Clean Waters and SAV: Making the Connection

A technical workshop to develop water quality strategies to protect and restore submerged aquatic vegetation

March 4, 2020 | Raleigh, North Carolina

Albemarle-Pamlico National Estuary Partnership

NORTH CAROLINA MARINE FISHERIES

THE PEW CHARITABLE TRUSTS

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EXECUTIVE SUMMARY

On March 4, 2020, seventy professionals from science, management, and conservation communities met at the NC Museum of Natural Sciences in Raleigh for the *Clean Waters and SAV: Making the Connection* technical workshop. The purpose of the workshop was to receive input for the 2021 NC Coastal Habitat Protection Plan (CHPP) regarding protection and restoration of submerged aquatic vegetation (SAV) through water quality improvements. The workshop included information on the scientific links between SAV health and water quality, processes used in other states to successfully restore SAV, and discussions on data needs and potential mechanisms to preserve and improve water quality for the protection and restoration of SAV. Attendees represented federal, state, and local governments, academic institutions, nonprofit organizations, and groups that operate to integrate those management, scientific, and public spheres, including:

> Albemarle-Pamlico National Estuary Partnership | Audubon NC | Chowan University | City of Jacksonville | CoastWise Partners | Duke University | East Carolina University | MD Department of Natural Resources | National Estuarine Research Reserve and NC Coastal Reserve | National Oceanic and Atmospheric Administration | NC Coastal Federation | NC Department of Transportation | NC Division of Coastal Management | NC Division of Energy, Mineral, and Land Resources | NC Division of Marine Fisheries | NC Division of Mitigation Services | NC Division of Soil and Water Conservation | NC Division of Water Resources | NC Sea Grant | NC State University | NC Wildlife Federation | NC Wildlife Resources Commission | The Pew Charitable Trusts | US Environmental Protection Agency | U.S. Fish and Wildlife Service | U.S. Natural Resource Conservation Service | University of North Carolina at Chapel Hill | University of North Carolina at Wilmington | VA Department of Game and Inland Fisheries

The morning portion of the workshop focused on information sharing. Participants first received an overview of the CHPP and its connection to the purpose of the workshop, including an overall workshop goal and associated expected outcomes. Next, participants learned about regional examples of collaborative water quality and SAV successes. Experts from Chesapeake Bay and Tampa Bay discussed how science was used to develop SAV restoration goals, the importance of public engagement to implement management actions, and the need for long-term monitoring to assess ecosystem health and progress. Information on the status of North Carolina estuarine water quality was the focus of the morning's next session, including both existing and developing state water quality strategies and the past and present water quality challenges those strategies address. Participants also learned about various water quality monitoring programs in the state and how an assessment of those data was informative about the conditions affecting SAV growth and survival in North Carolina. Next, a presentation on North Carolina's SAV system included information on ecosystem services provided, important distinctions between low- and high-salinity SAV communities, and recent information on status and trends. The morning session concluded with an overview of current North Carolina SAV conservation and management strategies implemented by the Albemarle-Pamlico National Estuary Partnership and the NC Department of Environmental Quality and its associated commissions.

The afternoon portion of the workshop focused on identifying potential near-term SAV conservation and management strategies in North Carolina and what additional information would be needed to develop long-term strategies. Through facilitated group discussions, ideas for both low- and high-salinity SAV were listed and then prioritized by the workshop participants. This workshop participant input will inform development of the 2021 CHPP, which includes SAV conservation as a priority habitat issue. The workshop ended with a reminder of the importance of collaboration in solving North Carolina's water quality and SAV challenges, as well as a call to action for participants to stay engaged in the issue.

All presentation slides and other supporting materials are available at www.apnep.org.

WELCOME

Dr. Tim Ellis, Quantitative Ecologist with the Albemarle-Pamlico National Estuary Partnership (APNEP), moderated the morning presentation session. He welcomed workshop participants and acknowledged that they represented a high diversity of expertise, as well as a collective wealth of experience in submerged aquatic vegetation (SAV) and water quality protection and restoration. He then introduced Sheila Holman, Assistant Secretary for Environment with the NC Department of Environmental Quality (DEQ), to provide opening remarks. She recognized the NC Coastal Habitat Protection Plan (CHPP) as the state's guiding document for management of coastal habitats, with coordinated implementation by APNEP and several DEQ divisions. These include the Division of Marine Fisheries (DMF), Division of Water Resources (DWR), Division of Coastal Management (DCM), and Division of Energy, Mineral, and Land Resources (DEMLR), along with strong collaboration from other management, scientific, and conservation organizations. North Carolina has the second largest estuary in the continental United States, and the biogeographic transition from a Mid- to South-Atlantic region within the estuary yields diverse and productive fisheries that have long been important to the state's economy. Submerged aquatic vegetation provides critical habitat for many of those fishery species, as well as water quality improvements and support of coastal resiliency. As such, it is one of North Carolina's most valuable, and fragile, aquatic resources. Information gathered from this workshop is critical for improved SAV protection and restoration recommendations for the 2021 CHPP.

> ***"Clean water is foundational to SAV health. In turn, SAV improves water quality - they are integrally linked."***
> - DEQ Assistant Secretary Sheila Holman

PURPOSE

Anne Deaton, Habitat Program Manager with the Habitat Enhancement Section of DMF, provided an overview of the history and process for implementing the CHPP. Authorized under the NC Fisheries Reform Act of 1997 (G.S. 143B-279.8), the CHPP summarizes the value of coastal habitats to fish and the ecosystem, habitat status, threats, and challenges, and includes recommended actions for habitat protection and restoration. The first iteration of the plan was in 2005 and since then it has been reviewed every five years, with a review currently underway for 2021. One of the 2021 CHPP priority habitat issues is SAV protection and restoration, with a focus on water quality improvements.

North Carolina has more than 130,000 acres of SAV, most of which is located within the Albemarle-Pamlico estuarine system, including the largest high-salinity SAV resource on the Atlantic Seaboard. There is strong potential to gain thousands more acres of SAV through restoration, particularly in low-salinity areas. One of the most serious and manageable threats to SAV in North Carolina is water quality impairment. Suspended sediments and nutrients reduce water clarity, which in turn limits light penetration necessary for SAV growth and survival. In North Carolina, coastal development is rapidly expanding alongside an increase in the intensity and severity of storm events, rising sea levels, and barrier island instability. As a result, runoff and associated increases in turbidity

and nutrient loading are major threats to the state's SAV habitat. There is evidence to suggest that much of North Carolina's low-salinity SAV habitat has diminished over the last several decades. The purpose of this workshop was to get input from a broad group of experts to make a strong case for management needs in a developing CHPP priority habitat issue paper on SAV.

Workshop Goal

Participants provided input for the 2021 CHPP to develop collaborative management strategies to preserve and improve water quality suitable for SAV growth in North Carolina coastal waters.

Expected Outcomes

1) Communicate the scientific links between SAV health and water quality and how other states successfully implemented water quality improvements that protected and restored SAV.

2) Identify gaps and priorities for monitoring SAV and water quality in North Carolina that are sufficiently robust to determine trends and needed water quality management changes.

3) Identify management strategies that can be implemented in the near-term for SAV protection and restoration while information gaps are being filled to support long-term management strategies.

REGIONAL EXAMPLES OF COLLABORATIVE WATER QUALITY AND SAV SUCCESSES

Chesapeake Bay: Science to management through collaboration

Rich Batiuk, former Associate Director for Science, Analysis, and Implementation at the U.S. Environmental Protection Agency's Chesapeake Bay Program Office and co-founder of CoastWise Partners, presented on the lessons learned from efforts to restore SAV to Chesapeake Bay. He noted that their process began with defining *clean water* in a simple way that everyone agreed with: "fish need oxygen, underwater grasses need light, and oysters need good food." Rooted in science and understood by the public, the resultant water quality criteria were promulgated into Maryland, Virginia, Delaware, and the District of Columbia's water quality standards. Mapping of Chesapeake Bay and tidal river finfish, shellfish, and SAV habitats helped determine where and when those criteria should be applied.

An SAV restoration goal of 185,000 acres was adopted by the Chesapeake Bay Program partners and incorporated into the previously mentioned water quality standards based on mapping the extent of SAV using historical photography from the 1950s and 1960s. Water clarity criteria were also adopted based on the seasonal light requirements at maximum depths of SAV growth. Taken together, the shallow waters of the Chesapeake Bay system are considered protected when the SAV acreage restoration goal is reached, there is sufficient water clarity to support the SAV acreage restoration goal, or a combination of both. Chesapeake Bay's SAV habitat and water quality restoration efforts are yielding improved outcomes with more than 100,000 acres of SAV mapped in 2017, up from a baseline of 38,000 acres in 1984. Although there was a tremendous amount of science guiding SAV and water quality restoration in Chesapeake Bay, it was strong collaboration among scientists, managers, and the public that resulted in goals and actions supported by all.

Tampa Bay: Path to full SAV restoration through collaboration

Holly Greening, former Executive Director and Senior Scientist for the Tampa Bay Estuary program and co-founder of CoastWise Partners, presented the key elements of success for the restoration of Tampa Bay. By the 1970s, Tampa Bay was polluted, with algal mats coverning much of the system. With their health and livelihoods threatened, citizens demanded action. This resulted in regulations on wastewater treatment and stormwater discharge. Most importantly, regional collaboration among resource stakeholders has been critical to the success of Tampa Bay's recovery, which began with setting a goal to restore SAV in the system to levels documented in the 1950s.

Much like the Chesapeake Bay example, scientific research on the light requirements for SAV growth and reproduction was informative. In Tampa Bay, this led to a management focus on chlorophyll *a* and nitrogen loading targets. A public-private partnership of local governments, regulators, industry, and others was formed to help meet restoration goals, which translated into voluntary development of a total maximum daily load (TMDL) for nitrogen and nutrient management criteria. Regulatory water quality goals were achieved through 500 projects and actions, leading to decreased nitrogen loads, specifically from point sources, and lower chlorophyll *a* concentrations throughout Tampa Bay. By 2016, Tampa Bay met its SAV recovery goal of 38,000 acres and has also seen improvements in its economy due to cleaner water. In addition to science-based goals and targets and strong regional collaboration, long-term monitoring and routine assessment continues to inform managers and stakeholders about the health of Tampa Bay and supports adaptive management of the ecosystem.

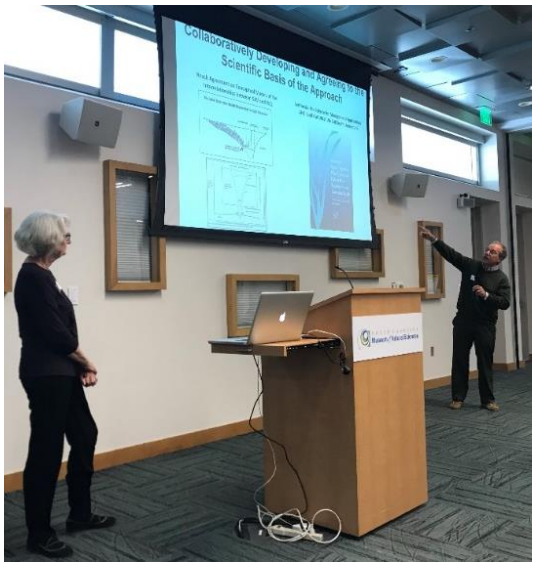
Chesapeake Bay: Management to dissemination, engagement, and continued research

Brooke Landry, Natural Resource Biologist with the Maryland Department of Natural Resources and Chair of the Chesapeake Bay Program's SAV Workgroup, presented on recent SAV initiatives in Chesapeake Bay that are part of their 2015-2025 SAV management strategy. This strategy centers on five components: supporting efforts to improve water quality; protecting existing SAV; restoring SAV; enhancing SAV research and monitoring; and enhancing citizen involvement, education, and outreach.

One initiative was to conduct an SAV regulatory review to determine if SAV is being adequately protected by current statutes, regulations, and policies, and to recommend improvements if not. Small-scale restoration through direct seeding efforts has had some success but is dependent on water quality improvements. Another initiative was a series of technical syntheses on Chesapeake Bay SAV habitat requirements and restoration targets that would identify and fill data gaps, as well as link SAV trends to management actions. Recently, the Chesapeake Bay Program's Science and Technical Advisory Committee conducted workshops to explore using satellite imagery to supplement or replace aerial imagery as a means of increasing the long-term stability of SAV monitoring in Chesapeake Bay. This methodology could be useful for North Carolina to consider. Submerged aquatic vegetation research and monitoring has also been enhanced through the establishment of twenty sentinel sites throughout Chesapeake Bay, as well as voluntary monitoring by citizens. Social marketing campaigns targeting boaters and waterfront homeowners was the last initiative presented. This aimed at changing negative perceptions about SAV and behaviors that threaten SAV such as boat propeller scarring and intentional removal around docks.

Five opportunities for collaboration applicable to North Carolina

Rich Batiuk and Holly Greening concluded this session of the workshop by summarizing five critical roles that collaboration played in restoring and protecting Chesapeake Bay and Tampa Bay that could be applied in North Carolina:



1) Collaboratively developing and agreeing to the scientific basis of the restoration approach, including conceptual models of the interrelationships between SAV and water quality, as well as information gaps.
2) Collaborative approaches to monitoring such that management decisions are dependent on data collection and analysis at a watershed scale and annual reporting is meaningful to the public.
3) Engaging citizens in data collection and conducting outreach to help the public understand and appreciate the issues and to modify public behaviors to promote SAV and water quality restoration.
4) Collaboratively developing and adopting SAV restoration goals and water quality standards, involving stakeholders in the implementation of management actions, and building in a system of accountability such that the public is informed about both restoration successes and reasons for any failures.
5) Implementing on-the-ground actions while synthesizing available science and filling data gaps, including efforts to improve watershed condition that generally have 'no regrets' such as improved stormwater and wastewater management, habitat restoration, and education.

STATUS OF NORTH CAROLINA ESTUARINE WATER QUALITY

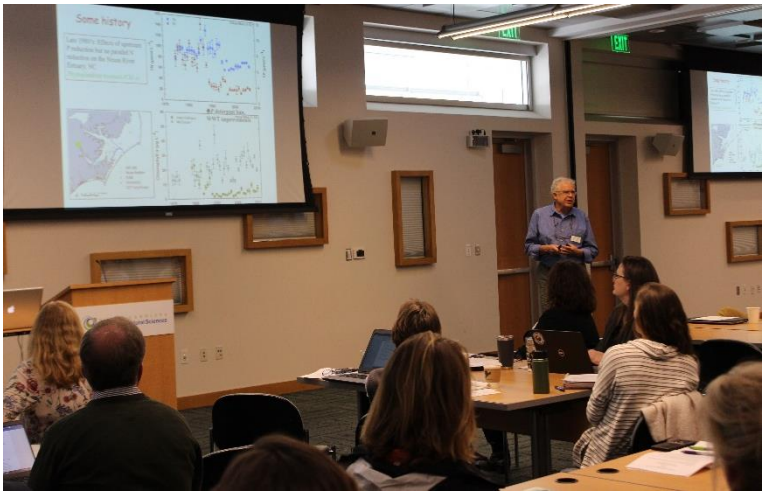
Existing and developing water quality strategies

Jim Hawhee, Environmental Program Consultant with the Nonpoint Source Planning Branch of DWR, presented on North Carolina's nutrient management strategies. The state's strategies have historically been driven by concerns over algal blooms and fish kills, not SAV decline. Early nutrient reduction efforts included the implementation of a statewide chlorophyll *a* standard in 1978, a nutrient sensitive waters (NSW) classification in 1979, a 1982 Chowan River nutrient strategy that was considered a resounding success until 2015, and a phosphorus detergent ban in 1988.

Currently, North Carolina's approach to nutrient management utilizes both federal and state authorities. The NSW water quality classifications allow for identification and prioritization of waterbodies most in need of restoration. Although a chlorophyll *a* criteria exists, there are no nitrogen and phosphorous criteria yet. Some nutrient TMDLs exist in strategically selected North Carolina watersheds. Regulators in North Carolina use a nutrient management strategy to reduce nutrients from multiple sectors and minimize new sources of nutrient loading. Management actions are focused on wastewater, agriculture, riparian buffer protection, new and existing development stormwater, and nutrient trading. The state is currently undergoing a process to develop numeric nutrient criteria for estuarine waters, beginning with Albemarle Sound and Chowan River. These criteria will be regulatory goals for the waterbodies and are aimed at protecting designated uses such as SAV habitat.

Past and present estuarine water quality challenges

Dr. Hans Paerl, Kenan Professor of Marine and Environmental Sciences at UNC's Institute of Marine Sciences (IMS), provided an historical perspective on water quality in North Carolina estuaries and discussed management challenges associated with both human- and climate-driven water quality impacts. He first noted that the key links between water quality and SAV are nutrients and light attenuation. Much of the water quality data available to study these factors come from the Neuse River-Pamlico Sound continuum where there has been considerable monitoring by both the state and Dr. Paerl's lab at IMS. Unlike Tampa Bay, which is a very point-source controlled system, only approximately 20% of North Carolina's nutrient inputs are from point sources. This presents management challenges when trying to curb nutrient loading.



"Understanding nutrients and light attenuation is really important to understanding how to conserve SAV."
- Dr. Hans Paerl

In the Neuse River estuary, upstream phosphorus reductions during the 1980's had no parallel nitrogen reduction downstream, which resulted in increasing chlorophyll *a* concentrations in the lower estuary that exacerbated eutrophication. The scientific recommendation was a 30% nitrogen input reduction for the system and a TMDL was

initiated in 1999. Because nutrients lead to excessive algal growth, chlorophyll *a* was the chosen metric for the TMDL with a 10/40 criterion. This means compliance was achieved when less than 10% of water samples collected in a year contained over 40 µg/L for chlorophyll *a*. Monitoring over the last two decades has shown that while inorganic nitrogen (nitrate) was reduced, organic nitrogen has increased. This has resulted in no net decrease of total nitrogen in the Neuse River estuary. The role of increasing organic nitrogen in eutrophication is currently being studied. Additionally, chlorophyll *a* downstream continues to be highly variable and may be increasing.

Research has also shown that the interaction of climate change and hydrologic perturbations with nutrient and sediment loads is influencing water quality. In particular, high rainfall from tropical cyclones results in significantly more loading of total nitrogen and phosphorus, which increases algal production and stratification, and ultimately extends zones of hypoxia. Furthermore, tropical cyclones also significantly increase organic carbon and transport and resuspend sediments, which together with increased chlorophyll *a* are the primary factors of light attenuation in the estuary. A major concern is that both the intensity and severity of tropical cyclones is increasing, and further study is needed to better understand how these large storm events affect the optical and habitat conditions needed to support SAV in North Carolina. For example, it took many years for SAV in Chesapeake Bay to recover from Tropical Storm Agnes in 1972.

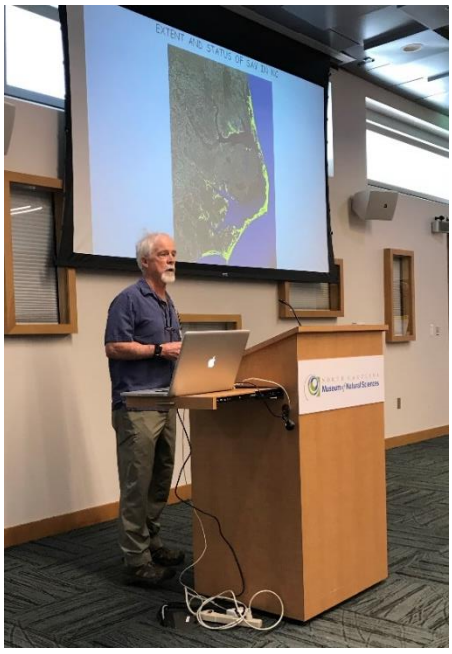
Water quality monitoring and assessment

Dr. Nathan Hall, Research Assistant Professor at UNC's IMS, provided an overview of available coastal water quality monitoring data and some initial findings from his assessment of status and trends for optical water quality properties in the Albemarle-Pamlico estuarine system. He noted that North Carolina has good water quality data for estuarine waters, particularly in the tributaries. However, monitoring in the open waters of Albemarle and Pamlico Sounds and along the barrier islands is very limited. While much of the available data come from the DWR Ambient Monitoring System, other state agencies like DMF also collect water quality parameters during their routine surveys. Another large data set comes from the Neuse River Estuary Modeling and Monitoring Project (ModMon) and a state ferry-based monitoring system for Pamlico Sound (FerryMon), both led through IMS.

Data on Secchi disk depth indicate significant decreases in water clarity over time for the Neuse River estuary but moderate to no change at other sampling locations. Data on attenuation of photosynthetically available radiation (PAR) for the Neuse River estuary show decreasing trends in water clarity consistent with Secchi disk depth trends. Colored dissolved organic matter (CDOM), a light attenuating factor, is increasing in the lower Neuse River estuary and appears to be closely linked to the salinity regime. As such, declines in water quality for this region could be harder to manage because they aren't related to nutrients alone. Chlorophyll *a* concentrations have also trended moderately up or down over the last twenty years across the Albemarle-Pamlico estuarine system, except in Albemarle Sound were there has been a rapid increase over time.

This trend in Albemarle Sound is associated with increasing reports of cyanobacteria blooms over the same time period that are corroborated by remote sensing information on cyanobacteria biomass throughout the Albemarle Sound region. One relevant case study from this region is Lake Mattumuskeet, where once-abundant SAV disappeared as cyanobacteria became prevalant in the system. Researchers are currently investigating nitrogen fixation by cyanbobacteria as a possible explanation for increasing chlorophyll *a* in Albemarle Sound. Albemarle Sound is also challenged by increasing turbidity. As the state continues to move forward with the process of developing numeric nutrient criteria for the Albemarle Sound region, SAV will be a critical biological endpoint to link water quality standards with the management of sources and stressors.

STATUS OF THE NORTH CAROLINA SAV SYSTEM



Dr. Jud Kenworthy, retired Research Biologist with the NOAA Beaufort Lab and leader of the APNEP SAV Team, presented on the extent and status of SAV in North Carolina. He began by reiterating the importance of collaboration and noted that although North Carolina is behind Chesapeake Bay and Tampa Bay in terms of implementing strategies for water quality improvements to support SAV habitat, it is important that this workshop is starting the process. Submerged aquatic vegetation are a foundation species that provide the structural habitat to support enormous biodiversity. They also control their environment by assimilating carbon, removing nutrients, and trapping sediment. However, as water quality conditions degrade, SAV are no longer in control, and the ecosystem ends up in an altered state. Restoring SAV is challenging, particularly at an ecosystem level. Not only is it expensive, but a recent metanalysis suggests it is highly uncertain, with only a 36% probability that SAV restoration will be successful. Taking steps now to protect North Carolina's SAV is key to limiting the difficulties associated with any necessary restoration in the future.

North Carolina has a complex and unique SAV community that can be largely separated into two groups by both salinity and temperature. The high-salinity group consists of a tropical species at its northern limit (*Halodule wrightii* or shoal grass), a temperate species at its southern limit (*Zostera marina* or eelgrass), and a cosmopolitan species that grows everywhere (*Ruppia maritima* or widgeon grass). The low-salinity group has a higher diversity of species that thrive in a range of oligohaline to mesohaline conditions.

A recent analysis of changes in the extent of high-salinity SAV in the Albemarle-Pamlico estuarine system between 2006 and 2013 indicates a loss of acreage ranging from approximately 3-10% depending on the region of the estuary. Regions in central and northern Pamlico Sound are less developed, receive less direct riverine input, and had lower estimated lost acreage of SAV. However, regions to the south, primarily consisting of Bogue and Back Sounds, are highly utilized with urban landscapes and tourism and had an annual loss rate of approximately 1.5% per year. This equates to a projected loss of approximately 20% of the SAV resource in this region by 2025. No regions gained SAV over this time, which is concerning given that SAV in North Carolina can grow at depths of generally two meters or less and there is ample available habitat in Pamlico Sound at these depths not currently covered by SAV.

> ***"The question is not what is the SAV crisis in North Carolina but rather how do we avoid the crisis. And the second question is why are the lights getting dimmer for some parts of our resource."***
> - Dr. Jud Kenworthy

The historical record for low-salinity SAV is long but quite fragmented. Some recurring themes for low-salinity SAV include large fluctuations in abundance, changes in species composition, proliferation of non-native species, persistent SAV, high turbidity, extreme weather events and large amounts of precipitation, and fluctuations in salinity. Recently, hydroacoustic surveys have been conducted to monitor low-salinity SAV at sentinel sites in Albemarle Sound and the Pamlico and Neuse Rivers. Significant and rapid declines were documented in many areas, including northwest Albemarle Sound, which experiences large and persistent algal blooms. From 2014-2017, the shorelines of these three subestuaries were also surveyed to estimate linear extent, and SAV was detected in less than half of areas where based on historical records it had previously existed. These data represent an urgent opportunity, particularly with the ongoing effort to develop numeric nutrient criteria, to start making progress on water quality improvements to benefit SAV before it is too late.

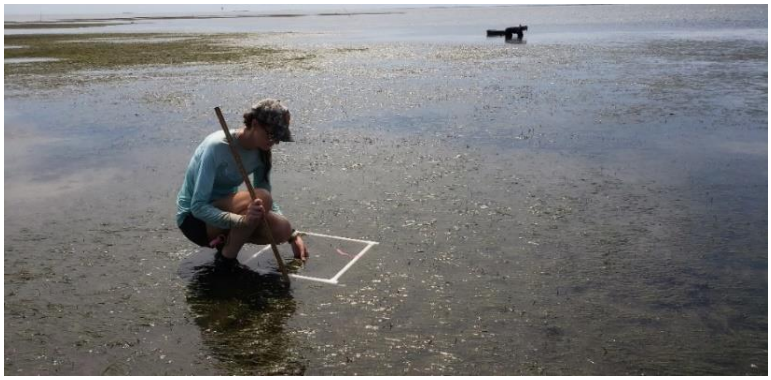
CURRENT NORTH CAROLINA SAV CONSERVATION AND MANAGEMENT STRATEGIES

Tim Ellis and Anne Deaton discussed existing and developing conservation and management strategies in North Carolina aimed at better understanding and protecting the state's SAV resource. During the late 1980's, the Albemarle-Pamlico estuarine system was among the first to be designated by Congress as an estuary of national significance. Nearly 100 studies were conducted from 1987-1994 to characterize the system and identify environmental challenges. Some of that work centered on investigations of water quality and SAV, and those reports are available through APNEP's website. In 2006, APNEP coordinated the adoption of an MOU between nine state agencies, nine academic institutions, four federal agencies, and two non-governmental organizations to conserve SAV through cooperative research, monitoring, restoration, and educational opportunities. Major accomplishments through this "SAV Partnership" included the state's first coastwide SAV mapping effort from 2006-2008 and the placement of educational signage at boat ramps. Other collaborative efforts included a 2012 study to develop SAV monitoring protocols, additional coastwide mapping of high-salinity SAV from 2012-2015, and the establishment of a low-salinity SAV sentinel site network beginning in 2014.

APNEP fully took the lead of the SAV Partnership in 2016 and established a team of partners to focus on SAV monitoring and assessment, as well as the development of policy and outreach actions in support of the APNEP 2012-2022 Comprehensive Conservation and Management Plan (CCMP) and the CHPP. Over the last four years, partners on this APNEP SAV Team have supported graduate research fellowships, monitored low-salinity sentinel sites, developed protocols for establishing a high-salinity sentinel site network, supported an ongoing economic study, drafted a strategic communications plan, and begun a third cycle of coastwide mapping of high-salinity SAV. Additionally, APNEP is developing a strategy for integrated SAV and water quality monitoring to determine ecosystem health and gauge management success. Elements of this strategy will address scientific needs, management needs, and gaps in existing monitoring and associated logistical hurdles, with a focus on cooperation and coordination as key elements of collaboration.

Several state-led management actions have also occurred over the last several decades. In 1991, the NC Marine Fisheries Commission (MFC) imposed rules restricting bottom-disturbing fishing practices like trawling, oyster dredging, and clam kicking in SAV beds behind the Outer Banks. In 1996, the NC Coastal Resources Commission (CRC) and the NC Environmental Management Commission (EMC) prohibited new channel dredging in SAV. The MFC issued an SAV Policy in 2004, which was quickly followed by the first CHPP-approved recommendations for SAV in 2005 and new coastal stormwater rules passed by the EMC in 2007. Finally, in 2012, the MFC revised its definition of SAV for rulemaking to take into account inter-annual variability in SAV distribution, the CRC modified dock siting protocols, and the NC Department of Environment and Natural Resources (now DEQ) issued a guidance document on SAV, with focus on dock siting.

Outcomes from this workshop will help inform North Carolina's next conservation and management initiatives for SAV through the CHPP, CCMP, and other plans.



GROUP ACTIVITY

Breakout session

Leda Cunningham, Manager with the Conserving Marine Life in the U.S. project of The Pew Charitable Trusts, moderated the afternoon group activity. Participants were divided into four groups and provided a list of questions to discuss from both a low-salinity and high-salinity SAV perspective. Each group identified 5-7 key responses for each of the following three questions:

1) What additional information is needed to define the status and trends in North Carolina SAV populations?
2) What additional information is needed to define water quality and loadings associated with SAV in North Carolina and the links between SAV and water quality?
3) What types of management strategies could be taken in the near-term for SAV protection and restoration while waiting on other information to support long-term strategies?

Whole group prioritizations

At the end of the breakout session, the input from all groups was compiled and organized into up to ten key responses per question. Workshop participants then prioritized the responses by placing their 'votes' using stick-on dots. After the votes were tallied, Holly Greening and Rich Batiuk summarized the results. This workshop participant input will help guide the development of recommended actions for the conservation and management of SAV habitat in North Carolina. Presented next is the prioritized (top five) input along with additional responses to the three questions.

LOW-SALINITY SAV

Q1: Information to define SAV status and trends

- *Obtain more data on SAV species composition and distribution*
- *Monitor and assess seasonal and annual variability in SAV distribution and abundance*
- *Enhance sentinel site monitoring*
- *Improve understanding of hydrological impacts on SAV distribution and abundance*
- *Implement more comprehensive SAV mapping to determine peak biomass and impacts of major storms, including using remote sensing methods*

Additional input from participants recognized information gaps in the functions of SAV as fish habitat and the impacts of non-native species on native SAV. The importance of citizen participation in SAV monitoring was noted as well.

Q2: Information to define water quality and links to SAV

- *Obtain additional flow and nutrient loading information to evaluate their impacts on SAV*
- *Track the relative inputs of nutrients from sources such as septic, forestry, and atmospheric deposition*
- *Evaluate the impacts of agricultural practices and changes in use, including chemical application, on SAV*
- *Develop and balance a nitrogen budget that includes nitrification by cyanobacteria*
- *Expand the spatial and temporal scales of the DWR Ambient Monitoring System (ABS) to provide water quality data relative to existing and potential SAV habitat*

Additional input from participants identified needs for bio-optical modeling, including better associated bathymetry data, enhanced groundwater and stream monitoring and assessment, and evaluations of BMP effectiveness to regulate nutrient loadings.

Q3: Near-term management strategies

- *Increase the use of watershed planning to develop and implement water quality improvement strategies at a local level*
- *Utilize living shorelines and other types of green infrastructure to control stormwater and improve water quality*
- *Acquire additional water quality data by using local government coalitions, citizen science, and networks of environmental advocates like Riverkeepers*
- *Provide outreach to citizens on the value of SAV*
- *Develop government policies and incentives for septic system maintenance and repair*

Additional input from participants included concerns about the impacts of confined animal feeding operations (CAFOs), a need for landscaper and homeowner education and certification on proper fertilizer use and septic system maintenance, implementation of a community-based social marketing campaign to influence behavior change, a need for more information on harmful algal blooms, a need to improve compliance with municipality stormwater permit requirements, and a recommendation to develop BMPs for SAV that could be integrated into emerging state initiatives on climate resilience.

HIGH-SALINITY SAV

Q1: Information to define SAV status and trends

- *Continue aerial surveys of SAV every five years and evaluate other remote sensing methods, including satellite imagery and drones, for more frequent areal extent monitoring*
- *Establish and routinely monitor sentinel sites*
- *Map potential SAV habitat with considerations for species suitability, recruitment conditions, and shoreline type, including a sensitivity analysis*
- *Update and improve the accuracy of bathymetry data*
- *Collect information on SAV species composition to evaluate temperature and other climate-change impacts like sea-level rise, as well as the distribution and impacts of non-native species*

Additional input from participants recognized information gaps on the impacts of extreme weather events on SAV and the need for monitoring indicators to assess SAV sublethal stress and disease.

Q2: Information to define water quality and links to SAV

- *Expand and enhance long-term ambient water quality monitoring in Pamlico Sound and other NC estuarine waters*
- *Integrate existing ambient water quality monitoring, including the DWR ABS, DMF Shellfish Sanitation Program, U.S. Geological Survey Flood Inundation Mapping Program, and others*
- *Collect more flow, ambient water quality, and stormwater runoff data to support nutrient and sediment loading estimates*
- *Collect data to support bio-optical modeling for SAV*
- *Develop hydrodynamic models for Pamlico Sound and other NC estuarine waters*

Additional input from participants recognized the importance of understanding the effects of herbicides and insecticides on water quality.

Q3: Near-term management strategies

- *Improve compliance and enforcement of existing rules that protect water quality and SAV, particularly regarding properly operating and maintained septic systems*
- *Conduct projects that demonstrate SAV propagation and restoration success*
- *Communicate the importance of SAV through information on socio-economic and ecological benefits*
- *Develop financial incentives to encourage the protection and restoration of SAV*
- *Encourage volunteers to collect additional information on water quality and SAV through citizen science initiatives, such as the Water Reporter app and the Chesapeake Bay SAV Watchers program, or to help monitor sentinel sites*

Additional input from participants included issues related to spatial planning, such as a need to better understand the impacts of various recreational and commercial uses of the estuary and surrounding watershed on SAV and BMPs to minimize negative effects from those activities, and a recommendation to develop innovative mechanisms for funding water quality improvement projects and programs.

NEXT STEPS AND TIMELINES FOR PROCEEDING WITH WORKSHOP OUTCOMES

After the group activity, Anne Deaton outlined the key steps that will follow this workshop related to the 2021 CHPP process. Most notably, information gathered from this workshop will be used to develop a CHPP priority habitat issue paper on SAV, with focus on water quality improvements. This paper will include background information describing the problem, a discussion on strategies, and draft recommended actions, including potential rule making recommendations. These actions will be specific, measurable, attainable, relevant, and time-bound (SMART). A final draft of this priority habitat issue paper is expected by July 2020, after which it will be reviewed by DEQ administrators and the CHPP Steering Committee. It will also be presented to stakeholders for input and to build support for proposed actions. The draft 2021 CHPP with finalized issue papers and recommended actions is expected by late Fall 2020 for DEQ commission-level input and public comment. The SAV conversation started at this workshop should also continue forward with focus on collaborative approaches to addressing research and monitoring gaps, implementing recommended actions that are feasible in the near term, and spreading the message on the importance of protecting and restoring North Carolina's SAV habitat and the waters that sustain it.

CLOSING REMARKS

Dr. Bill Crowell, Director of APNEP, thanked everyone for their participation and reiterated that bringing this diverse group of experts together to collaboratively discuss the connections between healthy SAV and clean water to improve coastal ecosystem management is a big step forward for North Carolina. There are many challenges to overcome, including improvements to monitoring and assessment capabilities and innovative approaches to management that target the needs of North Carolina's uniquely complex SAV community. The key to success lies in building and strengthening partnerships to develop and implement solutions to these challenges. Everyone has a role in that success and continued engagement on this issue is important.

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Workshop Steering Committee

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Cover: Blue crab in seagrass. *Photo courtesy of Jud Kenworthy*; Person measuring Secchi depth. *Photo courtesy of NC Division of Water Resources*; Seagrass in clear water. *Photo courtesy of APNEP* | Page 4: Sheila Holman providing welcoming address. Anne Deaton speaking. *Photos courtesy of APNEP* | Page 5: Albemarle Sound shoreline with turbid water. *Photo courtesy of APNEP* | Page 7: Brooke Landry speaking. Holly Greening and Rich Batiuk speaking. *Photos courtesy of APNEP* | Page 8: Jim Hawhee speaking. Hans Paerl speaking. *Photos courtesy of APNEP* | Page 9: Nathan Hall speaking. *Photo courtesy of APNEP* | Page 10: Jud Kenworthy speaking. *Photo courtesy of APNEP* | Page 11: Person sampling SAV. *Photo courtesy of APNEP* | Page 12: A breakout group in discussion. Anne Deaton and Trish Murphey moderating a breakout group. Workshop participants prioritizing their input. *Photos courtesy of APNEP* | Page 15: SAV in Currituck Sound. *Photo courtesy of APNEP*