Southeast Tidal Creeks Summit 2013

Breakout Group Summary

Acknowledgements

The organizers would like to thank the Summit presenters and the participants for making this event a success. We would also like to thank our home institutions and the NC State Biological and Agricultural Engineering Department, University of North Carolina (UNC)-Wilmington, the North Carolina Coastal Federation, and the Tidal Creeks Workgroup for their assistance with summit planning and implementation. Finally, we would like to thank the group breakout leaders and other note-takers for capturing the important discussion that occurred throughout the event.

The summit was made possible because of sponsorship from the North Carolina Sea Grant, South Carolina Sea Grant Consortium, Georgia Sea Grant, Governor's South Atlantic Alliance, NC Water Resources Research Institute, Greenman-Pederson, Inc., UNC-Wilmington, NC State University, Stantec Consulting Services, Tampa Bay Estuary Program, Moffat and Nichol, and SC Department of Natural Resources.

Southeast Tidal Creeks Summit Background

North Carolina, South Carolina and Georgia's Sea Grant programs partnered to organize the 2013 Southeast Tidal Creeks Summit held on December 16 and 17 in Wilmington, North Carolina. The Summit was a follow-up to the 2011 Southeast Tidal Creeks Summit held in Charleston and designed to provide a forum for exchange of information among scientists, resource managers, municipal and county government staff, environmental groups and concerned citizens on the status of tidal creeks in the southeast. The focus was on identifying research, management, restoration and outreach needs to better protect, manage and restore these valuable ecosystems.

The Summit's objectives were to:

- Identify the current state of knowledge regarding tidal creek research and management in the Southeast.
- Identify current issues and threats to tidal creek system ecology and function (management needs) and relevant future research efforts (e.g., classification, restoration, monitoring).
- Evaluate the current and potential management and restoration strategies to protect and enhance the ecology and function of tidal creeks (e.g., development setbacks, buffers, impervious cover limits, stormwater best management practices and restoration efforts).
- Identify recent trends in tidal creek science, management and status.

There were 156 pre-registered attendees representing Georgia, North Carolina and South Carolina, as well as a few from Maryland, Florida and Texas. Over 160 people were in attendance and primarily represented federal, state and local governments and academic institutions. A few private consultants and non-profit organizations were also represented. The Summit featured two general sessions, six concurrent sessions with 32 speakers, and optional field trips. The afternoon of the second day was dedicated to topical group discussions to help identify future directions for tidal creek efforts in the region. The breakout groups at the Summit discussed specific topics in an attempt to identify clear actions for future research, management, and outreach. The goal of this document is to relate the outcome of the group discussions which included eight small breakout groups. This summary report provides the topic description as presented to each breakout group; responses to questions regarding available data to address the topic and uncertain or missing/needed data; and their suggested activities for research, management and education/outreach.

The agenda, program, most of the oral and poster presentations in addition to the summary report are available at the following website: http://ncseagrant.ncsu.edu/news-events/events/tcs/.

Breakout Group Discussion Summaries

Preceeding the 2013 Summit, a Tidal Creeks Workgroup composed of researchers and coastal managers from NC, SC and GA was assembled to provide input on the Summit agenda and breakout format. Twenty-two members of this workgroup met once face-to-face during the fall of 2013 and provided guidance and facilitation assistance for eight breakout groups at the 2013 Summit. See Appendix A for a list of workgroup members. In addition, the summary report from 2011 was shared with the 2013 SE Tidal Creek Summit registrants prior to the 2013 Summit in an effort to help with these exercises.

Eight topics were identified for the summit attendees to discuss in breakout sessions. Attendees were allowed to self-select the group they wanted to participate in, choosing from the following topics: inventory and classification, hydrology, sediment, land use-stormwater, land use-effects, water quality, restoration and nekton and fisheries. Sign-up sheets with descriptions of the topic were made available at the beginning of the summit and until lunch on the second day.

Each discussion group attracted participants with various backgrounds (i.e. profession, training, geographical region, employers, etc.) and were tasked with identifying gaps in current knowledge for their topic and actions to advance the understanding and management of tidal creeks including coordinated approaches for research. Leaders were pre-assigned to each group to facilitate discussion. A set of questions was developed with input from the Tidal Creeks Workgroup to focus the discussion.

The following represents summaries from the discussions in each group. The sections were developed by the breakout group leaders and Summit planning committee members based on flipchart and individual notes taken during the breakouts. All of the summaries have the same headers but the interpretation and approach of each breakout group was unique. We have tried not to force consistency among the groups but instead present the information largely unaltered in this report.

Inventory and Classification of Tidal Creeks

Topic Description: State and local governments do not have adequate inventories and maps of tidal creeks and marshes within their jurisdictions. A reliable classification system and better understanding of the health of the systems would help their management efforts. There is currently no inventory of tidal creeks throughout the Southeast. In addition, there is no consistent classification scheme for tidal creek networks to provide the basis for understanding and integrating the ecological attributes of these systems, particularly in the context of their biogeography, hydrology, watershed characteristics, and short and long term ecological history. Differences are apparent longitudinally within a system (e.g., first order vs. second or third order) as well as spatially across systems (e.g., freshwater vs. marine, upland vs. salt marsh watersheds). The first order portions of upland creeks have a high degree of connectivity with terrestrial environments, a high variability in freshwater inflows, and lower volumes of water in comparison to the second/third order creeks, which maintain a larger volume of water during all tidal stages and a shorter, higher flushing rate. The spatial differences include land use of the surrounding watershed and location within the estuarine system. The creation of a classification scheme for tidal creeks in the region is needed, establishing a context for identifying the functions these systems support and services they provide. Additionally, the development of an inventory and classification system would provide a framework for regulatory decisions and management needs.

Group Participants: Mike Mallin (UNC-Wilmington), Erin Koch (SC Department of Natural Resources), Mike Wicker (US Fish and Wildlife Service), Eban Bean (East Carolina University), Heather Young (Coastal Carolina University), Jay Leverone (Sarasota Bay Estuary Program), Pace Wilber (NOAA-National Marine Fisheries Service), Mike Wessel (Janicki Environmental), and Saundra Upchurch (SC Department of Natural Resources).

Group Co-Leaders: Bob Van Dolah (SC Department of Natural Resources, retired) and April Turner (SC Sea Grant Consortium)

Why is this important?

The session began with a discussion about why tidal creeks are important. The group discussed the importance of tidal creeks as nursery habitats and why an inventory is critical for identifying significant habitats. The group agreed that a classification scheme would help reduce the ambiguity surrounding what a tidal creek means. They discussed the vulnerability of tidal creeks compared to other water bodies and that these systems serve as good habitat stress indicators (e.g., “canary in the coal mine” – early warning). It was also mentioned that Florida needs a classification system for nutrient criteria.

The topics of concern and questions discussed in detail during this segment focused on the following topics.

- Geomorphology concerns (associated with nutrients).
- The need for baseline information to understand status of /impacts to tidal creeks.
- Classification: Would classification help infer conditions in similar situations and whether or not regulatory mechanisms are working? If there was a classification scheme in place, would it be easier to convey what tidal creeks are? Would

classification increase public understanding of what tidal creeks are and how they are affected? Would classification help with defining what "tidal creek" means and how susceptible they are to impacts when compared to other water bodies?

- What ecosystem services are available from them?
- Inventory/Classification may help to break down some of the ambiguity of what is the salinity; providing measurable statistics; are we comparing apples to oranges?

The group discussed that the parameters for defining tidal creeks vary from state to state. For example:

1. In North Carolina (noted by Mike Mallin)
   - High salinity marine
   - Upland draining mesohaline
   - Upland draining fresh – oligohaline
2. In South Carolina (South Carolina Department of Natural Resources & South Carolina Department of Health and Environmental Control)
   - 1st, 2nd, 3rd order creeks
   - upland draining and salt marsh divisions
   - urban, suburban, forested (undeveloped)
   - fresh water tidal
   - Strayler classification used in NC; same logic used in SC
   - tidal creeks generally limited to < = 100 meters from marsh bank to marsh bank
3. In Georgia these parameters are not yet formally defined but would probably be very similar to South Carolina. The state is working with Skidaway to determine/define tidal creeks.
4. In Florida
   - Longest creeks, highest N loads
   - Highest landscape development index (LDI)
   - Lowest LDI
   - Closest to inlets, lowest phosphorus levels

A number of comments and questions were posed by members of the group regarding the discussion of coming up with a definition for tidal creeks that would be consistent across the four-state region. Some of the questions and comments from this discussion are provided below:

- How do you define a tidal creek? Is it a functional distinction?
- For purposes of our coastal environment, the group wanted to consider only waters that are tidally influenced.
- Landscape watershed development – How would we want to classify/terminology? – Have to capture landscape/watershed characterization.
- Do creeks have to have a termination point?
- Does there have to be a flow conveyance?
- There are plenty of creeks that have a starting point and "dead-end" into a salt marsh or mangrove (may be far from an upland in the marsh).
- Are ditches considered tidal creeks?
  - Engineered (ditches, dredge canals) vs. unmodified creek systems (this is a modifier).

  - Florida does not include engineered ditches – (considered mosquito ditches); similar thinking in SC & NC.
  - GIS and LIDAR data can be used to determine if ditches are significant conveyance from point A to B (e.g., fish using to move from one place to another or used to be a tidal creek or drainage ditch to nowhere); keeping ditches in the equation.
- Constrained vs. Unconstrained reaches was mentioned but decided not applicable to the coast (more in mountainous areas).

What are the available data sources?

- National Hydrography
- National Wetlands Inventory
- Coastal Change Analysis Program in NOAA
- State/County LIDAR (may not be available – proprietary)
- Imagery (e.g., aerial, satellite, high altitude/high resolution, low altitude); resolution of at least 1m pixel
- Soils data

What are the data gaps and uncertainties?

The group began with a discussion about "what makes a creek a creek"

- Geomorphology
  - Upland draining systems
  - Salt marsh/ mangrove draining
  - Engineered (ditches/dredge canals) vs. natural system
- Size
  - Stream order (1st, 2nd, 3rd)
  - Upper limit in size (or width) (e.g., 100m)
- These modifiers were then identified:
  - Landscape/watershed characterization
  - Salinity regime
  - Regular (lunar) vs. irregular (wind) inundation

It was suggested and agreed upon by the participants that some kind of standard for what defines a creek – geomorphology – is needed. The need to define the origin of creek (upland or lower outlet) to develop characterization was also noted. In Florida most of the smaller creeks run into an estuary and were historically ephemeral flow systems; however, now the way tidal creeks functions is completely different than in the past.

What are the research and action strategy needs?

Question to group: Do people agree that it would be a worthwhile effort to map tidal creeks in the four-state region? The group responded with the following needs:

- High priority to map tidal creeks (quantity/location)
- Standardized mapping criteria that states could apply and build for the region would be useful (protocols). It is easier to capture 2nd and 3rd order creeks, but difficult for 1st order creeks).
  - Document tidal extent

- Seek interstate funding to create a regionally consistent database (GIS) (standardized protocol).
- Strategy for periodically updating/ re-inventorying (long-term strategy – minimum of 3 years to do).

What are the management, education and outreach needs?

- Educate local politicians and general public
- Increase collaboration between researchers and outreach/educators providing programs to communities
- Identify funding sources

Hydrology of Tidal Creeks

Topic Description: Tidal influence results in water level fluctuations caused by the exchange of fresh and estuarine waters. Tidal creeks include intermittent creeks to the point where a major water body is encountered (e.g., river draining an upland watershed, estuarine bay or sound, ocean). The transport and retention of materials within tidal creeks and the associated habitats is related to the hydrologic characteristics — mainly flushing rate — which may be highly variable from creek to creek. A variety of factors play a role in determining flushing and the transport and retention of materials within salt marsh tidal creek networks. These include the size of the upland drainage area, amount of freshwater inflow, tidal range, creek dimensions including depth and slope, channel curvature and bottom friction. Creeks characterized by longer flushing rates retain more materials, including pollutants, that enter them compared to creeks with short flushing rates. Hydrologic processes, specifically freshwater inputs and mixing with tidal inputs are not well documented. The connections between groundwater and tidal creek hydrology/condition, and the influence of altered drainage patterns on tidal creek ecosystem function are also not well understood.

Group Participants: Christina Stringer (US Forest Service), Rick Peterson (Coastal Carolina University), Leigha Peterson (Coastal Carolina University), Paul Conrads (US Geological Survey), Jim Gregory (Watershed Hydrology Consultants, LLC), George Riekerk (SC Department of Natural Resources)

Group Co-leaders: Brooke Czwartacki (US Forest Service/College of Charleston) and Tim Callahan (College of Charleston)

Why is this important?

- Hydrology is the fundamental driver of tidal creek system dynamics.
- Anthropogenic impacts/stressors affect hydrological processes – these may be subtle and not easily observable.
- The flux of materials from surface/subsurface flows is equal to one half of watershed export.
- Natural resource managers and researchers need water balance/climate information to support their data.

What are the available data sources?

- Precipitation data – (State Climatology Offices, US Geological Survey)
- River outflows / stage data for large systems – (US Geological Survey)
- Confined aquifer data – (state agencies, US Geological Survey)
- Tide data – (NOAA)
- LiDAR elevation data – (state agencies)

What are the data gaps and uncertainties?

- River flow data for small systems (need instrumentation)
- Shallow groundwater (surficial aquifer) data – volume and value for targeted system
- Surface water/groundwater exchange, residence time

- Subsurface lithology
- Salinity data/boundary of freshwater and saltwater
- Long-term water balance datasets for tidal creeks
- Improved mapping/delineation of watersheds – specifically for low topographic slope
- Merging/standardizing of existing tidal creek/ tidal ecosystem classification systems
- Improved/updated data for hydrologic models (flexibility in models) and watershed planning

What are the research and action strategy needs?

- Develop a comprehensive and collaborative long-term monitoring initiative.
- Establish reference sites; we suggest using the National Estuarine Research Reserve (NERR) sites, and make it a priority to establish references on different classification types.
- Employ technology transfer – some information already exists which can be translated and extended to others.
- Engage all stakeholders at the beginning of all studies.

What are the management, education and outreach needs?

- There is a need to distill the research into a usable format for managers.
- Community involvement has shown to provide both an educational opportunity for citizens and helps fill data gaps. We can learn from successful citizen engagement programs (e.g. South Carolina Department of Natural Resources – South Carolina Oyster Restoration and Enhancement Program (SCORE) or Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) and adapt to gather local hydrologic data. This could include data collection and input through a web interface or smartphone app.
- Use outreach to obtain traditional ecological knowledge.
- Employ two way extension pathways bringing the science to stakeholders and local observations to mangers and researchers.

Sediments

Topic Description: Sediment plays a role in tidal creek health. Very little information is available with regard to how changes in tidal hydrology affect sediment dynamics in tidal creeks, sedimentation rates, and changes in channel depths. Therefore, there is a need to determine the role sediment plays in tidal creek health and how changes in tidal hydrology affect sediment dynamics.

Group Participants: Jenny Davis (NOAA CCFHR), Anne Deaton (NC Division of Marine Fisheries) James Hunt, Mary Grace Lemon (UNC Wilmington), Katie Luciano (South Carolina Department of Natural Resources), Gertrude McGillicutty (affiliation unknown), Wesley Mickler (UNC Wilmington), Carol Pride (Savannah State University), and Erin Udavre (UNC Wilmington).

Group Co-Leaders: Barbara Doll (North Carolina Sea Grant) and Anand Jayakaran (Clemson University)

Why is this important?

- Sea level rise will affect sediment transport dynamics in tidal creeks by altering boundary conditions. The rate, extent, and the primary and secondary impacts of this alteration are unknown.
- Coastal residents frequently complain of shallow sediment-filled tidal channels that were formerly considered productive fishing areas. It is unknown if the filling of these channels is due to watershed-based sedimentation or the absence of prop kicking and other flushing practices that were formerly allowed. Also, it is unclear as to what the "reference" morphology and hydrodynamic condition is for many small tidal systems.
- How do changes in human use such as trawling and dredging influence sediment transport in tidal channels? Of special concern are the effects of very deep harbor dredging?
- Natural versus anthropogenic sediment sources – There is a critical need to assess natural transport rates in tidal channels to better assess anthropogenic and climate related impacts on sediment transport.
- Determining if the sources and budget of marsh building sediments has an impact on marsh quality and function, whether sourced from the ocean or from upland areas. This information could be used to promote better management of coastal and upland resources.
- Sediment composition (biological) – Determining if the sediment is comprised of mineral or organic content is a critical aspect of understanding sediment dynamics and sources.
- Knowing how and where and when to control /manage sediment is important because poorly timed or poorly planned intervention/restoration can exacerbate the problem.
- Implications of re-suspension of contaminants in sediment (natural versus anthropogenic). A better understanding of the implications of contaminant suspension during channel dredging is important.
- Site specific uncertainties - There is a need to quantify how sediment dynamics vary spatially due to variability in tidal amplitude, currents, vegetation, salinity, etc.

What are the available data sources?

- NOAA Marsh monitoring of accretion – questions remain
- ACE National Estuarine Research Reserve South Carolina Department of Natural Resources, Jim Morris, SET data for 15 years in S.C.
- Rodriquez et al., University of North Carolina Institute of Marine Science on Intra-Coastal Waterway (ICW)
- Stephen Skrabal, University of North Carolina-Wilmington – metal contaminants in cores / re-suspension
- Reide Corbett, East Carolina University, sediment accretion rates and contaminant burial

What are the data gaps and uncertainties?

- How does dredging affect tidal creeks dynamics (i.e. harbor dredging, ICW, etc.)?
- Characterization of the fine scale variability of sediments; Developing a library of sediment types for photochemical transformation.
- Need to identify "reference" tidal creeks with documented form and function (morphology, sediment dynamics, flow, habitat, etc.).
- Need more hydrologic and hydraulic studies.
- The North River creation and restoration project should be expanded to investigate sedimentation and morphology relationships.
- Characterize the volume and role of upland versus in-marsh versus near shore / inlet sources of sediment.
- Sediment character (clay, silt, sand) and organic versus inorganic.

What are the research and action strategy needs?

Objectives

- Develop tools/sensors to document marsh/tidal sediment dynamics (re-suspension, sediment deposition & transport).
- Determine the changes in sediment dynamics as a result of changes in landuse (e.g., Identify a watershed that is slated for development and monitor or study it over time).
- Document how in-system human activities are affecting sediment such as dredging, prop kicking, trawling (e.g., LIDAR, photo-time-series analysis of creek and watershed).
- Identify sources and character of sediment (e.g., compare watersheds/ creeks with highly variable watersheds and conditions from relatively undisturbed to heavily developed).
- Classify creeks relative to sediment loading and dynamics (include sediment cores for a library). e.g., hierarchical multivariate analysis of creeks looking at sedimentation rates, flow, morphology, size and other relevant variable to determine/develop classes of creeks.
- Initiate a sociological study to gauge coastal shoreline residents / water peoples perspective on creek condition and change and impacts to resources and/or uses.
- Quantify transport, deposition and re-suspension of sediments (including marsh models and/or empirical data).
- Evaluate BMPs in the landscape to determine how they affect sediment load and character inputs to tidal creeks and how they can be improved.

What are the management, education and outreach needs?

- Once the agencies understand the sources and extent of the problem, they can change plans, rules or focus to address the appropriate sediment issue(s).
- Once understand sediment rates, sources, SLR, etc., agencies can make decisions about permits /dredging/ sediment disposal to better protect tidal creeks and associated marshes.
- Strong networking of state/federal/local agencies with scientists is needed when implementing the research agenda and determining appropriate responses or actions.
- Citizen science is needed to help with studies and monitoring (i.e., photo documentation).
- Outreach is needed to communicate to the public how dynamic tidal creeks systems are especially with respect to sediment loading and impacts.
- Better education for contractors, landscapers and homeowners on landscaping practices to prevent erosion and protect tidal creeks.
- Economic valuation of sediment impacts.
- Youth education on tidal systems and sediment dynamics.
- Improve agency websites to better educate citizens and developers on tidal creeks sedimentation.

Land Use – Stormwater Runoff

Topic Description: One of the major threats to tidal creeks is from stormwater runoff associated with coastal development including suburban, urban, and agricultural land uses. Coastal development can result in increased stormwater runoff, alterations to the habitat, and loss of ecosystem services. Stormwater runoff can impact systems through both input of freshwater, as well as the pollutants the water carries. Coastal watersheds of the southeastern U.S. typically have low gradient topography and highly variable water table conditions, characteristics that present unique challenges for stormwater management.

Therefore, many questions exist about the effectiveness of current stormwater treatment strategies, including how effective these systems function under real-life situations and management needs. In particular, are treatment strategies sufficient for protecting tidal resources?

Group Participants: Kyle Curtis (Coastal Carolina University), Diane Cowling (Savannah State University), Dave Fuss (Horry County Stormwater), Blaik Keppler (ACE-Basin NERR/SCDNR), Sarah King (NC Coastal Federation), Kevin Nunnery (Biohabitats), Karin Skipper (SC Department of Health and Environmental Control), Nicole Wisniewski (College of Charleston), Andrew Wunderley (Charleston Waterkeeper)

Group Co-Leaders: Dan Hitchcock (Clemson University) and Phil Prete (City of Wilmington, NC)

Why is this important?

- All were in agreement that this is very important and that stormwater control was even more important at the coast.
    - One participant mentioned that so many practices are being installed in NC that may or may not work. For example, ponds and other best management strategies are not being maintained and are not functioning as designed or built as designed. Impacts are apparent everywhere and sediment and other pollutants are prevalent.
- The context of the question was modified to focus on "coastal" areas:
    - Receiving water bodies are at the end of the line on the coast, there are multiple designated uses, stream of many inland/upstate rivers, recreation at the coast is high, and economic impacts of stormwater are not known.

    - Water quantity has been historically addressed, but what about other parameters? Ponds are installed for water quantity not quality. There is a need for practices to improve quality, which is especially important to water resources on the coast.
- The group discussed whether current design and regulatory guidance is sufficient.

What are the available data sources?

- We begin to see impacts at 20% impervious cover in the watershed.
- There is a correlation between population and impervious cover.

- We see degradation even under current guidance, not doing enough. A NCDENR study (Dohrman, 2009)[1] showed that the majority of permitted detention ponds in the coastal region were not meeting their permit conditions.
- Shellfish bed closures occur with 4 inches of rain in 48 hrs and closed until monitoring shows bacteria has receded to below threshold. Can we measure these closures? Are we using blanket policies without any basis? Is this based on science?
- The relationship between stormwater runoff and fecal loadings is known – but not the sources. What about the role of sediment in pollutant source/sink relationship?
- We know certain BMP effectiveness in terms of water quality and percent removal. There are some published case studies.
- BMP maintenance is critical for effectiveness. Are the performance levels accurate? Are all conditions considered in these experiments?
- Traditional BMPs may be working for typical pollutants, but may not be suitable for emergent contaminants (PAHs, pharmaceuticals, etc.).
- The role of sediment retention in ponds/basins may be linked to bacteria populations.
- LID strategies can be a substitution for ponds and other traditional practices, however, many barriers and obstacles exist.
- LID strategies within the landscape, siting, treatment train, etc to mimic natural flow paths. We are missing the boat on how to manage the entire landscape for site design. Ordinances and standards as they currently exist may be obstacles for LID implementation.
- High nutrients cause algal blooms and need better understanding and data including what triggers them.
- Sea level rise affecting water resources management, stormwater practice selection, siting, and design.
- Stormwater infrastructure/ BMP location data – What are the relationships?
- We can make connections between source of bacteria and the effects – outreach works if can get the message across.
- It's important to get people to "stop and think" about how what they do may affect water resources. We know there's a gap between science and the public. Does or can the average person understand connections between a bag of fertilizer and an algal bloom? Public seems to rely on regulations and agencies to protect resources.
- Groundwater levels may limit BMP selection and performance, which will be further exacerbated by to sea level rise.
- Wetlands can work not only for nutrient reduction, but also reducing discharge volumes.
- Is infiltration the way to go? Do we have the potential to contaminate groundwater?
- Can we translate impacts to economics or what it costs to fix a problem, impact on fisheries? Tourism? Water quality? That's what people would pay attention to.
- Fear of change and new ways of doing things.
- Site development and infrastructure can be expensive, how cost effective are BMPs, what's the return on investment? Pervious pavement is a good example. Develop relevant local case studies. Myths need to be dispelled, if possible. Can LID

[1] Dohrman and NC Division of Water Quality. 2009. High Density Detention Pond Permit Compliance and Inspection Efficiency in New Hanover County. UNC-Wilmington.

implementation increase developable land area for a development project and increase property values?

- How is health involved? Can human health impacts make people pay attention rather than pollutant concentration information? What about wildlife habitats – do people care about that?
- There are a number of example case studies where there are obstacles to LID. For example, in River Bluffs near Wilmington, large live oaks and soil suitable for infiltration would have had to be removed to meet conventional requirements, but LID allowed much of the natural landscape to be preserved. In Tonbo Meadows in Wilmington too many variances were required for nonconventional development practices, resulting in regulatory costs that prohibit developing in a sustainable way. Time and money are wasted.

What are the research and action strategy needs?

- Standardize the costs and economics of ecosystems services; need economic analyses and valuation of benefits to costs ratio.
- Economic "incentives" for developers cut both ways, economic analyses to quantify may show traditional development has a better cost - benefit ratio. Basic level of ecosystem services valuation is complicated. Economics (costs may be known but not values of benefits) are not understood by legislators and public; if not transparent then difficult to defend.
- What are intrinsic values? What is the value of good water quality besides what it means to fish, shellfish, etc?
- How does groundwater impact infiltration capacity? In a developed system, can we increase infiltration capacity and decrease the unintended consequences. Can we really mimic natural hydrography via LID to improve infiltration? More knowledge is needed.
- Social science needs – interacting with communities. Is there a social message and an effective mechanism for delivery? Research on what social marketing messages would work? Fertilizer companies for example – turn into a public relations battle. People want a nice green lawn but don't know the consequences.
- What does the perfect stormwater pond look like? Education and outreach message.
- Job impacts may be a way to get at economic impacts?
- Performance research needs and policy research needs.
- Economic research needs (e.g., what are the incentives? what incentives work? Stormwater fees are trivial so no incentive to offer credits. Are externality costs involved?)
- Willingness to pay? What is the tipping point for incentives to encourage voluntary action for residential BMP installation?
- Need more research on loading and contaminant removal calculations for BMPS.
- Identify critical surface hydro data.
- What are the benefits of treating stormwater close to the source rather than the point of impact?
- Land use change and hydrology - need to refine understanding of the relationship between them.

- Climate change/sea level rise impacts need to be explored – overlay inundation models with our stormwater and watershed models.
- Land-use change doesn't necessarily demonstrate hydromodification. Is there a disconnect between impervious surface and changes in stormwater routing and conveyance?
- City of Wilmington – 'Heal our Waterways' Initiative, born from the "Grey to Blue" watershed restoration plan, is working on retrofits and voluntary disconnections to increase infiltration.
- Research on how we compare pollutant loading and discharge versus onsite retention and treatment.
- Bill Hunt's work with effectiveness of residential downspout disconnection practices.
- Research needs in rainwater harvesting at a large scale. Is it too expensive?
- How can we more easily use harvested rainwater? What are the incentives? Cost savings? What are the hurdles? Regulatory? Lack of need? Others?

What are the management, education and outreach needs?

- The participants focused on the question of policy changes and removing of barriers. It was mentioned by participants that outreach needs should include policy needs and changes for informed decision-making.
    - For example, HOA/POA rules exist that limit rain barrel installs. Specific guidance for coastal BMP selection and maintenance is necessary for HOAs, the development community, engineers, real estate agents, and landscapers.
    - Required as regulation? Developer says – "just tell us what to do" so they know what rules and thresholds to include in budget.
- What about funding a lobbyist that represents stormwater protection in decision-making with legislators, etc? (Examples include The Nature Conservancy, Environmental Defense Fund, Sierra Club, etc.). Maybe something more towards the middle, so as not to be perceived/viewed as "radical."
    - League of Conservation voters has a voice in the state legislatures as well as the NC Coastal Federation.
    - Waterkeeper and Riverkeeper representatives may not have the same level of access, but they do have a handle on the technical issues that could be used to help.
- With lobbyists, is it better to be top down or bottom up? Working with locals versus at the state level. Municipalities and counties may not change policies if not mandated at the state level. Unless local communities say "we want this". Local legislators may be more accessible. A diffuse local approach versus a concentrated message at the state level.
- How do we do these things with decreased funds? Sponsors or partners are needed. Tidal Creek initiatives can benefit from "think tank" versus "lobbyist." There is a need to connect the knowledge base of tidal creeks with decision-makers. Legislators pay more attention to lobbyists, representing large groups.
- What about a reality TV show like Stormwater Wars? People are glued to the TV and the reality genre is very popular.
- People are so busy with limited attention span so there needs to be a short effectual message that doesn't cost too much.

- Need packaged, easy-to-understand material so non-scientists can benefit from it.
    - "Stormwater is bad" message is not effectual without technical solutions or action items to back it up. Find savvy mechanism to package solutions and action items.
- Education and outreach should include school children that can take message home to parents etc. Changing behavior is difficult.
- Showcasing good actors and highlighting success stories as examples. Aesthetics are one thing but what about the economic benefits?
- Needs summary:
    - Economic and technical performance research
    - Social media, K-12 education and other outreach mechanisms to convey the issues and solutions
    - Policy development and education of policy makers

Land Use—Effects on Tidal Creek Systems

Topic Description: One of the major threats to tidal creeks is from coastal development including suburban, urban, and agricultural land uses. Tidal creeks, particularly the headwater areas, serve as sentinel ecosystems, which provide early warning of these impacts. Coastal development can result in increased stormwater runoff, alterations to the habitat, and loss of ecosystem services. Stormwater runoff can impact systems through both input of freshwater, as well as the pollutants the water carries. Research clearly shows high levels of watershed development are associated with increased concentrations of fecal indicator bacteria, nutrients, chemical contaminants, turbidity, more variable fluctuations in salinity, and decreased quality of the macrobenthic and nektonic communities, as well as oysters. Similar to freshwater environments, impervious cover greater than 10-20% results in water and sediment quality impacts and greater than 20-30% impervious cover results in biological and societal impacts. Therefore, many questions exist about the impacts of coastal development (land use) on tidal creek systems, including secondary and cumulative effects. This can help determine if and how impacts can be measured and possibly lead to better policies, including the federal Clean Water Act and the Rivers and Harbors Act and other state and local regulations.

Group Participants: Lauren Bohrer (UNC-Wilmington), Brett Champion (Town of Mt. Pleasant), Heather Coats (NC Department of Natural Resources , Division of Coastal Management), Marissa Dueker (NC State University Center for Marine Sciences and Technology), Kay Lynn Hernandez (Cape Fear River Watch), Tara MacPherson (NC Department of Natural Resource's Division of Coastal Management), Gregory Meyer (FCCC), Anna Robuck (UNC-Wilmington, Center for Marine Science), Edward Sherwood (Tampa Bay Estuary Program), Renee Smith (Savannah State University), Holley Snider (NC Department of Natural Resources , Division of Coastal Management), Amanda Sturgeon (Coastal Carolina University), Caitlin White (UNC-Chapel Hill), Travis Clay Willis (NC Department of Transportation)

Group Co-Leaders: Chris Marsh (LowCountry Institute), Rick DeVoe (SC Sea Grant Consortium), and William Savidge (Skidaway Institute)

Why is this important?

- The group placed the effects of land use on tidal creeks into the following categories:
  - Hydrological: sedimentation, runoff, flashiness, alter groundwater.
  - Biological: nursery areas degraded, habitat loss resulting in changes to fish communities.
  - Ecological: nursery areas degraded, habitat loss and fragmentation.
  - Chemical: pesticides (lawn proliferation and agriculture) and nutrients that lead to eutrophication.
  - Socio-economic: decline of property values, loss of recreational and commercial seafood value, loss of access, decline in tourism and diminished quality of life.
  - Structural: loss of buffer, nature of development differs.
- Group members stated development is a feature of the landscape with predictable properties. The challenge is to manage development within tidal creek watersheds to minimize the negative consequences of the built environment on the watershed.

Effective science based proposals must be relevant, practical, and responsive to human needs.

- Group members identified issues, which focus public attention on tidal creeks to include:
  - Shellfish bed closures.
  - Degradation of recreational activities.
  - Impacts to commercial fisheries.
  - Conflicts over access and use.
  - Negative impacts on tourism.
- These issues were identified as secondary responses caused by the primary effects of shoreline and watershed development. Some well characterized primary drivers identified include:
  - Increased sediment, nutrient, and pollutant loading associated with increases in impervious surfaces.
  - Minimal setback of development from creek boundaries.
- The group also identified primary drivers with less empirical evidence:
  - Loss of biological and chemical "buffering capacity" of creeks.
  - Effects of fragmentation of the upland watershed.
  - Alteration of groundwater regimes.

What are the available data sources?

- A considerable historical body of research pertaining to tidal creeks in the Southeast was identified. The group notes these efforts have little interconnection.
  - North Carolina research includes UNCW's Tidal Creek Program, monitoring efforts on the Neuse River, SGIA, and D-CERF.
  - South Carolina efforts include Urbanization and Southeastern Estuarine Systems (USES), Land Use Coastal Ecosystems Study (LUCES), work done by Sanger, Holland, and others at SC Department of Natural Resources, and Clemson University studies on present and projected land use.
  - Georgia research is more fragmented, but includes efforts by GA DNR to monitor water quality and work by Sheldon and Alber at University of Georgia.
  - Florida efforts include the Tampa Bay Regional Program.
  - Federal efforts include the National Estuarine Research Reserves (NEERs) and Long-Term Ecological Research (LTER) sites in the Southeast and the NOAA Coastal Change Analysis Program (C-CAP).

What are the data gaps and uncertainties?

- Most knowledge of the effects of development upon tidal creek health and function is correlative and not causal, making it difficult to assess the efficacy of particular management strategies for preserving or remediating tidal creeks.
- Investment in routine monitoring of regional water quality has been concentrated in more mainstem open estuarine waters rather than within tidal creeks themselves.
- Considerable local and regional variability in response to developmental stressors. It is unclear whether it is possible to generalize predictions about tidal creeks' responses to development within the SE region.
- Lack of a common tidal creek + watershed system modeling framework that can unify understanding and decision making.

- Consequences of development on "hidden" parts of the system (microbial communities, hydrologic connections between creeks and groundwater)
- Lack of understanding of how changes impact charismatic components of the system that attract public concern (e.g., shellfish, recreationally valuable fish, dolphins).

What are the research and action strategy needs?

- The group identified the necessity of developing better technical approaches to be used for monitoring tidal creeks for evidence of impairment.
    - Technology for routine water quality and environmental monitoring within creeks and surrounding watersheds needs to be developed with widely and deeply integrated sensor networks to be included as part of monitoring and managing tidal creeks (real-time monitoring capabilities).

What are the management, education and outreach needs?

- The group discussed the need to articulate to managers and the public the benefits of properly managed development to both the public interest and the integrity of the tidal creek ecosystem.
- Effective advocacy for managers should include:
    - Articulating costs and benefits of alternative management strategies, taking into account both the explicit and implicit costs of different potential management decisions.
    - Engaging local stakeholders to increase ownership.
    - Giving regulators tools for effective decision making, especially since most decision-making regarding development occurs at the local government level.
    - Providing compelling data to overcome regulatory inertia and parochial interests.
    - Developing new GIS-based data tools for managers that incorporate layers of data critical for assessing impacts of development on tidal creek health (e.g., water table height and groundwater flow paths) to help institutionalize considerations of secondary effects of development upon tidal creeks in the regulatory and permitting decision making pathway.
- The general public also needs to be engaged in the preservation of tidal creeks by having access to tools for assessing creek condition, including:
    - Historical and current tidal creek monitoring data in forms accessible or interpretable by the casual public.
    - Public outreach that puts data in user friendly visual formats, such as maps and that use forms of social media in addition to more traditional research and management outlets.
    - Communication with the public in a two-way form, allowing citizens to input their observations of tidal creeks and to access data from other sources.

Water Quality

Topic Description: A major concern for tidal creeks is changing water quality. Water quality in tidal creeks can be impaired from a variety of sources including sewage leaks and spills, septic system leachate, stormwater, urban, and fertilizer runoff, marinas and boats, groundwater, and atmospheric deposition. The range of pollutants that can affect water quality include bacteria, viruses, nutrients, chemical contaminants, pharmaceuticals, sediment, and fluctuations in salinity. Two processes, eutrophication and hypoxia, are global concerns. Eutrophication is the process by which increased nutrients enter a system and generally result in algal blooms. Many algal blooms can be harmful due to the production of toxins or other negative environmental effects, and algal blooms can also cause hypoxic conditions. Tidal creeks in the Southeast naturally experience periodic low dissolved oxygen (DO), often hypoxic waters, on tidal or diel cycles. However, anthropogenic inputs may exacerbate the frequency and length of time low DO is experienced. Many questions exist about the changing water quality of tidal creeks. This includes the relationships between increased nutrients and biological responses as well as bacterial contamination and human health implications.

Group Participants: François Birgand (NC State University), Sue Ebanks and Sami Saryou (Savannah State University), David Graves (SC Department of Health and Environmental Control), David Huffman (UNC Wilmington), Susan Libes and Michael Trapp (Coastal Carolina University), Erik Smith (University of South Carolina), David Marshall (UNC Chapel Hill), Stan Sherman (NC Department of Environmental and Natural Resources), Matthew Stokley (NC Division of Marine Fisheries), Heather Ward (Waterkeepers Carolina)

Group Co-leaders: Dianne Greenfield (University of South Carolina/SC Department of Natural Resources) and David Bryant (NC Sea Grant). ***Note Taker****:* Cheryl Carmack (College of Charleston).

Why is this important?
Tidal creek water quality directly and indirectly affects ecosystem services, human, biological, and ecosystem health, and it sustains and protects traditional and potential uses of water bodies.

Specific topics addressed during this discussion segment included:

- Water quality is the foundation of a tidal creek ecosystem, and it affects biological and human health endpoints.
- Ecosystem services, as well as human services (boating, swimming, other recreational uses) and additional resources (fishing, shellfish harvesting, etc.) are all directly impacted by water quality.
- Related to ecosystem services, water quality affects tourism and other human uses, thereby impacting local economies that rely on tourism revenue.
- Water quality not only impacts inhabiting biota, but it also affects transient/migratory species, including those that rely on specific breeding grounds.
- Ongoing and anticipated development is likely to directly impact tidal creek water quality, making monitoring and assessments crucial.

What are the available data sources?
Numerous sources of water quality data exist from state, federal, university, and private sources, but a general need for a central clearinghouse was expressed.

Examples of tidal creek water quality data include but are not limited to the following:

- Most agencies and universities have water quality databases from monitoring programs (e.g., USGS, NOAA, NERR, state agency monitoring, research-specific monitoring, and others)
- LiDAR
- National Wetland Inventory maps
- EPA clearinghouse
- Maps of land-use, soil, and impervious cover – currently used by stormwater managers

What are the data gaps and uncertainties?
Data gaps and needs included refining the temporal and spatial resolution of water quality data, including delivery (flux), and the identification of key water quality indicators from tidal creeks to the coast. Data on biological indicators or biological responses are sparse, representing a major gap.

Specific gaps and uncertainties in water quality data were identified as follows:

- Convenient and accessible maps for stormwater pipe outfalls.
- Need for improved temporal (chronic vs. pulses of impaired water quality) and spatial (within/between systems) resolution regarding trends in water quality.
- Inconsistency in how different programs evaluate water quality (units, methods, parameters, etc.).
- More biological data are needed; existing information is primarily physical with basic chemistry (temperature, salinity, pH, DO, turbidity).
- There is virtually no water column/profile information. The general assumption is that tidal creek systems are well-mixed, but this is not necessarily always true
- Hydrology (flow/flux) data.
- Better understanding of scales of variability for water quality (e.g., within/between creeks, watersheds, or regions).
- Uncertainty in the best water quality indicators to use (certain pathogens, harmful algae, physical characteristics, nutrients, heavy metals, pollutants, pharmaceuticals, etc.).
- Biological responses to various aspects of water quality.
- Influences of benthic/sedimentary processes on water quality.

What are the research and action strategy needs?
Future research should focus on improving tools and techniques for evaluating water quality and assessing biological (species, communities) responses to relevant water quality parameters

Specific research/action items for evaluating tidal creek water quality were as follows:

- Develop and improve tools (analytical tools, predictive models) and technologies (molecular, instrumentation) to monitor, measure, and detect attributes (biological, chemical, and physical) of tidal creek water quality.
- A major research goal should be to better understand linkages between water quality and human/ecosystem health.
- Process-oriented studies should be conducted, focusing on water quality condition to biological responses. Such studies should include environmentally-relevant species as well as consider community and trophic structure responses.
- Generate a user-friendly clearinghouse where monitoring data from various groups could be combined and accessed.
- Determine how land use and urbanization/development relates to trends in tidal creek water quality.
- Evaluate how water quality condition drives key ecological rates and processes.
- Determine how water quality condition affects the susceptibility of a tidal creek system to hypoxia.
- Determine how sediments and benthic processes influence water quality along a tidal creek gradient.
- Socio-economic assessments of the 'value' of tidal creeks and how water quality impacts their value should be considered.

What are the management, education and outreach needs?
Education and outreach were considered central to evaluating and managing tidal creek water quality. Activities should focus on improving dialogue between researchers and managers, engaging local stakeholders (including property owners), and student education, including K-12. Outreach should also emphasize making information easily accessible and understandable to the general public.

Examples of education/outreach ideas for water quality include:

- Improve data visualization and interpretation tools for non-scientists
- In tandem with the need for a centralized clearinghouse, a better approach is needed to archive data so that they can be easily accessed by stakeholders
- Outreach should consider social media – have centralized websites include a Facebook page or an 'app' wherein trends in water quality can be followed
- Water quality monitoring and experimental results should be made easily available to managers for water quality decisions, making better integration between the research and management communities a priority
- Engaging the public in water quality issues is crucial. Examples include:
    - Presentations to local stakeholders and landowners – communicate why it is important for homeowners to have 'ownership' in water quality
    - Making data and information easily accessible and understandable to the public
    - K-12 education programs
    - Including stakeholders' interests in the research and decision processes
- When appropriate, communicate activities to the media in order to raise awareness

Restoration

Topic Description: Tidal creeks (including associated tidal wetlands, living shorelines, and oyster habitat) provide a range of services that are beneficial to coastal communities. Restoring these systems and habitats is critical to offset the current and future impacts. Because each project will likely have a different set of goals depending on the scale, location, intent and setting, it is important to consider what functions and ecosystem services need to be protected and restored for each specific circumstance. It may not be possible to restore or maintain all functions or services. Priority should be given to restoring sites that can provide services that are most beneficial and will have the highest likelihood for success. A wide range of agencies (e.g., NOAA Fisheries, NOAA Restoration Center, U.S. EPA, state departments of environment) are responsible for implementing restorations, each with different and often conflicting agendas, missions, and levels of funding. As a result, restoration projects are often not conducted in an integrated and coordinated ecosystem-based approach. It is important for all the agencies involved to have collaborations and partnerships that lead to integrated restoration activities that restore and potentially enhance the services provided to coastal communities.

Group Participants: Alexander Baldwin (Stantec), Sean Briggs (SC Department of Health and Environmental Control), Jennifer Butler (City of Wilmington, NC), Stephen Czwartacki (SC Department of Natural Resources), Michael Hodges (SCDNR), Jared Hulteen (SC Department of Natural Resources), Sena NcCrory (Rice University), Christopher Stout (SC Department of Health and Environmental Control), Victoria Vazquez (College of Charleston), Keith Walters (Coastal Carolina University), Travis Wilson (NC Wildlife Resources Commission), and Sabrina Woofter (NC Cooperative Extension).

Group Co-Leaders: Michael Burchell (NC State University, associate professor) and Sandra West (SC Department of Health and Environmental Control)

How do we define restoration?
Since tidal creeks are variable (size, salinity, vegetation, etc.) and are often considered more of a system with multiple components that may be restored, the group spent time discussing what restoration goals were most important to them and where we would focus our discussion.

- Components of the tidal creek system that can be restored include:
- Tidal creek (brackish and fresh)
- Brackish marsh platform
- Oyster reef
- Shoreline stabilization/living shoreline
- Restoration goals:
- Restore structure
    - Reconnect with tidal sources
    - Restore appropriate hydro-period
    - Re-vegetation
    - Reduce wind/current energy to stabilize areas
    - Reestablish stable terrestrial and marine boundary

- Replace lost ecosystem function/services

  - Water quality improvement (for recreation, biota) and to protect downstream resources
  - Faunal and benthos habitat
  - Rehabilitate degraded systems/buffering capacity
  - Endangered species protection
  - Restore genetic diversity
  - Economic/cultural uses restored

It was clear during the discussion that the participants had variable perspectives on types and goals of restoration that were most important. Based on the expertise of the group, we focused the discussion on brackish marsh and living shoreline restoration.

Why is this important?
Without adequate justification, restoration of these areas will not gain momentum. Therefore it is imperative that we clearly define to government agencies, NGOs and the general public the benefits of restoration. The following is a list of benefits defined by the participants (in no particular order).

- Economic value and jobs
  - Fisheries
  - Recreation and Tourism
  - Carbon sequestration potential (Blue-carbon markets)
- Health and safety of human population
  - Natural buffering capacity to water quality and tropical storms
  - Coastal resiliency to sea-level rise
  - Seafood safety
  - Other ecosystem services
- Environmental value
  - Improve habitat
  - Maintain coastal food webs
  - Ensure trophic resiliency
  - Provide aquatic fisheries/species protection
- Yet to be realized consequences of tidal marsh/stream degradation
- Restorations can be used to
  - Demonstrate how this systems can improve local environmental conditions
  - Improve understanding of how tidal ecosystems develop
  - Encourage multi-disciplinary collaboration in developing, implementing, and studying restoration sites
  - Educate the public on coastal issues

What is the current understanding of key restoration principles and outcomes?
The science of restoring these areas is not new, although it has only been seriously approached in the United States for the last 40 years. The current understanding of key restoration principles and potential outcomes include the following:

- The use of reference sites and other historic information to base designs are key to the success of restorations.
- Many baseline characteristics of natural systems are well understood.

- Many of the necessary structural design features required for restoration of these systems (hydrology, vegetation, soils, elevations) are well understood.
- Proper hydrology/hydroperiod/tidal regime is the key driver to restoration success.
- Site specific considerations should always be examined prior to restoration.
- Tidal creeks and associated tidal marsh platforms require elevations specific to local tidal regime.
- Providing adequate depths of topsoil is crucial for vegetation development.
- Target vegetation types should be identified from reference sites and planted at the proper elevation/tidal regime to ensure survival and coverage.
- Fertilization in some instances is important to provide quick vegetation coverage and spread.
- Ecosystem functions and services take time to develop, although vegetation coverage and colonization of local fauna can occur in the first few growing seasons.
- Soil properties, particularly organic matter, take years or decades to develop.
- Based on natural systems, basic nutrient cycling and material transport within marshes is understood.
- Certain species in these systems are indicators of ecosystem health.
- Many biotic vs. abiotic interactions are understood.
- We understand the implications of restoration for higher order organisms, because they are relatively easy to measure.
- Restoration can be expensive, but proper planning can improve efficiency.
- Cost data is available for tidal stream/marsh restoration, living shorelines, and oyster reefs.

What are the data gaps and uncertainties?

Unfortunately, restoration of tidal influenced systems proceed without considering all of the lessons learned. Sometimes, current scientific knowledge is ignored which can be addressed, for example, through outreach and searchable databases that can raise the profile of available case studies. Other times, restorations are completed using techniques that simply exceed the current scientific understanding. Both can result in failed projects, which will threaten how future restoration projects may be supported by the public. Other gaps in knowledge that can impact public acceptance of these restorations are related to quantifying criteria for restoration success and the true ecosystem service benefits these systems provide. Improvements in the following would advance the current knowledge related to restoring these systems:

- Quantifying success in restoration.
- Length of time to restore soil/sediments.
- How do we truly quantify all of the ecosystem services these systems provide?
- Water quality – how does marsh acreage and landscape position improve water quality?
- Need for more detailed understanding of material fluxes from restored marshes
- Do greenhouse-grown plants survive and thrive like transplanted plants?
- Groundwater/surface water interactions – locally and regionally.
- What is the impact of living shores on water quality?
- What is the true impact of oyster reefs on water quality?
- How do taxa influence each other in these systems?
- What are the complete interactions between ecosystem components?

- What are the costs of larger scale restoration?
- How can the rate of restoration be increased?
- What presently are the social/societal impacts of restoration (in this decade)?
- How to build larger community support for restoration in the current economy?
- Should we design restorations to include the possibility of sea level rise on a site-by-site basis?
- We need continued monitoring and improved techniques that will increase confidence in the data in these dynamic systems with many outside forcing functions.
- What do we not know, we don't know?

What are the research and action strategy needs?
In the future the Tidal Creek Summits should include an entire session devoted to research strategies. A few strategies that were discussed include:

- Funding is a concern. Establish multidisciplinary and multi-institutional groups to strengthen proposals.
- Design some restorations with an experimental plan in mind.
- Develop novel experimental ideas – lump in extra parameters when experiments are designed.
- Investigate new and improved monitoring techniques (especially robust, remote, high frequency systems) to address restoration research.
- Evaluate whether success of a restored system, should be evaluated according to benchmark years (i.e. 0-3 years, 3-6 years, 6-10 years, etc.).
- Terrestrial linkages to tidal creeks and marshes should be considered.
- Develop regional restoration databases for data sharing.

What are the management, education and outreach needs?
Education and outreach activities are a crucial component because awareness of these tidal creek systems can lead to more protection of these resources. As the public and other agencies increase their knowledge of the correct conditions of these systems and the benefits they can provide, it can build support for a) new restorations and b) for research to improve the impacts of these restorations. Below are a few ideas regarding education and outreach. Note the top three bullets were identified as particularly important by the participants:

- ☆ Find easy, tried and true ways to involve students and community members (i.e. small restorations to show results).
- ☆ Make outreach relevant in our current economic climate.
- ☆ Inventory of southeast tidal creek restoration projects.
- Engage cooperative extensions and utilize their expertise.
- Identify key issues important to coastal communities (tourism, fisheries, sea-level and marshes).
- Many homeowners in these communities embrace "feel good" activities that could be related to water quality protection, living shorelines, etc. and would participate in programs if made aware.
- To gain public support, planners need to show how proposed projects will provide positive benefits to communities.

- Use research results to communicate with decision makers – therefore the connection between researchers and outreach groups must be improved.
- Citizen scientist groups/watch groups can engage locals.
- K-12 education – involve the younger generation.
- Raise awareness following coastal storms; for example, to show resiliency and the need for marshes.
- Continue to foster environmental stewardship in each coastal town

<u>Nekton and Fisheries</u>

Topic Description: Tidal creek and wetland networks that occur along the lateral boundaries of south-eastern estuaries are critical habitats that are renowned for their natural beauty, biological productivity and value as critical nursery, refuge and feeding habitat for fisheries and birds. Because the tidal creeks and their adjacent wetlands are located at the interface of terrestrial, freshwater and marine ecosystems, they are important conduits for energy and material exchange, including pollutants within estuaries. They also buffer the land from storm surges and provide vital resources and services to coastal communities and economies. As a result of their geographic location at the land-sea interface, the health and functionality of tidal creek ecosystems are particularly vulnerable to changes in ecological processes resulting from changes in land use and land cover. Tidal creeks are ecologically important for their habitat, water conveyance, and nursery areas for the early life stages of resident and estuarine-dependent fish and crustacean species, and economically important for finfish and shellfish production. Resource managers at the state and local level need information and tools that can assist them with developing and implementing protection, mitigation and restoration strategies.

Group Participants: Anne Markwith (UNC Wilmington), Julie Davis (SC Sea Grant Consortium), Dana Sargent (n/a), Bill Weiss (LowCountry Institute), Katherine Doyle (Savannah State), Paul Rudershausen (NC State University), Ben Stone (SC Department of Natural Resources), Maria Dunn (NC Wildlife Resources Commission), Jessi Baker (NC Division of Coastal Management), Jim Gilliam (NC State University), Pat Geer (GA Department of Natural Resources), Amber Whittle (Florida Fish and Wildlife Conservation Commission), Fritz Rohde (NOAA)

Group Co-leaders: Lisa Vandiver (NOAA) and Gloria Putnam (NC Sea Grant)

What is this important ?

It was first suggested that we focus on a particular species or set of species (e.g., sentinels) to focus our discussion, but it was decided that was too constraining to the conversation at this point and that we can think broad now and then narrow down later.

The group generally tended to focus the discussion on 'fisheries' with a recognition that all fish help support the 'fishery' and that tidal creeks, as nursery grounds, were an integral part of supporting the production of nekton and fisheries.

There was a suggestion to make sure when we discuss 'fishery' we recognize that this includes the people that depend on the 'fishery' and to consider what will interest them.

It was also noted we need to consider that tidal creeks need to be fully functioning to provide nursery habitat.

What are the data gaps and uncertainties?

In fisheries, there is a general disconnect in our understanding of size classes, recruitment, fecundity of recreational / commercially important fish → by including tidal creeks in fishery studies we could likely get at these questions.

- States are not sampling tidal creeks, certainly not in the very small creeks or smaller more sensitive systems.
- State of the science currently does not link tidal creeks to fisheries. Additional research is needed to link life stages of fishery species to tidal creeks and also to look at trophic transfer that would suggest that tidal creeks support 'offshore' fisheries.
- Is there a common method to sample and assess these creeks to determine their quality for the fish that utilize them?
- Need to establish standard monitoring parameters (e.g., DO, temp, catch per unit effort) for fishery data to assure consistency (and enhance sharing) in datasets across states. Additional discussions are needed to determine whether this would require standardization of monitoring protocols.
- Need to be able to sample for smaller species.
- Need to define a tidal creek for the purposes of fisheries. The data needs are dependent on what portion of the creek (e.g., headwaters, estuary, bay) you are looking at.
- The group started to discuss the fact that we have a lot of fishery data (and possibly other data), it just needs to be compiled and analyzed. It was suggested that we could partner with GSAA who is currently identifying the locations of all of the datasets and working to establish a centralized database.
- Following a fairly lengthy discussion of how we could use existing fishery data to link fishery to tidal creeks, additional data needs became apparent, including the need for broader spatial coverage of fishery data.
- Some group members were concerned about focusing on recreational / commercially valuable species and disregarding the other components of the system. The group recognized that there is a general need to understand the system as a whole; however, they tended to think to look at the system as a whole it would be impossible to make the linkages between tidal creeks and fisheries.
- The group talked about how a sentinel species approach would provide the ability to establish a 'poster child' for tidal creeks. We also discussed that a 'sentinel species' was not intended to capture the entirety of tidal creek ecosystem dynamics but if selected carefully could improve how we understand or assess the health of a system. It was also acknowledged that some of the food web dynamics would/could be built into this 'sentinel species' approach since the prey species (e.g., mummichog, grass shrimp) would help support the production of the 'sentinel species'. Lastly, the group acknowledged that a 'sentinel species' approach would be helpful from a public outreach perspective.
- The group tended to agree that we couldn't study everything in the system but rather needed to choose a select few species that would likely have strong linkages to tidal creeks to help us determine the health of the creek and for use in education and outreach efforts.
    - The suite of species could be selected for looking at different outreach purposes including recreational, commercial, climate change, et cetera. Species could be selected based in part on how they use the system.

    - It would be important to include a prey species in the suite. Grass shrimp and killifish could be examples. It would also be important to think about trophic levels when determining the suite.
    - It was suggested that we could look at shrimp, blue crab, red drum, snook, and spotted sea trout. Give consideration to which species have EFH designations.
- Fisheries data does not evaluate plankton. Planktonic information is needed.
- Understanding of the effects of currents on larval dispersal.
- Need for preliminary classification of the data (identified below) to enhance the ability to sort the data.

What are the available data sources?

- There are multiple centralized database efforts underway, including:
    - Governor's South Atlantic Alliance Ecosystem Group → contact Patrick Geer (GA Department of Natural Resources) or Amber Whittle (Florida Fish and Wildlife Conservation Commission)
    - South Atlantic Fishery Management Council → available at SAFMC.net or through Roger Pugliese (South Atlantic Fishery Management Council)
- These datasets include data from the states (like program 120 – juvenile fish survey) which defines catch per unit effort. These data are collected through several different methods including gill-net, trammel net, trawl data. But stock assessments are very state specific. Coming up with spawning and recruitment data and correlation is difficult.

What are the research and action strategy needs?

- Research needs were lumped into three general categories:
    - Compile and analyze existing data
        - Utilize existing efforts under Governor's South Atlantic Alliance and South Atlantic Fishery Management Council.
        - Write a grant to get resources to support the analysis of this data, including looking at how the data has changed and how the systems have changed.
        - Analyze the linkages of fisheries to tidal creeks under existing data.
        - Identify data gaps to inform future research needs.
        - A first step should be to determine what is known in all four states.
        - Also need to get a clear understanding of the terminology used in different states for their management areas. This will help develop common terminology for sampling protocols and understanding data results.
    - Establish a general scientific understanding of the linkages of tidal creeks to food webs to fisheries.
    - Focus research efforts on a group of sentinel species to include shrimp, blue crab, sea trout, red drum, and snook (others?).

- In addition, the following research needs were identified:
    - Need a classification system for creeks so we can understand where data is collected and how it might apply to other systems (similar or not). Having information about the classification and health of a creek might help with stock assessments.

- Need spatial coverage and larval data. Note: Florida is matching data with creek size and information cataloging data. Larval nekton can now be identified to genus and species at zoosphere stage.
- Need to understand more about currents and how they impact fish in a tidal creek system, such as for larval transport.
- Note: 1. Make sure hydrology focused actions recognize this particular need, especially as models are developed. 2. Hydrology needs to be connected to sampling. 3. We are beginning to understand that nekton are not as passive as we once thought in their movements.

What are the management, education and outreach needs?

The following management/education/outreach were identified.

- A management need for each of the states is to clearly define their habitat designations. As an example, NC defines a habitat as 'primary nursery habitat' to provide some level of protection to that area. It would be important to understand these designations and their translation across states.
- In some states and for some fisheries, recreational fisheries depend on stock enhancements (in tidal creeks). There is a general need to understand the survival of these stocks to assist in prioritizing locations of stock enhancements in the future.
- Recreational and commercial fisherman might be used to assist in collecting fishery data. They general go to where the fish are located. Where can they plug in and how can we get information from them? One effort could be to create a smart phone app to assist in collecting such data. This would also help build relationships between the user and the 'manager'. There is also the "Rectext" work being done in NC and other states.
- Consider how citizen scientists can be used to help collect information.
- The general public seems to be fairly educated about fisheries, but not the connection of land use impacts on fish → this should be a focus of education and outreach efforts
- The information gained could assist in linking tidal creeks to state and/or federally managed species which could allow tidal creeks to be designated for greater protection (e.g., essential fish habitat)
- Outreach and education efforts could build off of the sustainable fisheries movement. Efforts could target the chefs on a volunteer basis. These efforts could promote locally harvested, sustainable fisheries. In addition, these efforts could help to link the fisherman and the tidal creek to the chef and/or restaurant. The restaurant / chef could provide information about the tidal creek the food was harvested from and/or the story of the fishermen.

  Efforts could also build off of the 'stop light assessments' that the fishery management councils currently use to convey fishery data. A stop light assessment for creeks could be used.

Appendix A – Tidal Creek Workgroup that met in Charleston in November 2013

FEDERAL AGENCIES

Carl Trettin	US Forest Service
Lisa Vandiver	NOAA Restoration Center
Brooke James	USDA Forest Service
Pam Kylstra	NOAA

STATE AGENCIES

Jim Gregson	NC DENR Division of Water Resources
Diane Reid	NC DENR Division of Water Resources
Dr. Peter Kingsley	SCDNR Marine Resources Research
Sarah Latshaw	SCDHEC-Office of Coastal Resource Management
Denise Sanger	SC DNR Marine Resources Research Institute
April Turner	SC Sea Grant Consortium
Rick DeVoe	SC Sea Grant Consortium

UNIVERSITY (Research, Teaching & Extension)

Gloria Putnam	NC Sea Grant
Mike Burchell	NC State University
Timothy Callahan	College of Charleston
Dan Hitchcock	Clemson University
Dianne Greenfield	USC Belle Baruch Institute for Marine and Coastal Sciences
William Savidge	Skidaway Institute
Barbara Doll	NC Sea Grant