Southeast Tidal Creeks Summit 2011 – Summary and Identified Research, Management and Outreach Needs

Prepared By:
Denise Sanger, Ph.D., Associate Marine Scientist, South Carolina Department of Natural Resources
Gloria Putnam, Coastal Resources and Communities Specialist, North Carolina Sea Grant
Barbara Doll, Ph.D., P.E., Water Protection and Restoration Specialist, North Carolina Sea Grant

Acknowledgements

The organizers would like to thank the Summit presenters and the participants, who provided written and oral comments during the meeting and follow-up survey responses. We also wish to thank Lisa Vandiver, Sarah King, Anne Blair and Leigh Wood for their excellent and very thorough note taking at the Summit, which helped significantly in preparing this summary of discussions. Thank you as well to Pam Kylstra, NOAA Coastal Services Center, for her help and guidance with planning and implementing the facilitated discussion sessions at the Summit. We would also like to thank the NC State Biological and Agricultural Engineering Department, UNC-Wilmington, and Clemson University for their assistance with summit planning efforts, as well as The Coastal Society and the GA, NC, and SC Sea Grant programs for their sponsorship of this event.

UNC-SG-14-02

Southeast Tidal Creeks Summit Background

North Carolina, South Carolina and Georgia's Sea Grant programs partnered to organize a Southeast Tidal Creeks Summit 2011 that was held on December 5 and 6, 2011, in Charleston, South Carolina. The Summit was designed to provide a forum for exchange of information among scientists, resource managers, local governments, environmental groups and concerned citizens on the status of tidal creeks in the southeast and to identify research, management and outreach needs to better protect, manage and restore these valuable ecosystems. The Summit was a success with 140 pre-registered attendees representing Georgia, North Carolina and South Carolina, as well as a few from Maryland and Florida. Attendees primarily represented federal, state and local governments and academic institutions. A few private consultants and non-profit organizations were also represented. The Summit featured 19 invited speakers in a series of sessions and discussion periods addressing research, management and restoration of tidal creeks. Numerous discussion sessions were facilitated by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center. The agenda, program and most of the oral and poster presentations are available at the following website: www.ncseagrant.org/2011tidalcreeksSummit.

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).

The goal of this document is to provide an overview of the state of tidal creek research and management and ecological threats as presented at the Tidal Creeks Summit and to relate the research, management, restoration and outreach needs as presented at the Summit in verbal or written comments at the event and in a follow-up survey.

Summit Approach

The Summit was organized as a series of sessions and discussion periods addressing research, management and restoration issues. The first session included a series of invited presentations providing an overview of tidal creek ecology and current knowledge about the influence of coastal development, hydrography and climate change on tidal creek systems. This session was followed by a facilitated discussion focused on the identification of research needs. The second session was focused on the management of tidal creeks and included the perspective of representatives from state management agencies in North Carolina, South Carolina and Georgia and the National Oceanic and Atmospheric Administration (NOAA). A facilitated panel and group discussion to identify management needs followed. The third session was focused on case studies highlighting various management efforts related to tidal creeks which included

stormwater programs, Geographic Information System (GIS) mapping efforts as well as natural resource protection and restoration. The final session was focused on restoration efforts currently underway as well as a discussion on future restoration needs. Presentations and discussions were supplemented with a poster session that included 25 presenters. The posters highlighted specific research, management and restoration studies occurring in the Southeast.

There is currently a lack of social science and ecosystem services information related to tidal creeks in the Southeast. To highlight some of the cultural and social uses of tidal creeks, Charles Seabrook, author of *The World of the Salt Marsh*, was our luncheon speaker. Mr. Seabrook is an environmental journalist with *The Atlanta Journal-Constitution* and a native of Johns Island, South Carolina. He has spent the last 25 years exploring a wide range of issues regarding tidal creek and salt marsh habitats including the cultural, social and ecological importance of these habitats.

While at the meeting, all attendees were asked to provide input on the current state of tidal creek research (n=56), management (n=51) and restoration (n=39), as well as integration/additional thoughts (n=46). In addition, attendees of the Summit were asked to complete an on-line survey (n=66) after the meeting to seek additional information about potential future directions. This information provided an avenue for all Summit participants to engage in the meeting and provide input even if they were not making a presentation and were not comfortable providing their input in a public forum.

Importance of and Issues Facing, Tidal Creek Ecosystems
(Summarized from presentations by Holland, Mallin, Sanger, Morris, Blanton and Kriesel)

Southeastern estuaries can be separated into two broad groups or classes: bar built or lagoonal estuaries and riverine estuaries. Bar-built, or lagoonal estuaries, form in the area behind sandy barrier islands and usually drain relatively small watersheds and relatively low freshwater inflows. The exchange of water between the bar-built estuaries and the sea occurs through tidal inlets and astronomical tides and winds are the major forces controlling water circulation and water height. Extensive salt marshes and tidal creek networks develop behind the barrier islands where wave action is reduced.

Riverine estuaries are usually one of two types. One type arises in the piedmont, has extensive watersheds, large freshwater inflows and wetlands along the fringing shoreline and in the river delta. Another type arises in the coastal plain, has a gentle slope and extensive wetlands along its lateral shores.

In North Carolina, South Carolina, Georgia and the northern parts of Florida, the primary habitat associated with tidal creeks is marsh (salt and freshwater). However, in southern Florida, salt marsh is replaced by mangrove habitat. Overall, salt marsh and mangrove tidal creek wetland networks are similar with regard to their importance as conduits between the terrestrial and marine environments, as well as their ecological values.

The general, focus of the Summit was on tidal creek and salt marsh ecosystems (herein referred to as just tidal creeks) from around the Albemarle/Pamlico Sound in North Carolina to Jekyll

Island in Georgia. The tide ranges from .6 to 2.7 meter(s) in these areas. Freshwater tidal creeks are also found in this area; however they were not a major focus of this Summit. Within this geographical area, tidal creeks can broadly be classified into creeks that drain some upland area and creeks that drain only salt marsh. Tidal creeks draining salt marsh environments are generally characterized by homogenous physiochemical conditions and biological characteristics throughout their length. However, the spatial variability in physiochemical and ecological characteristics along the length of a tidal creek draining significant amounts of uplands is great. Headwater areas of upland creeks have a high degree of connectivity with terrestrial environments, highly variable freshwater inflows and lower volumes of water in comparison to creek regions near the estuary which maintain a larger volume of water during all tidal stages.

The transport and retention of materials within tidal creeks and the associated salt marsh 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. There is currently no 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.

The productivity, chemistry and morphology of salt marshes naturally respond to changes in relative mean sea level and tidal amplitude (i.e. hydro-period or the amount of time the marsh is covered by tidal waters). This response can be positive or negative depending on the system. The feedback mechanisms maintain a dynamic equilibrium with mean sea level. However, there are limits to this feedback and ability for the marsh to keep pace with the rising sea level. As the rate of sea level rise (SLR) increases, the equilibrium elevation decreases and the water depth increases. There is a threshold rate of SLR or a tipping point beyond which stabilizing, negative feedback switches to destabilizing positive feedback. The Intergovernmental Panel on Climate Change current predicted rate of SLR due to climate change is 15 to 23 inches by the 21st Century. However, that is a conservative prediction with others predicting SLR of up to 55 inches over the same time period (Rahmstorf 2007). It is unknown if the current level of SLR will result in the reaching of a tipping point.

One of the major threats to tidal creeks is from stormwater runoff associated with 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. Current stormwater runoff mitigation practices often reduces the rate of runoff but does very little to reduce the volume of runoff. Research clearly shows high levels of watershed development are associated with increased concentrations of fecal indicator bacteria, nutrients, chemical contaminants, and turbidity, more variable fluctuations in salinity, and decreased quality of the macrobenthic and nektonic communities as well as oysters. In addition, eutrophication has been observed in tidal creeks in association with coastal development. 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.

Limited socio-economic information is available on the consequences of impairment to the environmental quality of tidal creek systems to coastal communities. One socio-economic study in Georgia evaluated the coastal real estate market using GIS tools and econometric models with a focus on three Georgia counties (Chatham, Glynn and Camden). Similar to other southeastern coastal areas, Georgia has experienced high population growth rates with sprawl and construction of lots of roadways. In this study, a hedonic price analysis was used to explain differences in property economic value based on a range of factors including square footage, age, lot size, proximity to open space or parks, view shed, access to water and presence or absence of a dock. Parks and open space were found to increase housing values resulting in potential trade-offs between higher value and more lots. Some studies show that conservation design can include more lots due to smaller lot sizes and different configurations as well as reduction in stormwater infrastructure (i.e., no giant ponds). Examining the real estate transactions between 2004 and 2006 revealed that proximity to the marsh is important for increasing property values: a marsh view adds $12,000, water access adds $80,000 and a dock adds another $24,000. These relationships were stronger with close proximity (100 meters or closer).

In summary, 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. Property in tidal creek watersheds is highly desirable as places to live. Because the tidal creeks and their adjacent wetlands are located at the interface of terrestrial, freshwater and marine ecosystems (Figure 1), they are important conduits for energy and material exchange, including pollutants with 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. These changes include increases in the volume and rate of stormwater runoff and associated pollution loads, hydrographic modifications and dredging, and loss of habitat from erosion and sea level rise. Impairment to tidal creeks can be grouped into impacts from: (1) human use of the land, (2) effects from human use of waterways, and (3) climate change. These impacts are being mitigated through a variety of means including improved land-use decisions, regulatory permitting and enforcement actions and increased public knowledge of the value of tidal creek systems. How much and what types of impacts tidal creeks can absorb from coastal development is currently unknown. At some point, however, a threshold may be crossed and creeks will no longer provide the diversity of free ecosystem services to coastal communities. It is therefore critical to identify the ecosystem services that tidal creeks provide coastal communities and determine which services have been lost or could be reclaimed.

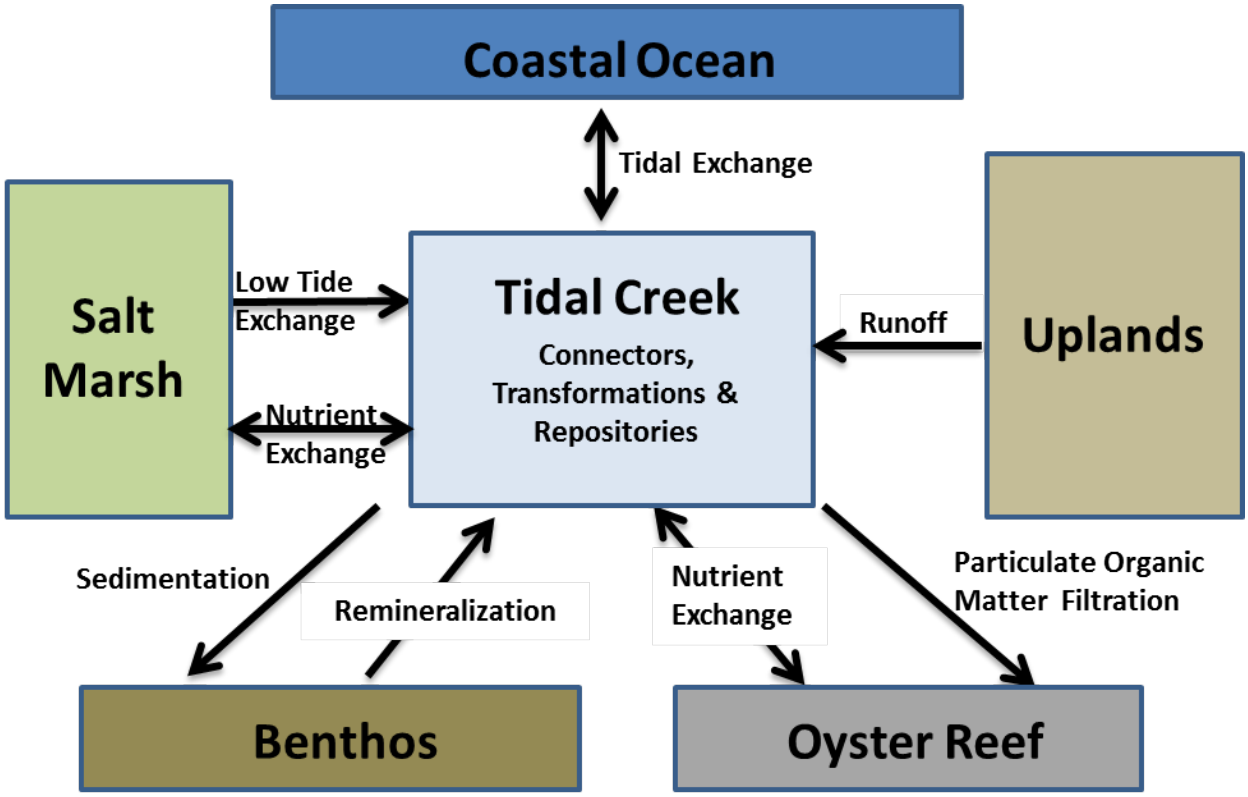

Figure 1. Schematic of tidal creek connectivity as presented by Holland (modified from Childers et al. 1993).

Perspectives on State, Federal and Local Tidal Creek Management

(Summarized from presentations by Gregson, Neale, Chestnut, O'Rourke, Wilber, Ahern, Doll, Prete and Teel)

States in the Southeast appear to manage tidal creeks in much the same way as the other water bodies in their jurisdictions and in accordance with federal mandates and standards. Regulations focus heavily on stormwater runoff, water dependent structures such as piers and docks and dredging. North Carolina, South Carolina and Georgia have made progress in recent years with mapping shorelines and attributes such as stabilization methods and presence of structures. This information can help show the cumulative effects of development and permitting activities on coastal communities, residents and the environment. Additional mapping and resource monitoring is, however, needed by the management agencies.

The North Carolina Department of Environmental and Natural Resources (NCDENR) is the primary agency responsible for coastal zone management, water quality and natural resources in North Carolina. NCDENR is working on a wide range of activities related to tidal creeks, including a Total Maximum Daily Load (TMDL) Implementation Plan that has been developed for the Lockwood Folly River. The goals of the plan are to reduce stormwater runoff from 94% of existing development, prevent runoff from new development, reduce sources of fecal coliform bacteria pollution and conduct education and outreach. There were also amendments made in

2008 to North Carolina's coastal stormwater regulations for the 20 coastal counties making the rules more stringent. These regulations include limitations on percent built upon area (i.e., impervious cover).

North Carolina is also currently working to delineate estuarine shorelines in the state to quantify the type and length of various shoreline types. This includes an inventory of piers, docks and shoreline stabilization techniques. The inventory will provide three layers of data: estuarine shoreline and classification, shoreline stabilization and classification, structures over the water and classification. The data should help the state understand cumulative effects of development and the effects of permitting activities on residents and environment.

The South Carolina Department of Health and Environmental Control (SCDHEC) is the primary agency responsible for coastal zone management (Office of Ocean and Coastal Resource Management-OCRM) and water quality (Environmental Quality Control-EQC) in South Carolina. South Carolina has 2,800 miles of shoreline. SCDHEC-OCRM issues permits for docks with limitations on size and placement. Square footage requirements are based on creek size. Applicants must show there is erosion and that marsh grass is inadequate as a buffer in order to get a bulkhead permit.

SCDHEC-OCRM has conducted estuarine shoreline mapping for land uses, water uses and access points. There is currently a lack of information on armoring shorelines and it is believed that more armoring will result in a loss of intertidal area. The office has also worked with the Town of Bluffton to develop a waterbody management plan for May River. The plan will make water quality information accessible, catalogue access points, conduct a flora and fauna inventory, provide for education and outreach, develop stormwater regulations and includes a land acquisition component.

For permitting purposes, SCDHEC-EQC regulates tidal creek water quality in the same way as any other water body in South Carolina. The water quality monitoring program has fixed monitoring sites at the mouths of 10-digit HUCs (hydrologic cataloging units) which are sampled bi-monthly, and a separate probability-based monitoring component, where new monitoring sites are selected annually and sampled monthly for one year. All monitoring sites are sampled for nutrients, fecal contamination, metals, conventional parameters (e.g. turbidity, five-day biochemical oxygen demand) and field measurements (e.g. dissolved oxygen, pH, salinity, water temperature). For the probability component, SCDHEC selects 15 tidal creek sites and 15 open water sites annually which also form the basis for the South Carolina Estuarine and Coastal Assessment Program (SCECAP). SCECAP is a joint program with South Carolina Department of Natural Resources with additional sediment and biological quality monitoring. Since 1999, SCECAP has sampled over 500 tidal creek and open water sites. Continued support and collaboration between SCDHEC and the South Carolina Department of Natural Resources is critical to maintain this monitoring program. To change regulations in South Carolina, a series of steps are required including stakeholder meetings, public hearings, board approval, legislative mandate and U.S. Environmental Protection Agency approval.

The Georgia Department of Natural Resources, Coastal Management Program (GADNR-CMP) is the coastal zone management, natural resources and water quality agency in Georgia. Georgia has 11 Coastal Zone Management counties. The program issues marsh and shoreline protection permits, revocable licenses, and waterbottoms leases. GADNR-CMP collects nutrient samples in

shellfish growing areas and conducts beach monitoring on Tybee, Jekyll and St. Simons Islands weekly for health advisories. The GADNR-CMP shellfish program monitors fecal bacteria levels in shellfish growing areas for commercial and recreational harvest. They also provide technical assistance on topics including wetlands restoration, low impact development and coastal hazards. GADNR-CMP is planning, designing and constructing living shoreline project to test efficiency of techniques. The Coastal Resources Division (CRD) has also completed updates to the National Wetland Inventory (NWI) for the six coastal counties. These updates are available on the Fish and Wildlife online mapper at www.fws.org. In addition to the NWI updates, CRD produced NWI+, the functional assessment compatible with NWI polygons. CRD also produced an impacted wetland inventory that includes all tidal wetlands. They also participate in the National Wetland Condition and Coastal Assessment surveys to identify the quality of wetlands and coastal habitats nationwide. GADNR-CMP is also investigating sudden marsh dieback. Preliminary results indicate the dieback is a response to drought conditions. Dieback sites show good recovery when droughts dissipate but it is a continual problem in Georgia.

On the federal level, numerous pieces of legislation exist that protect tidal creek ecosystems including the Clean Water Act, Fish and Wildlife Coordination Act, Magnuson-Stevens Fishery Conservation and Management Act, Marine Mammal Protection Act and Endangered Species Act. A number of agencies are involved in both permitting and commenting on projects that impact tidal creeks and salt marshes. Permits are issued by both state (water quality and coastal zone certification) and federal authorizations such as the U.S. Army Corps of Engineers (ACoE), with assistance and comments by the U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (FWS), National Oceanic and Atmospheric Administration (NOAA) and state natural resource agencies. Decisions to issue permits are based on water quality standards and public interest.

Despite recognition of the importance of wetlands (tidal creeks are an important component of coastal wetland systems), there is still a significant decline in the amount of wetlands overall. One tool in combating the decline is the Essential Fish Habitat (EFH) designations provided by NOAA. Greater weight is given for protection as species presence, concentration, growth, reproduction and survival, fisheries recruitment are documented. On the EFH scale, tidal creeks are level 3 of 4 for shrimp. This designation means that tidal creeks are considered to be critical for shrimp growth, reproduction and survival. Currently, scientists are working to describe growth, reproduction and survival of flounder in more detail to lift the species to a higher EFH listing. Current EFH designation for flounder is now limited to only "presence."

It is hard to understand indirect impacts to tidal creeks from federal and state permitted activities as there are cascading effects from human activities on adjacent systems. In addition, there are many factors that influence where development or permitted activities occur including: development pressure, economy, miles of shoreline, activities requiring permits, etcetera. The strength of the federal permitting process is however linked to the strength of the state permitting process. And states with strong coastal programs seem to have less development at the coast. Georgia's Coastal Marshlands Protection Act for example, helps protect land. To address adverse effects of permits, mitigation requirements can be used. For example, approval for extending Folly River Bridge over a creek was contingent upon monitoring and mitigation of quantifiable impacts. Another example is the Savannah Harbor Expansion Project which did not allow expansion of the tidal signature that resulted in reduced dissolved oxygen in tidal creeks, unless it was mitigated.

The southeastern region has experienced a broad multi-decadal as well as short-term degradation and decline of tidal creeks and wetlands. Federal permit decisions are based largely on water quality standards and public interest. Recognizing and documenting the value of tidal creeks as Essential Fish Habitat can elevate the level of federal protection they receive. Like state management agencies, federal programs find it hard to understand the indirect impacts to tidal creeks from projects impacting adjacent systems. Mitigation is recognized as a way to potentially offset tidal creek and marsh degradation.

Management of tidal creeks is also being conducted at the local level through a wide range of different activities throughout the Southeast. In particular, four local case studies were presented to highlight these types of activities.

Beaufort County, South Carolina, is applying new stormwater management approaches to tidal creeks at the county scale. Currently in Beaufort County, 85% of shellfish waters are open; however, Beaufort County has had to address flooding issues and recent shellfish closures in the upper reaches of the May River have resulted in an emphasis on runoff volume controls. Beaufort County has adopted a two-step process for stormwater volume control. Step 1: New development has to control hydrology up to 1.95 inches (95% storm event) to the same as pre-development. Step 2: on-site volume controls. Beaufort County also developed a web-based program www.bcgov.net/stormwater for homeowners to apply BMPs for their property according to the stormwater criteria so an engineer was not required to determine specific site requirements.

GIS tools are being linked with water quality modeling to develop management options for the Lockwoods Folly River in coastal North Carolina. A watershed plan was also developed for the Lockwoods Folly River in Brunswick County, North Carolina, in response to rapid coastal development in the watershed. Currently, 55% of the river is closed to shellfish harvest and another 45% is only conditionally opened. The watershed plan was created using information from U.S. EPA's pollutant loading model, BASIN. The model estimated loads of fecal coliform and nitrogen that would result from several development scenarios. Model scenarios evaluated the effectiveness of various percentages of Low Impact Development (LID). Target areas for best management practices (BMPs) retrofits including bioretention swales, constructed wetlands and wet detention ponds were also identified. The model runs indicated that pre-development status could not be achieved with a full build-out of residential development regardless of best management practices used and to adequately mitigate for the impacts of coastal development all impacts must be addressed through green development strategies. Monitoring and data collection found the highest fecal coliform counts in runoff from forest and open areas.

The North Carolina Coastal Federation, the City of Wilmington and Withers & Ravenel are working together to integrate LID in watershed management strategies to reduce bacterial pollution in impaired coastal waters through a Grey to Blue Program for Wilmington, N.C. The program was adapted from Portland's Gray to Green project, substituting blue for tidal creeks. They are currently focused on Bradley Creek (23% impervious) and Hewlett's Creek (19% impervious) watersheds, which are 85% developed with limited opportunity for mitigation/prevention of impacts. The program focuses on reducing the delivery of stormwater runoff through BMP installation and voluntary disconnection. The project relies on the LID atlas which is a graphical, web-based, geo-referenced GIS database being used to evaluate, catalogue

and prioritize retrofit projects, including volume reduction efforts. Models are being developed to show changes in the hydrograph over time with changes in location of the boundary of shellfish closures in the creeks. The goal of the project is to retreat the line of shellfish closure back up the creek through restoring hydrology. Retrofit projects will include sustainable city street design, LID and a voluntary stormwater disconnect program.

The Metro planning commission in Chatham County, Georgia, has established a resource protection committee that includes non-governmental organizations and local governments to develop a model resource protection ordinance for natural, historical and cultural resources. So far, some land acquisition and buffer projects have been implemented. The ordinance also includes a coastal stormwater supplement that transitions from traditional stormwater management to LID techniques (i.e. rain gardens, swales, green roofs, eliminating cul-de-sacs, site fingerprinting). The supplement is now mandatory in the county. They have also developed a roadmap for adapting to coastal risks identified by the NOAA coastal services center including flooding, erosion, sea level rise (SLR) and storm surge. However, the risk plan is currently on hold since the council is comprised of sea level rise skeptics. Chatham County is also working on a Unified Zoning Ordinance to protect natural resources, creeks and wetlands which calls for 35 feet buffers/setbacks. The county works closely with the Skidaway Institute as support and communication with researchers are key to ensuring good information, making informed decisions and acquiring data to show council members.

Perspectives on Restoration and Mitigation of Tidal Creeks
(Summarized from presentations by Burchell, Sherwood and Hitchcock)

Tidal creeks restoration could encompass a wide variety of approaches and activities such as outreach and education, legislation, land-use changes, water management, pollution abatement, on-the-ground reconnection for tidal function and/or strategic tidal creek and marsh creation. Marsh creation involves building marsh in areas that are conducive to providing ecosystem services. Marsh restoration has been practiced for over 30 years, so there is a good opportunity to learn from what has been done. Much less has been done in the field of tidal creeks restoration. As such, there is a need for science-based restoration. Through research, benefits of restoration can be maximized by increasing our understanding of these systems. Because of bi-directional flow and rapid temporal changes in tidal interactions, intensive monitoring of these systems is critical to improving our understanding.

Tidal creeks restoration and strategic restoration designs should be intended to maximize ecosystem services (e.g., improve water quality, carbon sequestration). An example of a large-scale tidal creek restoration project is the North River Farms project located in Carteret County, North Carolina. The North Carolina Coastal Federation purchased 4,000 acres of agricultural land for restoration and to provide a buffer from the adjacent cropland. The project, which was intended to reduce agriculture-based pollutant exports, created both tidal creek and marsh ecosystems that integrate into the existing surrounding marsh. The restoration has been intensively monitored and researched for hydrology, tidal stream habitat, water table and water quality.

Large scale restoration initiatives focused on tidal creeks are rare. One of the few in existence is the Tampa Bay Estuary Program (TBEP). Tampa Bay is dominated by mosquito ditches, mangroves, short tidal creeks and agriculture. Extensive long-term monitoring focused on larger water bodies in the Bay indicated there are different types of creeks which vary by salinity, abiotic and biotic measures. These systems also experience pronounced changes in algal production and benthic composition both seasonally (climate-driven) and spatially. Abiotic indicators of eutrophication and pollution were found to increase with increasing development. Florida has developed models of hydrology, pollutant loadings (nutrients) and trophic transfer of these impacts. Key management actions that have been taken thus far are intended to promote connectivity, reduce flashiness, promote nutrient flux and improve fish movement. In 2010, TBEP began a salinity barrier removal feasibility project. TBEP also recognize the need to conduct public outreach and education that demonstrates the unique nature of Tampa Bay tidal tributaries.

The mitigation of stormwater impacts is a complex issue. 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. Encouraging the infiltration of stormwater runoff is complicated by shallow groundwater elevations, especially in winter during the vegetative dormant season. Evapotranspiration, however, can have high seasonal influence on the water balance of these coastal watersheds; thus the role of vegetation, also called green infrastructure, is critical to stormwater runoff volume reduction in many ways. Currently, the common method for predicting watershed discharge under pre- versus post-development scenarios employs a curve number (CN) approach based on topography, soils and land use. The influence of groundwater position on runoff flows and volumes has been well documented; therefore the selection of the appropriate CN is highly dependent on water table position. For example, if the water table is near the surface, the appropriate curve number to be used for runoff prediction would approach the equivalent to that of an impervious surface. Stormwater runoff can be reduced using LID practices such as rain barrels, cisterns, green roofs, pervious surfaces, wetlands and rain gardens. However, there are limitations in certain coastal settings. For example, with a shallow water table, insufficiently treated stormwater could infiltrate and contaminate groundwater. Minimal soil storage due to shallow water table elevation can limit many LID practices, while an under-drain may also not be practical due to the lack of sloping topography. Investigations are now being conducting into the performance of infiltration-based practices in shallow groundwater scenarios. In these coastal areas, a treatment train – or series of stormwater control measures (SCMs) – that enhances rainwater storage, collection and reuse (rainwater harvesting) and encourages evapotranspiration (wetlands) may provide the best solution for the management of coastal stormwater volumes and flows. Furthermore, maintenance of SCMs is critical to guarantee more effective water quantity and quality management performance over time.

Tidal Creeks Summit: Identified Needs

The following sections highlight the information gathered from the Summit participants regarding what they saw as the research, management and restoration/mitigation needs related to tidal creeks. Additional details about this information was gathered can be found in Appendix A. A common theme identified during each discussion of needs was the overarching necessity to improve integration and communication among all stakeholders. Stakeholders include the research scientists, managers (e.g., coastal, local and fisheries) and the general public. Communication among the researchers and managers is essential for good decision making and future research efforts; however, a fundamental change in how we live on the land is needed, which will require education and outreach at the public level to identify this habitat as one deemed worthy of protection. There was also a general sentiment that we need to integrate more social science into research and outreach.

Research Needs

Inventory and Classification - An inventory of tidal creeks and watersheds based on a developed classification scheme needs to be conducted for the region, by state. This could include GIS layers with water quality, watersheds, etc. A classification scheme for tidal creeks is needed as a context for identifying the functions they support and services they provide. This system could potentially be modeled on an existing recognized system (e.g. order, surrounding land use, salinity, vegetation type, pattern of tidal asymmetry) and would provide a framework for regulatory decisions and management needs. Perhaps a baseline estimate of tidal creek numbers and lengths could be estimated using remote sensing technologies and monitored over time to detect changes (e.g., marsh area response to sea level changes).

Ecosystem Services - Tidal creek ecosystem services need to be quantified and their economic and societal value estimated. For example, the financial value of nutrient removal provided by marshes and tidal creeks needs to be established. Costs of treating and controlling stormwater flowing into tidal creeks might be compared to the economic effects of beach closures, shellfish closures and swimming restrictions to get an estimate of their value. There needs to be a broader societal understanding of the benefits of tidal creeks and the underlying economic values that are not apparent. What is the capacity and value of tidal marshes to sequester carbon? And at what point is a tidal creek basically "lost" in terms of providing significant ecosystem services?

Ecological Functioning - Tidal creeks cannot be understood as entities that are independent of the surrounding wetland and uplands. Therefore ecological interrelationships between tidal creeks, vegetated salt marsh and other intertidal and subtidal habitats need to be studied. The characteristics of tidal creeks that allow certain systems to perform as nursery or spawning areas for fish needs to be researched. For fresh and oligohaline tidal creeks and tidal canals, additional information is needed on their basic biological communities and chemistry, anthropogenic pollutant impacts and sensitivity to development pressure. Improved understanding is also needed of the function of tidal creeks as they are positioned throughout the landscape. For example, what species and age classes of those species are using inland creeks versus high salinity creeks near tidal inlets; what are the sediment and chemical functional differences between those creeks? In-stream water quality, particularly nutrients, needs to be related to

instream biological responses (i.e. chlorophyll, algae) and these dynamic water column parameters need to be connected with the more static and stationary response variables. Our knowledge is about the organization of tidal creek communities, food web structure, behavior and growth of key species and how anthropogenic changes likely impact them, is inadequate. Management implications exist for all of this information.

Secondary and Cumulative Impacts - Secondary and cumulative impacts of projects and erosion control structures such as bulkheads along tidal creeks and estuarine shorelines needs to be assessed. 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, including restrictions on shoreline armoring.

Stormwater Best Management Practices - Many questions exist about the effectiveness of current stormwater treatment strategies, including how effective these systems function under real-life situations and management needs. Are current treatment technologies working and are they sufficient for protecting tidal resources? Are the current strategies that retain water onsite (e.g., ponds, rain barrels, pervious pavers) impacting the health of estuarine ecosystems and organisms by changing hydrology? How important are the various water inputs (rainfall, residential irrigation) on stormwater runoff and tidal creek hydrology, health and function? Performance data for best management practices needs to be collected specifically for low country soils and habitats. Stormwater runoff mapping and hydrology need to be region specific (e.g., Lowcountry). Predictive models have characteristic runoff regimes and strategies for managing stormwater runoff through engineered systems.

Stormwater Ponds - What is the impact of algaecides, such as copper sulfate, on stormwater ponds and ultimately tidal creek nurseries?

Buffers/Setbacks - What are effective buffer widths and setbacks for development and stormwater treatment ponds to protect tidal creeks, according to habitat type and vulnerability? What are ways to get local and state governments to adopt/institutionalize buffers?

Monitoring - Standardized monitoring protocol is needed to determine the impacts from permitted projects and what impacts should be monitored, including direct or indirect. Monitoring is essential for evaluating trends.

Pollutant Loadings and Flushing - What are the actual impacts that pollutants associated with impervious cover have on the health and viability of salt marshes and estuarine organisms? For nutrient loading, what are the nutrient forms and types and rates of inputs to tidal creeks? A baseline loading rate or expected in-stream concentrations for fecal coliform in forested areas that are minimally impacted should be described as it would help to identify targets for restoration efforts and regulations. Are there better indicators that can be used (perhaps an indicator that is exclusive to humans)? Is there a human way? What is the distribution of pollutants in tidal, channelized systems (i.e., swashes and ponds) and how long does it take to flush an episodic pollutant loading event? Do episodic events build upon one another? Can transport and retention models be created to trace the location of point or nonpoint source pollution? What are the impacts of agricultural runoff on tidal creeks? What are the impacts of stormwater/non-point source runoff on organisms, particularly the ones people care about (e.g.,

oysters, fish), including potential effect on survival and growth and particularly in the early life stages? What are the sub-lethal effects of anthropogenic inputs to aquatic tidal creek organisms?

Hydrology and Models **-** Hydrologic processes, specifically fresh water inputs and mixing with tidal inputs are not well documented and simulation tools are not available. What are the flow dynamics of tidal creeks? It is not trivial to measure tidal creek discharge given various types of geometry and flow timing. It would be helpful to have standard operating procedures to do this along with guides on how to generate net flows and discharge from instantaneous data. Development of tidal flushing models is needed, including for wind-driven systems. We also need to better understand the 1) connections between groundwater and tidal creek hydrology/condition, 2) the exchange of nutrients and contaminants between tidal creeks and adjacent waters, 3) the influence of altered drainage patterns on tidal creek ecosystem function and 4) whether short flashy storm events affect fisheries.

Sedimentation - We need to know what role it plays in tidal creek health and how changes in tidal hydrology affect sediment dynamics in tidal creeks. We also need to learn how sedimentation rates, changes in channel depths, etcetera, occur in tidal creeks that have relatively undisturbed uplands. And also what levels of sedimentation rates, movement and circulation are necessary to prevent sediment overloading and at what point is it warranted to implement watershed controls and/or dredge.

Indicators - Fecal bacteria, viruses and protozoans reside for extended periods in sediments – survival and proliferation of specific pathogens and potential re-suspension is poorly studied and needs additional research. This information is important to managers and public health officials. Learning the bacteriological water quality trends of shellfish harvesting areas over at least a couple of decades would also be useful.

Anthropogenic Impacts - Better understand impacts of working lands on water quality (e.g., nutrients, pesticides, herbicides) – including timber lands on uplands and forested wetlands, no-fill lands like hayfields and pasture and crop lands. What are the impacts of prescribed burning? How do physical changes including on land and in water (e.g., dredging) impact chemical/biological response? Do we even understand the state of affairs now let alone as things change? Gaps exist in connecting biology and function to pollutant concentration or loading thresholds. There is a need to identify where tipping points occur to guide future planning and legislation for development and mitigation activities. Better understanding of cumulative impacts of multiple small-scale projects (boat ramps, docks) and how to quantify those impacts. Policy options for protecting and restoring tidal creeks need to be researched for their effectiveness.

Climate Change - To what extent can tidal creeks sustain the changes resulting from climate change and how quickly can they adapt? We need to better understand the potential effects of sea level rise on riparian zone processes of forested wetlands and how the loss or conservation of forested freshwater wetlands impacts brackish and salt-water habitats. Is there increased flooding due to loss of trees in a wetland system? How will septic systems be impacted by rising sea levels and how will this in turn affect tidal creeks?

Marsh Dieback - What is causing marsh dieback and will the incidence and extent change with sea level rise and changes in tidal amplitude? Is there a relationship between drought that kills spartina and marsh dieback?

Cultural - A greater understanding of the coastal cultural issues and values is needed to improve what research is conducted and how to relay it to target audiences most effectively.

Management Needs

Ecological Functioning - Resource managers need a better understanding of the basic functions and ecosystem services provided by a tidal creek system (e.g., nursery habitat for which species, foraging habitat for which species, abiotic functions, degree of storm protection) as well as a definition for a healthy creek. The concept of cumulative impacts and the potential carrying capacity of tidal creeks is a critical component to understanding the overall ecology and the services they provide. How are managed species utilizing tidal creeks and what are the potential impacts from a variety of impacts (to, in part, improve the use of the NOAA Essential Fish Habitat framework)?

Tools **-** 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. Information and tools are also needed to help them readily assess direct and indirect impacts from various projects/activities. They are also in need of appropriate cost-effective monitoring systems and strategies and "ready to use" products that can use data they may have or can readily obtain. Prioritization frameworks for identifying wetlands or other habitats for restoration/preservation/mitigation are also needed so the best areas of a system that provide the greatest ecosystem benefits can be protected or restored. Tools should include those that could be used by local or state governments to perform long-term assessments and monitoring that support adaptive management. In addition, simple predictive tools for determining volume and rate of stormwater runoff, pollutant loading and potential water quality impacts from development would be useful.

Clearinghouse - Managers identified a need to develop a clearinghouse of research projects, published reports and collaborative groups to provide a summary of ongoing and historical tidal creek research and monitoring activities. This information would be useful in commenting on and making permit decisions.

Education/Coordination - Increased understanding of the function and value of tidal creeks by the public and decision makers is needed to support the importance of regulations in protection and restoration of these systems. Better communication, collaboration and coordination between federal state and local governments and academia are also needed. Demonstration projects were noted as important for educating stakeholders.

Regulatory Change - The lack of management coordination from the local to the federal level was observed by many people as was the absence of an ecologically-based management approach for land use, water quality and natural resources. Historically, coastal environmental programs have focused on water quality. There is, however, a need to address the human health and well-being concerns of impaired coastal ecosystems including tidal creeks. In addition, there

is a need to identify gaps in current regulations that allow unintended impacts to tidal creeks. Mitigation for impacts to tidal creeks that is out-of-kind needs to be examined and revised. Managers at all levels also identified a need for more stringent regulations for tidal creeks to stem adverse impacts from development/pollution including higher limitations on National Pollution Discharge Elimination System (NPDES) permits in high functioning tidal creeks, buffers and limits on impervious surfaces and shoreline hardening. Special zoning around tidal creeks was noted as a potential avenue for protecting tidal creek systems and examples are needed. Incorporating watershed planning into TMDLs was identified as a potential way to address protection and restoration.

Communication and Information Transfer with Researchers - There is a need to improve communication and understanding between managers and researchers at both the state and local levels. Researchers need assistance translating and addressing research needs at the local level that can clearly be expressed using values understood by the public. Local planners also need to become engaged (actively recruited) to participate in forums such as the Southeastern Tidal Creeks Summit. Local managers also expressed concerns with unintended impacts of state mandated stormwater practices from management/maintenance practices after practices are in place (e.g., intensive use of algaecides/herbicides in ponds). Social scientists also need to become more involved and assist with showing how to motivate the pubic to take action and promote protective policies.

Inventories and Monitoring **-** Neither state nor local governments have adequate inventories and mapping for the 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. Additional monitoring is needed including guidance on how, what and where to monitor to determine and track the health of different systems.

Funds - State and local regulatory agencies need more funding for programs especially compliance and enforcement. Increased permitting fees or trust funds are possible ways to make programs self-supporting.

Restoration and Mitigation Needs

Restoration Goal **-** Tidal creeks and salt marshes provide a range of services that are beneficial to coastal communities. 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 services need to be protected and restored for each specific circumstance. It may not be possible to restore or maintain all services. Services that have a high likelihood of being restored or have the highest benefit should be selected. Too often restoration projects attempt to use a one-size-fits-all approach and should be tailored to be place specific. The scale of the project, baseline conditions, surrounding land use and appropriate reference sites are critical considerations for restoration success. Restoration projects should also be informed by sea level rise inundation models to prioritize location, elevation and design of systems as well as land acquisition priorities. Is there a threshold of development at which tidal creeks are not capable of being mitigated or restored?

Ecosystem-based Approach **-** There are a wide range of agencies (e.g., NOAA Fisheries, NOAA Restoration Center, U.S. EPA, State) responsible for implementing restorations, each with different and often conflicting agendas and missions. As a result, restoration projects are currently 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. For example, there is a need to demonstrate positive downstream cumulative impacts of multiple restoration projects. Linking watershed restoration activities to change in tidal creek ecology as well as improvements in fisheries production may open up funding opportunities and gain support from other agencies, public and legislators. Quantification of ecosystem services that are provided as the result of either restoration action or protection/conservation is also important.

Monitoring - Restoration projects should be monitored to determine if the project met expectations and a priori goals. There is a need to determine how much monitoring is needed, what parameters to monitor and how to monitor for success including functional benchmarks and endpoints. Demonstration projects should be conducted with sufficient sapling to show restoration benefits. Long-term monitoring is often not conducted due to expense, but it is critical for understanding functional benchmarks. Standardized monitoring protocols with criteria for restoration projects (mitigation and science-driven), ecosystem indicators that must be monitored and what should be monitored – develop tier of monitoring indicators.

Function of Restoration - Maximizing the success in creating the best possible habitat quality deserves more attention. Standard measurements of water quality are fine but too often seem to consume more attention and financial resources that might better be used for measuring or monitoring important factors such as structure/function that supports habitat use by fishes, shellfish, birds, etcetera. What are appropriate ecological criteria?)

Critical Factors - Regulators and natural resource managers need clear guidance on recommendations for ensuring a successful marsh restoration project (e.g., elevations, inundation frequency, plant sources, transplants versus container-grown or bare-root nursery plants, spacing of plants, soils, nutrient additions).

Clearinghouse - There is a need for long-term project identification, data archiving of monitoring data and project designs.

Specific Restoration Activities - Additional research/information is needed on hardened shorelines and alternatives to shoreline hardening. What are the impacts and benefits of shoreline stabilization; hardened versus living shorelines? What are the potential benefits of oyster reef restoration/construction on water quality? Restoration targets should be developed for watersheds that are highly impacted by shoreline stabilization including creating initiatives for alternatives to bulkheads.

Education and Outreach Needs

Tailor Education and Outreach - Not all people have the same level of background, knowledge and exposure to tidal creeks science and information and they usually are not motivated by the same factors. Therefore, grouping people into educational tiers and developing different outreach strategies for each tier is recommended. Education and outreach is not one size fits all. For example, fishing communities are very different from urban areas. Tidal creeks education will require multiple tools and approaches.

Assess Needs - Before an education/outreach program begins, we must first conduct a needs survey to identify the various groups we need to reach, gauge their knowledge and opinions and determine what would motivate them to change if change is desired.

Transfer Research to the Public using a Variety of Tools - It is essential that we make research information transferable to the public. The Internet, including social media such as Facebook, is a readily available option for providing information to the public. This information could include, for example, the impacts of stormwater runoff from development so that the target audiences better understand the impacts and challenges.

Inform the Public of the Importance of Tidal Creeks - Inform the public of the benefits of tidal creeks and the impacts that will result from degradation of these coastal water bodies. For example, communicating how coastal wetlands offer protection during major storms like hurricanes. The Oceans and Human Health Initiative OHHI is one example of tying research to effects on human health. Also, we need to educate the public on why it is economically advantageous to protect and conserve natural resources.

Increase Awareness of and Establish an Identity for, Coastal Waterbodies - It is important to have target audiences identify and associate with the target waterbodies. For example, the "Save the Bay" program, where governments came together to sign the Chesapeake Bay agreement, stimulated a unified effort which increased the notoriety of the bay and improved the public's awareness of its resources and the need to restore its health. The "Save the Bay" bumper stickers were a key element of this "branding" type program. Creating a unique identity for a waterbody like the Chesapeake Bay can be used in social marketing near the waterbody itself and throughout the basin draining to it.

Outreach and Education should be Cooperative among Local Governments, State and Federal agencies, Universities and Non-governmental Organizations - Expertise, resources and connections of these groups needs to be combined/coordinated to reach target audiences with tidal creeks research and information. This will likely improve the success and extent of the outreach effort.

Educate Decision Makers -Tidal creek science needs to be better linked to state and local coastal managers to prevent and/or reduce the impacts of land-use on critical coastal waterbodies. Currently, land-use decisions are made primarily at the local municipal level. Many local ordinances and zoning rules contribute to sprawl and increase the impacts to coastal waters. For example, the requirement of the number of parking spaces to meet maximum capacity at shopping centers. Local governments also need assistance with figuring out how best to modify zoning and ordinances to better protect natural resources.

Educate Developers and Site Planners – The development community also needs to understand the importance of tidal creeks and the impacts of land-use changes on them. If educated about effective tools that reduce the impacts while also saving them money, perhaps they will make better choices for protecting tidal creek water quality and health.

Include a session focused on outreach and education at the next Summit – Education is a major component of managing human interaction with tidal creeks. Public understanding, education and support are fundamentally important for protecting tidal creek and marsh habitats. Therefore, perhaps a subcomponent of a future tidal creek meeting could focus on outreach efforts to restore, protect, or reduce impacts of tidal creeks in the Southeast.

Literature Cited

Rahmstorf, S. 2007. A Semi-Empirical Approach to Projecting Future Sea-Level Rise. Science 315(5810):368-370.

Childers, D.L., S. Cofer-Shabica, L. Nakashima. 1993. Spatial and Temporal Variability in Marsh-Water Column Interactions in a Southeastern USA Salt Marsh Estuary. Marine Ecology Progress Series 95:25-38.

Appendix A: Paper Survey Questions

At the Summit, participants filled out questionnaires to identify what they saw as needs related to tidal creeks: 1) research (n=56), 2) management (n=51), 3) strategies/restoration (n=39) and 4) integration/additional thoughts (n=46). Each questionnaire asked for common information including name (optional); which category best described the respondent (resource manager/regulator, scientist/researcher, student, or other); and whether they represented local, state, federal, or academic organizations.

The following text was included for each of the different questionnaires.

- Please capture on this page what you feel are the critical research needs related to tidal creeks. You may include both basic and applied research. After you have developed your list, please rank them 1, 2, 3 etc., according to their priority.

- Please capture on this page what you feel are the most critical resource management needs related to tidal creeks. This can include items related to policy changes, legislation, regulation, enforcement, outreach and/or research. After you have developed your list, please rank them 1, 2, 3, etc., according to their priority.

- Please capture on this page what you feel are the most important strategies/restoration needs related to tidal creeks. This can include items related to basic and applied research, pilot projects, policy changes and/or education. After you have developed your list, please rank them 1, 2, 3, etc., according to their priority.

- Please capture on this page any needs for research, management or strategies/restoration you feel might not have been captured yet. In addition, please highlight what you think have been the key messages or points from the Summit. If appropriate, please rank them according to their priority.