depositional systems that are basically capturing marine deposits from a long period of time and were actually mined for phosphorus. He wondered if you take that into account along with resuspension, what if the system was already exceeding these numbers, how would you get it out? Tim said you reduce the sources of phosphorus going into the system, you have to focus on what you can, you have to start somewhere—limit erosion from uplands, discharges from agriculture, industries, cities, etc., and focus on the ones causing the largest loads into the system. Jim said that ties into a reference condition. Tim said we're likely almost there, and Hans agreed but noted that in many places it is natural trapping of sediments from marine sources. Tim thought those would be buried under more recent sediments coming in from the freshwater loads into the system. Hans said we need to determine what is really limiting primary production and blooms before making any conclusion based on stoichiometric ratios, we need to ask the algae, the ratios do not always hold. He does not believe the ratios can predict the sediment water column dynamics in our system. In the Neuse and Currituck Sound work done, nitrogen was more limiting than phosphorus. There are arguments for dual nutrient controls into the system in other areas because of this. Based on the regression he did, it suggests that phosphorus is a strong controller in the Albemarle Sound, and nitrogen as well. You just have to decide what level you want to be at before you have trouble. Again, he feels these are already well established and maintained, only way to decrease loads into the sounds.

Martin agrees that asking the algae is important, are the biomass that are present an issue to the system. If the eutrophication display in the system doesn't result in an issue, then managing for N or P when there isn't an issue does not make sense. The step before assessing N&P limitation is whether you need to take the biomass down. Anne remarked that you need to determine whether or not the use is impaired. Michelle agreed and said the issue is where, it's a big system with so many embayments, it's hard to determine where there is an issue. Tim noted that the problem is all along the shoreline and the tributaries coming in it is shallow, exposed to light. Michelle said based on what she's observed it's more heterogeneous than that, and you also have to consider the hydrology, wind tides, residence times, affects different embayments differently depending on their orientation. Currituck may be more susceptible not because of loading, but due to location. We do not have enough information, not even have water level data. She agreed with Martin and Hans approach.

Tim asked what the remote sensing data says. Jim reminded the group that as part of the process APNEP had collaborated with NASA Develop to try and develop a relationship between N&P, but unfortunately the correlations were poor between the satellite color and state chlorophyll *a* data. Tim said they also looked at NOAA data and the chlorophyll showed a mean concentration of 20 and it was worth looking into. Jim thought it would be exciting if we had that capability but may not be there yet. Tim reiterated that when you hit 0.05 you see a problem and though he is not sure it would be the same everywhere in the sound, he guesses it would likely be a problem along the shorelines. He doesn't think it should be above 0.08. Hans said that Bob Christian had done work in the Neuse on N&P looking at regeneration rates and that almost all of that can support production of estuary which is why nitrogen is so important. He said the Vollenweider model is based on auto correlated data.

Astrid said you have to be careful with the ratios, because what the algal cells do will alter the ratio tremendously. If they are in a growth spurt they need phosphorus for the organelles, if they are in a cell building process they need more nitrogen to make proteins. They do not grow stoichiometrically based on the

same ratios, humans do not, no living organisms does. It might be misleading if you assume a steady rate. Also looking at dissolved rates, it is inorganic nutrients and is what is left over, it might be ecologically irrelevant. Jim asked if we could look at other forms of TN/TP for criteria, that we hadn't really teased out all of the relationships and long term changes. In terms of criteria TN/TP may be enough. Astrid said that is what the bioassays have the power to determine. She used the analogy of looking at someone's health, if they are overweight, you probably can't determine what is making them unhealthy if you look in the fridge, it's likely the one thing that isn't left anymore, and that's what the algae do. Hans reiterated that the high regeneration rates were important and the ratios may not tell you much about the growth potential, it's the rate of supply nutrients controlling growth. He thinks the stoichiometric relationships work better in deep systems that are stratified. Tim said these have been used in shallow lakes for decades.

Anne went back to Jim's question about other forms of TN/TP. She noted that we are seeing a shift in species, there were other contributions such as nitrate in groundwater, that those in agriculture feel like they have had a great deal of success in reducing nitrate fertilizer applications. Do we need to tease out the standard based on speciation, and then how to you relate it back in terms of implementation? Tim noted there were form conversions, and that it doesn't disappear, nitrate converts to ammonia. Anne noted those conversions occur in the soil as well. Astrid said you do not need to study all of the algae, you can look at bioassays. You can start somewhere when the culprits are around, see how the algae respond. She used an example from the west coast where they saw less toxicity with nitrate than urea, with the same critter, you may have a different growth response but may also have a different toxicity response depending on what is out there. She talked about the different forms of nitrogen and that we generally know how quickly each are processed in the system. Hans noted that algae respond to the soluble forms of nitrogen.

Michelle noted there seemed to be support for the bioassay proposal and asked if they were proposing to do in different parts of Albemarle Sound to address the spatial heterogeneity issue. Hans said that would be logical, and the easiest thing to do would be to collect samples from different places then incubate in one place. Martin said you can use a two dimensional approach, and get river data so you don't have to do every part of the sound. Michelle noted the when you are talking about different parts you are not necessarily capturing everything coming into the estuary. There are different land uses depending on the embayment. Hans suggested identifying key locations to test initially, it's important to look at what is stimulating the growth of algae and impacts on community composition. Look at areas to see if they are different or characteristic of large parts of the system.

Jim said he gets the sense the group is not comfortable moving forward developing nitrogen and phosphorus criterion. Tim still maintains that the technology has been around, even simple studies not needed, because the information already exists. He recommends establishing standards now and changing them later if warranted. Jim said that it's not as easy as going back and changing it later, we do through triennial review. When we talk about impairments and developing nutrient management strategies we're talking about tackling issues in terms of decades. Tim noted that without the standards it's harder to restore what you have, that's it's more expensive to try and go back and fix something.

Anne went back to Martin's comment about asking the algae, and if the biomass of algae that are present is a problem? Since the issue is whether or not the use is impaired, where do you hit impairment with a certain biomass? Michelle said looking at the data, they've given a great deal of thought to that, how much algae and cyanobacteria is too much. She believes you can say with confidence that the entire Albemarle is not impaired, there may be small embayments that are starting to show signs of eutrophication. Jim said he could take issue

with that given recent bloom events. Elizabeth said we do not have a good phytoplankton baseline, she is shocked there are samples she has seen that look like a eutrophic lake from the Chowan and Albemarle. The exception has been the blooms for the past two summers in the Chowan. Jim noted that we'd seen a lot of bloom activity on the Chowan that doesn't extend into the Albemarle proper. He said there were other arms that are showing high algal levels, the Pasquotank was on the 303d list for the first time this year. Hans said there was evidence of bottom water hypoxia with the blooms and went back to Anne's point of eutrophication vs. impairment. Michelle noted those were hard questions to answer, it's hard to tell with these discrete measurements taken as a snapshot at one point in the day. Astrid said she heard reports of bivalves and mussels were dying and asked if anyone had any information. Michelle pointed out we were talking about nutrient criteria for the Albemarle and not the Chowan. Hans noted they thought they solved the problem there in the early 80s.

Michelle said Jill Paxton's estuarine monitoring team would be the best to ask regarding anecdotal data. She heard there were some in Yeopim / Edenton Bay. Jim said based on his experience the issues are largely in the Chowan and not Albemarle.

Conceptual Proposals

Martin Lebo said much of his proposal he's been talking about all along. The conceptual model is to look at whether or not the system is impaired and whether there is a biomass issue with respect to algal toxins. Nutrients set the productivity level in the system, they set food base for commercial fisheries and other aquatic life. Low is not always good, and high is not good either, you have a sport fishery you are trying to manage the Albemarle Sound for. You need to find if there is an algal issue that needs to be addressed, and whether or not you need to set numbers just to have numbers if you are not impaired for chlorophyll. He imagines there will be specific locations that need more attention, for instance the Chowan, but that is a Chowan watershed loading issue that needs to be addressed.

Lauren said she put her proposal in as a place holder since we are trying to capture the thought process along the way to come back and look at more in depth later. She does not think we have captured the right parameter to focus on for Phase II. The research proposals and dual nutrient proposals are good. We need to see what the data shows, it's more appropriate to see the derivation, it doesn't have to be TN/TP.

Jim stated his proposal did not represent an endorsement from leadership. There are different approaches aside from the traditional TN/TP. His sense is that a mechanistic model may not be practical for Albemarle Sound. Which leaves us with EPA approved guidance or approaches. We have a stressor response such as wit the Tetra Tech report from Mike Paul. There is also a reference condition approach, and of the three pilot areas being looked at in the state, Albemarle seems to be in the best shape so a reference condition approach may be appropriate. There may be aspects we haven't gotten to, such as toxicity risk. We've talked a lot about aesthetics, there is a difference between the algae being dangerous vs. ugly. We've also talked about spatial & temporal averaging.

In discussing a statewide path toward developing criteria we may not have the Cadillac approach for the whole state. There is concern about setting a standard, EPA requirements about backsliding and what might be allowed if new information becomes available in the future. Lauren said each state has the ability to make revisions if new information comes out. Jim asked for instance if we set a criteria of 20 and later find out 25 is a more appropriate number, would be run into antidegradation and backsliding issues. Connie said no, that antideg comes in if you say 40 is protective but no one likes it so you decide to use 60. If it's wrong at 40 and

you have the science to prove that the system is healthy at 45 that would be ok, but not just because you like another number. Lauren said there would be assessment / implementation questions, but that the number going up by itself is not a problem. Connie noted that just because a number is lower or higher it's not necessarily more stringent. It's still as safe as it was before, regardless of whether the number goes up or down. People make assumptions if you change the number but that is not the purpose, the purpose is on being protective, but not overly so or under protective.

Connie asked what the group meant when they talk about chlorophyll being chronic, what they mean. Martin said when he uses it, it is as a condition displayed over time, it is a time component or time averaging vs. an instantaneous measurement. Connie said in her world chronic is associated with toxicity for instance, but it appeared Martin was using it to describe an averaging period. He clarified that chronics have a time component, how much exposure on a long-term basis and still not be hurt. Connie asked if he thought there might be a chronic number over a longer period of time and a single sample max. Martin clarified that both be explored, a seasonal average, if there is algal toxins or oxygen issues associated with peak values, that a maximum be considered. Clifton said even if you are interested in the high end or short duration effects, you were essentially targeting a chlorophyll a distribution. You can pick various statistics that might be representative of that distribution, you may want to be on the right side of that distribution, but you assess against a central tendency, you get an acceptable rate on the right side because you shift the whole distribution. There are different ways you could do it.

Anne asked about the proposal on page 23 listed under other thoughts for discussion, would question #1 be the same as a reference condition? Jim says it makes a stronger tie between causal and designated use because of the response parameter. Martin said you could set the number based on a reference condition and still get a violation based on response. Anne said it sounds like we're talking about nested approach. Connie said EPA has done a great deal of work bioconfirmation with nutrients, they are not as fond of it in other places. Jim reiterated that DWR/DEQ was not endorsing this proposal, but providing an alternative for discussion.

Hans asked what the reference condition in Albemarle Sound was based on. Jim replied it was based on a general sense / perception based on comparison to other systems in the state. Clifton believes we should have quantitative data to back it up. Hans mentioned that a concern that many have is that what is being seen in the Chowan is a result of climate change, base on what was done in the 80s, the physical conditions are changing, intense rainfall, droughts, temperature changes.

Tim asked when the last basin assessment was done in the Chowan (2007) and Nora said one was being done now. Jamie McNees with the Basin Planning Section said that agriculture and the population had decreased in the basin, they were currently assessing the data and determining how loads were calculated. Hans said there were good reports from the 80s. Michelle thinks there will be a hard time with loading and does not think there is a gauge in the North Carolina side of the Chowan. Heather Patt of the Basin Planning Section noted there were some land use changes, an increase in poultry production, and that buffers had been removed. There was an increase in development near Edenton before the recession. There are some forestry mulching issues, and Ahoskie's wastewater plant went from being a non-discharge back to being a discharge. There are no mandated buffers. Anne noted people want to live near the water and want the view. Astrid said we need an understanding of how nutrients move from the Chowan into Albemarle Sound. Anne noted that 2/3 of the Chowan basin was in Virginia and that it was hard to get data. Hans said there were specific recommendations from the 80s in terms of load reductions. Anne said around 20 municipalities went to non-discharge, BMPs were implemented, and the two big issues were the fertilizer plant and pulp mill. It was an implementation

plan that the state funded. Astrid asked if there same critters were present then? Hans replied Anabaena. Elizabeth said it was Anabaena that transitioned over to microcystin.

Anne asked about p. 23 #3 at the top, assumes that is if we decide causal criteria are necessary. Martin said current condition not want to get worse. Hans said N&P clarify not made recommendation but not exclude either, ideally get to criteria end phase.

Jim talked about moving to Phase II. When planning for the statewide NCDP, it was originally estimated that Phase I would be conducted 2013-2014. A research period was built in between Phase I & II. He plans to start writing up the proceedings in October then share the draft with the group. He noted that since he had inherited the full NCDP duties including the SAC & CIC, he did not have the capacity to continue leading the Albemarle group. In discussion with APNEP, they were not sure how continuing to lead the group fit in with APNEP priorities. Dean Carpenter said that support had originally stemmed out of a larger group evaluating contaminant issues that had kicked off in August 2014. The group is responsible for 4 of the 58 actions in APNEP's Comprehensive Conservation and Management Plan (CCMP). There are 13 teams responsible for implementing CCMP actions. There are 2 actions related to metals and emerging pollutants of concern, and 2 related to nutrients, neither of which are strongly related to criteria development, as there were other groups responsible for leading that charge and for developing nutrient management strategies. The opportunity came up for APNEP to be involved with estuarine criteria development as a pilot and it was considered a special project. in recent discussions it appears it would be more appropriate for the Albemarle Nutrient Criteria Development process to be rolled back in with the SAC. Jim noted that APNEP could be an asset to the group, any research proposals could be vetted through the APNEP Science and Technical Advisory Committee.

Michelle said her sense was the group had not come to many conclusions but rather had identified a number of questions. Jim noted we were ahead of where we would have been. Hans said the real questions is whether there is an impairment issue. It's dependent on the use issue.

Lauren asked if the proposals had been ranked yet. Jim said not yet and hoped the group could accomplish that through email. The proposals will be ranked then we can identify potential funding sources and hopefully take advantage of the next field season. He will complete the Phase I write up and Albemarle will be rolled back into the SAC process. He noted that a number of members present were also members of the SAC--Hans Pearl, Astrid Schnetzer, Martin Lebo, Lauren Petter. Anne Coan sits on the CIC. Jim thanked everyone for their participation and contributions, particularly for the last few meetings and adjourned the meeting.

Appendix III: Albemarle Sound Classification and Analysis (Report)

Albemarle Sound Classification and Analysis conducted under the Nutrient Scientific Technical Exchange Partnership Support (N-STEPS)

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Executive Summary

This report summarizes classification and exploratory analyses of physical, chemical and phytoplankton data collected between 1968 and 2013 in Albemarle Sound, North Carolina (NC) to support the nutrient criteria development efforts of the NC Division of Water Resources (DWR) as outlined in its Nutrient Criteria Development Plan (NCDP). The NCDP outlines nutrient criteria development efforts for three major water body types – 1) reservoirs and lakes, 2) river and streams, and 3) estuaries by first developing nutrient criteria in one specific water body in each of these groups. The specific water body chosen for nutrient criteria development in estuaries is Albemarle Sound.

Classification analysis is an important first step for analysis in support of nutrient threshold development. Classification within a data analysis context puts monitoring sites into groups within which the natural dynamics of water quality and water quality responses are expected to be similar; essentially separating apples and oranges. The classes or groups resulting from this analysis are based on statistical similarities within groups for the variables measured. This type of classification could be thought of as a "statistical classification". A good statistical classification reduces variability or noise associated with natural variability, so that the effect or signal associated with anthropogenic effects can be more clearly detected. Once preliminary classes were defined, statistical characteristics of nutrient variables as well as simple correlations between nutrient concentrations and chlorophyll and dissolved oxygen were described for each class.

Various statistical techniques were used to classify sites within the Albemarle estuary. Multivariate techniques using water chemical variables were used. These methods create a "map" of samples where those with similar characteristics are plotted closer together than those with more different characteristics. By labeling sites with proposed groupings, one can investigate structure in the data. This was also done using algal species data, where sites plotted closer together are more similar in species composition. Biological composition often reflects underlying physical/chemical differences and can, therefore, inform classification.

TREED regression was also used to explore functional similarity among sites. Instead of using set characteristics to group sites, this technique uses similarity in the underlying relationship between a stressor and some response variable to classify or order objects. TN-chlorophyll and TP-chlorophyll responses were modeled as a function of major presumed classification gradients (salinity, temperature, depth) and the effect of these drivers on differences in these functional relationships was used to inform classification as well.

The results of these analyses indicated that a preliminary two group classification of the Albemarle Sound proper and adjacent tributary Class SB/SC waters was most defensible. This difference was most related to differences in salinity and depth, but also likely to residence time and turbidity.

Once these classes were defined, distributional statistics (e.g., mean, median, percentiles) of nutrient variables were calculated for each class to describe differences. These were based on grab samples as well as long-term averages. Nutrient concentrations were higher and clarity and dissolved oxygen lower in non-sound adjacent SB/SC waters than in the Albemarle Sound proper, although chlorophyll a was similar among the two classes.

Correlation analyses, which measure the strength of association between two variables, were also conducted and presented as regression plots (nutrients vs. chlorophyll and dissolved oxygen). Chlorophyll a increased with TP in non-Sound waters and with TN in the open Sound sites. Dissolved oxygen declined with both TN and TP in non-Sound waters and increased slightly with TN and TP in open Sound waters.

Introduction

This report summarizes water quality and phytoplankton data from Albemarle Sound, North Carolina (NC) to support the nutrient criteria development efforts of the NC Division of Water Resources (DWR) as outlined in its Nutrient Criteria Development Plan (NCDP). The NCDP outlines nutrient criteria development efforts for the three major water body types – 1) reservoirs and lakes, 2) river and streams, and 3) estuaries by first developing nutrient criteria in one specific water body in each of these groups. The specific water body chosen for nutrient criteria development in estuaries is Albemarle Sound.

Albemarle Sound is part of the Albemarle-Pamlico Estuarine System, the second largest estuary in the continental United States. The study area for the Albemarle Sound nutrient criteria development effort generally includes all of North Carolina's estuarine waters north and west of Roanoke Island, which compromises an area of 769 mi^2 (1992 km^2). At this time, estuarine waters are being characterized according to DWR's "S" classification (SA, SB and SC), which denotes tidal salt waters. The Class SB designation includes "saltwaters protected for primary recreation which includes swimming on a frequent or organized basis and all Class SC uses" and Class SC waters include "saltwaters protected for secondary recreation, fishing, aquatic life including propagation and survival, and wildlife. All saltwaters shall be classified to protect these uses at a minimum."

Because the nearest outlet to the ocean from these waters is through Pamlico Sound and Oregon Inlet, these estuarine waters are characterized by low to moderate salinity (0-15ppt) and wind driven tides. Criteria recommendations during this estuarine pilot effort under the NCDP will be targeted more narrowly for Albemarle Sound and its tributaries that share an SB designation, which encompasses an area of 585 mi^2 (1514 km^2). The Roanoke, Chowan, and Pasquotank (Albemarle in Virginia) river basins drain to Albemarle Sound.

Numeric nutrient criteria (NNC) for Albemarle Sound are presently being evaluated by a nutrients workgroup hosted by the Albemarle-Pamlico National Estuary Partnership (APNEP). Materials documenting the progress of that workgroup and supporting the Albemarle Sound nutrient criteria development process can be found at http://apnep.org/web/apnep/nutrients.

This report was developed as part of an NSTEPS support project for Classification and Analysis of Albemarle Sound water quality data in support of ongoing nutrient thresholds development work in that estuary. This classification and analysis is intended to support the analysis phase of criteria development for estuaries in NC.

This report summarizes water chemistry data from 20 sites within Albemarle Sound proper and 37 sites from contiguous waters (Figure 1). Algal taxonomic data were also compiled from those sites from which phytoplankton samples were collected and analyzed in support of the classification effort. Three types of summaries are provided:

1. **Statistical Classification of Albemarle Sound**. Classification within a data analysis context puts monitoring sites into groups within which the natural dynamics of water quality and water quality responses are expected to be similar; essentially separating apples and oranges. These are based on statistical similarities among the variables measured and their responses. This type of classification could be thought of as a

"statistical classification". A good statistical classification reduces variability or noise associated with natural variability, so that the effect or signal associated with anthropogenic effects can be more clearly detected.

Classification in the statistical context should not be confused with surface water classifications that are regulatory designations applied to surface water bodies, such as streams/rivers, reservoirs/lakes and estuaries. Surface water classifications define the best uses to be protected (e.g. swimming, fishing, drinking water supply) and carry with them an associated set of water quality standards to protect those uses. Surface water classifications could be thought of as "best-use classifications" for regulatory purposes.

2. **Descriptive Statistics**. Descriptive statistics described the distribution (minimum, maximum, median, etc.) of the results for the groups found in the classification.

3. **Statistical Correlations**. Statistical correlations show how strongly pairs of variables are related (e.g. chlorophyll-a and nitrogen) but cannot ascertain cause and effect.

Part 1: Classification

Nutrient criteria recommendations during the estuarine pilot effort under the NCDP are targeted specifically for Albemarle Sound and its tributaries that are classified (i.e., best-use classification) as SB designated waters and encompass an area of 585 mi2 (1514 km^2, Figure 1). The Roanoke, Chowan, and Pasquotank (Albemarle in Virginia) river basins drain to Albemarle Sound.

Albemarle Sound is part of the Albemarle-Pamlico Estuarine System, the second largest estuary in the continental United States. Waters in Albemarle Sound are characterized by low to moderate salinity (0-15ppt) and wind driven tides because the nearest outlet to the ocean from these waters is through Pamlico Sound and Oregon Inlet.

The purpose of classification is to identify potential natural spatial units for nutrient dynamics, i.e., those units within which distributions and stressor-response relationships for nutrients would be expected to be similar. That is, by dividing the Albemarle Sound into smaller units for analysis, differences in natural nutrient generating and/or processing factors, or in confounding variables that occur as a result of natural spatial variability will be reduced, producing tighter stressor-response relationships. In this section we explored the effect of dividing the sampling frame (Figure 1) into "River" (class SB and SC waters located outside Albemarle, Croatan, Currituck and Roanoke Sounds proper), and "Sound" classes, Albemarle, Croatan, Currituck and Roanoke Sounds, and of dividing by different maximal sampling depths. It is important to note that the use of "River" here is a construct – these locations are not freshwaters, they are classified

as Class S waters by NC. This term is used simply to distinguish them from the open water Sound sites.

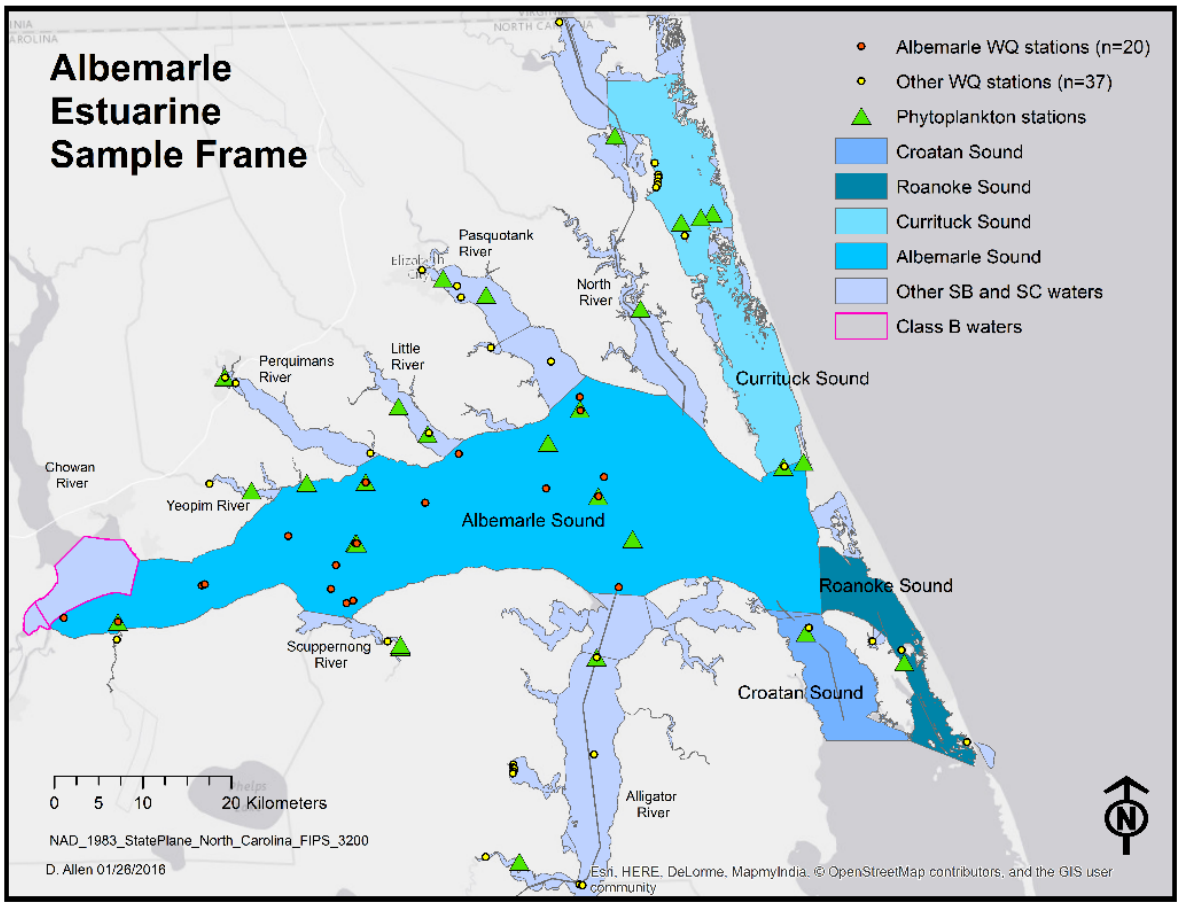


Figure 1 – Study area water quality and phytoplankton sampling stations.

We used water chemistry and phytoplankton data from the Albemarle Sound sampling frame provided by NC Department of Environmental Quality (NCDEQ). The water quality data were downloaded from STORET by NCDEQ on 4/20/2015. Their processing steps included: reconciling station information across time, removal of blank fields, removal of qualified data that failed to meet QA requirements, and assignment of non-detect results the PQL value. The data were further processed by Tetra Tech to convert values to standard units, calculate total nitrogen (TN) from total kjeldal nitrogen (TKN) and nitrate-nitrite, and remove outliers. Three chlorophyll a values of 0.01 µg/L, five orthophosphate values of 0.0 mg/L, two TN of 0.04 mg/L were removed, as were 2 total phosphorus values of 12.0 and 26.0 mg/L. All variables except dissolved oxygen (DO), pH and temperature were log-transformed. The five Secchi depth measurements recorded in inches were also removed as possibly inaccurate (values 0, 1, 2, 3 and 4 inches). More than half of the ammonia values were recorded as 0.0 mg/L, so that variable was omitted.

We employed principal components analysis (PCA) with water chemistry data, non-metric multidimensional scaling (NMS) with phytoplankton data and TREED regression with water chemistry data. PCA and NMS are multivariate ordination techniques that identify similarities in samples or sites based on multiple variables simultaneously. Distance between samples or sites is proportional to dissimilarity (i.e, more dissimilar samples or sites are more distant). While PCA and NMS identify site differences in underlying water chemistry or phytoplankton composition, TREED regression splits study sites into groups within which sites demonstrate a similar bivariate relationship between a predictor and response (e.g., total nitrogen (TN) and chlorophyll *a*). In other words, it defines sites that lie along similar chlorophyll yield curves. For the TREED analysis, salinity, maximum sampling depth, and temperature were used as splitting variables for the study sites.

Water chemistry

Of 4,644 possible water chemistry samples from the range of available sites, a dataset without any missing values was available for 2,330 samples, representing data from 27 distinct sites from the pool of 57 sites. Nutrient values included were from the shallowest sample depth, whereas

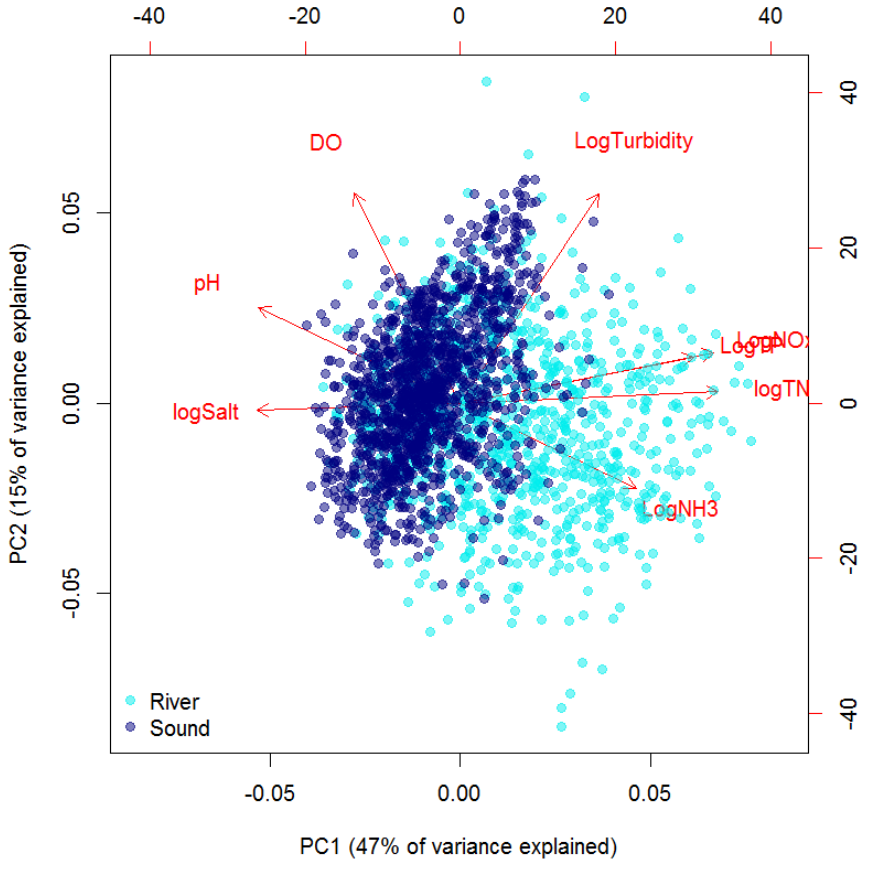


Figure 2 – PCA of water chemistry samples coded for waterbody type: River (SB and SC waters not in the Sounds proper, cyan) or Sound (navy). The red vectors represent the relative weight or loading of the variables in the multivariate space. Log-transformed total phosphorus (LogTP) underlies log-transformed nitrate-nitrite (LogNOx).

salinity, dissolved oxygen, and water temperature were averaged over all sampling depths at each site. We first explored differences among open sound and estuarine tributary or river sites (i.e., labeled *Other SB and SC waters* in Figure 1). In general, the open water Albemarle, Roanoke, Croatan, and Currituck Sound samples (blue dots to left in Figure 2) separated from river samples (red dots to right in Figure 2) on the basis of higher salinity and pH (vectors to left in Figure 2) and lower nutrient values (TP and TN vectors to right in Figure 2). Dissolved oxygen (DO) and temperature were orthogonal to the nutrient and salinity vectors, indicating gradients in these factors across both river and sound sites.

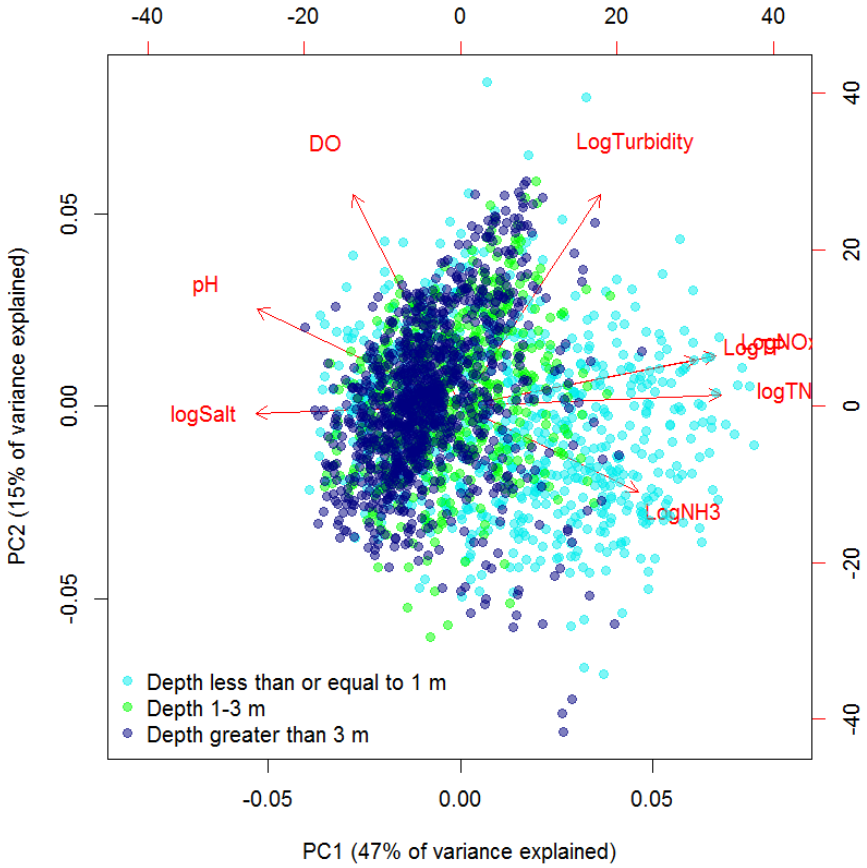


Figure 3- PCA of water chemistry samples coded for maximum sample depth. Vectors as in Figure 2.

In a second analysis, classification by depth was explored using a 1 and 3m cutoff. In this case, a maximum sampling depth of > 1 m split sites along the same lines, with deeper sites (green and blue dots to left in Figure 3) having higher salinity and pH, and shallower sites (cyan dots to right in Figure 3) having higher nutrient values (Figure 3).

TREED regression analysis, which once again identifies groups of samples lying along similar chlorophyll-nutrient response relationships or yield curves, indicated that higher salinity waters had steeper TN-chlorophyll curves, as did samples collected in the warmest waters (Figure 4). This suggests a functional split between more saline waters, where the chlorophyll response to nitrogen was greater, and less saline waters, where the chlorophyll response was less or even declined as TN concentration increased. Similarly, segments or samples associated with warmer temperatures also showed a steeper response. This could also be a seasonal effect.

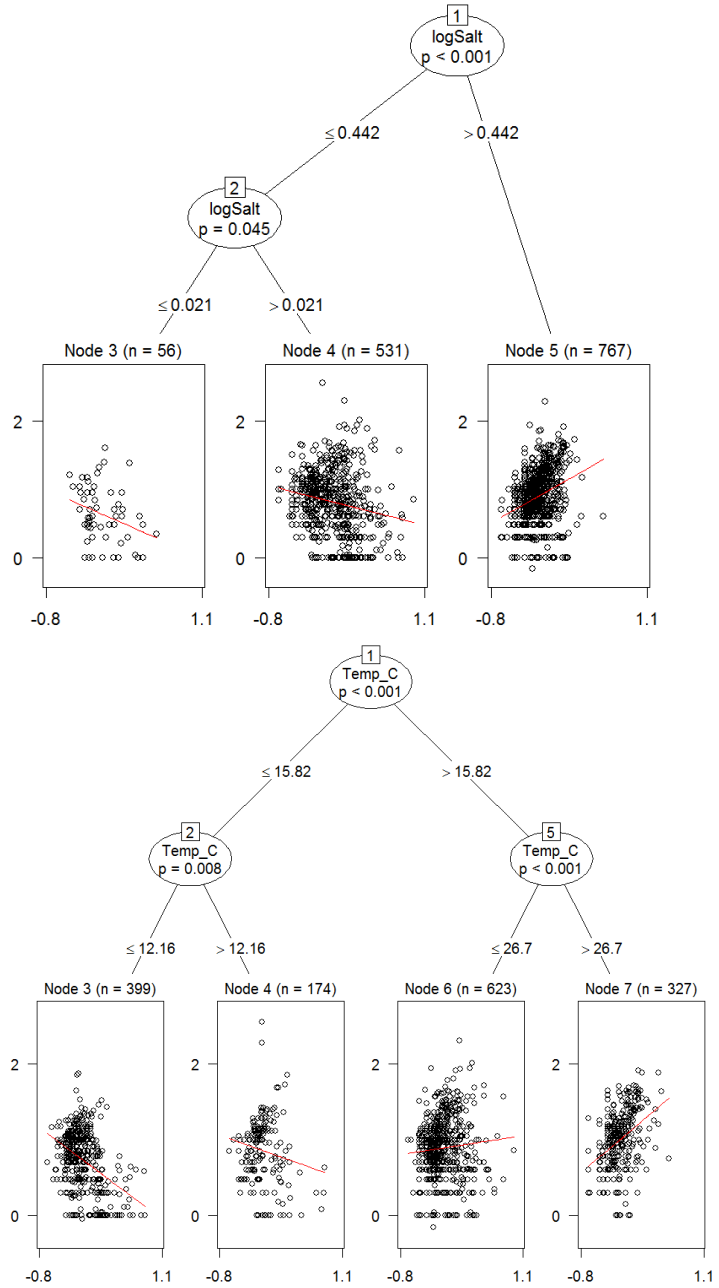


Figure 4 – TREED regression of chlorophyll a as a function of TN concentration using log-transformed salinity (top) and water temperature (bottom) as splitting variables. Red lines indicate linear regression models for each subset of data generated by the TREED model.

Relationships between chlorophyll a and TP were similar to those between chlorophyll a and TN (e.g., Figure 5 for salinity and temperature), except that chlorophyll responses were positive across the salinity gradient and steepest in higher salinity waters, in contrast to the positive chlorophyll responses to TN in the highest salinity waters only. As with TN, responses were strongest in the warmest waters, either spatially or seasonally.

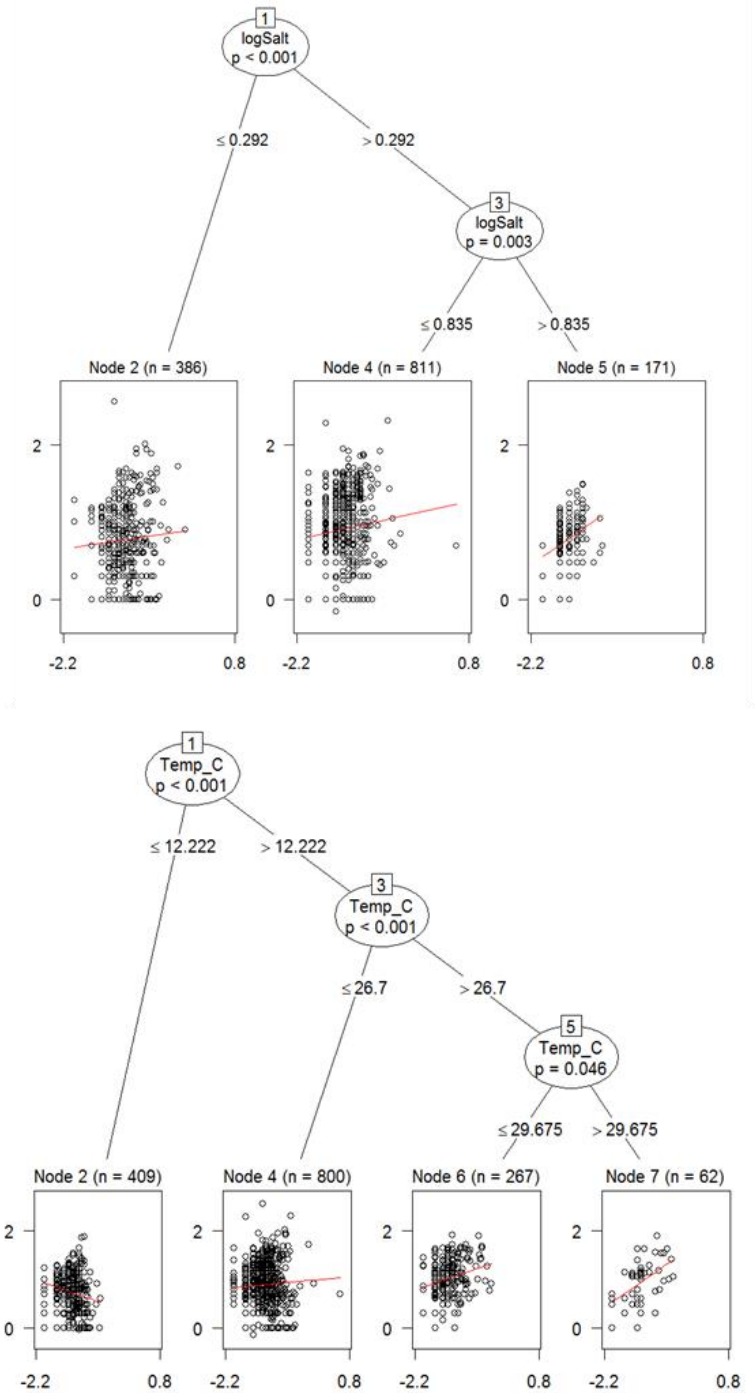


Figure 5 – TREED regression of chlorophyll a vs. TP using salinity (top) and temperature (bottom) as splitting variables. Red lines indicate linear regression models for the different salinity and temperature based sample subsets.

Relationship of the chlorophyll yield curve with depth was more complicated, but in general samples with intermediate maximum sampling depths (between 0.2 and 6 m for TN, 0.1 and 3m for TP) had higher chlorophyll yield curves (Figure 6). This indicates that samples from the medium depths were associated with the strongest chlorophyll responses to TN and TP than the shallowest (~<0.2m) and the deepest areas. This may be a function of residence time/flushing or turbidity in shallower areas, while the deeper waters, likely towards the eastern edge of the Sound, may be influenced by flushing as well.

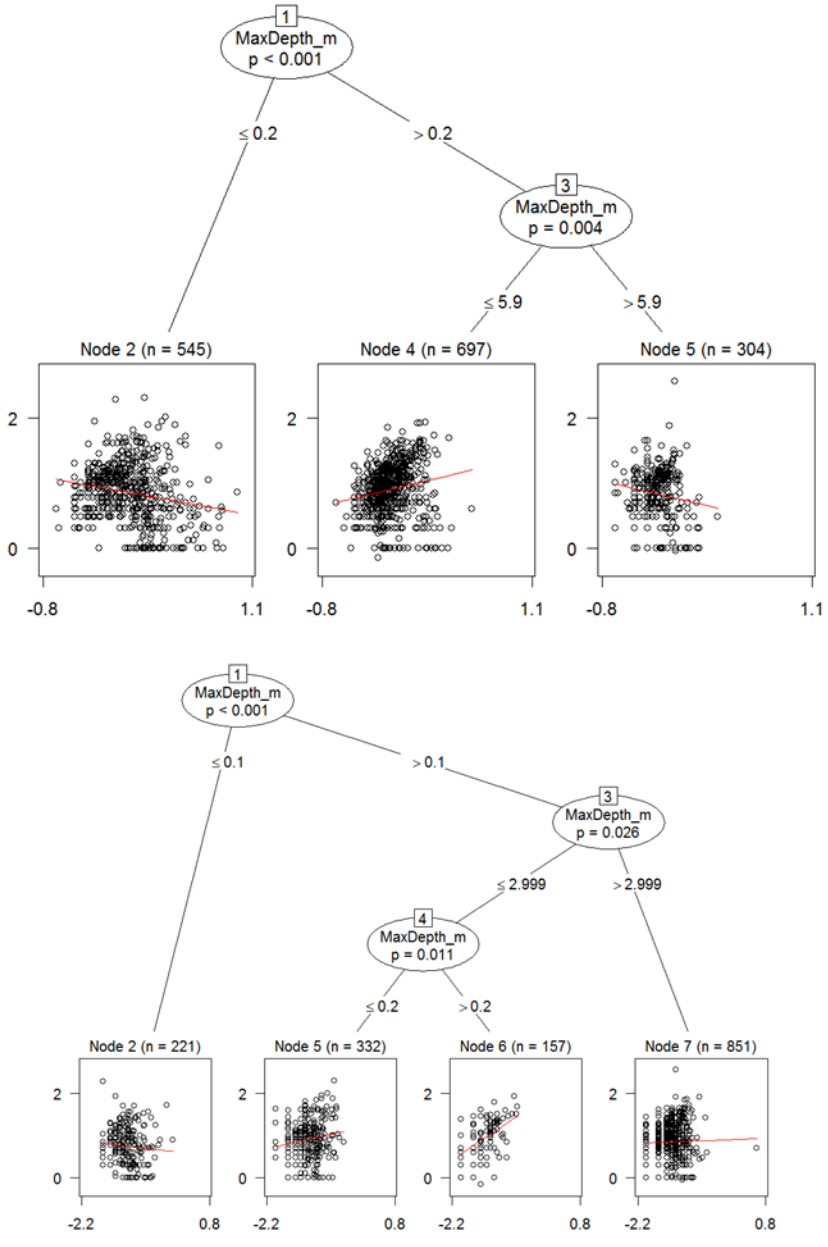


Figure 6 – TREED regression of chlorophyll a as a function of TN (top) and TP (bottom) concentration using log-transformed depth as a splitting variable. Red lines indicate linear regression models for the different depth based sample subsets.

The above results, especially the salinity results, suggest potentially stronger responses to TN in the open sound and stronger responses to TP in the less saline non-sound regions. To test this suggestion, samples were coded as sound and river to see if the TREED analysis would split the sample populations by these codes and produce different regressions. When samples were coded as either river or sound, Sound samples had a steeper, positive response to TN and a negative response to TN, whereas the River samples had a steeper, positive response to TP than the Sound sites (Figures 7).

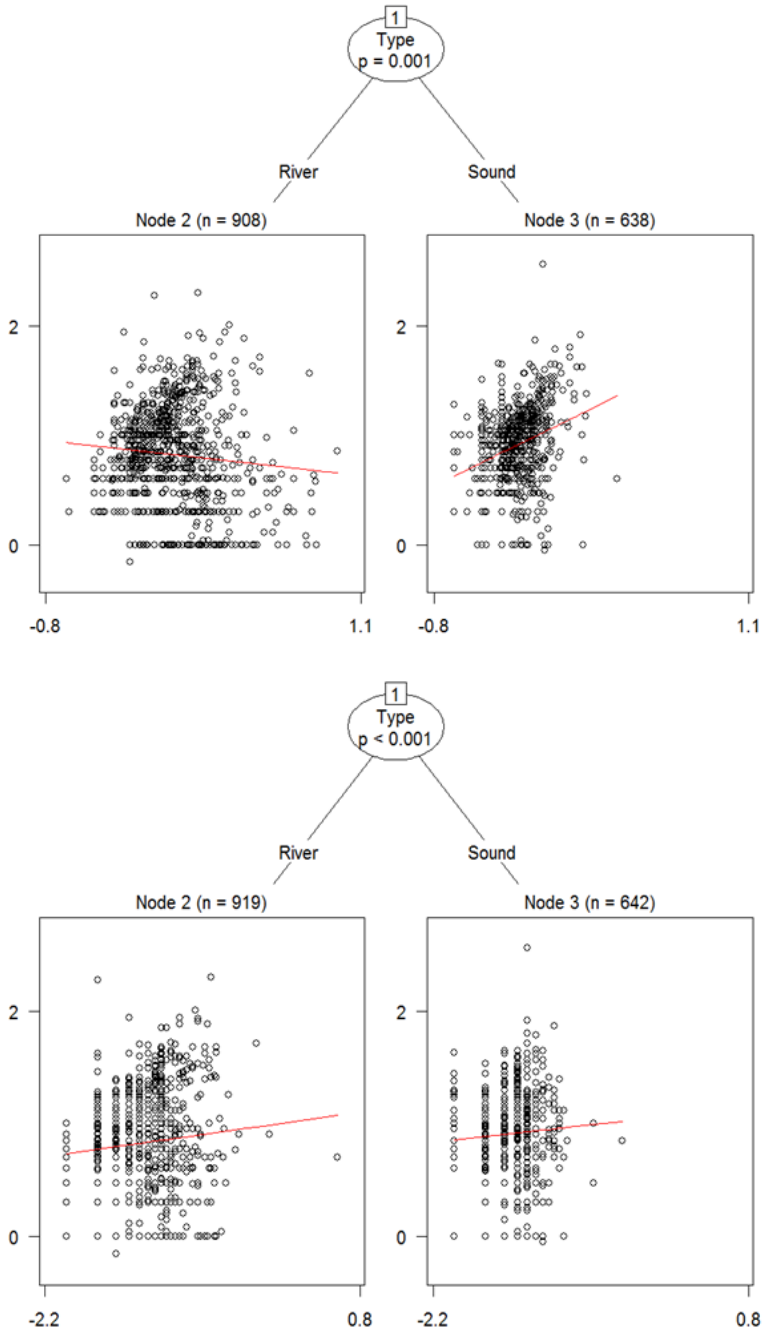


Figure 7 – TREED regression of chlorophyll a vs. TN top) and TP (bottom) using coding as sound or river. Relationships for TN are steeper than those for TP. Moreover, relationships with TP remain positive in rivers, but not so for rivers with TN.

In general, these results suggest considering sounds separately from rivers, in that deeper locations in the sound tended to have different nutrient concentrations. Similarly, sites in the sounds (deeper, higher temperature, more saline) had different yield curves (positive chlorophyll *a* vs. TN or TP slopes). We next looked at differences in phytoplankton composition amongst sites.

Phytoplankton

The NMS of phytoplankton composition was generally consistent with the water chemistry results. Samples obtained from Albemarle Sound locations differed in phytoplankton composition from those from non-sound, River sites. Samples (included for comparison) from other adjacent Sounds, namely the Roanoke, Croatan, and Currituck Sounds, were distinct in taxonomic composition from Albemarle as well (Figure 8).

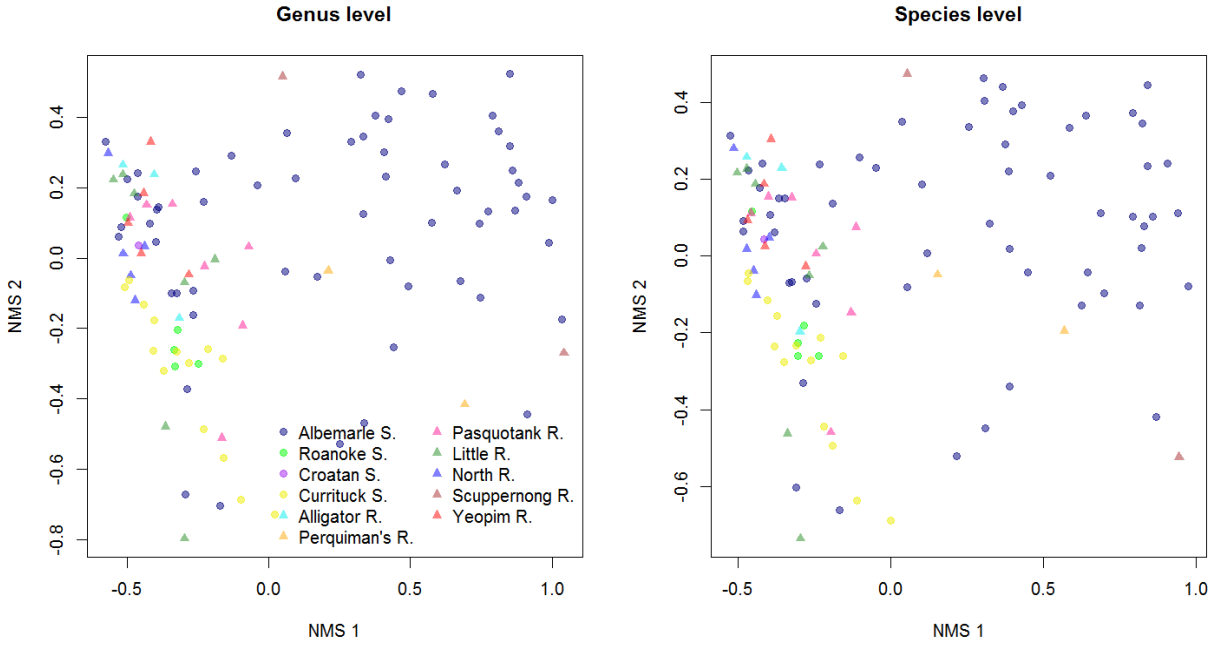


Figure 8 – NMS of estuary phytoplankton genera (left) species (right) based on Bray-Curtis distance.

For 60 phytoplankton samples, concurrent water chemistry data were available (collected within 20 days of the phytoplankton sample). NMS of those samples revealed changes in algal species composition along nutrient gradients (Figure 9a). Five species of potentially harmful phytoplankton were identified in the dataset (Appendix 1). Weighted-average species scores along the NMS axis had no obvious pattern in relation to nutrient gradients. Samples associated with higher nutrient concentrations were, however, associated with gradients along which *Anabaena circularis* and *Chattonella* sp. were more common; whereas samples with lower nutrients were associated more with *Microcystis firma* (Figure 9b).

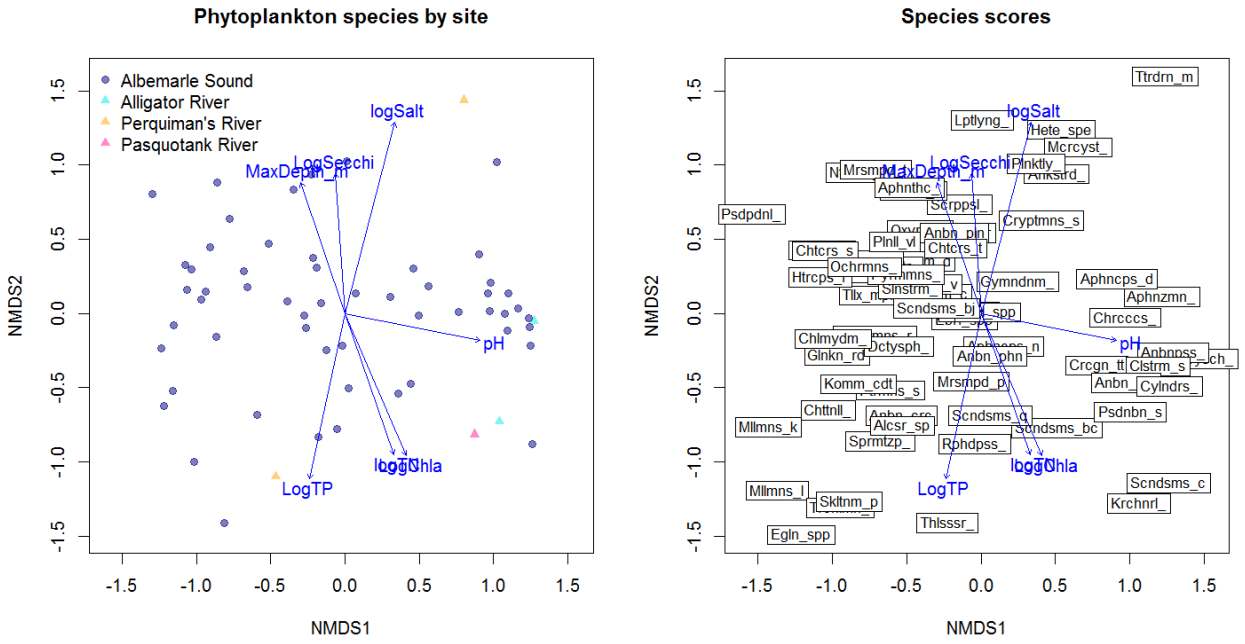


Figure 9a – NMS of estuary phytoplankton species based on Bray-Curtis distance and water chemical parameters expressed as vectors in relation to the phytoplankton samples (left). Weighted average species scores in relation to the environmental vectors (right). Taxa names are in Appendix 2.

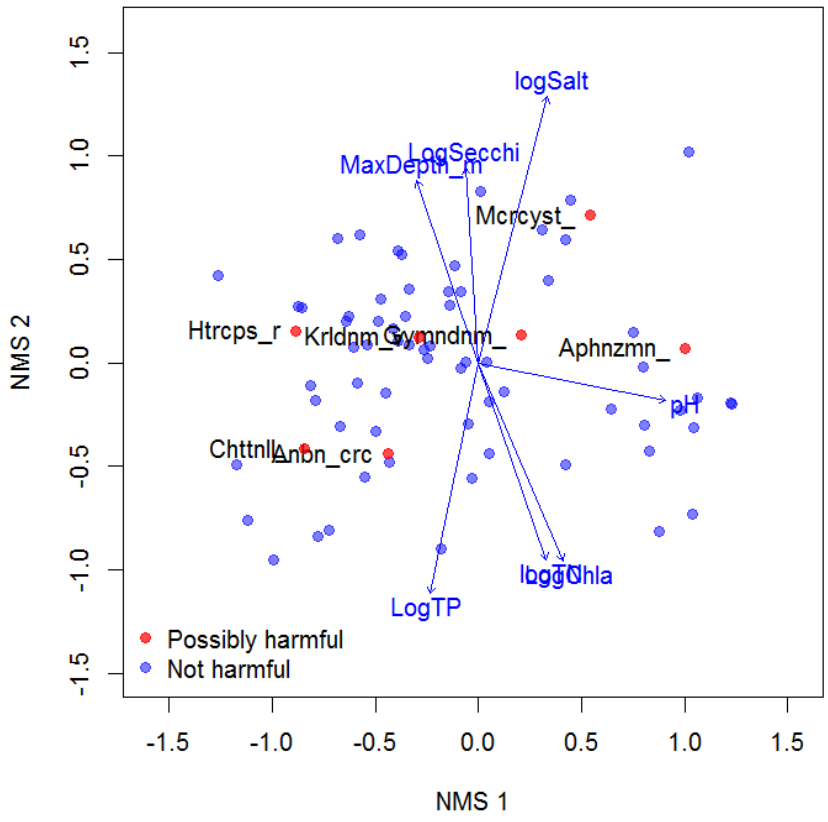


Figure 9b – Weighted average species scores in relation to the environmental vectors. Potentially harmful species are shown in red and labeled (see Appendix 1 for taxa names).

The obvious classification structure, given these analytical results, is to explore non-sound areas separately from open sound sites, especially for Albemarle Sound proper. Salinity appears to be a major driver and phytoplankton structure appears to differ among Albemarle and adjacent sounds (Croatan, Currituck, and Roanoke), even though nutrient yield curves and nutrient concentrations appear similar.

Alternative classification options include not separating open sounds and non-sound "river" locations and considering all waters together, although that appears less defensible, at this point.

Part 2: Descriptive analyses and stressor-response

Once classes were developed, NSTEPS was tasked with developing descriptive statistics and simple correlations among variables within each class. This section describes those results.

Boxplots and cumulative distribution functions (CDFs) were developed for nutrient values, dissolved oxygen (DO), Secchi depth (a measure of clarity where smaller values mean less clarity), and chlorophyll *a* for the two proposed classes: 1) Albemarle Sound proper and 2) Adjacent Class SB and SC waters. Data were analyzed both as grab samples (all values, Figures 10a-d and Table 1) and as long term site averages (Figures 11a-c and Table 2). Boxplots and CDFs are visual representations of chemical or physical parameters that allow easy comparison of central tendencies, ranges, and percentile values among groups. Nutrients were measured at one depth, whereas DO was measured at regular depths along a vertical profile in the water column. DO values here are averaged over all depths sampled. Depth-averaged DO values were very similar to surface values (Figure 12).

Consideration was given to using 8-digit HUCs as additional classification variables, but all monitoring stations with the exception of one were contained in one 8-digit HUC, 03010205 (Figure 13). The remaining station had only a few parameters measured (Figure 14).

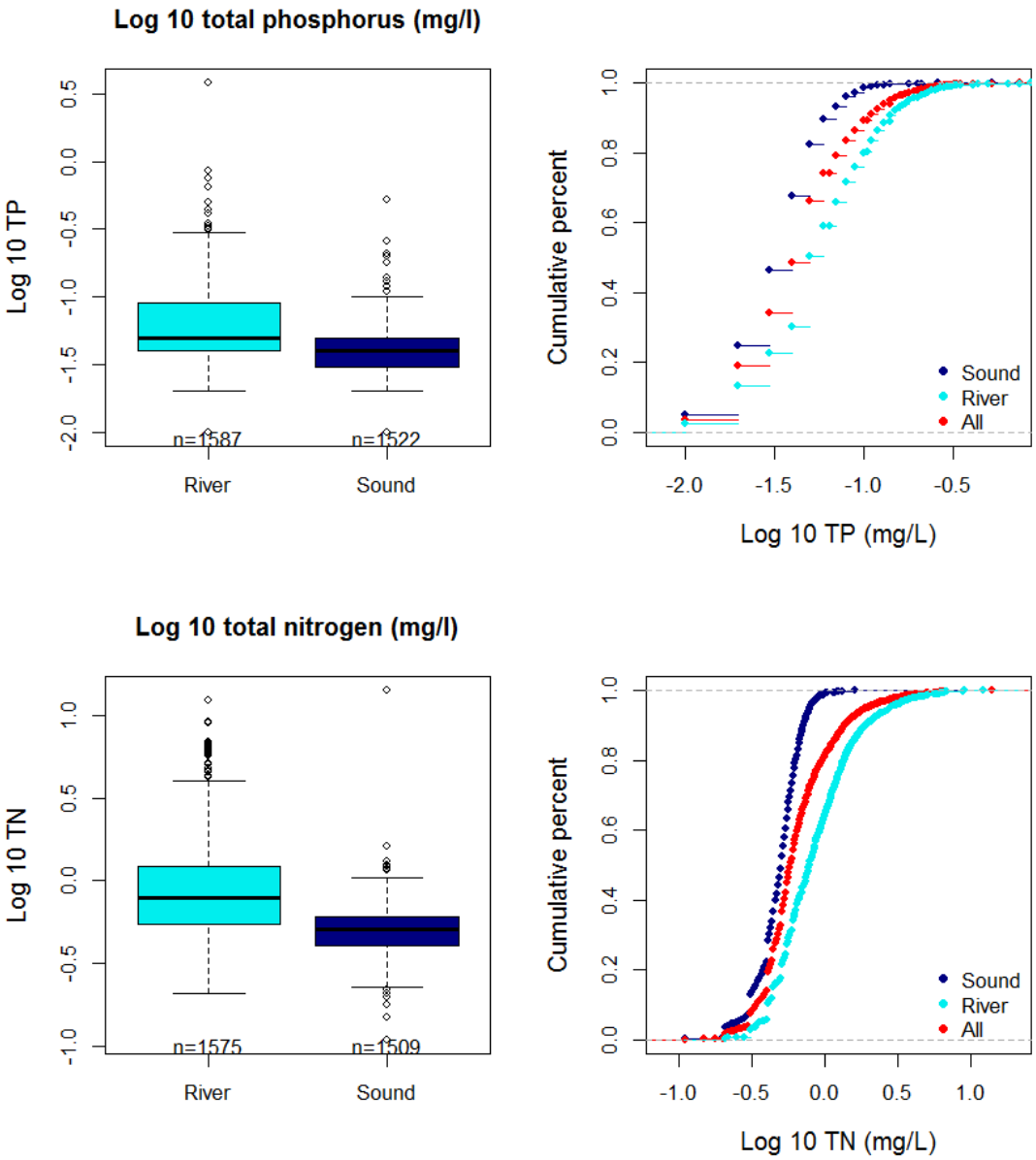


Figure 10a – Box and whisker plots and cumulative distribution functions of TP and TN from grab samples. Sample size is given below each box. Box and whisker plots show the interquartile range (boxes), median (line), 5th and 95th percentiles (whiskers) and outlier points. The CDF provides a visual representation of all percentiles of values (e.g., the 90th percentile is the concentration associated with the cumulative percent value of 0.9). Steeper curves indicate a tight distribution of values, whereas broader curves indicate a broad distribution. Right shifted curves have higher values for all percentiles than curves to the left.

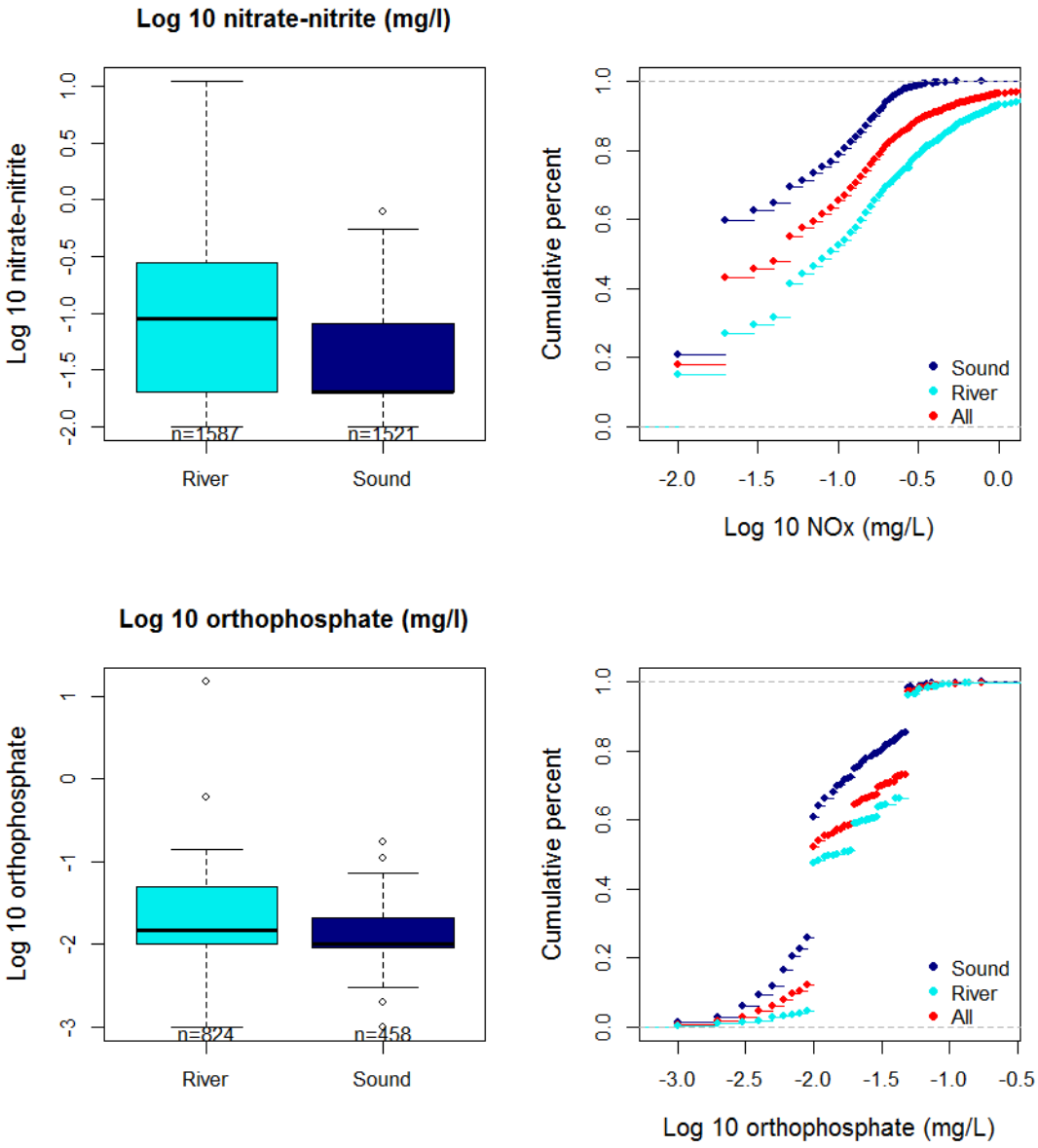


Figure 10b - Box and whisker plots and cumulative distribution functions of nitrate-nitrite and orthophosphate from grab samples. See Figure 10a legend for descriptions of plots.

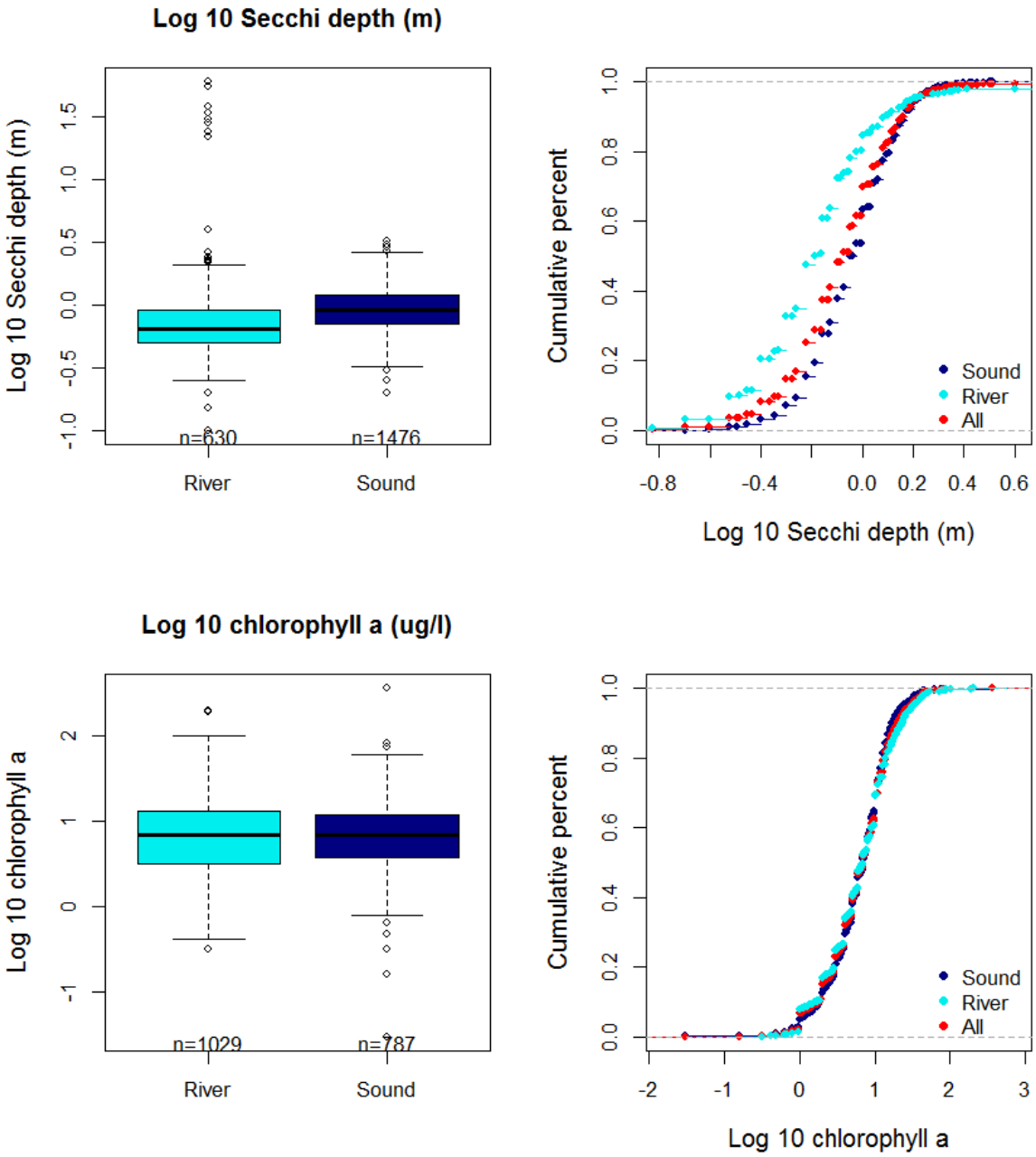


Figure 10c - Box and whisker plots and cumulative distribution functions of Secchi depth and chlorophyll *a* from grab samples. See Figure 10a legend for descriptions of plots.

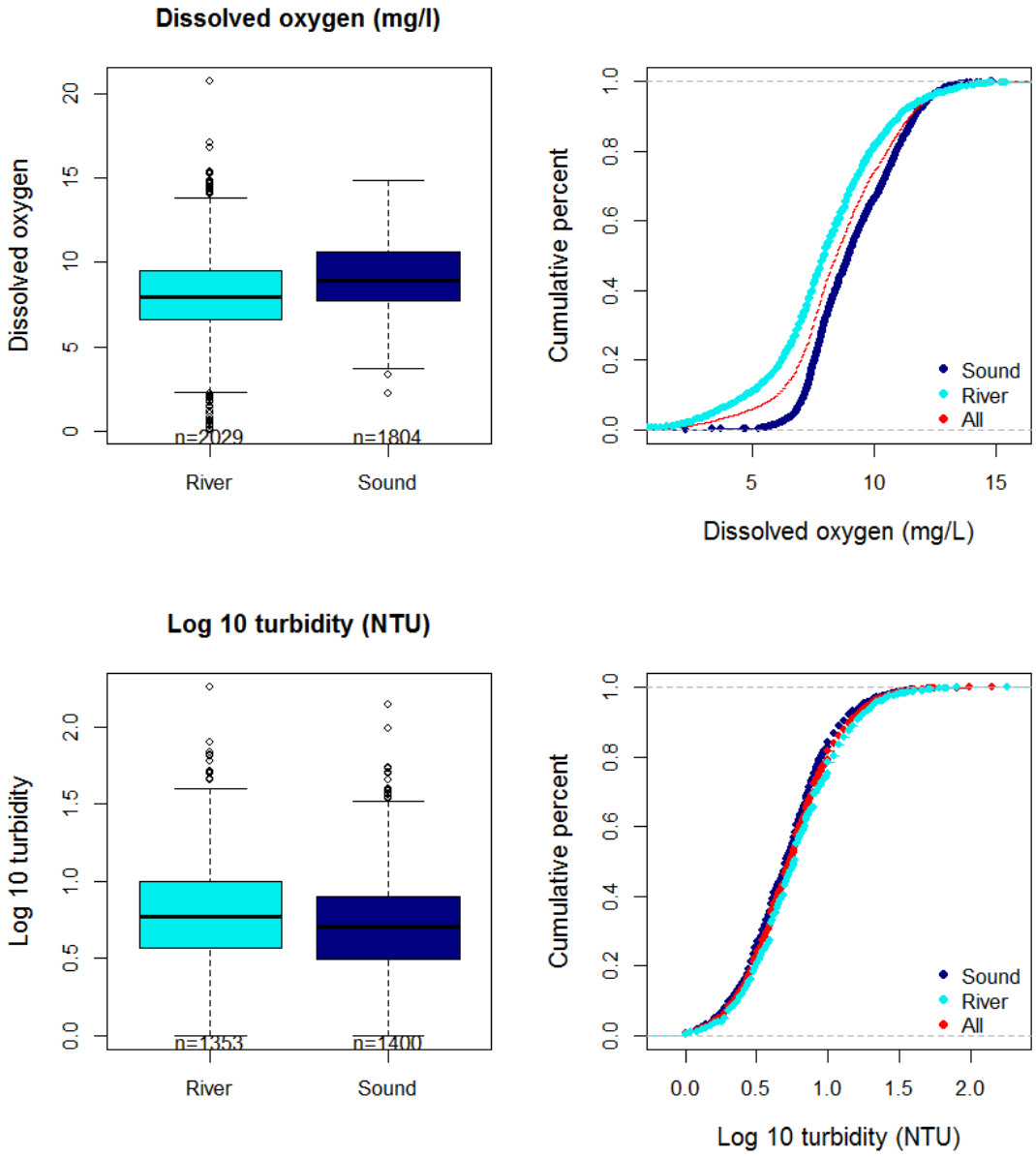


Figure 10d - Box and whisker plots and cumulative distribution functions of dissolved oxygen (DO) and turbidity from grab samples. Dissolved oxygen is averaged over all depths; all other parameters were sampled at one depth only. See Figure 10a legend for descriptions of plots.

Table 1. Water chemistry descriptive statistics using grab samples; dissolved oxygen (DO) was averaged over all depths. "River" class here denotes other SB and SC waters adjacent to Albemarle Sound, as shown in Figure 1. The "Sound" class is Albemarle Sound proper sampling locations alone. Statistics are also shown for all sites (Albemarle Sound + Other SB and SC waters combined; unlabeled first row for each variable).

		N	Mean	10th percentile	25th percentile	Median	75th percentile	90th percentile
DO (mg/L)		3833	8.6	6.0	7.3	8.4	10.1	11.5
	River	2029	8.0	4.8	6.6	8.0	9.5	11.0
	Sound	1804	9.2	7.1	7.8	8.9	10.6	11.7
TP (mg/L)		3109	0.045	0.020	0.030	0.050	0.070	0.110
	River	1587	0.058	0.020	0.040	0.050	0.090	0.140
	Sound	1522	0.035	0.020	0.030	0.040	0.050	0.070
TN (mg/l)		3084	0.65	0.35	0.45	0.59	0.85	1.38
	River	1575	0.86	0.41	0.55	0.79	1.23	1.90
	Sound	1509	0.49	0.31	0.41	0.51	0.61	0.72
NOx (mg/l)		3108	0.056	0.010	0.020	0.050	0.160	0.360
	River	1587	0.093	0.010	0.020	0.090	0.275	0.710
	Sound	1521	0.033	0.010	0.020	0.020	0.080	0.170
OP (mg/l)		1282	0.017	0.008	0.010	0.010	0.050	0.050
	River	824	0.020	0.010	0.010	0.015	0.050	0.050
	Sound	458	0.013	0.005	0.009	0.010	0.021	0.050
Chl a (µg/l)		1816	6.4	1.8	3.5	7.0	12.0	20.0
	River	1029	6.5	1.7	3.2	7.0	13.0	23.4
	Sound	787	6.3	1.9	3.8	7.0	12.0	17.2
Secchi depth (m)		2106	0.85	0.50	0.60	0.85	1.10	1.45
	River	630	0.69	0.35	0.50	0.65	0.90	1.25
	Sound	1476	0.92	0.60	0.70	0.90	1.20	1.50

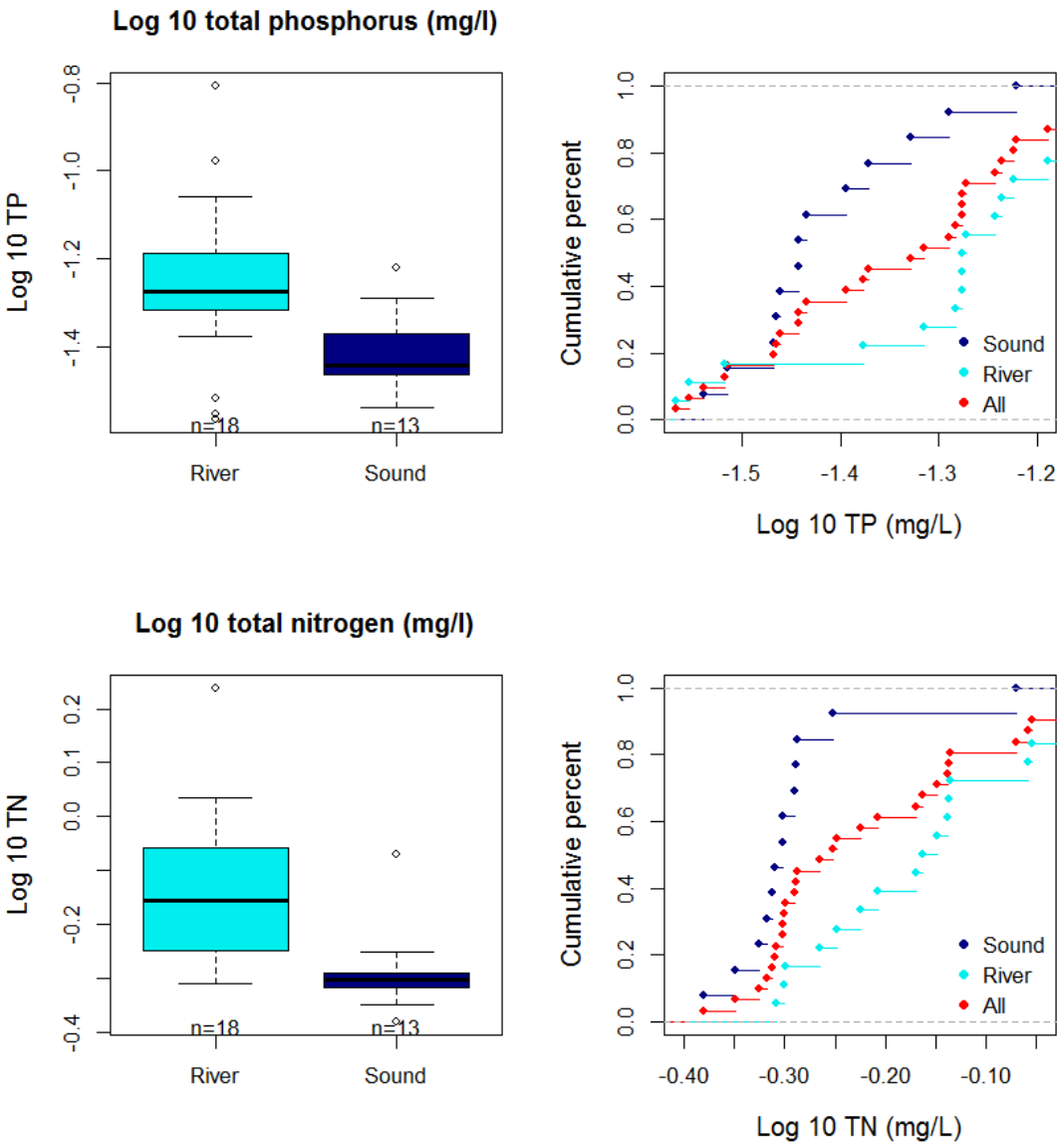


Figure 11a - Box and whisker plots and cumulative distribution functions of TP and TN, long term site averages. See Figure 10a legend for descriptions of plots

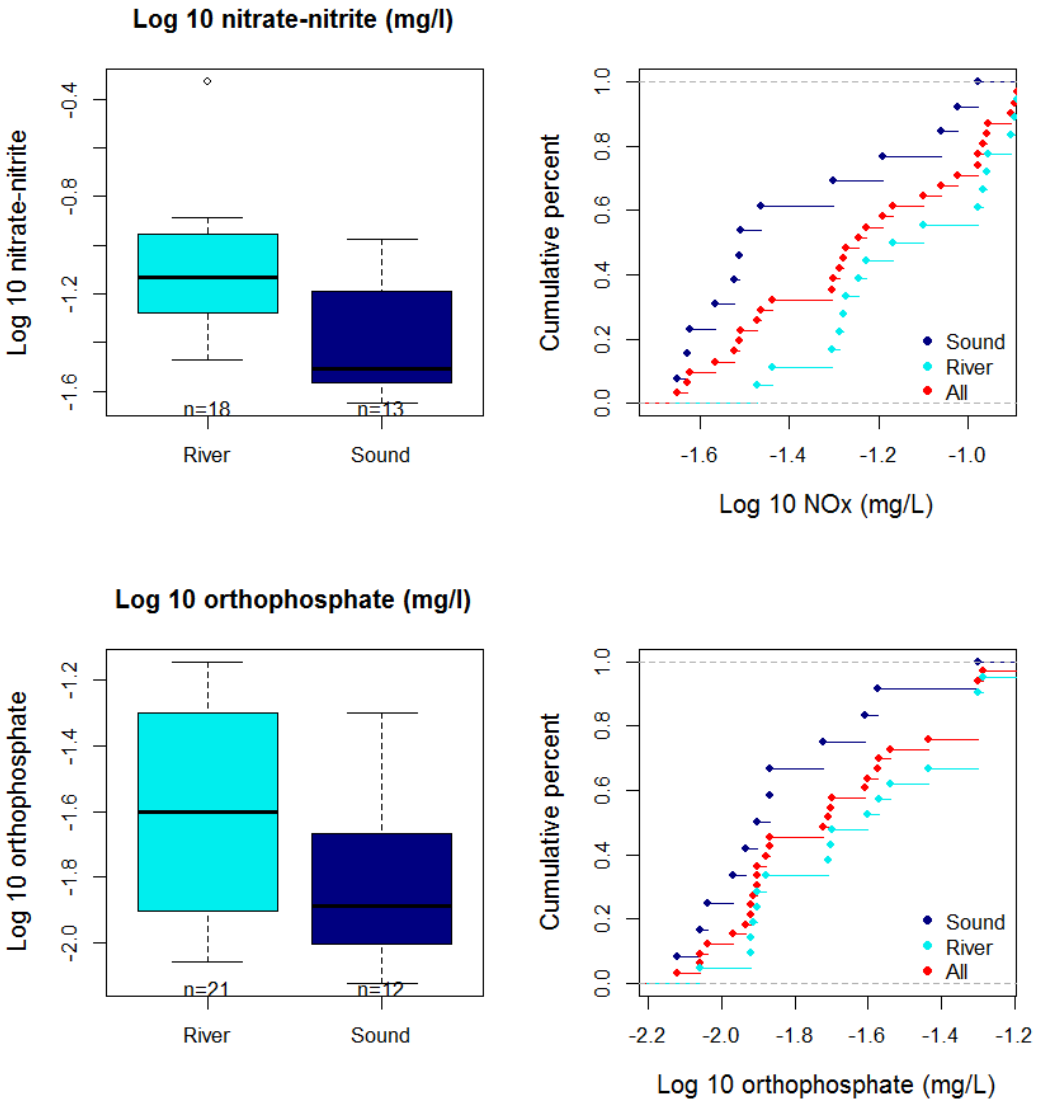


Figure 11b - Box and whisker plots and cumulative distribution functions of nitrate-nitrite and orthophosphate, long term site averages. See Figure 10a legend for descriptions of plots.

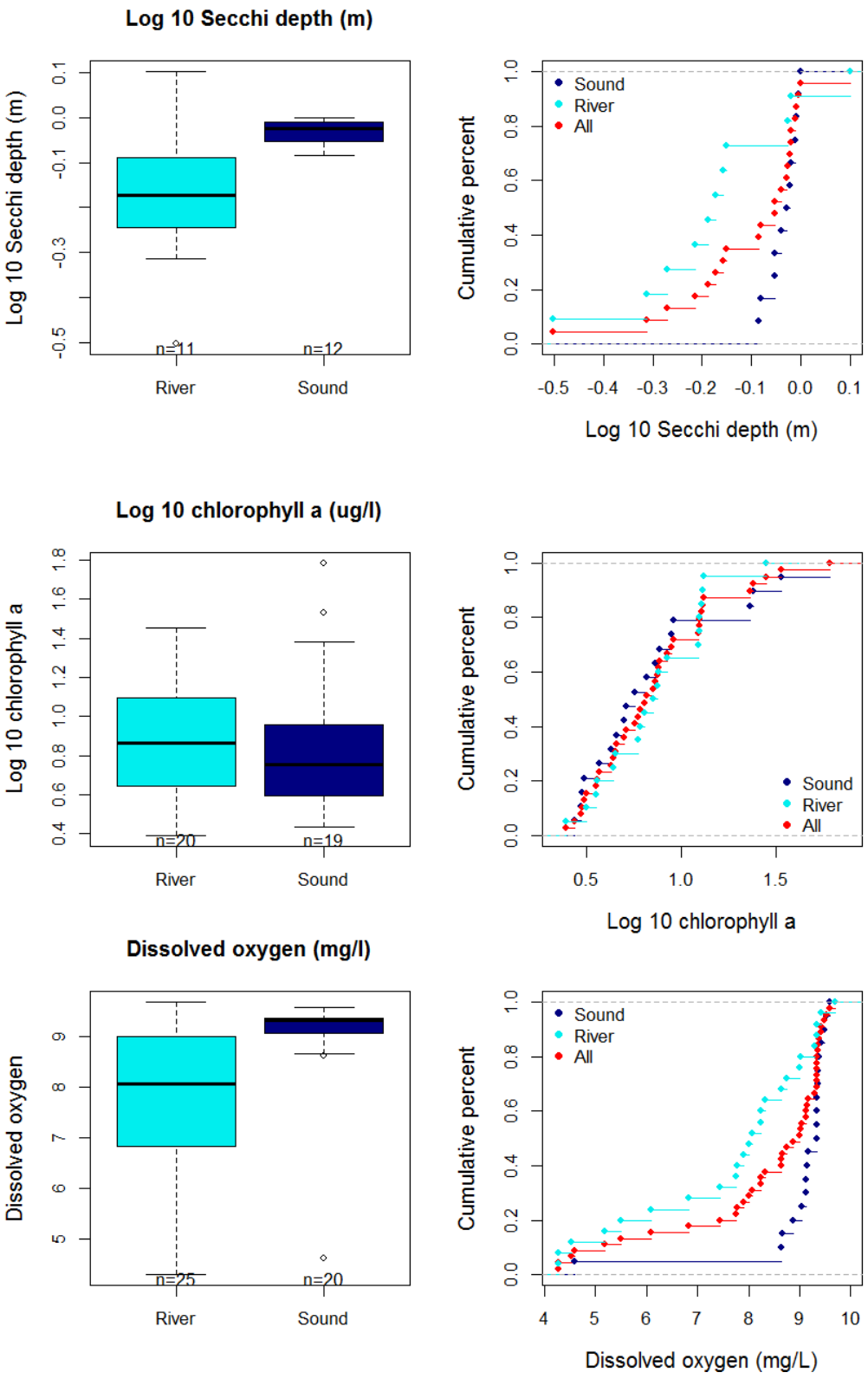


Figure 11c - Box and whisker plots and cumulative distribution functions Secchi depth, chlorophyll *a* and dissolved oxygen long term site averages. See Figure 10a legend for descriptions of plots.

Table 2. Water chemistry descriptive statistics using long term site averages; dissolved oxygen was averaged over all depths. "River" class here denotes other SB and SC waters adjacent to Albemarle Sound, as shown in Figure 1. The "Sound" class is Albemarle Sound proper sampling locations alone. Statistics are also shown for all sites (Albemarle Sound + Other SB and SC waters combined; unlabeled first row for each variable).

		N	Mean	10th percentile	25th percentile	Median	75th percentile	90th percentile
DO (mg/l)		45	8.2	5.3	7.9	9.0	9.3	9.4
	River	25	7.6	4.8	6.8	8.1	9.0	9.3
	Sound	20	9.0	8.7	9.1	9.3	9.4	9.5
TP (mg/l)		31	0.048	0.030	0.035	0.048	0.058	0.073
	River	18	0.056	0.030	0.049	0.053	0.063	0.092
	Sound	13	0.039	0.031	0.034	0.036	0.042	0.050
TN (mg/l)		31	0.62	0.48	0.50	0.56	0.73	0.88
	River	18	0.72	0.50	0.57	0.70	0.84	1.07
	Sound	13	0.51	0.45	0.48	0.50	0.51	0.55
OP (mg/l)		33	0.021	0.009	0.012	0.019	0.037	0.050
	River	21	0.025	0.012	0.012	0.025	0.050	0.050
	Sound	12	0.015	0.009	0.010	0.013	0.020	0.026
NOx (mg/l)		31	0.061	0.027	0.034	0.057	0.105	0.125
	River	18	0.081	0.045	0.053	0.074	0.111	0.128
	Sound	13	0.041	0.024	0.027	0.031	0.064	0.093
Chl a (µg/l)		39	7.3	3.1	4.3	6.6	12.3	23.4
	River	20	7.3	3.5	4.5	7.3	12.5	13.0
	Sound	19	7.3	3.0	4.0	5.7	9.0	25.8
Secchi depth (m)		23	0.79	0.55	0.68	0.89	0.96	0.99
	River	11	0.67	0.49	0.57	0.67	0.82	0.96
	Sound	12	0.93	0.84	0.89	0.94	0.98	0.99

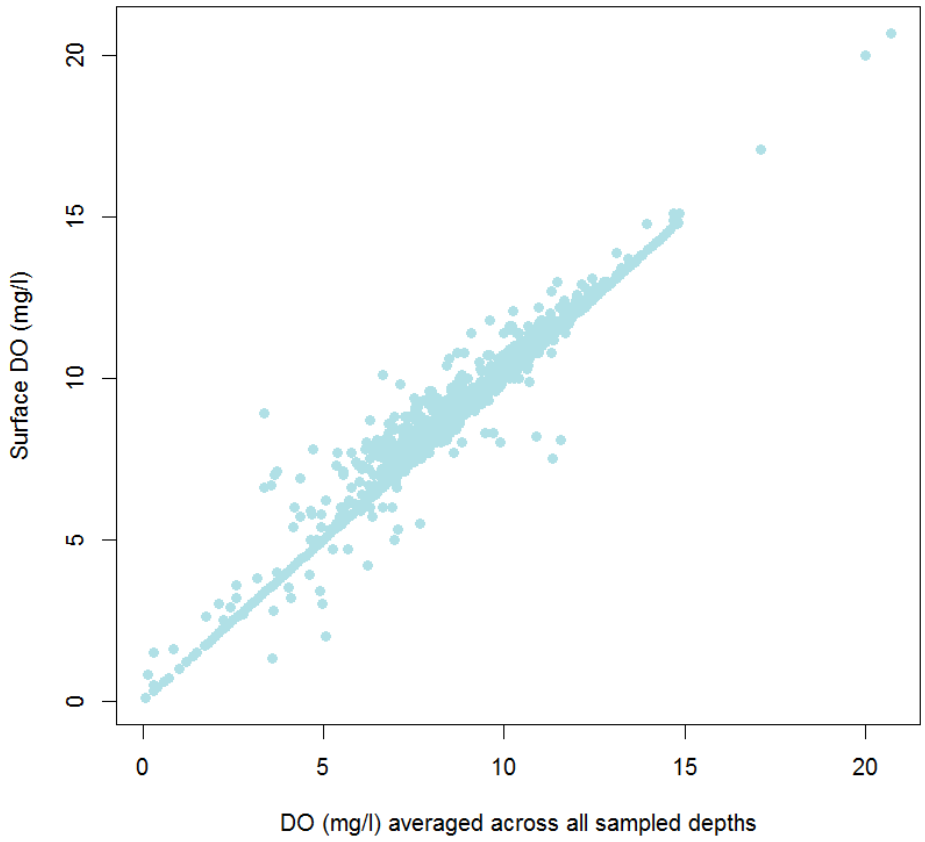


Figure 12 – Surface DO in relation to depth-averaged DO (grab samples)

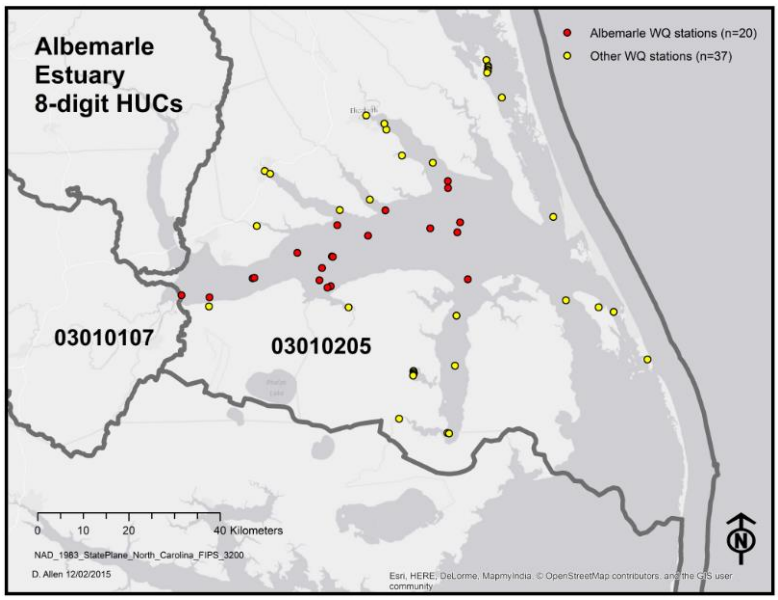


Figure 13 – Eight-digit HUCs in the study area

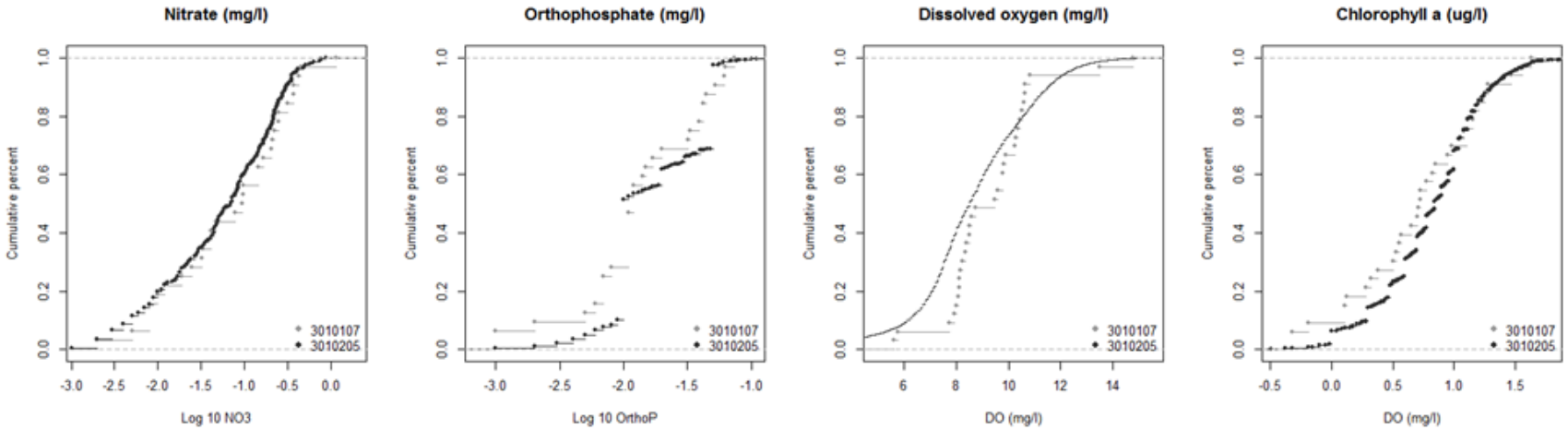


Figure 14 - Cumulative distribution functions of available water chemistry values from grab samples in study area by 8-digit HUC.

Correlation/Stressor-Response models

Chlorophyll *a* and dissolved oxygen (DO) were examined as responses to TP and TN concentrations on both long term (averages of all samples for a site, Figures 15 and 16 for chlorophyll a and dissolved oxygen respectively) and annual average (annual averages of samples for each site, Figures 17 and 18 for chlorophyll a and dissolved oxygen respectively) basis. Chlorophyll *a* increased with TP in the non-sound SB/SC (river) subset of sites, but not the open sound subset (Figure 15). There was no apparent relationship between chlorophyll and TN over the long term scale. Results were similar but more pronounced when annual instead of long term averages were used. Chlorophyll *a* increased with TP in the non-sound SB/SC (river) subset of sites, but not the open sound subset (Figure 17). Chlorophyll *a* increased with TN in the sound subset of sites, but not the non-sound SB/SC (river) subset (Figure 17).

Long-term average dissolved oxygen decreased with increasing TP and TN across all sites and with TN when river sites were assessed alone. For annual average data, dissolved oxygen decreased with increasing TP and TN across all sites and in river sites. However, DO increased with TP and TN when sound sites were assessed alone (Figure 18).

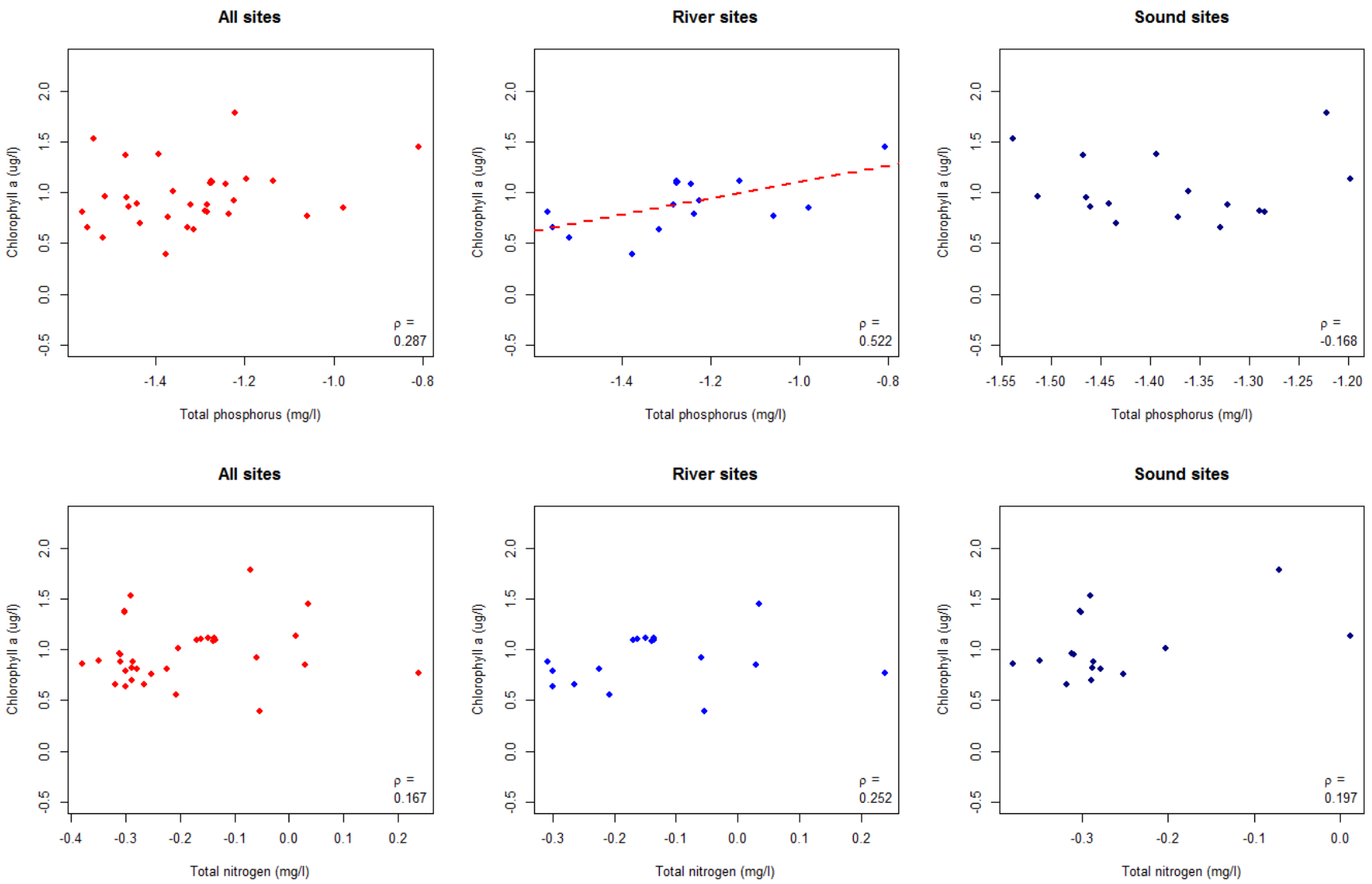


Figure 15 – Chlorophyll *a* as a function of TP (top) and TN (bottom) for long term average nutrient concentrations for all (left), river (center) and sound (right) sites. Spearman's correlation coefficients are in the bottom right corner. Red dashed lines indicate statistically significant linear regressions ($p < 0.05$).

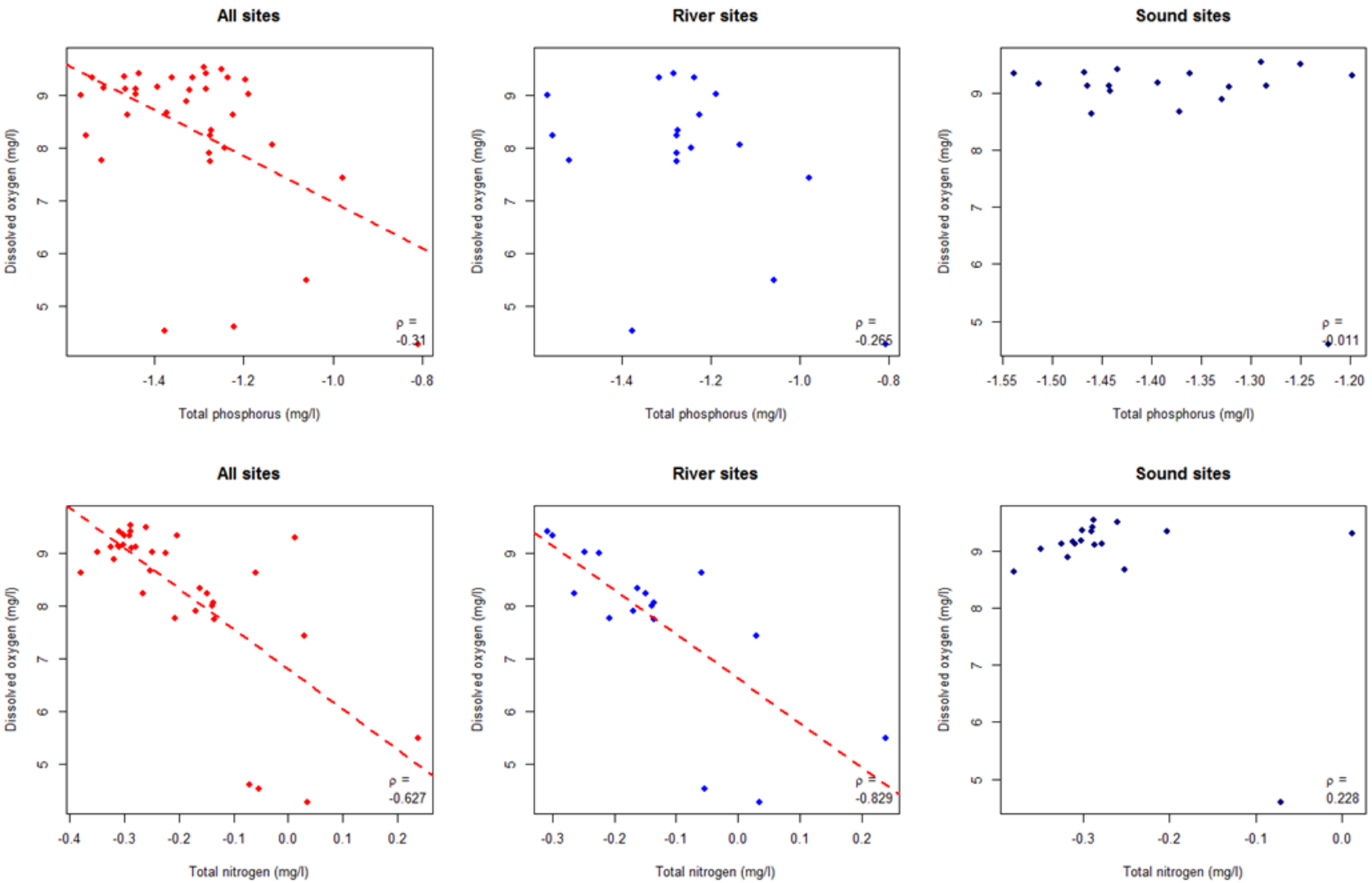


Figure 16 – DO as a function of TP (top) and TN (bottom) for long term average nutrient concentrations for all (left), river (center) and sound (right) sites. Spearman's correlation coefficients are in the bottom right corner. Red dashed lines indicate statistically significant linear regressions ($p < 0.05$).

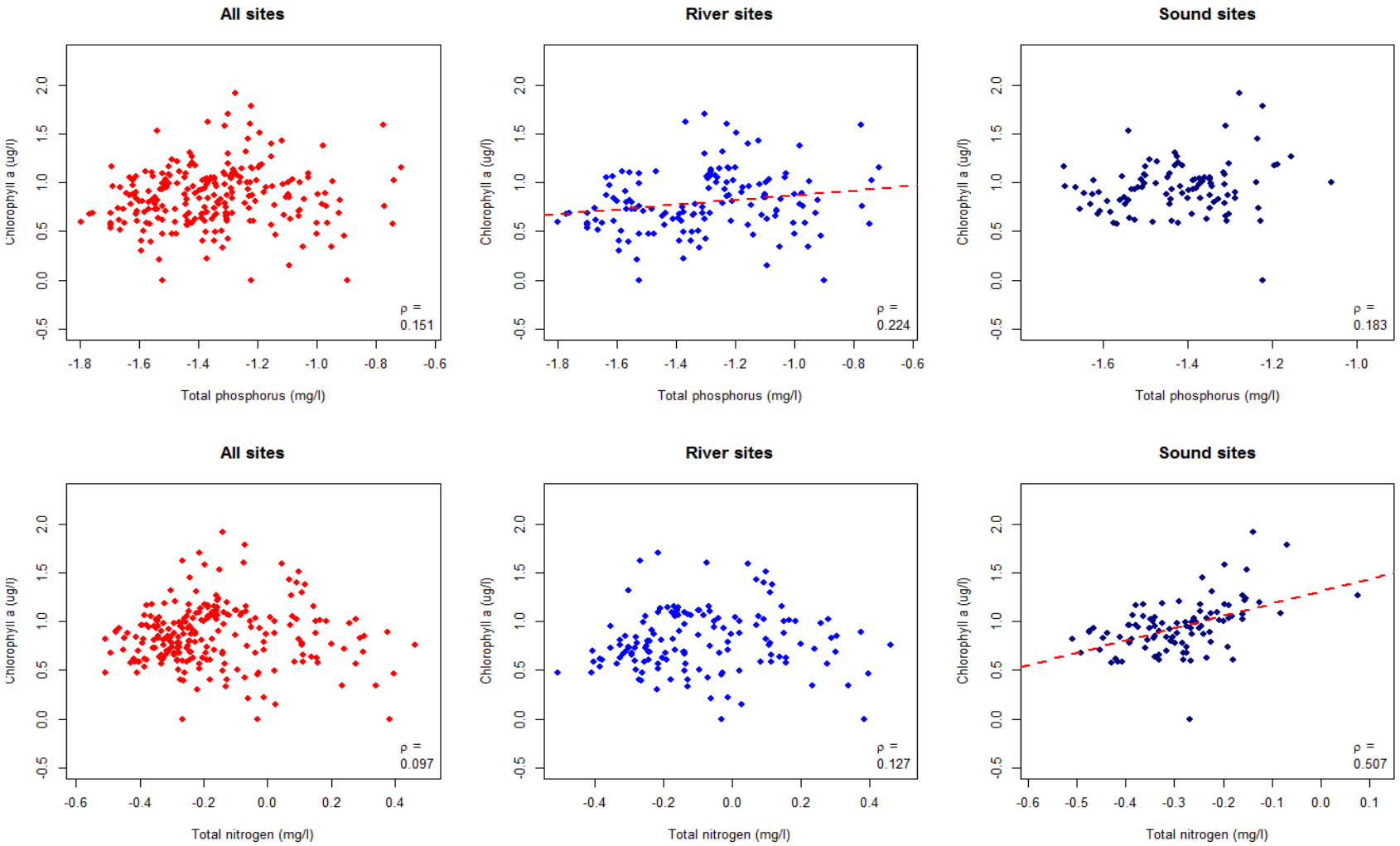


Figure 17 – Chlorophyll *a* as a function of TP (top) and TN (bottom) for annual average nutrient concentrations for all (left), river (center) and sound (right) sites. Spearman's correlation coefficients are in the bottom right corner. Red dashed lines indicate statistically significant linear regressions ($p < 0.05$).

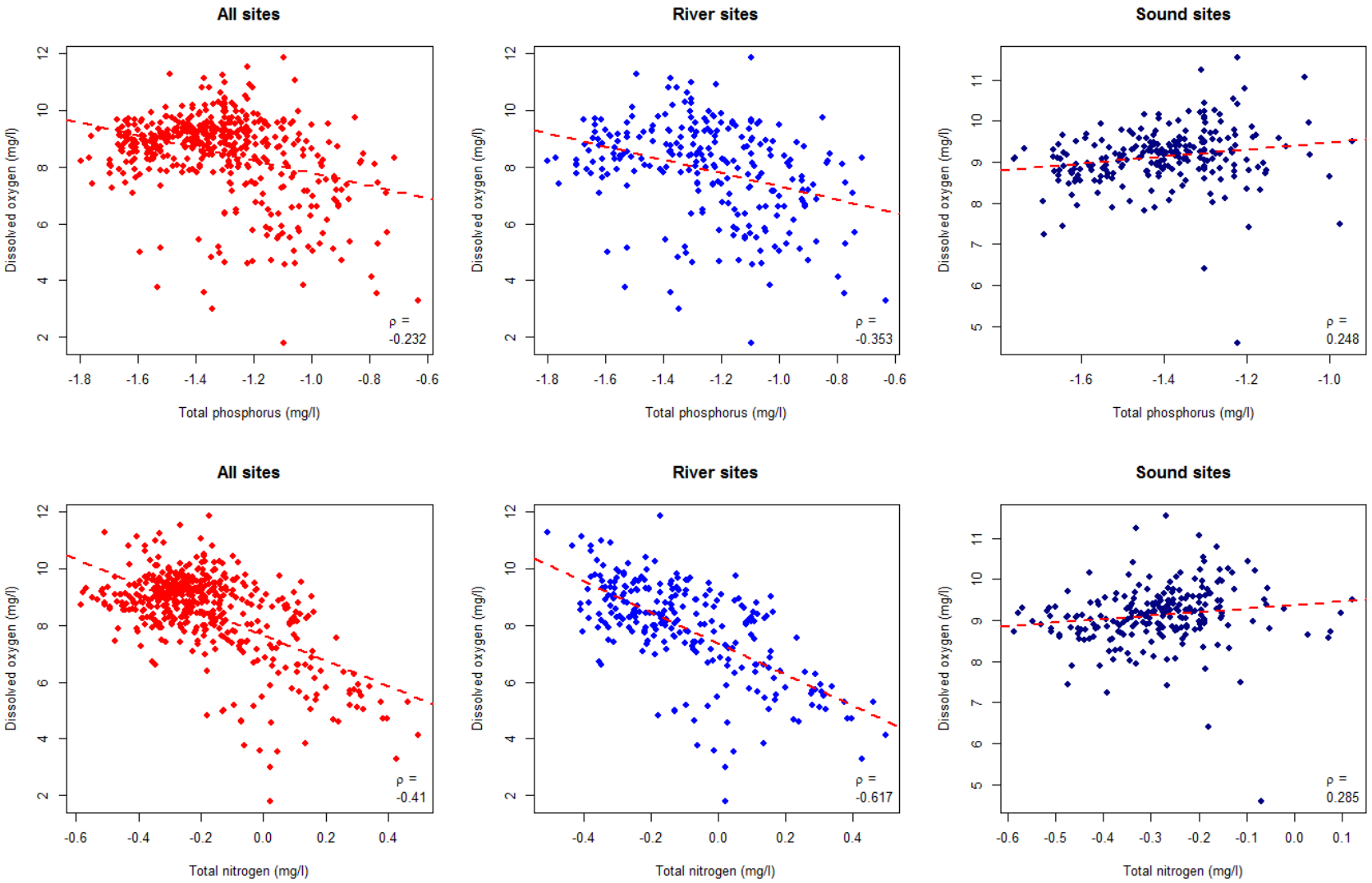


Figure 18 – Dissolved oxygen as a function of TP (top row) and TN (bottom row) for annual average nutrient concentrations for all (left), river (center) and sound (right) sites. Spearman's correlation coefficients are in the bottom right corner. Red dashed lines indicate statistically significant linear regressions ($p < 0.05$).

Principal Observations

1. **Water chemical parameters and chlorophyll yield curves (from TREED regression) support the separation of non-sound SB/SC (river) and sound sites into separate classes.**
2. **Phytoplankton communities support the separation of Albemarle Sound proper from other sites.**

Given the limited data available to use for classification, the most obvious and striking classification was by open sound and non-sound SB/SC (river) sites within the Albemarle Sound system. Additional classes could be pursued, for example by individual tributary SB/SC water system or by season, but given the data provided, these classes seemed appropriate and defensible on chemical and biological bases.

3. **Chlorophyll *a* concentrations are very similar in river and sound sites. Nutrient concentrations are generally higher in non-sound SB/SC (river) sites. DO concentrations are slightly higher in sound sites when grab samples are evaluated, and markedly higher when long term averages are evaluated.**
4. **Modest increases in chlorophyll *a* with increasing nutrient concentrations were observed, with increases in response to TP for non-sound SB/SC (river) sites and to TN for open sound sites.**
5. **Stressor response analysis reveals a large decrease in dissolved oxygen in non-sound SB/SC (river) sites with increasing nutrients, while sound sites exhibited an increase in DO with increasing nutrients.**

These observations may be due to several factors, but are consistent with a model of the more riverine/tributary non-sound SB/SC water systems as carbon importers driving a primarily net heterotrophic system where nutrients enrich decomposition, and a net autotrophic sound system where nutrients drive primary production. This is speculative and deserves further investigation and analyses.

Appendix 1. Potentially toxic phytoplankton species

Species	Abbreviation	Potential toxicity
Rhizosolenia spp.		Algal bloom taxon
Chattonella spp.	Chttnll	Genus with potential to produce brevetoxin, belongs to Raphidophyceae (unicellular flagellates)
Anabaena circinalis	Anbn_crc	Neurotoxin producing cyanobacterial species
Anabaenopsis circularis		Potential Synonym of *Anabaena circinalis* variety
Aphanizomenon spp.	Aphnzmn_	Potentially bloom producing cyanobacterial genus
Microcystis firma	Mcrcyst_	Same genus as toxic *Microcystis aeruginosa*
Gymnodinium spp.	Gymndnm	Potentially toxic depending on species
Heterocapsa rotundata	Htrcps_r	One species in this genus (*Heterocapsa circularisquama*) identified as toxic
Heterocapsa triquetra		One species in this genus (*Heterocapsa circularisquama*) identified as toxic
Karlodinium veneficum	Krldnm_v	Responsible for fish kills (karlotoxins)

Appendix 2. Taxa name abbreviations

Taxon	Shortened name	Taxon	Shortened name
Anabaena aphanizomenoides	Anbn_phn	Komma caudata	Komm_cdt
Anabaena circinalis	Anbn_crc	Leptolyngbya spp.	Lptlyng_
Anabaena planctonica	Anbn_pln	Mallomonas akrokomos	Mllmns_k
Anabaena spiroides	Anbn_spr	Mallomonas alpina	Mllmns_l
Anabaenopsis circularis	Anbnpss_	Mallomonas spp.	Mllmns_s
Ankistrodesmus falcatus	Ankstrd_	Merismopedia punctata	Mrsmpd_p
Apedinella radians	Apdnll_r	Merismopedia tenuissima	Mrsmpd_t
Aphanizomenon spp.	Aphnzmn_	Microcystis firma	Mcrcyst_
Aphanocapsa delicatissima	Aphncps_d	Navicula spp.	Nvcl_spp
Aphanocapsa incerta	Aphncps_n	Nitzschia acicularis	Ntzsch_c
Aphanothece saxicola	Aphnthc_	Nitzschia longissima	Ntzsch_l
Aulacoseira spp.	Alcsr_sp	Ochromonas spp.	Ochrmns_
Chaetoceros spp.	Chtcrs_s	Oxyrrhis marina	Oxyrrhs_
Chaetoceros throndensenii	Chtcrs_t	Paulinella ovalis	Plnll_vl
Chattonella spp.	Chttnll_	Planktolyngbya undulata	Plnktly_
Chlamydomonas spp.	Chlmydm_	Prorocentrum minimum	Prrcntr_
Chlorogonium spp.	Chlrgnm_	Pseudanabaena spp.	Psdnbn_s
Chroococcus spp.	Chrcccs_	Pseudopedinella pyriforme	Psdpdnl_
Chroomonas spp.	Chrmns_s	Pteromonas spp.	Ptrmns_s
Chrysochromulina spp.	Chrysch_	Pyramimonas spp.	Pyrmmns_
Coelastrum spp.	Clstrm_s	Raphidiopsis spp.	Rphdpss_
Cosmarium spp.	Csmrm_sp	Scenedesmus acuminatus	Scndsms_c
Crucigenia tetrapedia	Crcgn_tt	Scenedesmus bicaudatus	Scndsms_bc
Cryptomonas erosa	Cryptmns_r	Scenedesmus bijuga	Scndsms_bj
Cryptomonas spp.	Cryptmns_s	Scenedesmus quadricauda	Scndsms_q
Cylindrospermopsis raciborskii	Cylndrs_	Scrippsiella trochoidea	Scrppsl_
Cylindrotheca closterium	Cylndrt_	Selenastrum spp.	Slnstrm_
Dictyosphaerium pulchellum	Dctysph_	Skelotonema costatum	Skltnm_c
Ebria spp.	Ebri_spp	Skelotonema potamos	Skltnm_p
Euglena spp.	Egln_spp	Spermatozoopsis exultans	Sprmtzp_
Golenkinia radiata	Glnkn_rd	Synedra spp.	Syndr_sp
Gymnodinium spp.	Gymndnm_	Teleaulax amphioxeia	Tllx_mph
Hermesinum adriaticum	Hrmsnm_d	Tetraedron minimum	Ttrdrn_m
Heterocapsa rotundata	Htrcps_r	Tetraedron trigonum	Ttrdrn_t
Heterosigma. species	Hete_spe	Tetrastrum heterocanthum	Ttrstrm_
Karlodinium veneficum	Krldnm_v	Thalassiosira nordenskioldii	Thlsssr_
Kirchneriella species	Krchnrl_		

Appendix IV: A Legal Analysis of Developing Numeric Nutrient Criteria in North Carolina's Estuaries (Report)

A Legal Analysis of Developing Numeric Nutrient Criteria in North Carolina's Estuaries:

January 2016

North Carolina Coastal Resources Law, Planning and Policy Center

By*: Tyler M. O'Hara*
J.D. Candidate, University of North Carolina – Chapel Hill

TO: Jim Hawhee
FROM: Tyler O'Hara
TOPIC: Numeric Nutrient Criteria Edits
DATE: 01/07/2016

I. TABLE OF CONTENTS

II. INTRODUCTION

When Congress passed the modern Clean Water Act ("CWA", or "Act") in 1972 with the goal of restoring and maintaining the Nation's waters, the Act emphasized the importance of developing and implementing "area-wide treatment management planning processes" to control the sources of pollutants. 33 U.S.C. § 1251(a)(5). To help achieve this goal, the Act governs the standards and enforcement of effluent limitations. 33 U.S.C. § 301(a). However, by the late 1990's, the U.S. Environmental Protection Agency ("EPA") found significant evidence that the traditional narrative nutrient criteria used by states to develop water quality standards ("WQS") had failed to adequately deter increasing nutrient levels. As a result, the EPA Administrator issued a report calling for states to adopt *numeric* nutrient criteria ("NNC") by December 2003.

North Carolina responded to the EPA's new commitment to nutrient criteria management in 2004 by developing a nutrient criteria development plan to address the State's water-quality issues. The purpose of this report is to outline the contemporary legal framework for developing numeric nutrient criteria in North Carolina's waterways. By analyzing and applying current case law to the plan, potential legal challenges can be preemptively addressed.

III. BACKGROUND

1. The Clean Water Act

The Federal Water Pollution Control Act (33 U.S.C. § 1251 et seq.), more commonly known as the Clean Water Act ("CWA"), is a "comprehensive water quality

statute designed to 'restore and maintain the chemical, physical, and biological integrity of the Nation's waters.'" (*PUD No. 1 of Jefferson County v. Washington Dept. of Ecology, supra,* 511 U.S. 704, quoting 33 U.S.C. § 1251(a)). In order to accomplish the CWA's goal of eliminating discharge of pollutants into navigable waters, the Act created "effluent limitations," which restricts the "quantities, rates, and concentrations of chemical, physical, biological, and other constituents." (33 U.S.C. § 1311).

When Congress adopted the CWA, it recognized the primary responsibility of the states to prevent or reduce pollution. (33 U.S.C. § 1251(a)). As a result, each state may enforce its own water quality laws with approval by the EPA Administrator, so long as its effluent limitations are not "less stringent" than those established by the CWA (33. U.S.C. § 1370) (*See City of Burbank v. State Water Resources Control Board*, 35 Cal. 4th 613) (holding that a state's water quality "board" may consider economic factors to justify imposing pollutant restrictions as long as those restrictions are *more* stringent than the CWA requires).

The CWA uses three legal terms of art while explaining the roles of the states and the EPA Administrator: "uses," "criteria," and "standards."[1] 33 U.S.C. § 1313(c)(2)(A). A state designates the "uses" for its navigable waters and sets "water quality criteria" for those waters "based upon such uses." *Fla. Wildlife Fed'n, Inc. v. Jackson*, 853 F. Supp. 2d 1138 (quoting 33 U.S.C. § 1313(c)(2)(A)). A state also develops "standards", which are comprised of both the uses and corresponding criteria and must "protect the public health or welfare, enhance the quality of water and serve

[1] "Legal terms of art" are words that have particular or specialized meanings in law that are potentially different than the word's common usage. *See* http://legal-dictionary.thefreedictionary.com/Term+of+Art for a further explaination.

the purposes of" the Act. *Id.* Additionally, a standard must "be established taking into consideration [the waters'] use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes, and also taking into consideration [the waters'] use and value for navigation." *Id.*

However, if a state's standard is found to be inconsistent with CWA requirements, or if the EPA Administrator "determines that a revised or new standard is necessary" in order to meet the requirements, the Administrator is mandated to "promptly prepare and publish proposed regulations setting forth a revised or new" standard. 33 U.S.C. § 1313(c)(4). Unless a state adopts its own new or revised standard, with approval from the EPA, the Administrator must adopt the revised or new standard within 90 days after its publication in the *Federal Register*. However, whether this 90-day limit is judicially enforceable is unclear. See *Miss. Comm'n on Natural Res. v. Costle*, 625 F.2d 1269, 1278 (5th Cir. 1980) (missing the 90-day limit was inconsequential when the court finds no consequences of the tardiness). Generally, there are two main types of standards state governments utilize to meet CWA nutrient pollution requirements; narrative criteria and numeric criteria.[2]

a. Narrative Nutrient Criteria

Under the CWA, water-quality criteria can be either numeric or narrative. A useful analogy to explain the difference between the two: a state could adopt a narrative

[2] In addition to the two types of nutrient criteria, there are also several generally recognized approaches for developing these standards. "Reference conditions" is an approach that analyzes the historical data and relatively unimpaired water bodies in order to provide a baseline by which criteria can be adopted in a broader class of waters. A "stressor-response" approach calls for a regression analyses or scientific study that relates nutrient inputs to desired environmental outcomes or thresholds. Lastly, a "water quality simulation model" simulates the relationship between physical, chemical, and biological processes to study water quality scenarios.

standard - don't drive too fast. Alternatively, a state could use a numeric speed limit - don't drive over 70 miles per hour; or a state could use a combination of both - don't drive over 70 and don't drive too fast under certain conditions. *Fla. Wildlife Fed'n, Inc. v. Jackson*, 853 F. Supp. 2d 1138, 1145-1146. Originally, narrative criteria was the preferred method of state governments for regulating nutrient pollution due to its perceived flexibility.[3]

b. Numeric Nutrient Criteria

NNC are expressed as numerical concentrations and/or mass quantities or loadings, or simply as narrative statements with a scientifically defensible translator mechanism to derive or calculate numerical concentrations and/or mass quantities or loadings. NNC generally fall into one of two categories; Causal NNC or Response NNC. Causal NNC detail the quantity of nitrogen or phosphorus compounds appropriate for a water body. Response NNC detail quantitative thresholds for environmental responses typically resulting from nutrient inputs.

2. North Carolina Nutrient Criteria Development Plan

In 1998, the EPA issued a report that found narrative criteria to be inadequate to address the nation's water-quality issue and that roughly 40% of assessed waters nationwide had not achieved their water-quality goals. Letter from Carol Browner, Adm'r, U.S. Envtl. Prot. Agency and Dan Glickman, Sec'y U.S. Dep't of Agric., to Albert Gore, Jr., Vice President of the United States (Feb. 14, 1998). As a result, the EPA

[3] For example, Florida's originally adopted standard stated "nutrient concentrations of a body of water [must not] be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." *Fla. Admin. Code r*. 62-302.530(47(b).

Administrator and the Secretary of Agriculture adopted a Clean Water Action Plan designed to improve the situation. *See* U.S. Dep't of Envtl. Prot. & U.S. Dep't of Agric., *Clean Water Action Plan: Restoring and Protecting America's Waters* 58-59 (1998). As part of the effort to implement this plan, the EPA Administrator issued a report emphasizing that excessive nutrients were a significant part of the water-quality problem and expected all states to adopt and implement numeric nutrient criteria. *National Strategy for the Development of Regional Nutrient Criteria,* 63 Fed. Reg. 34,648, 34,650 (June 25, 1998).

Prompted by these events, North Carolina developed a nutrient criteria plan which was agreed upon by the EPA in 2004. North Carolina Department of Environment and Natural Resources Division of Water Resources, *North Carolina Nutrient Criteria Development Plan* (June 2014). In order to re-establish mutual agreement with the EPA, the 2004 plan was updated after the North Carolina Division of Water Resources ("NCDWR") held a nutrient forum in 2010 and several other public forums from 2012-2014 to receive input from stakeholders. *Id.* at 2. The subsequent amendments reflected the State's commitment to the plan and to provide a schedule of the progress toward the adoption of nutrient criteria for all state waters. *Id*. The updated plan, entitled the "North Carolina Nutrient Criteria Development Plan" ("NCDP") reflects the comments and critiques expressed during public forums by: (1) creating a Scientific Advisory Council to assist the DWR with NNC development; (2) identifying High Rock Lake, Albemarle Sound, and the central portion of the Cape Fear River as pilot areas for nutrient criteria development; (3) identifying a process through which the DWR will

evaluate nutrients throughout North Carolina; and (4) affirming the DWR commitment to implementing the NCDP. *Id*.

3. Potential Nutrient Criteria

The primary focus of the revised plan is to develop NNC based predominantly on "the linkage between nutrient concentrations and protection of designated uses" *Id.* at 3. The NCDP defines "nutrient criteria" as either of the following:

- Casual and response variables expressed as numerical concentrations and/or mass quantities or loadings; or
- Casual 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.

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

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

IV. RELEVANT CASE STUDY

With the EPA determining the necessity of NNC relatively recently, the legal framework is still bare. However, Florida was one of the first states to attempt to implement NNC and ran into several issues with the EPA and various CWA provisions. By taking note of several of Florida's pitfalls, states should be able to use the case as a good outline to follow.

1. Fla. Wildlife Fed'n, Inc. v. Jackson, 853 F. Supp. 2d 1138

Facts

In 1998, the EPA Administrator issued the "National Strategy for the Development of Regional Nutrient Criteria," a report that recognized that narrative nutrient criteria was insufficient and that numeric criteria should be adopted by all states by December 31, 2003. *Fla. Wildlife Fed'n, Inc. v. Jackson*, 853 F. Supp. 2d 1138. The Florida Department of Environmental Protection ("FDEP") had previously adopted narrative nutrient criterion: ". . . nutrient concentrations of a body of water [must not] be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." *Fla. Admin. Code r. 62-302.530(47)(b)*. However, over time the narrative criteria was shown to be insufficient at addressing rising nutrient levels, and by at least 2001 the Florida Department of Environmental Protection ("FDEP") was working on developing their own NNC.

The FDEP began working on developing NNC as early as 2001. Working in conjunction with Florida's state water management districts, the FDEP spent millions of dollars conducting detailed studies and compiling data. However, as a result of delays,

projected completion deadlines were missed without the adoption of new NNC. In December 2003, the FDEP submitted its first plan for developing NNC, calling for the implementation of NNC rulemaking to begin in August 2004 and the draft rule to be submitted to the state Environmental Regulation Commission ("ERC"), which is responsible for approving water-quality criteria, in October 2015. *See* Water Quality Standards & Special Projects Program & Watershed Assessment Section, Fla. Dep't of Envtl. Prot., *State of Florida Numeric Nutrient Criteria Development Plan* (Dec. 2003). While the FDEP predicted that ERC approval could take 12 months barring dissent, the FDEP stressed its limited control over the ERC's schedule, therefore, making it difficult to predict a completion date. Id.

In July 2004, the EPA responded to the FDEP's proposed 2003 plan, describing it as a "reasonable process" and that completing the process by the FDEP target dates would increase the protection of state waters from nutrient over-enrichment. Letters from James D. Giattina, Dir. Water Mgmt. Div. U.S. Envtl. Prot. Agency, to Mimi Drew, Dir., Div. of Water Res. Mgmt., Fla. Dep't of Envtl. Prot. 1 (July 7, 2004). However, the EPA also warned that failure to meet the target dates could potentially lead to a determination by the Administrator, under the CWA, to propose and adopt new or revised standards. The EPA stated:

> If the State has not met the milestones as scheduled in the plan, EPA will evaluate whether a federal promulgation would be appropriate. At that time, the Administrator may determine that new or revised standards are necessary to meet the Clean Water Act (CWA), and choose to promulgate water quality criteria for nutrients applicable to surface waters within Florida in accordance with Section 303 of the CWA.

Id. at 1-2. After missing the October rulemaking deadline, the FDEP moved the schedule back 18 months, predicting that the rulemaking would instead be implemented in April 2006, and that the FDEP would submit a draft rule to ERC by April 2007. *See* Letter from Jerry Brooks, Deputy Dir., Div. of Water Res. Mgmt., Fla. Dep't of Envtl. Prot., to Andrew Bartlett, Water Mgmt. Div., U.S. Envtl. Prot. Agency (Dec. 14, 2004). While the FDEP continued to compile data, they subsequently missed the 2006 deadline as well. As a result, the FDEP submitted another revised schedule in September 2007 projecting the rulemaking to begin in January 2010 and submission of a draft rule to the ERC between January 2010 and January 2011. *See* Water Quality Standards & Special Projects Program, Water Res. Div., Fla. Dep't of Envtl. Prot., *State of Florida Numeric Nutrient Criteria Development Plan* (Sept. 2007). This was notably more than five years after the original projection. Id.

In July 2008, five environmental groups filed the first of several complaints, naming the EPA and the EPA Administrator as defendants (the "Wildlife" parties). Over time, an additional 13 entities- the Florida Department of Agriculture and Consumer Services, the South Florida Water Management District, and 11 trade associations- intervened as additional defendants. The Florida Wildlife parties sought relief under the CWA's citizen-suit provision, which allows a citizen to sue the EPA Administrator to compel her to perform a duty the CWA makes nondiscretionary. 33 U.S.C. § 1365(a)(2). The Wildlife parties claimed that the 1998 Clean Water Action Plan constituted a "determination" that Florida's narrative nutrient standard was inadequate and a new standard was necessary. The parties asserted that the determination was invalid and

that even if it was, the rule goes too far. The result would be to impose a nondiscretionary duty on the EPA Administrator to “promptly” publish new proposed standards. The Administrator denied this was a determination.

In 2009, the EPA Administrator made an explicit "determination" under CWA § 303(c)(4), 33 U.S.C. § 1313(c)(4), that new criteria, specifically numeric criteria, were necessary to meet the Act's requirements. Pursuant to § 303(a)(1), such a determination by the Administrator creates an explicit statutory duty to “promptly propose and adopt new criteria unless Florida [does] so first.” *Fla. Wildlife* at 1143. Since Florida did not adopt new criteria, the EPA Administrator used model and field studies to adopt new lake and spring criteria to determine at what level nutrient increase generally causes harmful effects. *Id.*

After the 2009 determination, the Wildlife parties filed an amended complaint that added a claim for relief based on that determination as well, claiming that the determination was invalid.

Holding(s)

The ruling upheld the Administrator's determination that numeric nutrient criteria are necessary for Florida waters to meet the Clean Water Act's requirements, upheld the Administrator's lake and spring criteria, invalidate the stream criteria, upheld the decision to adopt downstream-protection criteria, upheld some but not all of the downstream-protection criteria, and upheld the Administrator's decision to allow—and the procedures for adopting—site-specific alternative criteria.

1. Stream Criteria

The EPA Administrator was unable to develop acceptable stream criteria based on modeling and field studies and so adopted stream criteria using a different approach. She identified a representative sample of minimally-disturbed streams for which nutrient data were available, calculated annual geometric means for each stream and in turn for the sample set of streams, and set the criteria at the 90th percentile. The Administrator apparently concluded only that an increase above this level ordinarily causes a change in flora and fauna—not that it causes a *harmful* change. If there is a basis in sound science for disapproving a nutrient increase that causes *any* increase in flora and fauna, not just a harmful increase, the Administrator did not cite it. And even if the Administrator's conclusion was that an increase in nutrients to a level above the 90th percentile ordinarily causes a *harmful* change in flora and fauna, the Administrator again did not cite a sound-science basis for the conclusion. Without any further explanation, the Court found stream criteria to be arbitrary or capricious.

Stream Criteria Discussion

The Administrator divided the state into five regions based on geography and, for each region, identified a representative sample of minimally-disturbed streams for which nitrogen and phosphorous data were available. She calculated annual geometric means for each nutrient for each stream and in turn for the sample set of streams. The rule sets nitrogen and phosphorous criteria at the 90th percentile for four of the regions and at the 75th percentile for the last; the difference turns on the parameters used to select the

sample streams. The criteria include duration and frequency components: a stream is impaired only if the annual geometric mean for a nutrient exceeds the limit in more than one of any three consecutive years.

Each side criticized the EPA Administrator's implementation of this approach. For example, each side criticized the Administrator's selection of sample streams. The environmental parties criticized the duration and frequency components, which are matters of scientific judgment on which the rule would survive arbitrary-or-capricious review. But the state and industry parties pointed to a more fundamental problem—one that turns not on scientific judgment but rather on substantive law and the requirement for an agency to provide a reasoned explanation of its action. The state and industry parties claim the Administrator aimed at the wrong target.

2. Downstream Protection Values ("DPVs")

The Administrator adopted downstream-protection criteria that she referred to as "downstream protection values" or "DPVs." The goal was to protect a water body—in this case, a lake—from nutrient pollution introduced through upstream waters. The decision to adopt DPVs was not arbitrary or capricious. The Administrator allowed DPVs to be set through modeling or, in the absence of modeling, at one of two "default" levels. For a lake not in compliance with the lake criteria—an impaired lake—the default DPVs are the same as the lake criteria. Neither the provision for DPVs based on modeling nor the default DPVs for an impaired lake are arbitrary or capricious. But the default DPVs for a lake that is in compliance with the lake criteria—an unimpaired lake—suffer from a

flaw analogous to that in the stream criteria. The default DPVs for an unimpaired lake are the ambient conditions at the "pour point"—the point at which the stream enters the lake. The Administrator's theory apparently is that any increase from ambient conditions ordinarily causes a change in flora and fauna—not that it causes a harmful change. Here, as with the stream criteria, the Administrator has cited no basis in sound science for disapproving any nutrient increase, not just a nutrient increase that causes a harmful increase in flora or fauna.

3. Site-Specific Alternative Criteria ("SSACs")

The Administrator authorized—and established a procedure for adopting—site-specific alternative criteria that take the place of the otherwise-applicable criteria for a specific water body or set of water bodies (such as a watershed). SSACs must be based on sound science and must protect designated uses. The decision to authorize SSACs—and to establish this procedure for adopting them—was not arbitrary or capricious. Some parties assert that the regulation would allow SSACs for a set of water bodies so extensive that, under the governing law, the SSACs could properly be adopted only through rulemaking, not through the more-abbreviated SSAC procedures. The assertion is not ripe for judicial review at this time, because no such SSAC has been proposed or adopted, and there is no reason to believe one ever will be.

V. COMPARATIVE STATE ANALYSIS

North Carolina's efforts to establish NNC can be informed by the methodology utilized by other states. In particular, this analysis will focus on states that have

developed NNC's for estuaries as part of their own NCDP. By comparing and contrasting the approaches taken by each state, the DWR will be able to combine the "best practices" of each to create a more comprehensive NCDP.

1. Florida: Sarasota Bay

a. Introduction

In October 2009, the Sarasota Bay Estuary Program (SBEP) Policy and Management boards directed the Technical Advisory Committee (TAC) to develop numeric nutrient criteria for the estuarine waters of the Sarasota Bay system. Specifically, the project seeks to: (1) develop a database of water quality and nutrient loads for each of the major bay segments; (2) define the chlorophyll *a* thresholds that meet light attenuation and seagrass targets in each bay segment; (3) define the quantitative relationships between nutrient concentrations or loading and chlorophyll *a* concentrations in each bay segment; and (4) estimate the numeric nutrient criteria, i.e., the nutrient concentrations or loading consistent with the chlorophyll *a* thresholds, for each bay segment. *SBEP Report* at 1-3.

b. Conceptual Approach

As a result, a distinction is made between a target, i.e., a desired chlorophyll *a* concentration and a threshold, i.e., a chlorophyll *a* concentration above which undesirable chlorophyll *a* concentrations exist and should not be exceeded. The chlorophyll *a* threshold for each segment is "the sum of the target and the standard

deviation around the mean annual chlorophyll *a* concentrations for that segment". **Therefore, the sum of the mean chlorophyll a concentrations for 2001-2005 and the standard deviation around the mean annual chlorophyll a concentrations for that segment are the thresholds that were used in the development of the NNC in the SBEP estuarine waters**. *SBEP Report* at iii (emphasis included). They are: (1) Palma Sola Bay – 11.8 µg/In order to establish NNC based on the best available data, the TAC used five SBEP estuarine segments: (1) Palma Sola Bay; (2) Sarasota Bay; (3) Roberts Bay; (4) Little Sarasota Bay; and (5) Blackburn Bay. A water quality subcommittee of the TAC then began the NNC development process by reviewing existing seagrass and chlorophyll *a* data and proposing a set of chlorophyll *a* targets to support the development of the NNC. The review confirmed that the recent extents of seagrasses were meeting the established targets and thus determined that the recent chlorophyll *a* concentrations and resultant water clarity must be protective of the seagrasses in each segment. Upon review of the chlorophyll *a* concentration data, it was deemed appropriate to include not only the data from the 2004-2005 time frame but also data from several antecedent years (2001-2003). The resultant mean chlorophyll *a* concentrations from this overall period (2001-2005) were established as the targets for each segment. These targets were: (1) Palma Sola Bay – 8.5 µg/L; (2) Sarasota Bay – 5.2 µg/L; (3) Roberts Bay – 8.2 µg/L; (4) Little Sarasota Bay – 8.2 µg/L; and (5) Blackburn Bay – 6.0 µg/L. *SBEP Report* at ii-iii.

Additionally, the subcommittee recognized that there may have been years in which these targets may be exceeded without causing significant reduction in seagrass

cover. Therefore, an “allowable” amount of variation would not elicit a significant degradation in water quality and therefore seagrass coverage. The subcommittee defined this level of variation as “the standard deviation around the mean annual chlorophyll *a* concentrations in each segment for the entire period of record”.L; (2) Sarasota Bay – 6.1 µg/L; (3) Roberts Bay – 11.0 µg/L; (4) Little Sarasota Bay – 10.4 µg/L; and (5) Blackburn Bay – 8.2 µg/L.

The water quality data used in these analyses included monthly chlorophyll *a*, TN, TP, salinity, color, turbidity, and other variables. The nutrient and hydrologic loading estimates were developed by applying the Spatially Integrated Model for Pollutant Loading Estimates (SIMPLE) which was designed and calibrated by Jones Edmunds & Associates, Inc. for Sarasota County.[4] In addition to the water quality and nutrient loading data, estimates of residence times for each segment were derived based on the physical features and hydrologic loads for each segment.*SBEP Report* at iii.

A linear regression model approach was used to develop statistically defensible relationships between potential stressors and water quality responses. The independent variables used in the model building process included nutrient loadings, nutrient concentrations, and estimates of residence time. The loadings data included monthly hydrologic, TN, and TP loads as well as cumulative total loads extending from two to six months (e.g., 2-month cumulative TN load = TN load current month + TN load one-

[4] See, http://www.sarasota.wateratlas.usf.edu/upload/documents/Scope%20Exhibit%20A%20from%20Final%20Contract%2006-07-06.pdf, or http://www.sarasota.wateratlas.usf.edu/upload/documents/Brett%20S%20I%20M%20P%20L%20E_SC.pdf for additional information regarding the SIMPLE process and its’ application.

month prior). The water quality constituents included TN and TP concentrations along with numerous other constituents. *SBEP Report* at iv.

The stressor-response relationships for the Roberts Bay, Little Sarasota Bay, and Blackburn Bay segments indicated very similar responses in chlorophyll *a* concentrations to changes in nutrient concentrations. Two terms specifically, TN concentration and season, explained more than 60% of the variation in the chlorophyll *a* data. These results indicated that there are significant relationships between chlorophyll *a* and TN concentrations in each of these segments and that these relationships vary between the wet and dry seasons. The relationship between chlorophyll *a* and TN concentrations in Sarasota Bay was more complex. That relationship depends upon location within the segment (north vs. south) and the ambient water color. **Based on the quantitative relationships between chlorophyll *a* and TN concentrations in each of these segments and the chlorophyll *a* thresholds, the NNC expressed as mean annual TN concentrations were determined for each segment**. *SBEP Report* at iv (emphasis included). These criteria are: (1) Roberts Bay – 0.54 mg/L; (2) Little Sarasota Bay – 0.60 mg/L; Blackburn Bay – 0.43 mg/L; and (4) Sarasota Bay – 0.28-1.34 mg/L (based on ambient water color for the period 1998-2009). *SBEP Report* at iv. However, since no significant relationship was found between chlorophyll a concentrations and either nutrient (TN or TP) concentrations or loadings in Palma Sola Bay, an alternative method for proposing NNC for that segment was necessary.

The SBEP water quality subcommittee of the TAC considered three potential candidate methods for estimating the TN criterion for Palma Sola Bay. These methods

included a logistic regression approach, a changepoint analysis approach, and an approach similar to that used to define the chlorophyll *a* thresholds. While all three potential candidate methods give relatively similar results, the subcommittee recommended the third option – i.e., that based on the 2001-2005 ambient TN data. The proposed NNC for Palma Sola Bay was a mean annual TN concentration of 0.93 mg/L. *SBEP Report* at 63.

2. New Hampshire: Great Bay Estuary

a. Introduction

When the EPA Administrator first called for states to develop NNC, New Hampshire's WQS contained only narrative criteria for nutrients to protect designated uses. While the New Hampshire Department of Environmental Services ("DES") is the agency responsible for developing nutrient criteria for New Hampshire's estuaries, in 2005, the Piscataqua Region Estuaries Partnership (PREP) formed a technical working group to give input on establishing NNC and to provide additional supporting research in its development. The designated uses focused on in this analysis were primarily contact recreation (swimming use) and aquatic life use support. For aquatic life use support, DES investigated nutrient thresholds for the protection of the benthic invertebrate

community, dissolved oxygen, and eelgrass. Chlorophyll-a and nitrogen concentrations were evaluated for the primary contact recreation designated use.

b. Method

The overall approach taken by DES was to divide the estuary into twenty-two different segments and then develop correlations between median values (or other statistics) for nutrients and response variables in the different segments. While states with a variety of estuaries are able to compare median nutrient concentrations and response variables, New Hampshire could not follow this approach because there is only one large estuary in the state. However, the Great Bay Estuary is composed of eight tidal rivers and several distinct embayments and the nutrient concentrations in these different segments span a wide range and have differing levels of eutrophic response. As a result, DES decided to split the estuary into 22 segments of roughly homogeneous water quality and to look for correlations across the segments. The advantage of this approach was that variability in the datasets was muted by taking median values for each assessment zone, which improved the quality of the correlations. Additionally, this approach is supported by the notion that correlations between nitrogen and chlorophyll-a in Canadian estuaries are only evident when data is aggregated over longer time periods and across biogeochemical ocean provinces. The disadvantage of the approach is that spatial and temporal variability of water quality within an assessment zone is lost. However, this month-to-month variability is typically

confounded by the complexity of phytoplankton population dynamics. DES ultimately concluded that the advantages of this approach outweighed the disadvantages.

Several different nutrient concentration thresholds for different designated uses and environmental conditions were developed because different eutrophication indicators occur for different levels of nutrient enrichment. For example, the nutrient concentration threshold to protect against large phytoplankton blooms would be expected to be higher than the threshold to maintain submerged aquatic vegetation. In addition to the thresholds for nutrient concentrations, thresholds for response variables such as chlorophyll-a and water clarity were also developed. These response thresholds provide a means to determine impairments based on measurements of eutrophic effects if nutrient concentration data are missing. The nutrient and response thresholds are used together to make impairment determinations.

c. Conceptual Model

The estuarine eutrophication model used by the National Oceanic and Atmospheric Administration relates external nutrient inputs to primary and secondary symptoms of eutrophication.[5] Phytoplankton blooms (as measured by chlorophyll- a concentrations) and proliferation of macroalgae are primary symptoms of eutrophication, while low dissolved oxygen, loss of submerged aquatic vegetation (e.g., eelgrass), and harmful algal blooms are secondary symptoms. Harmful algal blooms,

[5] Bricker, S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks, and J. Woerner. 2007. Effects of Nutrient Enrichment In the Nation's Estuaries: A Decade of Change. NOAA Coastal Ocean Program Decision Analysis Series No. 26. National Centers for Coastal Ocean Science, Silver Spring, MD. 328 pp. Published Online: http://ccma.nos.noaa.gov/publications/eutroupdate/.

the proliferation of certain species of phytoplankton or cyanobacteria which produce toxins, typically occur offshore in the Gulf of Maine so this indicator was not considered for the Great Bay Estuary.[6] Instead, the secondary effects of accumulated organic matter in sediments on benthic infauna were considered. This approach is consistent with the conceptual model of coastal eutrophication presented by Cloern (2001) and the guidance for developing numeric nutrient criteria for estuaries from EPA (2001). DES used a variety of data sources to estimate thresholds for nutrients and response variables for each of the primary and secondary indicators in the conceptual model. The methods used for each indicator can be found in the DES report (Appendix E).

d. Proposed NNC

The New Hampshire Department of Environmental Services ultimately proposed the following NNC for New Hampshire estuarine waters in the Great Bay Estuary. The values were first used as interpretations of the water quality standards narrative criteria before being promulgated as water quality criteria in Env-Wq 1700.

Table 2. Proposed NNC for New Hampshire Estuarine Waters in the Great Bay Estuary

Designated Use/ Regulatory Authority	**Parameter**	**Threshold**	**Statistic**	**Comment**
Primary Contact Recreation 1,2 (Env-Wq 1703.14)	Chlorophyll-a	20 ug/L	90th percentile	This criterion has been used by DES for 305(b) assessments since 2004.

[6] Townsend, D.W., N.R. Pettigrew, and A.C. Thomas. 2005. On the nature of *Alexandrium fundyense* blooms in the Gulf of Maine. *Deep-Sea Research* 52: 2603-2630.

Aquatic Life Use Support – to protect Dissolved Oxygen 1,3 (RSA 485-A:8 and Env-Wq 1703.07)	Total Nitrogen	0.45 mg N/L	Median	
	Chlorophyll-a	10 ug/L	90th Percentile	
Aquatic Life Use Support – to protect Eelgrass 1,4 (Env-Wq 1703.14)	Total Nitrogen	0.30 mg N/L 0.27 mg N/L 0.25 mg N/L	Median	The range of values for the criteria corresponds to the range of eelgrass restoration depths: 2m, 2.5m, and 3m.
	Light Attenuation Coefficient (Water Clarity)	0.75 m-1 0.60 m-1 0.50 m-1	Median	

3. New Jersey: Barnegat Bay

a. Introduction

New Jersey Department of Environmental Protection ("NJDEP") provides a detailed plan for enhancing the existing nutrient criteria for freshwaters and developing new nutrient criteria for coastal waters through an assessment of these relationships. The plan may include numeric criteria as well as numeric translators of narrative criteria and will be developed to address existing and future nutrient-related impairment in New Jersey waters. New Jersey's objectives to support and enhance this effort are: (1) continued enhanced monitoring in rivers and coastal regions on nutrients and response variables; (2) the assessment of causal relationships for nutrients and response variables; (3) the methodology for developing ecoregional nutrient reference levels; and (4) the development of new assessment methodologies to define thresholds of use impairment based on ecosystem response variables; (5) the development of new/enhanced criteria; and (6) the promulgation of the new and revised criteria through

amendments to the Surface Water Quality Standards and implementation of the new assessment methodology through the Integrated Monitoring and Assessment Reporting process.

The New Jersey plan explains the details of each of these steps by waterbody type, including priorities, milestones, and where possible, timelines for nutrient criteria development and further study. The NJDEP intends to employ a comprehensive approach with a regional perspective, under the paradigm of comprehensive water resource management, in selecting priority areas. Barnegat Bay has already been identified as a priority area and will serve as the model under the Estuaries waterbody type, with an approach which relies heavily on extensive partner involvement in developing the scientific basis for nutrient management findings, including target nutrient levels or loadings, as part of a regional watershed approach for monitoring and assessment.

b. Conceptual Approach

Developing a water quality based management plan for the Barnegat Bay involves a multi-faceted approach. The NJDEP, along with numerous partners, are conducting a comprehensive water monitoring program.[7] The NJDEP has contracted with USGS to conduct the modeling and other related work like determining the bathymetry of the Bay. Once the monitoring is complete, the hydrodynamic and water quality models can be developed and linked together so that the Department can simulate the fate and transport of nutrients and the water quality responses related to

[7] The study can be found at http://www.nj.gov/dep/barnegatbay/.

nutrient levels and other relevant parameters. For a full explanation of the different models utilized by the NJDEP, see Appendix C.

4. Mississippi: St. Louis Bay Watershed

a. Introduction

In 2009, the Mississippi Department of Environmental Quality ("MDEQ") was awarded a grant from the EPA Gulf of Mexico Program to develop pilot nutrient criteria for a Mississippi Estuary. MDEQ selected the St. Louis Bay watershed for this intensive study. The study was designed to include intensive and comprehensive data collection including physical, chemical, and biological monitoring efforts. If MDEQ is unable to establish linkages between nutrient concentrations and biological responses, then one fall-back position may be to establish reference condition thresholds using a percentile of concentrations at least disturbed sites. This plan was mutually agreed upon by MDEQ and the EPA in 2010.

MDEQ believes that it is of utmost importance that criteria for these coastal water bodies be related to a measurable impairment of a designated use. Estuaries and coasts are the most downstream of all state waters, and are therefore the ultimate nutrient "sink". Criteria needed to protect these waters can be translated, or modeled, upland to determine allowable loadings from freshwater inputs. MDEQ is considering this approach as an alternative to establishing reference condition-based criteria in upland freshwaters as they have done with streams and rivers.

b. Conceptual Approach

MDEQ's general approach includes four key aspects: (1) reviewing historical data from Mississippi coasts and estuaries to assess status and trends in nutrient concentrations and associated biotic effects; (2) determining what additional data are needed to develop effects-based nutrient criteria for coasts and estuaries; (3) participating in Gulf Alliance Partnership workshops and meetings to coordinate nutrient criteria development activities; and (4) formulating analytical approaches for using historical and additional data to develop nutrient criteria for coastal and estuarine water bodies. Designated uses for coastal and estuarine water bodies include shellfish harvesting, recreation, fish consumption, and aquatic life support. Effects-based indicators linking nutrients with these designated uses will be included in additional data collection efforts. The approaches considered for linking nutrients with effect-based indicators include empirical approaches/relationships, loading models, and cause-effect studies. Other key factors that needed to be addressed were defining and developing numeric nutrient criteria include: geographic region, water body types, seasonality, and designated uses.

i. Form

The form of the nutrient criteria for coastal and estuarine water bodies will be effects-based rather than EPA's default 304(a) criteria for nutrients. These effects-based nutrient criteria will, wherever possible, reflect localized conditions and protect specific designated uses.

ii. Classification

Within regions, coastal and estuarine systems will be classified according to various factors such as size (e.g., small bays), hydrologic and/or salinity regime, seasonal responses, and other factors that might affect the response of coastal and estuarine systems to nutrient loading and concentration and attainment of designated uses. Classifications will become more apparent upon analysis of the data.

iii. Prioritization and Coverage

Since the large estuaries comprise most of the surface area of coastal and estuarine water bodies, the first priority of nutrient criteria will be for the large estuarine water bodies. The next priority will be to determine if numeric criteria are needed for all coastal and estuarine water bodies, or if there is a size category below which narrative criteria should be retained. If a size category is determined, the applicability of the numeric criteria developed for the large estuaries will be assessed for this intermediate category of estuarine water bodies. Additional numeric nutrient criteria will be developed if the large estuarine nutrient criteria are not considered adequate in protecting and supporting the highest attainable use for these intermediate water bodies.

iv. Data Collection

A data collection program was developed in 2004 based on guidance used in designing the EPA National Coastal Assessment Program. The design considered the parameters to be sampled, which included: Dissolved Oxygen, at least one diurnal event, pH, Temperature, Salinity, Turbidity, Total Dissolved Solids, Ammonia Nitrogen,

Nitrite plus Nitrate Nitrogen, Total Kjeldahl Nitrogen, Total Phosphate, Chlorophyll *a*, and Benthic Macrofauna. However, because of potential funding limitations, benthics were not included during the first year of sampling. The sampling interval was quarterly, beginning in April 2003. The sampling and analytical methods followed the US Environmental Protection Agency National Coastal Assessment Program Guidance. Diel sampling for DO and nutrients will also occur once during the spring high flow period (e.g., May) and once during the summer low flow period (e.g., August) at all stations.[8] Based on this and other factors, data analyses conducted in 2007 indicated the need for additional collection of Chlorophyll *a* data. Additional data collection efforts continue across the Mississippi coastal region.

[8] It should be noted some data was lost during Hurricane Katrina.

APPENDIX

A) EPA Guiding Principles on an Optional Approach for Developing and Implementing a Numeric Nutrient Criterion that Integrates Causal and Response Parameters

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

B) EPA Water Quality Standards Handbook - Chapter 3: Water Quality Criteria

http://water.epa.gov/scitech/swguidance/standards/handbook/chapter03.cfm

C) EPA Administrator Memo: Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions

http://www2.epa.gov/sites/production/files/documents/memo_nitrogen_framework.pdf

D) Numeric Nutrient Criteria For Sarasota Bay

http://www.sarasotabay.org/documents/SBEP-NNC-Final-Report.pdf

E) New Hampshire Nutrient Criteria for the Great Bay Estuary Department of Environmental Services Final (June 10, 2009)

http://des.nh.gov/organization/divisions/water/wmb/wqs/documents/20090610_estuary_criteria.pdf

F) New Jersey Nutrient Criteria Enhancement Plan 2013

http://www.nj.gov/dep/wms/bears/docs/2013_final_nutrient_plan.pdf

G) Mississippi's Plan for Nutrient Criteria Development 2010

http://www.deq.state.ms.us/mdeq.nsf/0/98DB638B05F9B5F786257837005AD048/$file/Nutrient_Criteria_Development_Plan_October2010_Final.pdf?OpenElement

CITATIONS

1) North Carolina Nutrient Criteria Development Plan (2014)

2) Fla. Wildlife Fed'n, Inc. v. Jackson, 853 F. Supp. 2d 1138

3) A brief history of nutrient criteria development in North Carolina estuaries

4) EPA Water Quality Standards Handbook

5) El Dorado Chem. Co. v. United States EPA, 960 F. Supp. 2d 838

6) Federal Water Pollution Control Act

7) EPA Guiding Principles on an Optional Approach for Developing and Implementing a Numeric Nutrient Criterion that Integrates Causal and Response Parameters

8) National Strategy for the Development of Regional Nutrient Criteria

http://www.gpo.gov/fdsys/pkg/FR-1998-06-25/html/98-16941.htm

9) *National Strategy for the Development of Regional Nutrient Criteria,* 63 Fed. Reg. 34,648-34,650 (June 25, 1998).

10) Hawhee, Jim, *North Carolina Estuarine Nutrient Criteria Overview,* Albermarle - Pamlico National Estuary Partnership (Aug. 2014).

11) Letter from Carol Browner, Adm'r, U.S. Envtl. Prot. Agency and Dan Glickman, Sec'y U.S. Dep't of Agric., to Albert Gore, Jr., Vice President of the United States (Feb. 14, 1998).

12)

http://www.gpo.gov/fdsys/pkg/FR-1998-06-25/html/98-16941.htm

Appendix V: Albemarle Sound Estuarine Literature Compilation (Memorandum)

TETRA TECH

MEMO

To:	Tiffany Crawford, Lauren Petter, Steve Kroeger, Jim Hawhee
Cc:	Jacques Oliver
From:	Yukiko Ichishima, Michael Paul, and Kristen Perry
Date:	September 2, 2015
Subject:	NC Albemarle Sound Estuarine Literature Compilation

1.0 DEVELOPMENT OF LITERATURE REVIEW TO SUPPORT PROBLEM FORMULATION FOR NORTH CAROLINA ESTUARIES UNDER N-STEPS

1.1 BACKGROUND

Tetra Tech, Inc. (Tt) was asked to identify literature relevant to the development of nutrient criteria for estuaries in North Carolina, specifically the Albemarle Sound and to provide these citations in a digital database. Furthermore, Tt was asked to organize the citations into groups based on several major themes including conceptual nutrient effect pathways, assessment endpoints, and methods applied to derive nutrient criteria. Tt was asked to identify and organize this literature, but not to provide a synthesis.

This memo provides a brief summary of the full list of entries, the organization of citations into groups, and brief descriptions of the characteristics of each group.

1.2 DESCRIPTION OF FULL LIST OF ENTRIES IN ENDNOTE DATABASE

The North Carolina Department of Water Resources (NCDWR) requested members of the Albemarle-Pamlico National Estuary Program (APNEP) and the North Carolina Nutrient Criteria Development Plan Scientific Advisory Council (SAC) to submit references relevant to eutrophication effects on estuaries (causal pathways, assessment endpoints for estuaries, and methods/approaches). To this, Tt identified additional literature from applicable sources (e.g., N-STEPS website, CADDIS website, California Numeric Nutrient Endpoint documents, past Tt projects pertaining to estuarine criteria and endpoints, etc.) where citations could be found related to estuarine numeric nutrient criteria development. Each EndNote entry consisted of author, year, title, abstract (if applicable), and URL (if applicable). Physical copies of peer-reviewed literature were not obtained for this effort due to copyright issues, but some publicly available documents are included. Not all the entries in the EndNote database were applicable to this effort, and thus were reviewed and manually binned into appropriate subject-specific folders within the database. A total of 3,962 unique references from the following sources have been entered into the EndNote database:

(1) List of references solicited by NCDWR/APNEP from the SAC

Tetra Tech Inc., Center for Ecological Sciences
1 Park Drive, Suite 200, Research Triangle Park, NC 27709
Tel 919-485-2073 tetratech.com

(2) References and documents from the NSTEPS website[1]
(3) CADDIS website[2]
(4) Florida's Numeric Nutrient Criteria Methods document & its references
(5) Florida's Proposed Estuarine Numeric Nutrient Criteria (NNC)
    - Preamble
    - Proposed Numeric Nutrient Criteria Technical Support Document & Appendices
    - SAB Report related to EPA's Proposed NNC for Florida
(6) Great Bay documents
(7) Tampa Bay documents
(8) EPA's Estuarine Guidance Document[3] and other national documents
(9) Chesapeake Bay documents
(10) Massachusetts Estuaries Program's studies to determine nitrogen loading thresholds for MA's embayments
(11) Yaquina Bay case study
(12) California Numeric Nutrient Endpoint (CA NNE) documents
(13) Literature from relevant past projects that have favored peer-reviewed literature and government reports over gray literature.

1.3 LITERATURE ORGANIZATION

Tt queried the database based on subject area and subtopics (described below) using the "SmartGroup" function in EndNote. The query was conducted based on titles, abstracts, and keywords (if applicable), which went into a SmartGroup folder. Because the SmartGroup function only approximately identified appropriate literature, Tt manually reviewed each entry in the SmartGroup folders based on the titles and abstracts, and then binned those into separate subtopic folders.[4]

If a reference covered multiple topics, the reference was binned into all relevant subtopic folders. For example, if a reference was a study conducted in the Chesapeake Bay, discussed seagrasses, water clarity, and phytoplankton, this one reference would be binned into 4 topic folders: Chesapeake Bay, SAV, clarity, and phytoplankton folders. Please note that, based on the limited information provided by the titles and abstracts, Tt hedged towards greater inclusiveness than less (i.e., binned into more folders that might potentially be applicable). Not all references were estuarine-related, however some were binned when appropriate for each subtopic in the context of developing numeric nutrient criteria.

The subject areas and subtopics are provided below, along with a brief description of each as well as the number of citations in each folder.

Subject area	Subtopics	Description of literature included in each folder	Count
Causal Pathways	Causal pathway	Includes literature about how nutrients affect estuaries and its ecosystem; generic overarching	265

[1] http://www.nsteps.org/
[2] http://www.epa.gov/caddis/
[3] USEPA. 2001. Nutrient Criteria Technical Guidance Manual - Estuarine and Coastal Marine Waters. EPA-822-B-01-003. U.S. Environmental Protection Agency. http://www2.epa.gov/nutrient-policy-data/criteria-development-guidance-estuarine-and-coastal-waters.
[4] The "SmartGroup" function was only used to filter relevant references, and is different from the manually-created subtopic folders seen in the table.

Subject area	Subtopics	Description of literature included in each folder	Count
		discussion of eutrophication and its effects on the ecosystem.	
	Conceptual model	Includes literature discussing conceptual models and/or included a drawing.	38
	Indicators/indices	Assessment of eutrophication and indicators.	128
Endpoints	Benthics/invertebrates	Nutrient effects on benthic communities (including invertebrates).	91
	Blooms/HABs	Nutrient effects on blooms and/or HABs (or trends).	194
	Clarity/light attenuation	Nutrient effects on water clarity.	115
	Diatoms	Nutrient effects on diatoms.	49
	DO/hypoxia	Nutrients effects on dissolved oxygen, anoxic, or hypoxic conditions.	165
	Epiphytes	Nutrient effects on epiphytes.	74
	Fish	Nutrient effects/low dissolved oxygen on fish.	54
	Macroalgae	Nutrient effects on macroalgal species.	172
	Nitrogen forms	Discussed endpoints and nitrogen forms (e.g., nitrate, nitrite, nitrogen, etc.)	330
	Phosphorus forms	Discussed endpoints and phosphorus forms.	188
	Phytoplankton/chl-a	Nutrient effects on phytoplankton or chlorophyll (measure of phytoplankton).	265
	SAV/seagrass/eelgrass	Nutrient effects on seagrasses (including eelgrass).	242
Approaches	CA NNE	California Nutrient Numeric Endpoints-related documents.	6
	Methods	This subtopic is a catch-all sub-folder to include studies that discuss development of NNC, loads, TMDLs, targets/thresholds/indices; use statistical analyses, remote sensing, light attenuation coefficients, and other methods.	116
	Models	This folder includes studies that used water quality models or modeling to examine effects of nutrients.	172
	Reference conditions	Includes studies using reference conditions.	13
	Stressor-response	Includes studies using empirical stressor-response relationships.	6
	Target/threshold	Paper discusses a target or threshold for an endpoint (or an estuary).	43
	TMDL-related	Papers that discuss TMDL development.	13
Geographical Areas	Albemarle	Papers that specifically talk about studies that took place in the Albemarle.	4
	Chesapeake Bay	Chesapeake Bay-specific studies.	109
	Florida	Florida-specific studies.	179
	Massachusetts	Massachusetts-specific studies.	100
	New Hampshire/Great Bay	New Hampshire- and Great Bay-specific studies.	13

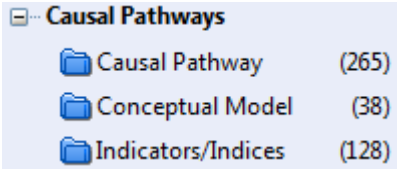
Subject area	Subtopics	Description of literature included in each folder	Count
	North Carolina	North Carolina-specific studies.	48
	Northeast estuaries	Studies that took place on the northeastern half of the Atlantic coast of the United States.	44
	Other estuaries	Studies that took place in other estuaries in the United States.	83
Documents	National reports	Reports submitted by USEPA, USGS, etc.	49
	NCDWR documents	Papers suggested for addition through solicitation of papers by North Carolina DWR/APNEP. Notes added in by submitters have been copied into the "Research Notes" field in the EndNote database.	61
Other	N to P ratios	Papers that discuss N:P ratios.	51
	Reviewed TMDLs	Nutrient TMDLs extracted from ATTAINS.	49

1.4 SUMMARY OF LITERATURE FOUND IN SUBTOPIC FOLDERS

Below is a brief description of the references found in the major sub-folders.

1.4.1 Causal Pathways Folders

1.4.1.1 Causal Pathway Sub-folder



Tt identified many references pertaining to eutrophication effects on estuaries (265 references), the vast majority of which were peer-reviewed articles. Approximately a dozen entries were books or book sections, and approximately two dozen reports were written for federal or state government entities; many of the reports were the ones submitted to the solicitation by NCDWR. Based on a brief scan of the abstracts, the covered topics appear to be replete with information on various angles about effects of eutrophication.

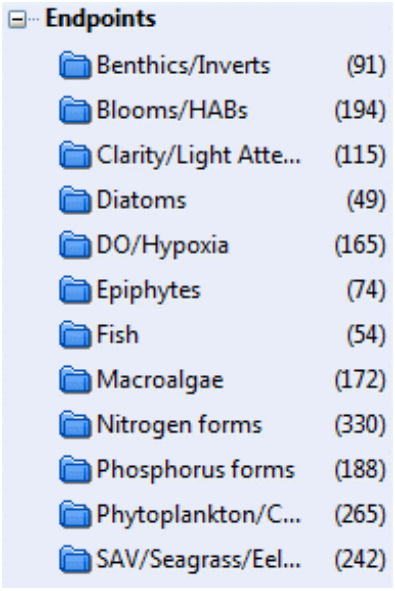
1.4.1.2 Conceptual Model Sub-folder

There were 38 references identified for this sub-folder, the majority being peer-reviewed, with a handful of reports written for government or state entities. The number of references in this sub-folder may have been affected by the fact that the query was based on titles and abstracts only and was difficult to determine whether the reference had any conceptual model drawings. It is unclear from this brief scan of the abstracts how complete the descriptions are on conceptual models.

1.4.1.3 Indicators/Indices Sub-folder

This sub-folder was created to catch any references that might discuss developing indices. The majority of the 128 references were peer-reviewed articles and discussed the assessment of eutrophication. Many of these papers were studies on the effectiveness of the EU eutrophication assessment framework.

1.4.2 Endpoints Folders



1.4.2.1 Benthics/Invertebrate Sub-folder

This sub-folder contains 91 references, the majority being peer-reviewed articles, a few book sections, a state report, and a USGS report. Information about nutrient effects on benthic communities appear to be less common.

1.4.2.2 Blooms/HABs Sub-folder

This sub-folder contains 194 references pertaining to nutrients and algal blooms/harmful algal blooms (HABs). There are many studies that examine nutrient effects on blooms/HABs. Most of the references are peer-reviewed articles, a few book sections, a handful of theses, and about a dozen state and government affiliated reports (e.g., NOAA). Note, this sub-folder includes both phytoplankton and macroalgal blooms.

1.4.2.3 Clarity/Light Attenuation Sub-folder

This sub-folder contains 115 references about water clarity and nutrients. The majority of references are peer-reviewed articles; and about a half-dozen reports written for estuary programs, state, and government organizations (e.g., USEPA, USGS). The majority of the references talk about water clarity in the context of protecting seagrasses (e.g., Chesapeake Bay [approximately 30 entries], Florida estuaries [approximately 30 entries]).

1.4.2.4 Diatoms Sub-folder

This sub-folder contains 49 references that address diatoms and nutrients. All entries are peer-reviewed articles. In general, information about nutrient effects on diatoms in estuaries was less common.

1.4.2.5 DO/Hypoxia Sub-folder

This sub-folder contains 165 references. There is plenty of information about nutrient effects on dissolved oxygen, especially since most states have a DO numeric nutrient criteria to protect fish and benthic communities. The majority of references in this folder are peer-reviewed articles and approximately a dozen were state, government, and estuary program-related reports.

1.4.2.6 Epiphytes Sub-folder

This sub-folder contains 74 references that address epiphytes and nutrients. All entries are peer-reviewed articles, except for one, which was a conference proceeding. In general, information about nutrient effects on epiphytes in estuaries were less numerous. Many of the references address epiphytes in relation to shading of seagrasses.

1.4.2.7 Fish Sub-folder

This sub-folder contains 54 references that relate to fish and nutrients. All entries are peer-reviewed articles, except for three, which were state or government reports. In general, information about nutrient effects on fish in estuaries appeared less common. Much of the information appear to be in relation to effects of nutrients on DO concentrations, and the effects that DO concentrations (hypoxia/anoxia) have on various fish species.

1.4.2.8 Macroalgae Sub-folder

This sub-folder contains 172 references that deal with nutrients and macroalgae. The majority are peer-reviewed articles; approximately a half-dozen reports written for state, government, and other organizations; and approximately a half-dozen book sections. There appears to be more information regarding macroalgae than other endpoints, but it is unclear from this brief review how site-specific the results are.

1.4.2.9 Nitrogen forms Sub-folder

This sub-folder contains 330 references that discuss studies that monitored various nitrogen forms in relation to its effects on ecosystems. The majority of references are peer-reviewed articles; with about a half-dozen books and book sections; about a dozen reports written for government, state, and other organizations; and two theses. There are a lot of citations, however the studies cover a broad range of issues.

1.4.2.10 Phosphorus forms Sub-folder

This sub-folder contains 188 references that discuss studies that monitored various phosphorus forms in relation to its effects on other organisms. The majority of references are peer-reviewed articles; with about a half-dozen books and book sections; about a dozen reports written for government, state, and other organizations; and one thesis.

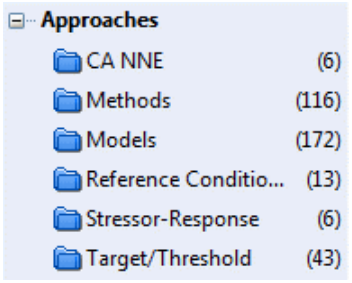
1.4.2.11 Phytoplankton Sub-folder

There is an abundance of literature on nutrients and phytoplankton (265 entries). The majority of references are peer-reviewed articles; two books and book sections; two conference proceedings, approximately a dozen reports written for government, state, and other organizations; and two theses.

1.4.2.12 SAV/Seagrasses/Eelgrass Sub-folder

There was similarly an abundance of literature on nutrients and SAV/seagrasses (242 entries). The majority of references were peer-reviewed articles; with two books and book sections; about two-dozen reports written for government, state, and other organizations; and two theses.

1.4.3 Approaches Folders



1.4.3.1 California NNE Sub-folder

This sub-folder contains 6 references found regarding the CA NNE approach. Five reports are written for the California State Water Resources Control Board, and one is a white paper that analyzed the approach.

1.4.3.2 Methods Sub-folder

This sub-folder contains 116 references that address about various methods used to determine nutrient effects on various organisms. This sub-folder includes studies that used statistical analyses, remote sensing, examined the development of numeric nutrient criteria, or calculated or examined nutrient loads/ targets/thresholds/indices. The majority of references are peer-reviewed articles, with approximately three-dozen reports written for government, state, and other organizations.

1.4.3.3 Models Sub-folder

This sub-folder contains 172 references that discuss a vast range of modeling methods used to predict ecosystem responses to nutrients. The majority of the references are peer-reviewed while approximately a dozen references were written for state, government, or local government.

1.4.3.4 Reference Condition Sub-folder

This sub-folder contains 13 references, all peer-reviewed articles except for one state report and one website that is linked to a government project. There may be more references that discuss reference condition approaches, however this was not possible to know without reading the full text of the articles.

1.4.3.5 Stressor-Response Sub-folder

This sub-folder contains 6 references, three peer-reviewed articles and three state and government reports. Again, there may be and are likely more references that use empirical stressor-response approaches, however this was not possible to know without reading the full text of the articles.

1.4.3.6 Target/Threshold Sub-folder

This sub-folder contains 43 references, the majority being peer-reviewed, with approximately a dozen state and government reports. This folder was created to see if there would be any studies that specifically mention derived, or examined nutrient targets or thresholds.

1.4.4 Geographical Areas Folders

1.4.4.1 North Carolina Sub-folder

There are 48 references (all peer-reviewed except for the CHPP report and a book entry) binned into this sub-folder. Four of these citations reference the Ablemarle Sound.

1.4.4.2 NCDWR Documents Sub-folder

There were 61 documents submitted to NCDWR. The majority are peer-reviewed articles, one book, one book section, and nine reports written for state and government organizations. Notes associated with each reference are documented in the “Research Notes” field in the EndNote database.

Appendix VI: North Carolina Water Resources: Utilizing NASA Earth Observations to Monitor Harmful Algal Blooms in the Albemarle Sound of North Carolina (Report)

NASA DEVELOP National Program

NASA Langley Research Center
Spring 2015

North Carolina Water Resources

Utilizing NASA Earth Observations to Monitor Harmful Algal Blooms in the Albemarle Sound of North Carolina

DEVELOP

Technical Report

Final Draft – April 2, 2015

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I. Abstract

Harmful algal blooms (HABs) cause significant ecological damage to aquatic systems by disrupting water chemistry, producing toxins, and blocking sunlight to submerged aquatic vegetation and other organisms. In the Albemarle and Pamlico Sounds, the USGS North Carolina Water Science Center monitors HABs by taking point samples throughout the region, but they lack a method to monitor the spatial extent of HABs throughout the sounds during the year. For this project, Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) Level 2 OC3M-derived chlorophyll-*a* data were downloaded from NASA Goddard Space Flight Center's Ocean Color Website via a Linux operating system. The OC3M algorithm uses multispectral reflectance bands available from Aqua MODIS to calculate the concentration of chlorophyll-*a*, which is used as a proxy for the presence of algae. Chlorophyll-*a* concentration values from these layers were then extracted from days with spatially and temporally corresponding *in situ* water samples for comparison. Then, images of monthly chlorophyll-*a* means were processed into a time-series video representation of algae extent throughout the sounds. End-users can use the 10-year time-series to supplement their *in situ* data to assess HAB behavior throughout the region.

Keywords
North Carolina, Remote Sensing, Harmful Algal Blooms (HAB), Albemarle Sound, Pamlico Sound, bio-toxins, submerged aquatic vegetation (SAV), Earth Observations

II. Introduction

The Albemarle and Pamlico Sounds in North Carolina are part of the Albemarle-Pamlico Estuarine Complex, the second largest estuarine system in the United States, after the Chesapeake Bay (Korfmacher, 2002). This system receives drainage from approximately 30,000 square miles of watershed including discharge from the Chowan, Roanoke, Pasquotank, Neuse, and Tar-Pamlico Rivers (Mallin et al., 2000). The Albemarle-Pamlico system supports a diverse seagrass and submerged aquatic vegetation (SAV) population, as well as rich fisheries characterized by a mix of estuarine and pelagic species (Mallin et al., 2000). SAV ecosystems play a vital role in the sound by providing habitats for fish and aquatic invertebrates (Paerl and Otten, 2013). The biodiversity and overall health of the estuary has become compromised over recent decades due to increased urbanization and industrialization in response to rapid population growth along the North Carolina coast. In addition, shifting agricultural interests during the 1980s led to a decline in tobacco farming and an expansion of commercial swine production (Mallin et al., 2000). Together, these activities have increased urban and agricultural runoff into the estuarine ecosystem, which increases the rate that nutrients are entering the system, causing eutrophication. Eutrophication includes increases in algae populations which deplete dissolved oxygen in the water and create hypoxic zones (Ryther and Dunstan, 1971). Subsequently, hypoxic zones lead to death of aquatic flora and fauna species (Ryther and Dunstan, 1971). Eutrophication also creates optimal growth conditions for Harmful Algal Blooms (HABs)(Paerl and Otten, 2013; Fu et al., 2012).

Harmful algae are capable of producing neurotoxins and hepatotoxins in concentrations lethal to wildlife and domestic animals (Lopez et al., 2008; Mallin et al.,2000). They can also manufacture endotoxins and dermatotoxins, causing serious irritation and various sublethal effects (Clercin, 2012). Human exposure to HABs includes inhaling the toxins that HABs release into the air, drinking water contaminated by HABs, or eating fish or shellfish exposed to HABs. The consequences of exposure include gastrointestinal, neurological, dermal, or respiratory irritation, varying in severity from mild to fatal depending on the amount and type of HABs present (Seltenrich, 2014; Trevino-Garrison et al., 2015). While only certain species of harmful algae produce deadly chemicals, all HABs deplete dissolved oxygen, alter water chemistry, and prevent sunlight from reaching the bottom of the sound (Paerl and Otten, 2013).

Between 2004 and 2014, the state of North Carolina monitored HAB activity in the Chowan and Pasquotank rivers, and routinely monitored chlorophyll-*a* on a monthly basis at stations in the Albemarle Sound. Chlorophyll-*a* is essential for photosynthesis and is one of the photosynthetic pigments present in algae. Nearly a quarter of water samples conducted by North Carolina's Water Science Center during the summer of 2012 contained dangerous, toxin-producing phytoplankton. Several genera of *Anabaena, Anabaenopsis, Aphanizomenon, Aphanocapsa, Microcystis,* and the particularly aggressive *Cylindrospermopsis raciborskii* were detected. The synergistic

effect of nutrient pollution and reduced light availability in the water column has caused damage to previously healthy areas of SAV throughout the Albemarle and Pamlico Sounds (Mallin et al., 2000).

The objective of this project was to monitor the extent of HABs using chlorophyll-*a* concentration as a proxy for HAB concentration in the Albemarle and Pamlico Sounds in North Carolina using NASA Earth observation imagery and ancillary data gathered between 2004 and 2014. The project also sought to give end-users a tool to assess water quality as it related to HAB extent at a large spatial and temporal scale (Figure 1). The USGS North Carolina Water Science Center and the Albemarle-Pamlico National Estuary Partnership were interested in a 10-year history of algal bloom activity throughout the estuary system for the identification of patterns in HAB extent as it related to seasonal and climatic fluctuations. The partners can use the results of this project to expand their current knowledge of HABs and later predict HAB extent through statistical modeling.

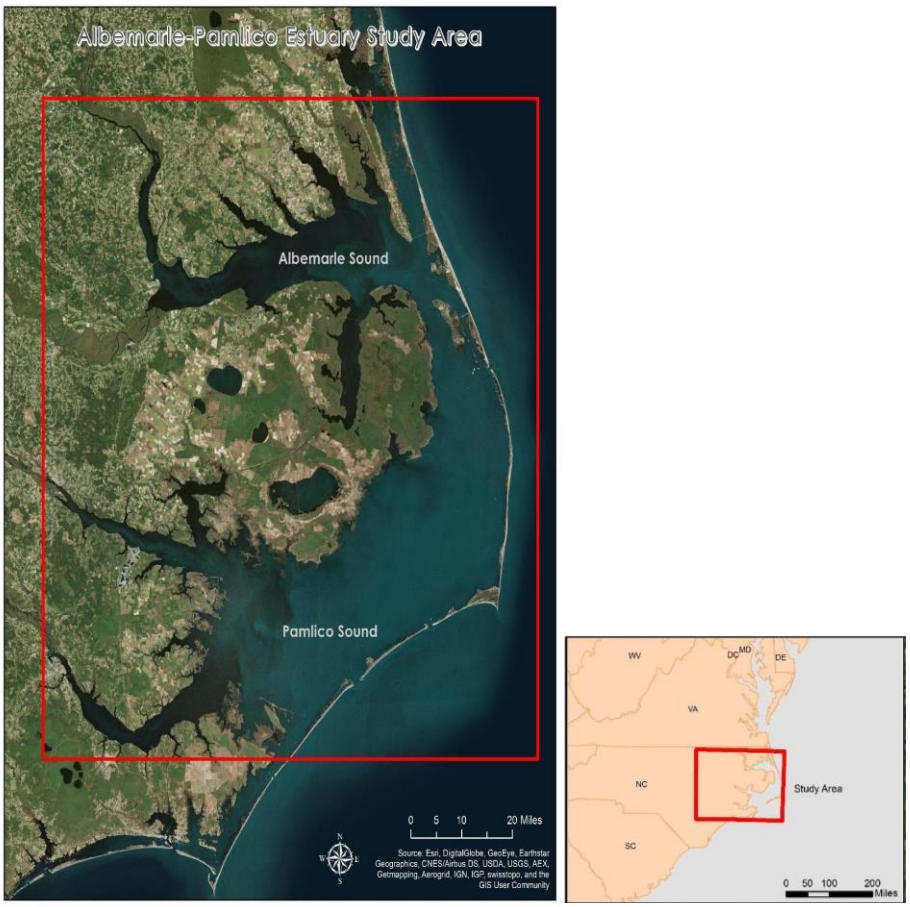

Figure 1: Study Area: The Albemarle and Pamlico Sound.

III. Methodology

Data Acquisition:

NASA's Earth-observing Moderate Resolution Imaging Spectroradiometer (MODIS) instrument, onboard the Aqua satellite, provided ocean color products used to represent algae extent throughout the Albemarle-Pamlico Estuary. The Aqua MODIS Level 2 daily swath data were downloaded from the NASA Goddard Space Flight Center's Ocean Color Website using a Linux operating system from January 2004 to December 2014. These data layers were reduced to a study area encompassing the Albemarle and Pamlico Sounds. Any image that did not at least capture the entire bounding box was rejected to prevent inclusion of partial images.

In situ water quality data were provided by the USGS North Carolina Water Science Center. Additional water quality data were downloaded from the National Water Quality Monitoring Council website along with water sampling station coordinates (Figure 2).

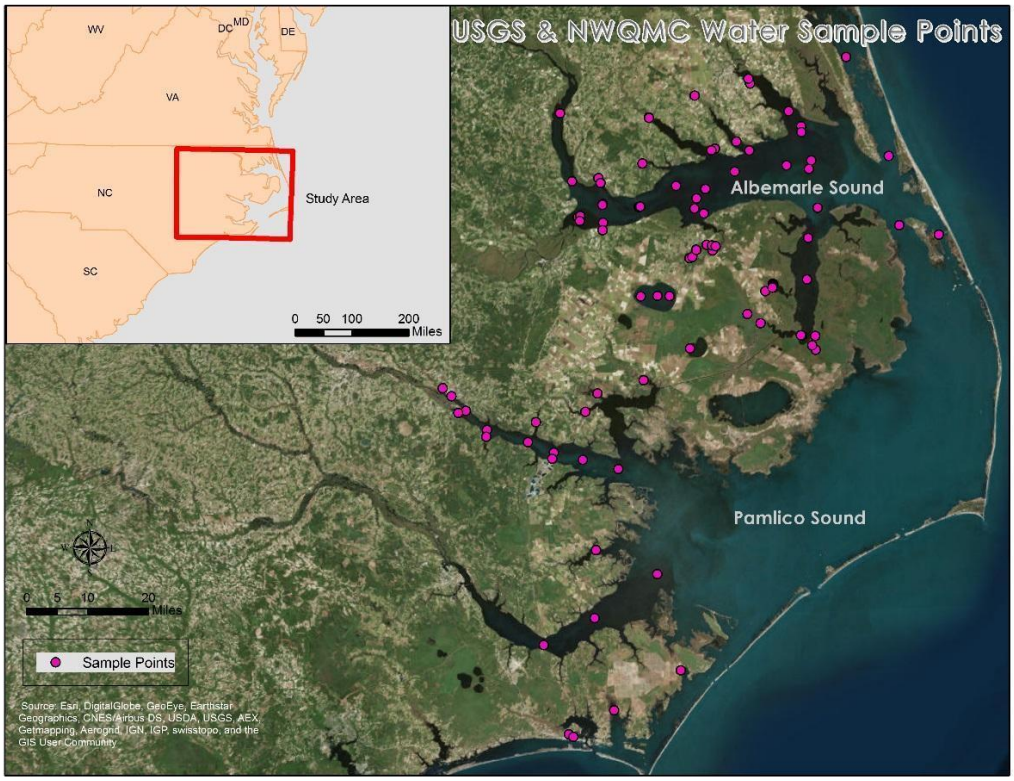

Figure 2: The locations of National Water Quality Monitoring Council water quality sampling stations in the Albemarle-Pamlico Sound.

Data Processing and Analysis:

Data processing involved utilizing NASA SeaDAS, an image analysis program for processing ocean color data. All layers were reprojected using SeaDAS from their original sinusoidal form to the projected coordinate system, NAD 1983 State Plane North Carolina FIPS 3200. In SeaDAS, the standard OC3M algorithm was applied to produce a chlorophyll-*a* result layer for each day in the data set. The OC3M algorithm, uses reflectance values from MODIS band wavelengths 443, 489, and 547 (Equation 1). The blue wavelength is represented by the greatest of several input remote-sensing reflectance (R_{rs}) value from the 443 or 489 band, and the green wavelength is represented by R_{rs} from the 547 band. The results were saved as GeoTIFF files and exported for use in Esri ArcGIS software.

$$log_{10}(chlor\_a) = a_0 + \sum_{i=1}^{4} a_i log_{10}\left(\frac{R_{rs}(\lambda_{blue})}{R_{rs}(\lambda_{green})}\right)^i$$

Equation 1: The standard OC3M algorithm.

Using Esri ArcMap, the OC3M algorithm derived chlorophyll-*a* layer was separated from each daily multispectral composite file and copied to a new single layer raster file. Each raster layer was further processed using a Python script to create uniform extent and pixel size.

A single, composite table was created in Excel that listed all *in situ* sample dates, latitude coordinates, longitude coordinates, and chlorophyll-*a* concentrations. These points were used in SeaDAS to extract MODIS chlorophyll pixel values for comparison. MODIS chlorophyll-*a* values were extracted at station locations from images acquired within one day of the *in situ* sample date.

There were a total of 4,405 daily MODIS image files relevant to the study timeframe and location. Many *in situ* sample points occurred on a date or in a location where a clear, cloud-free MODIS image pixel was not available; therefore, the values from these samples were not considered in the analysis. Of the 3,135 total *in situ* chlorophyll sample points taken during the study period within the study area, only 628 sample values could be compared to MODIS-derived chlorophyll-*a* concentrations. This represents the total number of *in situ* samples in the area that satisfied the conditions of being performed within a day of MODIS image acquisition, and having occurred at a location represented by a MODIS image pixel containing a valid chlorophyll concentration value. To measure how well MODIS-derived chlorophyll-*a* concentrations fit the *in situ* measurements, a Pearson's correlation coefficient was calculated using Excel's CORREL function. This value was then squared to find the coefficient of determination, or R^2 value. Additionally, the mean squared error was calculated to measure error between the chlorophyll-*a* values.

In order to visualize long-term chlorophyll trends over the 10-year study period, monthly mean chlorophyll-*a* concentrations were calculated from the MODIS derived values. This was done by taking the mean of the daily collocated pixel values for a one month period while filtering out images with 'no data' pixel values. These data were used to create monthly chlorophyll-*a* concentration maps for the study period.

IV. Results & Discussion

Analysis of Results:

The correlation between MODIS derived chlorophyll-*a* concentrations and *in situ* data showed a poor relationship. A high mean squared error of 79.78, and a low R^2 value of 0.0196 revealed little to no correlation between the two sets of chlorophyll-*a* concentrations (Figure 3). Thus, Aqua MODIS satellite imagery may not provide an accurate way of determining chlorophyll-*a* concentrations in the complex coastal waters of the Albemarle and Pamlico Sounds using the standard OC3M algorithm.

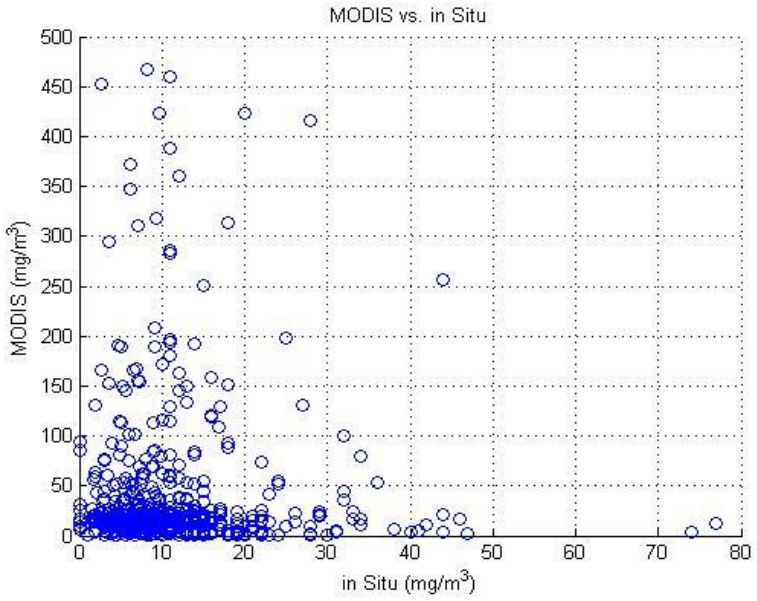

*Figure 3: Scatterplot of Chlorophyll-*a *values indicating a low correlation between* in situ *data and MODIS derived values.*

MODIS derived daily chlorophyll-*a* concentrations were also highly variable. Thus the low correlation between *in-situ* chlorophyll-*a* concentrations and MODIS-derived chlorophyll-*a* concentrations and high MODIS variability indicates that illustrating the monthly average for a time series may be misleading (Figure 4).

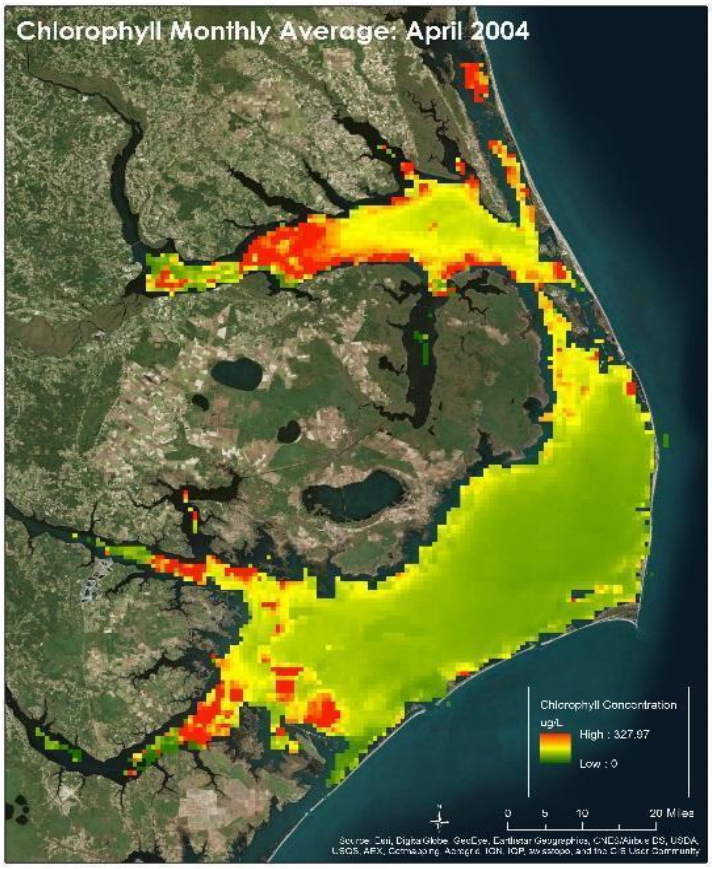

Figure 4: Monthly chlorophyll-a concentration for April 2004. Areas in red indicate areas of high chlorophyll-a concentrations.

Errors & Uncertainty:

Chlorophyll-*a* has widely been used, with success, to track the spatial extent of algae in many parts of the world (Siswanto et al., 2013). However, chlorophyll-*a* is also the predominant photosynthetic pigment in eukaryotes, cyanobacteria and prochlorophytes. Thus, chlorophyll-*a* is not a direct indicator of a HAB (Siswanto, 2013. Since the OC3M algorithm used to calculate chlorophyll-*a* was developed from global *in situ* data from various coastal regions and oceans, it may not be the optimal algorithm for calculating chlorophyll-*a* concentrations in the Albemarle-Pamlico Estuary. The Albemarle-Pamlico Estuary is considered an optically complex region due to variable, typically high concentrations of suspended particles in the water column (Miller et al., 2011). The increase in suspended particles can reduce the blue-green reflectance ratio, which can result in artificially inflated chlorophyll-*a* levels for the region (Siswanto, 2012). However, recent research has revealed that the accuracy of chlorophyll-*a* analysis in optically complex waters is greatly dependent upon the availability of specific algorithms developed in the region or water body of interest

(Cannizzaro and Carder, 2006). Other research has found that the MODIS sensor is not able to accurately detect algae or cyanobacteria (Reinart and Kutser, 2006). MODIS does not have spectral bands around 700 nm, which is where chlorophyll-*a* reflectance values, in eutrophic waters will peak (Reinhart and Kutser, 2006). Thus, detecting chlorophyll-*a* using the MODIS sensor may only happen when concentrations are very high (Reinart and Kutser, 2006).

The OC3M algorithm is used for calculating near-surface chlorophyll-*a* (O'Reilly et al., 2000). Water samples collected by the USGS occurred at various depths below the water surface. The water sample data from the National Water Quality Monitoring Council did not contain information regarding sampling depth. Since the vast majority of all *in situ* data did not include sample depth information, all sample points were considered in the analysis. This sampling difference may also contribute to the poor correlation between the two sets chlorophyll-*a* concentrations. Furthermore, there are inherent problems associated with collecting *in situ* water sample data that may have further contributed to the lack of correlation between the MODIS chlorophyll-*a* concentrations and water sample data. These problems include, the act of water sampling from research vessels, whether performed with flow-through systems or surface grabs, can disturb the natural distribution of algae and cyanobacteria. This could mean that some *in situ* results may not represent real water conditions (Kutser et al., 2006).

V. Conclusions

Although corollary confidence is low, further analysis can be done using the data collected from this project to produce a more refined analysis of algae extent throughout the study area. The possibility remains for the application of alternative algorithms or estuary-specific algorithms based on other available reflectance bands from MODIS or other sensors to give an accurate representation of the HAB events plaguing the Albemarle-Pamlico Estuary system. Future work could incorporate established processes to detect the cyanobacterial pigment, phycocyanin, as a way to monitor HABs (Vincent et al., 2004). Another alternative would include modelling of selected genera of algae and cyanobacteria. It has been shown that different genera of algae, in differing types of water, show great variance in their reflectance properties. For example, the cyanobacteria *Aphanizomenon* and *Anabena* along with algae genera such as *Scenedesmus* and *Chroomonas* show greatest reflectance percentage in coastal waters around the 675 nm range. In open water, these species showed a reflectance peak closer to 550 nm (Kutser et al., 2006). Knowledge of the dominant taxa present throughout the Albemarle-Pamlico Estuary and their reflectance characteristics in optically complex coastal waters will be vital to determining which sensors and algorithms are most useful to detect HABs in the area.

VI. Acknowledgments

- Dr. Kenton Ross - National Program Science Advisor
- Jeffrey Ely - Geoinformatics Scientist
- Nathan Owen - Center Lead

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

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Appendix VII: Ranked Phase I Research Proposals

Research Recommendations from Phase I of the Albemarle Sound Nutrient Criteria Development Effort

Subject Area	Description	Average rank (of 18)	% of respondents say proposal is "necessary."
Clarity	Bio-optical model: During Phase 2, develop and calibrate a biooptical model similar to that employed by Biber and others (2008), for exploring whether alternative CHLa criteria would be needed to protect SAV in the Sound. This activity should explore whether water clarity near the Sound's SAV beds would be sensitive to CHLa, versus largely controlled by other sources of turbidity, and the degree to which the other sources of turbidity are natural vs. controllable. SAV-based chlorophyll-a (or water clarity) criteria should have a spatial component based on historical SAV distribution (see related research recommendation below), and should considered natural interannual variability. It would be cautioned against adopting chlorophyll/clarity criteria that require the entire Sound to have higher clarity than reflected in the historical SAV depth/distribution.	5.25	75%
Clarity	Establish historical spatial coverage of sea grasses in the Albemarle Sound, including areas in which the non-light factors and rising sea level provide suitable habitat.	5.5	100%
Clarity	Evaluate and select an appropriate light partitioning model capable of distinguishing between CDOM, chlorophyll a, and TSS influences on clarity. The degree to which these parameters contribute to a clarity impairment would influence a recovery strategy. On appropriate spatial scales, determine secondary benchmark values for CDOM, chlorophyll a, and TSS. If the clarity standard is not met, exceedances of these secondary benchmarks would be used to diagnose and potentially regulate the specific source(s) of the clarity impairment. Benchmark values would also need to be evaluated in light of (potential) chlorophyll a and TSS stand-alone criteria protective of other uses.	5.5	75%

Subject Area	Description	Average rank (of 18)	% of respondents say proposal is "necessary."
Clarity	Historical SAV distribution: Revisit available information on the historical depth and distribution of SAV in Albemarle Sound. Determine if aerial photography allows better determination on the SAV depth/distribution in previous decades. Also identify areas where SAV is unlikely to grow due to natural conditions (waves, substrate, etc.). Use this information to help set reasonable long-term average goals for the spatial extent of SAV and water clarity in Albemarle Sound.	6.75	100%
Nitrogen, Phosphorus	Before implementing long-term nutrient management strategies/steps, we need to know which nutrients are controlling (limiting) algal growth, especially during periods favorable for algal bloom formation. Approach: Nutrient limitation bioassays conducted on waters collected at the headwaters and from Albemarle Sound proper. These should probably be conducted at the beginning and mid-bloom periods (spring-summer) and they should be the in situ type (incubated under natural light and temperature conditions). Methodologies are available (Paerl et al., 1999, 2008; Calandrino and Paerl 2011).	8	75%
Nitrogen, Phosphorus, Clarity	Algal bioassays: Perform algal bioassays to determine nutrient (N, P) and light limitations on algae from Albemarle Sound and adjacent river segments.	8.5	75%
Dissolved Oxygen	Engage with fisheries biologists and fisheries management experts to refine DO recommendations. A species-by-species evaluation of the spatial and temporal habitat utilization within Albemarle Sound (or statewide estuaries) should be considered, particularly for fish species that have already been identified as being particularly sensitive to low DO. The results of historic DMF fish surveys could be utilized for this purpose.	8.5	50%
Phytoplankton and Cyanotoxins	CHLa and algal toxins: Collect additional algal toxin data as needed to develop an empirical relationship between CHLa and algal toxin concentrations. Include data from adjacent river segments in this analysis.	8.75	75%

Subject Area	Description	Average rank (of 18)	% of respondents say proposal is "necessary."
Clarity	Drawing upon a previous USGS survey, evaluate data availability and spatial and temporal characteristics of Secchi depth and PAR meter monitoring from various professional sources, including DWR, DMF, USGS, and others. This information can help estimate monitoring intensity, which can be used to hone duration, frequency, and spatial extent recommendations for this parameter.	9	50%
Phytoplankton and Cyanotoxins	Establishing linkage of nutrient inputs (loading) to algal growth/bloom potentials in Albemarle Sound. Approach: Establishing space-time relationships between N and P inputs (dissolved and particulate inorganic and organic forms) and phytoplankton biomass and community composition at established NCDENR Ambient monitoring locations.)	10	25%
Nitrogen, Phosphorus, Chlorophyll	A repeat study of conducted by USGS in 2012 using the USGS laboratory for total phosphorus, total nitrogen, and chlorophyll a. Same sites would be included in the study with co-temporal collection and analysis of same parameters by NC DEQ.	10.5	25%
Dissolved Oxygen	Impacts of the abovementioned variables [climate, episodic events, nutrient inputs, limiting nutrients] on optical habitat conditions for SAVs and DO conditions for benthic flora and fauna. Approach: Observational data on above parameters in conjunction with aerial SAV coverage and DO conditions (at established NCDENR Ambient monitoring locations).	10.5	25%
Phytoplankton and Cyanotoxins	Natural range of phytoplankton assemblage present in the Albemarle Sound across years and in different regions. Year-to-year variation in salinity (both higher and lower) should be factored into the characterization. If species that may form algal toxins are present, follow-up testing for presence of toxins that may affect recreational uses or aquatic life should be done.	10.5	25%
Clarity	Use historic secchi and pH data from all sources to determine if water clarity has changed through time and what parts of the Albemarle may or may have impaired levels of water clarity. Use this information to determine which areas of the Albemarle may or may not be impaired. If water clarity impairments are determined from the secchi and pH data, the sources of those impairments should be investigated further.	10.5	75%

Subject Area	Description	Average rank (of 18)	% of respondents say proposal is "necessary."
Dissolved Oxygen	During Phase 2, consider whether NC's existing DO criterion should be lowered to 3.2 mg/L outside spawning/nursery periods, and the 5 mg/L criterion used as a 30-day average outside spawning/nursery periods. This research can be primarily literature-based.	11	25%
Chlorophyll	The current DWR data base should be analyzed by an independent reviewer(s) from the university system or federal agency who is knowledgeable about statistics and aquatic ecology. They must: (1) determine if a significant correlation exists between chlorophyll a and P or N at annual or summertime time steps concentrations by station, by all stations in the Albemarle Sound drainage, by open-water sound stations, river stations and (2) if a meaningful predictive regression model appeared possible with the current DEQ data set, data collection, and lab analysis procedures. If not, recommendations should be made to revise appropriate data collection and analysis procedures. This analysis need not be expensive-a report prepared for USGS in 2014 by Duke University students was very informative and well done report (http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/8486/LocklierMcGeeZhangMPFinal.pdf?sequence=1 Even though this report found relationships between P and chlorophyll a, much as did the Tetratech report, developing a regression model to show a predictive relationship, such as that suggested here, requires a more detailed analysis.	11.25	0%
TSS	Seek internal and external financial or logistical support to resume TSS sampling at appropriate stations in Albemarle Sound. Corroborate historical measurements with new samples to evaluate potential trends. TSS samples may also be necessary to inform proposed clarity criteria.	15.25	25%
TSS	Conduct further literature research regarding the impacts of TSS on estuarine aquatic life uses. Should the values above be determined to have no significant effects on aquatic life uses, the reference approach utilized may be protective of Albemarle Sound's designated uses.	15.75	25%