APNEP Nutrients Workgroup Meeting
Edenton, North Carolina
May 25, 2016

DRAFT Meeting Notes (*revised 7/18/16*)

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

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 measureable 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 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, observed a decline in Batchelor 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 Batchelor 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.*

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 chorophyll 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 microsystin 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*

Relative Probability of Acute Health Effects	*Cyanobacteria (cells/mL)*	*Microcystin-LR (µg/L)*	*Chlorophyll-a (µg/L)*
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 the 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 they 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.