2012 Climate Connection Workshop Series

Climate Variability and Impacts to South Carolina's Natural Resources

Final Workshop Report

Prepared by the South Carolina State Climatology Office

Supported by the Carolinas Integrated Sciences & Assessments (CISA)

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Acknowledgements

First and foremost, these workshops would not have been possible without support from our sponsors, the Carolinas Integrated Sciences and Assessments (CISA) program.

We would like to extend our sincere gratitude to our speakers, their co-authors and supporting agencies, and the 150+ listed participants that helped contribute to the success of these workshops by donating their time and valuable input. Their wide-ranging expertise allowed for a very informative environment and great dialogue regarding climate and natural resources.

We are also grateful to the personnel at our three host facilities: SC Department of Natural Resources in Charleston, SC; Saluda Shoals Park in Columbia, SC; and the Greenville County Government Complex in Greenville, SC. Special thanks to Mary Ellen Williams of the Marine Resources Research Institute for being so accommodating. We appreciate you taking time out of your busy schedule to ensure that our first workshop was executed as smoothly as possible.

Last but not least, we would like to acknowledge Julie Holling and Kay Daniels, who worked tirelessly from the early planning stages to helping administrate on the day of the workshops. We could not have done it without your efforts.

Sincerely,

Hope Mizzell

and

Ivetta Abramyan

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Background

The South Carolina State Climatology Office conducted a series of three workshops across the state of South Carolina titled "The Climate Connection Workshop Series: Climate Variability and Impacts to South Carolina's Natural Resources". The purpose of these workshops was to increase awareness and utilization of climate knowledge to improve natural resource management. At each workshop, discussion was facilitated regarding the relationship between natural resources and climate, including the need for new approaches and partnerships to cope more effectively with climate variability. The workshops were held in Charleston, SC on September 13, 2012; Columbia, SC on October 24, 2012; and Greenville, SC on December 5, 2012. The series attracted a total of 151 participants including representatives from federal, state and local government, scientists, land and water resource managers, utility representatives, NGOs, media, private companies and other interested stakeholders. The workshops were funded by a grant from the Carolinas Integrated Sciences and Assessments (http://www.cisa.sc.edu/), a program supported by NOAA's Regional Integrated Sciences and Assessments (RISA). A website was created to house all workshop materials for the purpose of accessibility, networking and education. Some of the information available online includes presentations, participant lists, agendas, research, training and future events. The workshop website can be accessed at http://www.dnr.sc.gov/ccworkshops/.

Over 26 speakers from varying backgrounds shared their research and perspectives on climate and natural resources with workshop participants. The presentations encompassed a wide range of topics covering climate-related ecological, physical, biological, and human impacts. The presentation summaries are included in the Appendix. Each workshop also consisted of an interactive session that utilized the Turning Technologies audience response system to fully engage workshop participants. We used the intuitive polling software integrated with PowerPoint to collect real-time responses from participants to a series of 12 questions regarding climate issues, impacts, actions, needs and challenges. Results were not only instantly displayed, but also organized in detailed reports that were used for further analysis. Most questions contained weighted responses allowing participants to prioritize their top three answer choices. The participants also helped formulate the questions by contributing to the answer choices before each vote. This system allowed us to engage the audience, gather opinions anonymously and generate productive discussion among the participants. The data was then graphed and analyzed to be included in this report.

Audience Polling Results

This section summarizes results from the interactive, audience response portion of the workshop. The graphs in figures 1 through 8 show responses from all three workshops, color-coded by location, and displayed in stacked columns corresponding to each particular question. For the graphs displayed, the results reflect the participants' ranked and weighted responses expressed as a percentage of the total number of weighted points. The audience was polled one time for each question, but asked to enter their first, second and third choice which was weighted in descending order (10 points for first priority, 7 points for second priority and 4 points for third priority). The graphs display the cumulative percentage of the three entries for all participants. The percentages shown in each figure are independent of each other since they are calculated on a per-workshop basis and not out of the total number for all three workshops.

The focus of the first few questions was to identify the participants' work experience, background and their primary sources for climate information. The majority of the workshop participants were from government agencies, with a higher representation from state government than federal government. There was roughly an equal representation by the private sector, local government and other organizations. Most of the attendees had at least 20 years of experience working in their respective fields.

Statewide, participants responded that they generally obtain their climate information from NOAA, followed by the State Climate Office. Some geographical variations show that the media is utilized more frequently for climate information by Greenville participants, which may be attributed to a greater diversity in their background and affiliation. The Intergovernmental Panel on Climate Change (IPCC) is utilized more by the Charleston community, probably due to the heightened interest in sea level rise and climate change among the coastal workshop attendees.

Issues and Impacts

Several questions focused on identifying and prioritizing the primary climate-related issues and impacts to natural resources in South Carolina. Drought was selected as the primary climate-related issue affecting the state by participants at all three workshops (Figure 1). The state endured several multi-year drought episodes over the last 15 years with much of the state in drought at the time of the workshops. Sea level rise was also viewed as a significant issue, especially among Charleston participants. Temperature extremes received the third highest number of votes overall, followed by severe weather. Winter weather and high winds received the lowest prioritization. Consistent with their selection of drought as the highest priority, participants selected water quantity as the primary climate-related impact to natural resources (Figure 2). Shoreline change was also a concern, but mostly at the Charleston workshop where a quarter of the participants chose it as one of their top three priorities. Water quality and ecosystem integrity at all three workshops collectively were ranked as a priority.

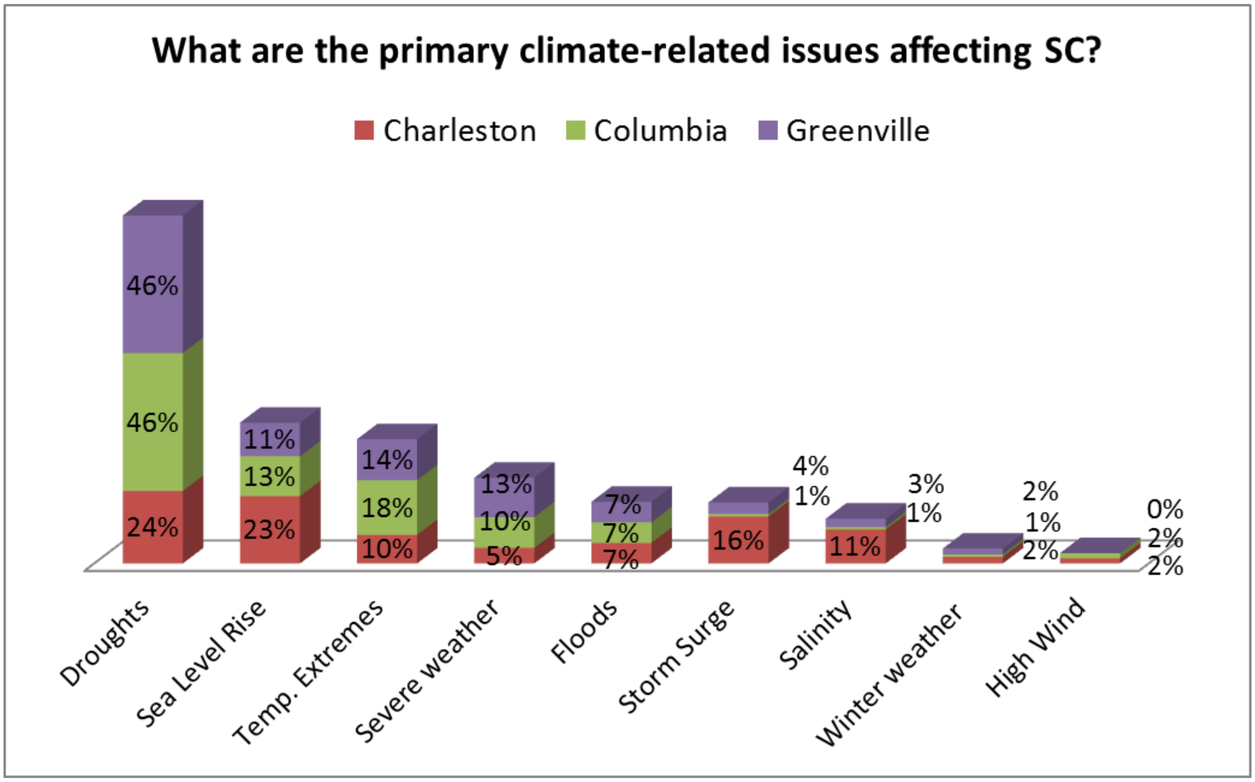

Figure 1. **Primary climate-related issues affecting South Carolina**

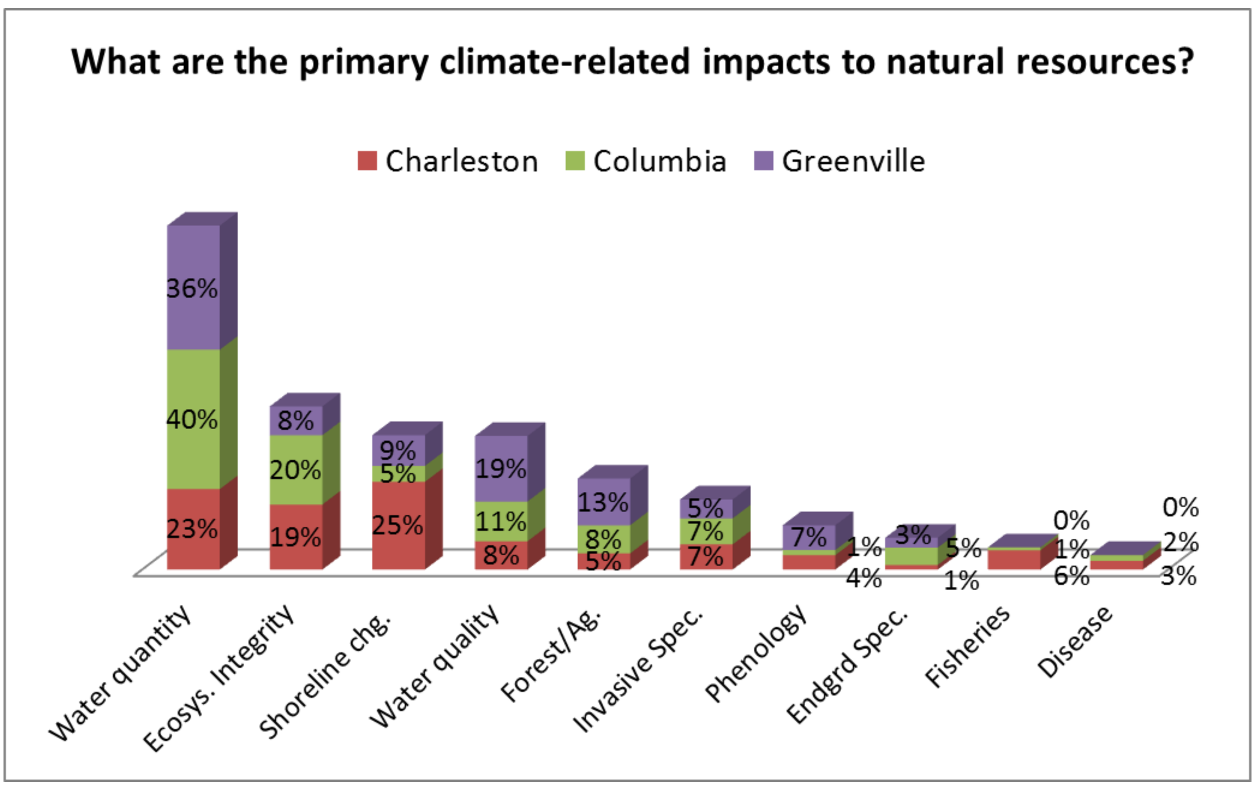

Figure 2. Primary climate-related impacts to natural resources

Actions

A series of questions targeted actions agencies are undertaking to address climate-related issues. Responses revealed that the majority of agencies are participating in a variety of actions, predominantly focused on research, outreach and education (Figure 3). A higher percentage of participants at the Greenville workshop indicated they were conducting risk and vulnerability assessments while no one at the Columbia workshop indicated that as an action. Some participants throughout the state voiced that their agencies were not doing anything to address climate-related issues. Out of the agencies conducting outreach and education, most are targeting the general public, students, local governments, conservation partners and employees (Figure 4). While few attendees specifically indicated their outreach was targeted toward outdoor enthusiasts, landowners and industry workers, some may have considered them as the general public. Most agencies are undertaking climate-related impacts on the ground by conducting research and monitoring (Figure 5), while some were developing indicators and adaptation strategies. Reducing stressors and taking no action received the lowest prioritization. There was some inconsistency between two of the questions in terms of the extent to which agencies are doing nothing about climate impacts.

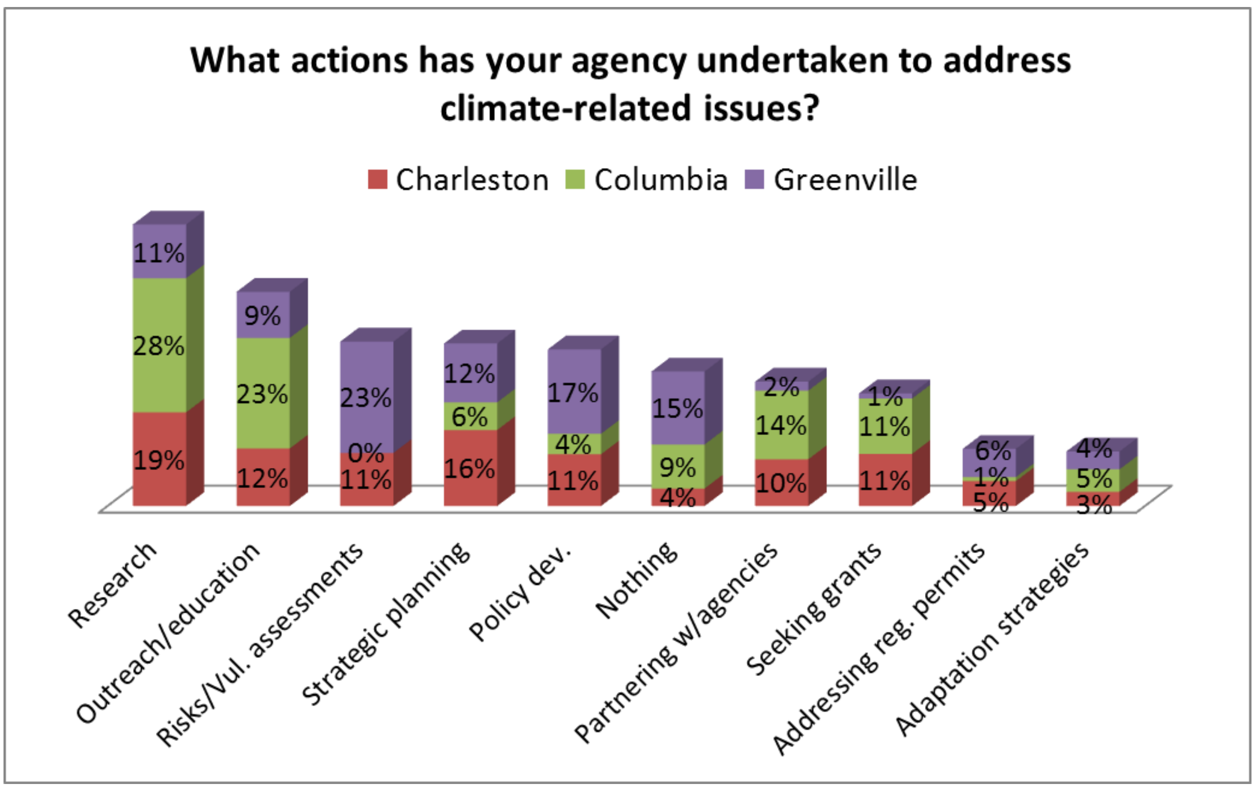

Figure 3. Actions agencies have taken to address climate-related issues

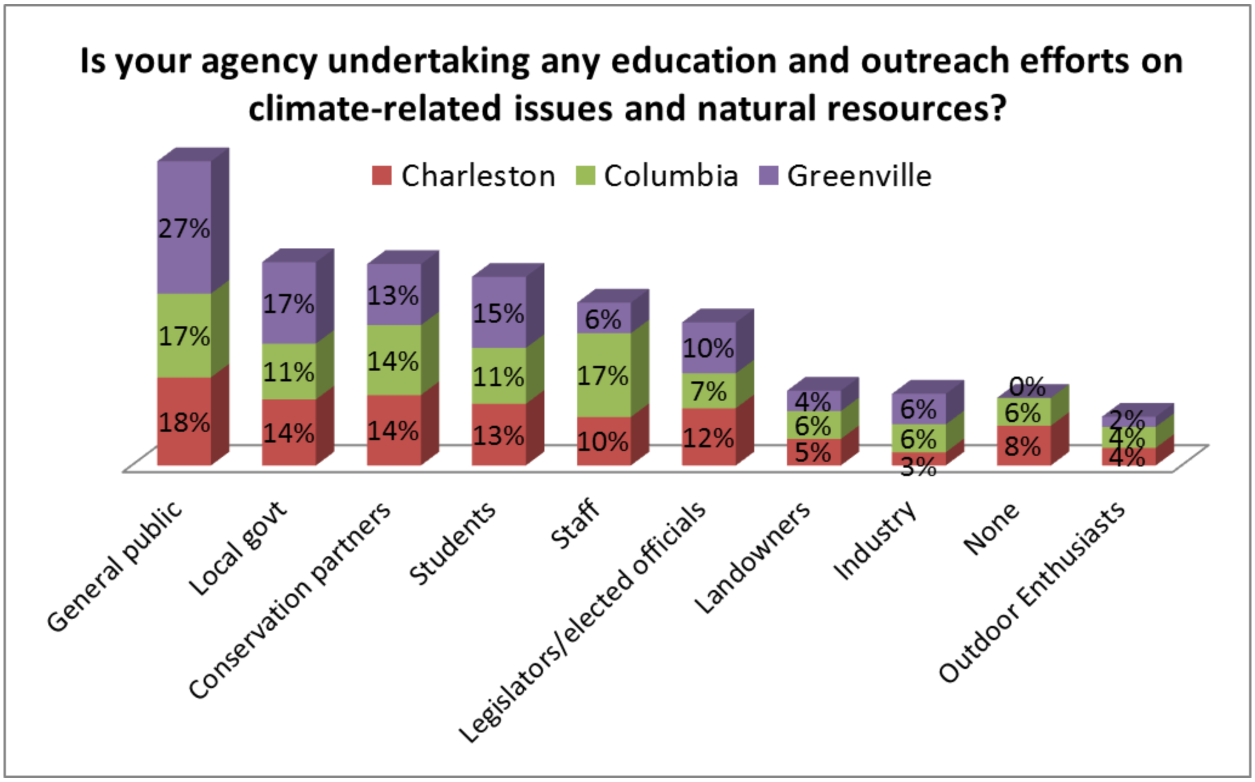

Figure 4. Education and outreach efforts on climate-related issues and natural resources

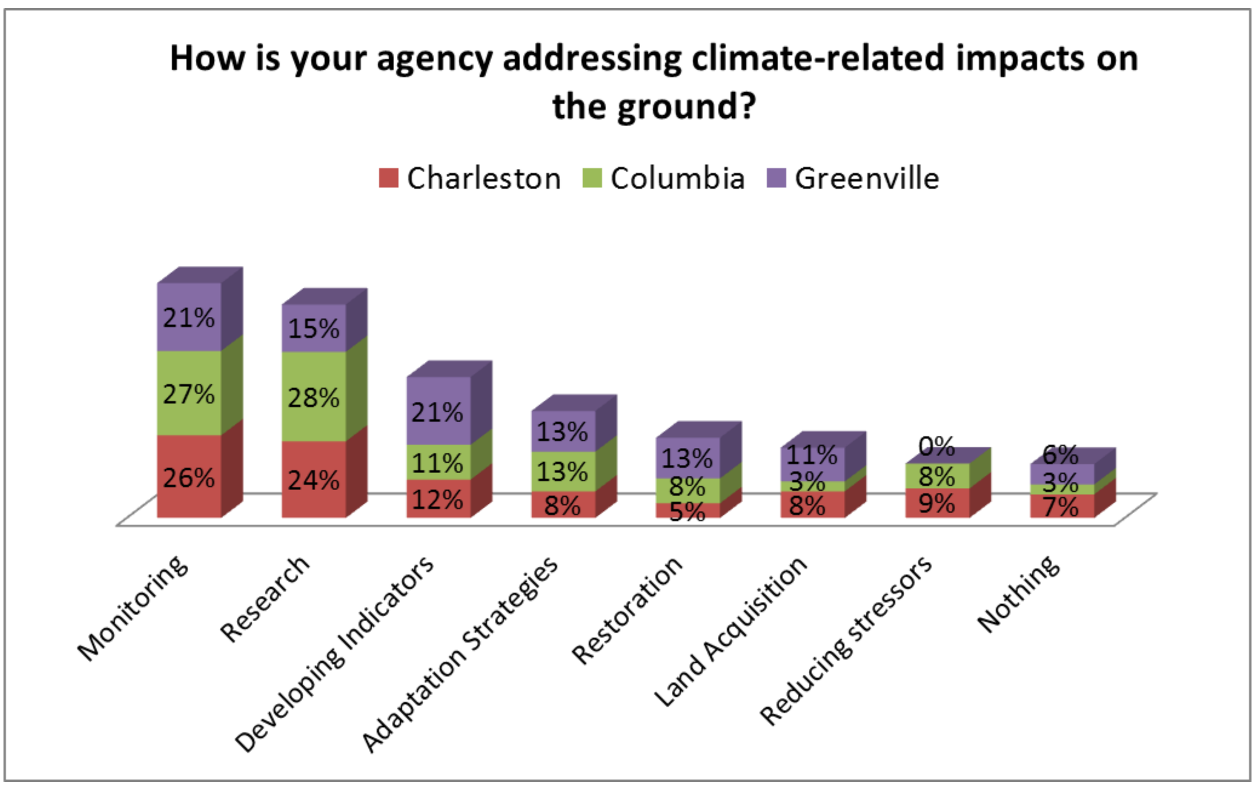

Figure 5. Addressing climate-related impacts on the ground

Needs/Challenges

The final set of questions focused on identifying the needs and challenges regarding climate-related work. The majority of participants expressed a need for localized information on effects and impacts, a centralized information area with data and tools to support decision making and monetary resources to improve natural resource management related to climate variability (Figure 6). When asked about the limiting factors preventing agencies on focusing on climate-related work, the primary challenge was lack of funding, followed by lack of time, expertise and political support, respectively (Figure 7). Even though lack of climate data received the lowest prioritization (Figure 7), we did ask a follow-up question focused on identifying climate data needs (Figure 8). Polling results from the participants indicated that their primary climate data needs include simplified and localized climate information, increased station and parameter coverage, standardized downscaled climate modeling and the digitization of historical records (Figure 8).

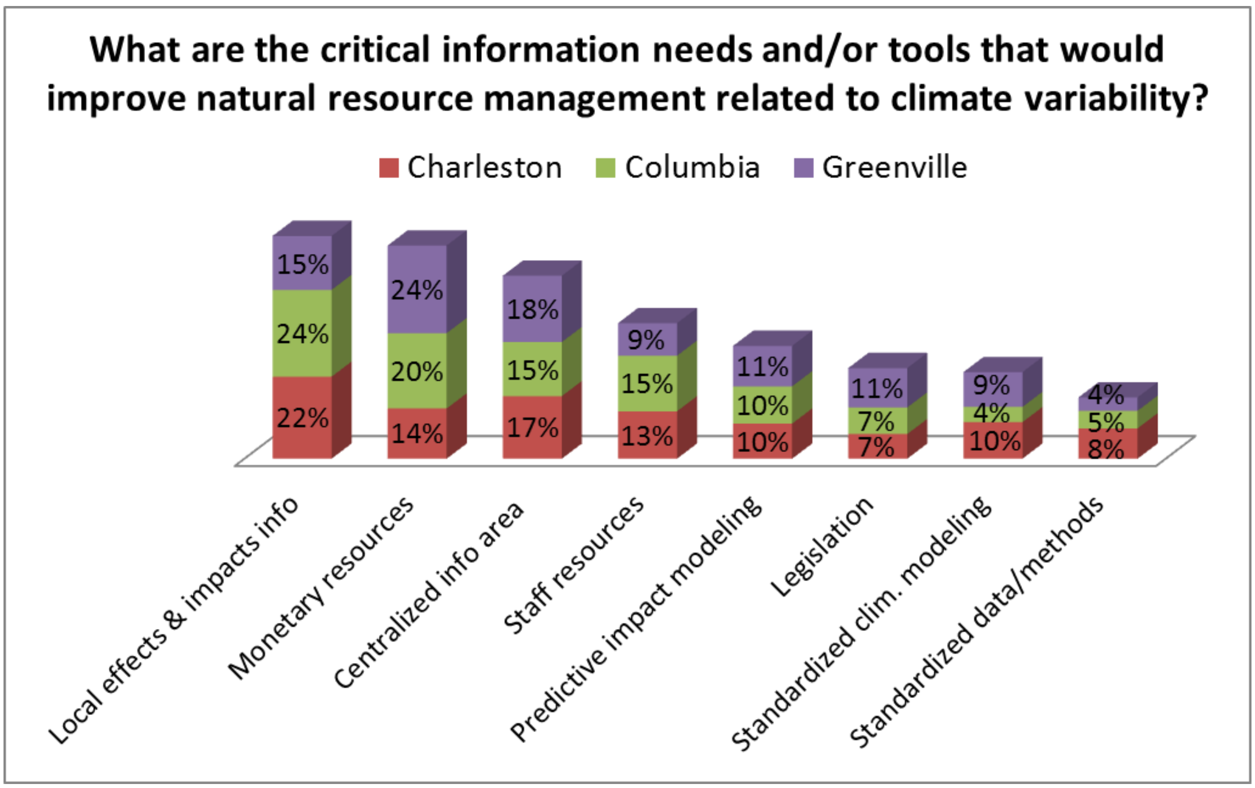

Figure 6. Critical information needs and/or tools to improve natural resource management related to climate variability

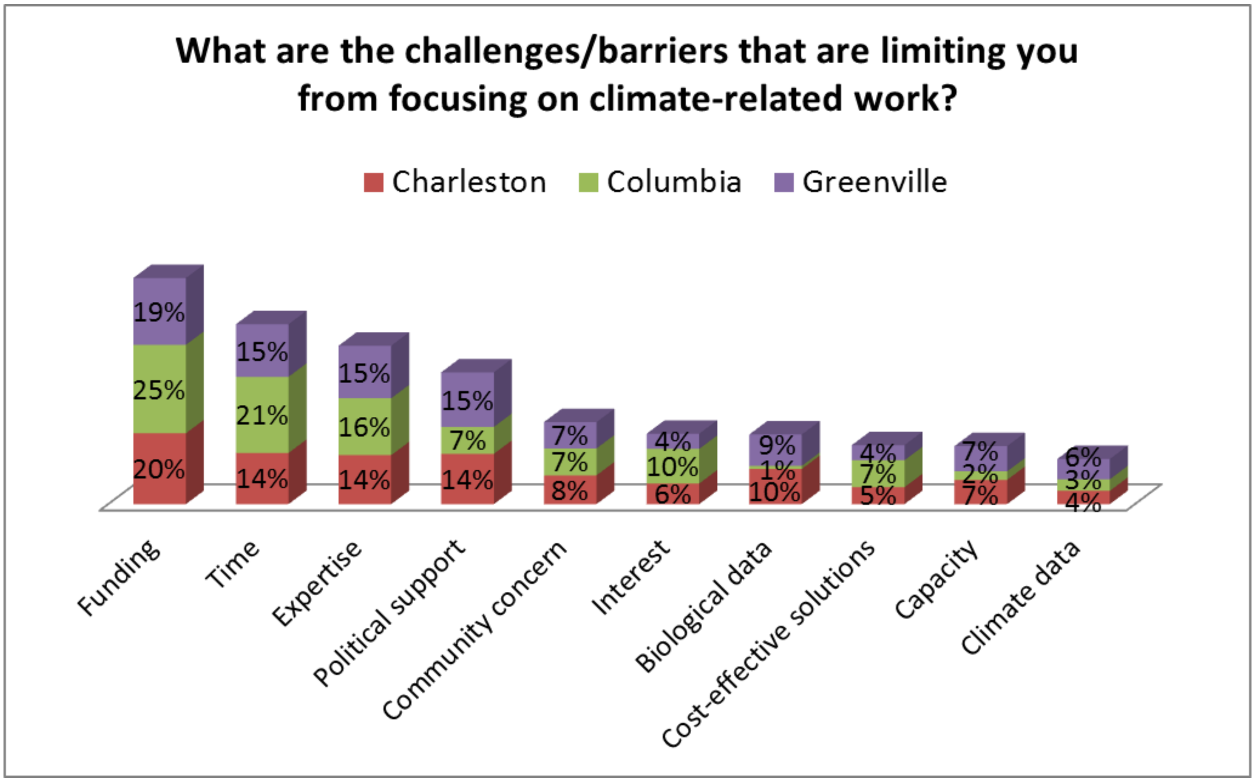

Figure 7. Limitations on climate-related work

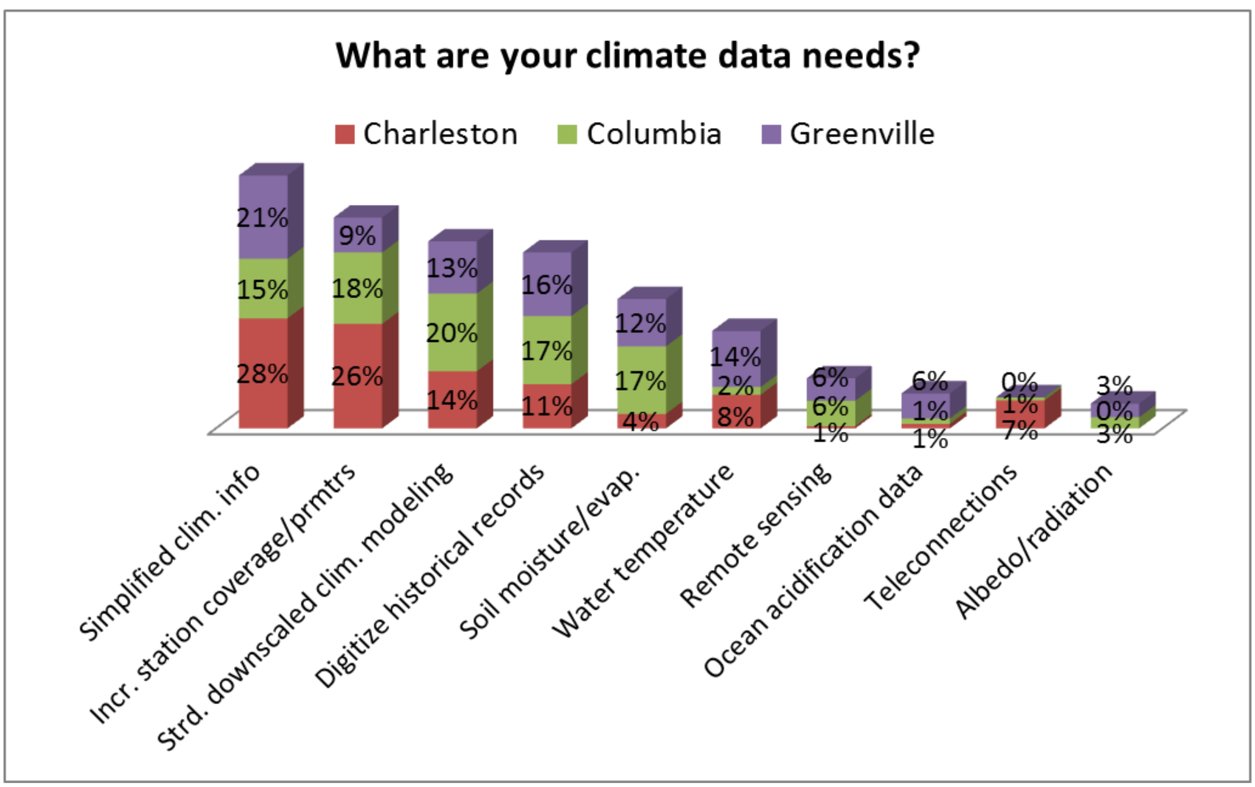

Figure 8. Climate data needs

Progress and Next Steps

This final section summarizes the workshop participants' recommendations for next steps the State Climate Office can take to support natural resource management under climate variability and change, as well as activities conducted by the State Climate Office since the last workshop. The majority of attendees requested additional workshops, but there were also requests for webinars, reports and a listserv with up-to-date information on future developments. Indirectly related to the workshops, in 2013, the SCDNR released a report titled "Climate Change Impacts to Natural Resources in SC" which was open for public comment for 45-days (http://www.dnr.sc.gov/pubs/CCINatResReport.pdf). A final version of the report should be released during fall of 2013.

Direct post-workshop goals for the SCDNR include developing easy to understand climate-related materials, enhancing online resources, investigating interest in joint workshops and communicating training opportunities. The SCDNR will utilize email lists and enhance the web portal to improve communication. The workshop website can be accessed at http://www.dnr.sc.gov/ccworkshops/. Some of the information available online includes the workshop presentations, participant lists, agendas, research, training and future events.

Appendix 1: Workshop Agendas

September 13, 2012 - Presentations and Agenda

Marine Resources Research Institute Auditorium, Charleston, SC

Time	Topic
9:00 – 9:15 am	**Welcome** Ken Rentiers SCDNR- Land, Water and Conservation, Deputy Director
9:15 – 9:35 am	**SC Climate Trends and Variability 1901-2010** Hope Mizzell SCDNR-Land, Water and Conservation, SC State Climatologist
9:35 – 10:00 am	**Understanding South Carolina's Climate Controls** Hope Mizzell SCDNR-Land, Water and Conservation, SC State Climatologist
10:00 – 10:20 am	**Analysis of 60 years of water temperature data from Charleston Harbor** Steve Arnott SCDNR-Marine Resources Division, Associate Marine Scientist
10:20 – 10:40 am	Break
10:40 – 11:10 am	**Climate and Estuarine Fauna** Dennis Allen Baruch Marine Field Laboratory, Research Professor and Resident Director
11:10 – 11:30 am	**Influence of Climate on Shrimp Abundance** David Whitaker SCDNR-Marine Resources Division, Assistant Deputy Director
11:30 – 11:50 pm	**Salinity Intrusion: Integrating Riverine and Coastal Forces** Paul Conrads US Geological Survey, Surface Water Specialist
12:00 – 12:50 pm	Lunch
12:50 – 1:20 pm	**Climate Changes Everything** Raye Nilius SC Lowcountry Refuges Complex, Project Leader **Got Data! Needs for Monitoring and Partnering in a Changing Climate** Nicole M. Rankin U.S. Fish and Wildlife Service, National Wildlife Refuge System Inventory and Monitoring Network
1:20 – 1:50 pm	**Prolonged Drought Linked to Blue Crab Decline** Michael Childress Clemson University, Biological Sciences Associate Professor
1:50 – 2:05 pm	**National Integrated Drought Information System: Pilot Project in the Carolinas** Amanda Brennan Carolina's Integrated Sciences & Assessments, Research Assistant

2:05 – 2:30 pm	**South Carolina's Wildlife Action Plan** Derrell Shipes SCDNR-Wildlife & Freshwater Fisheries, Chief of Statewide Projects, Research, and Survey
2:30 – 2:45 pm	Break
2:45 – 3:15 pm	**National Fish, Wildlife, and Plants Climate Adaptation Strategy** Arpita Choudhury Association of Fish and Wildlife Agencies, Science and Research Liaison
3:15 – 4:30 pm	Open discussion

October 24, 2012 - Presentations and Agenda

Saluda Shoals Park, River Center, 5605 Bush River Rd, Columbia, SC 29212

Time	Topic
9:00 – 9:15 am	**Welcome** Hope Mizzell SCDNR- Land, Water and Conservation, SC State Climatologist
9:15 – 9:35 am	**SC Climate Trends and Variability 1901-2010** Hope Mizzell SCDNR-Land, Water and Conservation, SC State Climatologist
9:35 – 9:55 am	**Understanding South Carolina's Climate Controls** Ivetta Abramyan SCDNR-Land, Water and Conservation, State Climatology Office Research Assistant
9:55 – 10:20 am	**Water Level Trends in Aquifers of South Carolina** Scott Harder SCDNR-Land, Water and Conservation, Hydrologist
10:20 – 10:40 am	Break
10:40 – 11:05 am	**What's Going on With My Trees: Climate Effects on Forest Health** Laurie Reid SC Forestry Commission, Forest Health Specialist
11:05 – 11:30 am	**Effects of Changing Climate Patterns on Reptile and Amphibian Populations in SC** Steve Bennett SCDNR-Wildlife and Freshwater Fisheries, Herpetologist
11:30 – 11:55 pm	**Wood Ducks of the Savannah River Site: Indicators of Changing Environments** Robert Kennamer Savannah River Ecology Laboratory, University Georgia, Research Professional
12:00 – 1:15 pm	Lunch

1:15 – 1:45 pm	**Climate Change at Congaree National Park: Realities and Communication Challenges** David Shelly Education Coordinator, Old-Growth Bottomland Forest Research and Education Center Congaree National Park
1:45 – 2:10 pm	**The Application of a Statistical Downscaling Process to Derive 21st Century Climate Predictions** David Werth Savannah River National Laboratory, Research Scientist
2:10 – 2:30 pm	**South Carolina's Wildlife Action Plan** Derrell Shipes SCDNR-Wildlife & Freshwater Fisheries, Chief of Statewide Projects, Research, and Survey
2:30 – 2:50 pm	Break
2:50 – 3:15 pm	**On-line Tool for Assessing Local Impacts of Ecosystem Stress and Management Options** Steven McNulty Ecologist and Team Leader, USDA Eastern Forest Environmental Threat Assessment Center
3:15 – 4:30 pm	**Open discussion**, Facilitated With Audience Response Technology

December 5, 2012 - Presentations and Agenda

Greenville County Government Complex, 301 University Ridge Ste. 4800, Greenville, SC 29601, Conference Room A

Time	Topic
9:00 – 9:15 am	**Welcome** Ken Rentiers SCDNR- Land, Water and Conservation Division, Deputy Director
9:15 – 9:35 am	**SC Climate Trends and Variability 1901-2010** Hope Mizzell SCDNR- SC State Climatologist
9:35 – 9:55 am	**Understanding South Carolina's Climate Controls** Ivetta Abramyan SCDNR-Land, Water and Conservation, State Climatology Office Research Assistant
9:55 – 10:15 am	**Water Level Trends in Aquifers of South Carolina** Scott Harder SCDNR-Land, Water and Conservation, Hydrologist
10:15 – 10:35 am	Break

10:35 – 11:00 am	**Effects of Changing Climate Patterns on Freshwater Habitats** Mark Scott SCDNR-Freshwater Fisheries Research Biologist
11:00 – 11:25 am	**What's Going on With My Trees: Climate Effects on Forest Health** Laurie Reid SC Forestry Commission, Forest Health Specialist
11:25 – 11:50 pm	**Managing Wildland Fire in Rapidly Changing Times** Johnny Stowe SCDNR-Wildlife Biologist and Heritage Preserve Manager
12:00 – 1:30 pm	Lunch
1:30 – 1:55 pm	**Climate Change: Realities and Communication Challenges** David Shelly Education Coordinator, Old-Growth Bottomland Forest Research and Education Center Congaree National Park
1:55 – 2:20 pm	**Economic Impacts of Changing Lake Levels in the Savannah River Basin** Rob Carey and Lori Dickes SC Water Resources Center, Strom Thurmond Institute of Government and Public Affairs
2:20 – 2:45 pm	**Urban Growth Along the I-85 Corridor** Jeff Allen Director, SC Water Resources Center, Interim Director, Strom Thurmond Institute of Government and Public Affairs
2:45 – 3:00 pm	**South Carolina's Wildlife Action Plan** Derrell Shipes SCDNR-Wildlife & Freshwater Fisheries, Chief of Statewide Projects, Research, and Survey
3:00 – 3:15 pm	Break
3:15 – 4:30 pm	**Open discussion**, Facilitated With Audience Response Technology

Appendix 2: Presentation Summaries

Over 26 speakers from varying backgrounds shared their research and perspectives on climate and natural resources with workshop participants. The presentations encompassed a wide range of topics covering climate-related ecological, physical, biological, and human impacts. (Not all summaries are available.)

List of Presentations

Analysis of 60 years of water temperature data from Charleston Harbor
Steve Arnott
SCDNR-Marine Resources Division, Associate Marine Scientist
Presented September 13, 2012

An analysis of Charleston Harbor water temperature records (daily since 1950) revealed that a number of significant associations exist with climate indices, including the Atlantic Multidecadal Oscillation, Arctic Oscillation, North Atlantic Oscillation and El Niño–Southern Oscillation. Year-to-year variation in water temperature was most pronounced during the winter months, and correlated with abundance of some fish species routinely monitored by a SCDNR estuarine survey. Winter temperatures have widespread ecological effects in South Carolina estuaries, and influence economically important activities such as recreational angling.

Climate and Estuarine Fauna
Dennis Allen
Baruch Marine Field Laboratory, Research Professor and Resident Director
Presented September 13, 2012

Long-term measurements of more than 100 physical, chemical, and biological variables in the North Inlet estuary, SC over the past 30 years have revealed changes in and relationships between environmental conditions and faunal assemblages. We have observed increases in water temperature, decreases in freshwater runoff, decreases in the abundances of key faunal populations, and alterations in the timing of biological events. Rising sea level is affecting salt marsh grass production and the geomorphology of habitats critical to ecologically and economically important species. Although major shifts in the composition of communities and food web structure have not been evident, the observed changes indicate that the character and productivity of estuaries will be different in the decades ahead.

Climate Changes Everything
Raye Nilius
SC Lowcountry Refuges Complex, Project Leader
Presented September 13, 2012

Climate Changes Everything: An introduction to sea level rise and an overview of the climate change effects on refuge lands including nesting habitat for loggerhead sea turtles, shorebirds, and seabirds at Cape Romain National Wildlife Refuge. Climate change adaptation strategies are summarized.

Dying of Thirst: Forecasting the Impact of Drought on Blue Crabs
Michael Childress, Kirk Parmenter
Clemson University, Biological Sciences Associate Professor
Presented September 13, 2012

Over the past 10 years, blue crab landings in South Carolina have decreased while average marsh salinity has increased due to persistent drought. To better understand this relationship between salinity and crab population structure, we constructed a spatially-explicit, individual-based model of blue crabs in the ACE Basin National Estuarine Research Reserve. We used USGS river discharge records and in situ salinity measurements to model the spatial, seasonal, and annual variations in salinity and other water quality parameters. Field and laboratory studies provided essential information linking salinity to fishing, disease, settlement, growth and predation. Crab abundance was influenced by the baseline levels of river discharge, decreasing in low flow rivers due to increased disease, and increasing in high flow rivers due to decreased predation. A hindcast / forecast simulation beginning with historical flow averages from 1970 and projected to 2050, predicts a peak crab abundance in 2009 with decreasing abundances thereafter. This model provides a useful framework to evaluate how crab population drivers such as fishing, disease, and predation are likely to change in response to climate change and future droughts.

Got Data! Needs for Monitoring and Partnering in a Changing Climate

Nicole Rankin
U.S. Fish and Wildlife Service, National Wildlife Refuge System Inventory and Monitoring Network
Presented September 13, 2012

Sea-level rise, saltwater intrusion, and severe drought conditions will impact the over 16 million acres of protected lands along the coast of South Carolina and Georgia. In the face of climate change, there is a need for monitoring and partnering, and this presentation highlights some active partnerships as well as identifies current monitoring and needs. On refuges, our partners (USGS, NOAA, SCDNR) are monitoring changes forested wetlands and marshes, studying carbon sequestration in managed marshes, and operating large scale monitoring programs in and near refuges in SC and GA. The FWS Inventory & Monitoring Network is currently working with partners and refuges to establish monitoring efforts including monitoring marsh elevation and sea-level rise, performing water resource inventory and assessments, modeling habitat changes due to sea-level rise, monitoring fish communities, adding to current monitoring networks, and working with others to build science capacity (Landscape Conservation Cooperatives and Climate Science Centers). With partners, we need to expand these efforts to produce more advanced climate models, develop climate change adaptation strategies, implement these strategies across landscapes, and monitor to understand and evaluate the effectiveness of our strategies.

Influence of Climate on Shrimp Abundance

David Whitaker
SCDNR-Marine Resources Division, Assistant Deputy Director
Presented September 13, 2012

A general trend observed over the last four decades of an apparent increase in the frequency of warmer-than-normal winters appears to be resulting in increased survival of white shrimp spawners, resulting in more stable populations. However, mild winters appear to be interfering with brown shrimp recruitment mechanisms, thus resulting in smaller populations of that species. Also, reduced annual rainfall and increasing salinities in the estuaries appears to be having negative impacts on both white and brown shrimp populations.

Lake Thurmond Economic Impact Analysis

Jeff Allen, Lori Dickes and Rob Carey
Strom Thurmond Institute, Clemson University
Presented December 5, 2012

This analysis estimated the economic impacts due to changes in water elevation on J. Strom Thurmond Lake. Impacts were estimated based on changes in gross retail sales, the number of lake adjacent real estate transactions, and on home values, as measured by sale price. The study region included the six counties bordering the lake: Columbia, Elbert, Lincoln, McDuffie, and Wilkes counties in Georgia, and McCormick County in South Carolina. The analysis was carried out in three stages: First, regression analysis was used to estimate the marginal effects on retail sales and the number of real estate transactions. Second, the dollar values associated with these marginal effects were used as inputs to an input-output (I/O) model to estimate the impact on the broader local economy through indirect and induced effects. Finally, hedonic modeling was used to estimate the effect of changing lake levels on home value.

Findings indicate a statistically significant impact from retail sales and real estate transactions, with an estimated impact of 37.5 jobs (or job-equivalents) and $7 million in output per foot change in lake level for the six-county region. These impacts are larger both in absolute dollars and as a portion of the total six-county economy than those estimated for Hartwell Lake in an earlier study. This is likely due to less economic diversity in the Thurmond Lake region relative to the counties surrounding Hartwell Lake.

The total estimated economic impact over the drought period of April 2007 through December 2008 was a loss of approximately 500 jobs over the six-county region, and some $288.7 million in output, which constitutes 3.1 percent of total regional output. Local (county and municipal) governments lost approximately $10.9 million in net revenue due to lost economic activity. The number of real estate transactions estimated to have been foregone over the course of the drought due to lower lake elevation was 104, or 31 percent of the number of actual transactions that took place over this period.

In addition, hedonic modeling was used to understand the broader economic impacts of drought on residential property values across this region. Hedonic modeling is based on the idea that the value of a home is a function of a range of property attributes like the number of bedrooms and bathrooms, as well as amenities like access to lakes, parks, and others. There is substantial evidence that proximity to water and the size of lake frontage are positively related to home value. We hypothesized that lake level would also be perceived as an amenity when the lake was close or at full pool and a disamenity when the lake was low; below full pool at some identified level.

Only three counties, Columbia, Elbert, and Lincoln, GA, had sufficient real estate data to estimate lake level impacts. Columbia County, incorporating the City of Augusta, had the most real estate transactions and is more economically diverse than the other two counties. In

Columbia County, at the lowest levels below full pool individual real estate prices may decline by as much as 1.5% as lake level declines. The lake level variable had a statistically significant impact across all three counties. Each county has its own unique economic, social, political, and environmental characteristics resulting in different relationships between lake activity, lake levels and real estate prices. Future research should consider adding additional years of data and clarifying the lake level variation that results in statistically significant impacts.

In summary, this analysis begins to understand the complex relationship between declining lake levels and broader economic impacts. As drought becomes more frequent and sustained, future research should continue to work to understand how consumers and businesses respond to these changes and internalize these into their broader pricing preferences.

Managing Wildland Fire in Rapidly Changing Times

Johnny Stowe
SCDNR-Wildlife Biologist and Heritage Preserve Manager
Presented December 5, 2012

Fires have burned over the landscape of Southeastern North America (SE NA) for many millennia. Prior to humans entering the continent at the end of the Pleistocene Epoch (about 13,000 before present [BP]), fires ignited by lightning burned large expanses. Southeastern North America, especially the Gulf Coast, has one of the highest incidences of lightning-strikes on the continent. The first humans that came into the region brought fire with them from the Old World, where evidence strongly-supports the fact that people had been using fire for at least 700,000 years. As documented by W.A. Watts based on pollen stratigraphy research conducted at White Pond (an isolated freshwater wetland near Elgin, SC), as the massive ice sheets of the Wisconsinan glaciation receded at the Pleistocene-Holocene transition, the vegetation of SE NA began to shift from jack pine (*Pinus banksiana*) and spruce (*Picea* spp.), species that today form the boreal forest of large parts of eastern Canada and some of the United States, to an oak (*Quercus* spp.), hickory (*Cordis* spp.), beech (*Fagus* XX), and ironwood (*Ostrya* and *Carpinus*) -dominated mesic, deciduous forest with a climate similar to, but warmer than, the northern hardwood area of today's western New York state. Conifers were rare or absent during this period (12,800-9,500 years BP). This forest then shifted to one dominated by southern pines (*Pinus* spp.), sweetgum (*Liquidamber styraciflua*), and blackgum (*Nyssa* spp.), until about 7,000 years BPE when oaks began declining and pines became more prominent. Research in Alabama shows a dramatic increase in corn (*Zea mays*) and pine pollen about 3,000 years BP. This corn-pine link combines with the overall progressive dominance of "southern" pines from pre-Columbian through historic times to indicate not only a change in long-term weather patterns, but increased fire frequency resulting from ignitions by growing human populations, and other factors associated with this demographic shift, as well. Longleaf pine, which once dominated > 60 million acres from Virginia to Texas, requires frequent fire (every 1-6 years). Lightning fires and those lit by Native Americans, and then by the African and European settlers who displaced them, shaped the longleaf pine and other forests, woodlands, savannas and prairies in SE NA. In the 1920s, the traditional, time-tested, multi-cultural use of fire in the region was attacked by the federal government and others, first by the "Dixie Crusaders," and then by Bambi and Smokey the Bear, and this combined with changing land uses to disintegrate the southern landscape. Fire science began at Tall Timbers Research Station, and despite a well-funded, many-decades-long attack on all wildland fire, the culture of wise prescribed fire use has persisted in pockets of the South. These remnants of natural and cultural heritage are being rekindled today by groups such as state prescribed fire councils, the (North American) Coalition of Prescribed Fire Councils, and the Longleaf Alliance. Existing accelerating changes in the landscape of the South (in its demography [population and attitudes] and land-use patterns) are combining with climate changes to make wildland fire management increasingly complex, making wildfire prevention and suppression, as well as the use of prescribed fire, increasingly vital. Fire is an inescapable force that cannot be tamed by a command-and-control strategy. Fire management in SE NA and other places requires a balanced approach that recognizes both the good as well as the bad sides of fire, from both a natural resource as well as a cultural perspective, in order to continue the paramount goal of public safety, while protecting property and natural resources and the economy and quality of life that depend on them.

National Integrated Drought Information System: Pilot Project in the Carolinas

Amanda Brennan
Carolinas Integrated Sciences & Assessments (CISA), Research Assistant
Presented September 13, 2012

Amanda Brennan (Climate Outreach Specialist, CISA) presented work on the development of a drought early warning system (DEWS) pilot program for the coastal regions of the Carolinas. This work, conducted in partnership between the National Integrated Drought Information System (NIDIS) and the Carolinas Integrated Sciences and Assessments (CISA), seeks to better understand drought effects on environmental resources in coastal ecosystems and inform drought planning and response processes. The presentation provided background information on CISA and NIDIS, outlined the elements of a drought early warning system, and detailed progress to date on development of the program. Specifically, the presentation shared information on 4 pilot projects, which were designed by stakeholders at a workshop in Summer 2012, and are currently under development. The projects include evaluation of drought indicators and indices, development of a seafood safety forecast for fishermen who harvest drought-sensitive seafood, a drought forecasting communications pilot, and a project to improve drought impacts reporting. More information on the pilot program can be found at: http://www.drought.gov/drought/regional-programs/coastalcarolinas/dews-coastal-carolinas-home.

On-line Tool for Assessing Local Impacts of Ecosystem Stress and Management Options

Steven McNulty
Ecologist and Team Leader, USDA Eastern Forest Environmental Threat Assessment Center
Presented October 24, 2012

The impacts of climate change are increasingly complicating ecosystem management and planning. Land managers are struggling to keep pace to address growing droughts, wildfires, flooding, insect outbreaks, and catastrophic weather disturbances, and to fulfill agency mandates for proactive planning. Increasingly, the land manager is forced into the conundrum of “Cheap, fast, and accurate: Which two do you want?” TACCIMO is being developed to address this challenge. TACCIMO (Template for Assessing Climate Change Impacts and Management Options) is a simple to use, web-based tool that provides the information foundation required to rapidly assess the effects of climate change and adaptive management options for ecosystems across the conterminous US (also includes Caribbean and Alaska). TACCIMO draws on a constantly growing database of over 1,000 peer reviewed scientific publications to assess thousands of possible effects and management options that are location specific. Once the location and topics of interest are selected, TACCIMO searches its extensive database and generates reports that include maps, climate projections, specific effects, and management options with citations.

Potential Effects of Changing Climate Patterns on Freshwater Habitats

Mark Scott
SCDNR-Freshwater Fisheries Research Biologist
Presented December 5, 2012

Climate is a primary forcing phenomenon driving ecosystem dynamics, and aquatic systems are particularly susceptible to alterations in the hydrologic cycle. Our ability to predict the consequences of climate change is limited by uncertainty in climate predictions compounded by complexity in ecological system behavior. Climate will interact with host of other *ongoing* system alterations, such as land use change, with which organisms must cope. Changes in precipitation timing and amount will affect **water quantity** and **quality**, and **timing of flows.** Some of the unique characteristics of aquatic ecosystems in South Carolina that must be considered when planning for climate change impacts include:

- High level of aquatic organism diversity and endemism.
- Migration of organisms is limited to within drainage networks, preventing natural migration across watershed boundaries.
- Barriers to connectivity within drainages are widespread, limiting natural migration upstream and downstream.

Data collected during the South Carolina Stream Assessment are being used to model potential consequences of climate change for streams in the state.

Salinity Intrusion: Integrating Riverine and Coastal Forces

Paul Conrads
US Geological Survey, Surface Water Specialist
Presented September 13, 2012

The location of the freshwater-saltwater interface is an important factor in the ecological and socio-economic dynamics along the coast. Salinity is a critical coastal response variable that integrates hydrological and coastal dynamics such as streamflow, precipitation, sea level, tidal cycles, winds, and tropical storms. The position of the interface determines the freshwater and saltwater aquatic communities and the freshwater availability for municipal and industrial water intakes. Freshwater tidal marshes support a larger biodiversity as compared to brackish and saltwater tidal marshes.

The position of the freshwater-saltwater interface results from the interaction of three principle forces - streamflow, mean coastal water levels, and tidal range. During periods of high streamflow, it is difficult for salinity to intrude upstream, and the freshwater-saltwater interface moves downstream towards the ocean. During periods of low streamflow, the freshwater-saltwater interface is moved upstream by tidal forcing, by an increase in mean coastal water level, a change in tidal range, or a combination of the two. During periods of extended drought, the migration of the freshwater-saltwater interface upstream can result in shifts in the aquatic and riparian ecological communities, freshwater intakes taken offline, and increase human exposure to saltwater tolerant pathogens, such as *Vibrio*. Specific conductance data (field measurement used for computing salinity) can be used to evaluate the salinity response to climate conditions such low-flow and drought conditions along the coast. The salinity response of five coastal rivers in South Carolina is presented.

South Carolina Climate Trends and Variability 1901-2010
Hope Mizzell
South Carolina State Climate Office, State Climatologist
Presented September 13, October 24, and December 5, 2012

This study provides an overview of South Carolina's climatic trends and variability over the last century. Most studies nationally have focused on large-scale temperature and precipitation trends, but examination of regional and local trends are needed to monitor the significance of the state's climate signal and advance our understanding of the complex physical controls on the region's climate. The behavior of several climatic elements since the 1900s were evaluated for 66 sites in Georgia, South Carolina and North Carolina to determine the variability of the system on annual, seasonal and decadal scales, including the use of threshold approaches to assess climate patterns.

Changes in South Carolina's surface temperature and precipitation over the last 100 years were analyzed using station data from the US Historical Climate Network (USHCN) and the National Weather Service Cooperative Network (COOP). Observations from 66 USHCN stations spanning the period 1901–2010 and 26 COOP stations spanning 60 to 100 years provide adequate spatial coverage for the three-state region. The USHCN is a dataset that includes adjustments for changes in station location, urbanization and time of observation and the COOP network provided the daily data needed for supplemental threshold approach evaluations.

Seasonal temperature and precipitation trends based on USHCN data were analyzed using the least squares method. Results showed a general precipitation decrease in the majority of the region for summer (≥1.0" decrease for 55 out of the 66 stations), with 36 out of the 66 stations experiencing a decreasing precipitation trend ≥ 2.50". The fall season trend analysis was the inverse of summer with all stations across the study area experiencing an increasing precipitation trend (61 stations had an increasing fall precipitation trend ≥1.0"). The winter average precipitation trends show mixed results with a drier trend in the higher elevations and the river headwater regions and a wetter trend in the outer and inner coastal plains. Spring precipitation trends are geographically similar to winter, but with a weaker signal. South Carolina temperature patterns are less clearly defined with differential changes in minimum temperature (Tmin) and maximum temperature (Tmax). Winter and spring Tmax has generally warmed , but the Tmin during these seasons has shown little variation or actually cooled over time. Summer and fall Tmax and Tmin don't consistently demonstrate a uniform trend with some stations warming while others have cooled across the region.

There are limitations to using a linear trend to analyze climate variability so moving averages and various threshold approaches were analyzed. The 10-year moving average for statewide annual precipitation shows a decreasing precipitation trend during the 1950s, increasing trend during the 1960s with a decreasing trend over the past decade. The 10-year moving average for statewide temperature shows a decreasing temperature trend from the late 1950s through the 1960s with a steady temperature increase since the 1970s. Future analysis should evaluate potential forcing mechanisms contributing to these local variations over time.

The Application of a Statistical Downscaling Process to Derive 21st Century Climate Predictions

David Werth
Savannah River National Laboratory, Research Scientist
Presented October 24, 2012

Reliable climate projections are critical to predicting the future water supply for the United States. These projections cannot be provided solely by global climate models (GCMs), however, as their resolution is too coarse to resolve the small-scale climate changes that can affect hydrology, and hence water supply, at regional to local scales. A process is needed to 'downscale' the GCM results to the smaller scales and feed this into a surface hydrology model to help determine the ability of rivers to provide adequate flow to meet future needs.

We apply a statistical downscaling to GCM projections of precipitation and temperature through the use of a scaling method. This technique involves the correction of the cumulative distribution functions (CDFs) of the GCM-derived temperature and precipitation results for the 20^{th} century, and the application of the same correction to 21^{st} GCM projections. This is done for three meteorological stations located within the Coosa River basin in northern Georgia, and is used with a hydrological model to calculate future river flow statistics for the upper Coosa River. We also created such a simulation with unscaled GCM results taken from the original simulations. The contrast between the two was clear – the use of downscaling led to significantly greater flows in the basin than flows determined from the unscaled GCM, which produced strong decreases in basin flow. A water management plan based on the latter would require more planning and expense than one based on the former. The method applied for this work has shown itself to be computationally inexpensive and useful for identifying and correcting the large errors in GCM depictions of the local-scale climate.

Understanding South Carolina's Climate Controls

Ivetta Abramyan
South Carolina State Climate Office, Research Assistant
Presented October 24, 2012 and December 5, 2012

Global climate oscillations have distinctive effects on different regions of the world. This study was driven by the need to better understand the factors behind South Carolina's temperature and precipitation variability, including snowfall occurrence. Precipitation during winter months is critical for adequate recharge of groundwater and surface water since this is a time of both low evaporation and demand. While statewide snowfall events are rare in South Carolina and are not a significant factor in hydrologic recharge, impacts from these events across other sectors such as energy, emergency management, and transportation can be significant.

The El Niño/La Niña Southern Oscillation (ENSO) and the Arctic Oscillation (AO) are important large-scale climate patterns, comprised of a positive and negative phase, that both have an effect on South Carolina's winter weather. During the ENSO positive phase, El Niño, South Carolina experiences colder than normal temperatures and higher precipitation in the winter months. During the negative phase, La Niña, the opposite is true. The AO has a strong winter temperature signal, predominantly yielding colder temperatures in the negative phase and warmer temperatures in the positive phase. Unlike ENSO, which affects both temperature and precipitation, the AO does not seem to have an effect on winter precipitation. Neither have a significant impact on temperature or precipitation during summer months.

Analysis of winter temperatures and total winter precipitation for Charleston, SC, and Walhalla, SC, with respect to ENSO and AO phases shows substantial variations between phases and among geographical regions. The minimum and maximum winter temperatures for Walhalla, SC, both reflect what we would expect to see, with warmer temperatures associated with La Niña and a positive AO phase. Charleston maximum temperatures show a larger difference between El Niño and La Niña winters than the minimum temperatures. There is an even greater difference between the AO positive and AO negative winter temperature signal for Charleston, with lower maximum and minimum temperatures during the negative AO phase. At both locations, rainfall was enhanced during El Niño and reduced during La Niña. However, the precipitation variations in Walhalla are not as pronounced as temperature, with only a slight decrease in La Niña winters. The variations in Charleston precipitation are greater than in Walhalla, with a substantial decrease in La Niña winters. Monthly precipitation departures from normal for Charleston for the December – May period with the respect to the winter average ENSO index also indicated similar results with the strongest signal during climatological winter. Additional studies with increased station coverage are needed to confirm that both temperature and precipitation signals are strongest along the coast and weaken as you move further inland.

This study also relates changes in ENSO phase to shifts in the frequency of measurable snowfall in Walhalla, SC. Events with amounts of ≥ 1.00 inch, ≥ 3.00 inches and ≥ 5.00 inches from 1950-2010 were analyzed in relation to El Niño, La Niña and Neutral phases. Events ≥ 1 inch are dispersed almost equally, with about ⅓ of the events occurring in each phase. Events ≥ 3 inches occur in the El Niño phase 50% of the time and in the La Niña phase 23% of the time. Events ≥ 5 inches occur in the El Niño phase 50% of the time and in the La Niña phase 33% of the time. This suggests that there may be a higher likelihood of heavier events during an El Nino period.

In addition to ENSO and AO, the effect of the Bermuda High on interannual variability was examined in relation to steering of tropical systems and synoptic weather patterns. The position of the Bermuda High affects hurricane tracks and its strength may also be associated with summer droughts in the southeast. A case study of two consecutive summers, one wet and one dry, was presented to demonstrate how the westward extension of the Bermuda High controls which region will be impacted by the flow of moisture. In addition to position shifts, the strength of the central pressure also plays a role in climate variability, as a weakened Bermuda High leads to less moisture advection into the southeast due to a weaker anticyclonic circulation.

Water Level Trends in Aquifers of South Carolina

Scott Harder
SCDNR-Land, Water and Conservation, Hydrologist
Presented October 24, 2012 and December 5, 2012

Ground-water levels were examined to document and evaluate short- and long-term trends observed in each of the major aquifers in the State. Data were compiled from ground-water monitoring networks maintained by the South Carolina Department of Natural Resources (SCDNR), the South Carolina Department of Health and Environmental Control (DHEC), and the United States Geological Survey (USGS). The data were used in the support of ground water management and allocation, assessment of droughts, ground-water flow modeling, and resource assessment. Hydrographs from approximately 170 wells were reviewed with periods of record ranging from 1 to 56 years; however, only those sites with at least a 10-year period of record were included in this study.

Long term ground-water level declines were observed in each of the major aquifers in the state. These declines are likely a result of both drought and ground water pumping. Many well sites experienced a strong response to the multi-year droughts of 1998-2002 and 2007-2008. However, while some wells experienced a recovery after these droughts, other well sites did not. Significant upward trends were only observed in areas where water users have supplemented water supply with surface water or transitioned from ground water to surface water.

In the Piedmont, water-level declines varied substantially from 1 to 2 ft to over 10 ft during these drought periods. Though water levels typically returned to baseline levels in many wells, several sites experienced little to no recovery with overall downward trends of 10 to 12 ft. over the past twelve years.

Middendorf aquifer levels in eastern Berkeley County have declined by approximately 55 ft. since the early 1990s. In southern Florence County and southern Lexington County, water levels have declined by approximately 10 ft. in the Middendorf aquifer with little to no recovery after the 1998-2002 and 2007-2008 droughts. Similar declines are noted in the Middendorf aquifer in Aiken, Allendale, and Barnwell Counties, where water levels have dropped 3 to 10 ft. since the mid-1990s.

In the Black Creek aquifer, water levels in southern Marion County and southern Florence County have declined by 40 ft. and 16 ft. over their respective periods of record. In Aiken, Allendale, and Barnwell Counties, water levels have dropped 4 to 12 ft. in the Black Creek aquifer since the mid-1990s, similar to declines observed in the Middendorf aquifer in these counties.

Floridan aquifer water levels have experienced a leveling off or a slight recovery during the past ten years after steady declines throughout the 1970s and 1980s at several wells sites in Beaufort County. Observations in southern Colleton County and southern Charleston County indicate water-level declines in the Floridan aquifer of about 8 and 12 ft., respectively, since 2000. Observations in central Charleston County indicate a decline of about 20 ft. since the early 1980s, while observations in northern Colleton County indicate a decline of about 20 ft. since the late 1970s.

There are many challenges for the State's water managers in the interpretation of ground-water level data throughout the state. First, water-level declines can be caused by drought and/or localized pumping for water supply and irrigation as well as from the cumulative effects of pumping over broader regions. In addition, uncertainties in recharge areas and recharge rates for the State's aquifers add to the complexity of understanding ground water level behavior. Many of the wells in the network have only been monitored for 10 to 15 years and, hence, may lack a sufficient period of record from which to adequately evaluate trends. Lastly, despite having over 170 continuously monitored wells by DNR, DHEC and the USGS, large areas of the state, particularly the middle coastal plain, currently have little to no continuous monitoring.

These challenges make it difficult to evaluate the significance of these observed water-level declines; however, these trends highlight the importance of maintaining a state ground-water monitoring network and the establishment of long-term ground-water datasets. Future work should include adding wells in those aquifers and areas of the State where current monitoring is poor or nonexistent. In addition, a more detailed study on ground-water level trends should be completed that takes into account climate variability and local/regional ground-water use.

Such a study is needed to differentiate the effects of drought and ground-water pumping on water level behavior.

What's Going on With My Trees: Climate Effects on Forest Health

Laurie Reid
SC Forestry Commission, Forest Health Specialist
Presented October 24, 2012 and December 5, 2012

Climate change can have several effects on trees all which may affect forest health. Some effects are physical, such as damage due to wind, snow, frost, or ice, while others may cause the tree to be more susceptible to insects or diseases by modifying the trees' defenses. Warming temperatures can allow for changes in species boundaries, change insect life histories by allowing for additional generations, or increase insects or pathogens survival. Nutrient cycling can be affected by changes in the soil nutrient availability, amount and seasonality of litter inputs, decomposition rates, and litter quality. Changes can also occur to hydrological processes, soil moisture, and species composition.

These changes can have broader effects such as the change in species composition and it's relation to wildfire. Tree mortality increases debris levels which can lead to increased fire risk, fire frequency, and fire intensity due to increased fuel loads, longer fire season, and more extreme fire weather conditions. Fire is beneficial in a forested setting as it accelerates nutrient cycling, favors fire adapted species, and can induced seed germination.

The effects of drought differ with different plant species. In some species, drought may boost secondary metabolites or cause the leaves to be waxier, both of which makes the plant less desirable to insect feeding. However, in other plant species, drought can increase the sugar and nitrogen content of the leaves, making them more desirable to insect feeding. In some cases, drought can stress a tree making it more susceptible to weak, opportunistic pathogens, such as *Armillaria* root disease and *Hypoxylon* Canker. Drought can also modify tree defenses making them more susceptible to insect attack, such as attack by *Ips* engraver, Southern Pine, and Black Turpentine beetles to pine trees.

Wood Ducks of the Savannah River Site: Indicators of Changing Environments

Robert Kennamer
Savannah River Ecology Laboratory, University Georgia, Research Professional
Presented October 24, 2012

Data from long-term population studies will be critical for understanding how wildlife species might adapt to unfolding climate change. We know that birds rely on environmental signs to indicate the onset of favorable breeding conditions, and annual changes in temperature and rainfall patterns can cause shifts in the timing of natural food resource availability. Successful breeding therefore is highly dependent upon the flexibility of birds to time their reproduction adequately with their critical food supplies. Wood ducks rank among the top waterfowl species harvested in the United States and are particularly important to hunters in the Southeast, including South Carolina. In this presentation, researchers at Savannah River Ecology

Laboratory, near Aiken South Carolina, illustrate the use of climatological data from a local National Weather Service station and long-term surface-water level data from Savannah River Site (SRS) wetlands to develop a predictive model of wetland hydrologic conditions. Long-term wetland hydrologic patterns on the SRS suggest prominent global climatological cycle influences. For wood ducks using nest boxes on the SRS, duckling production, prevalence of yearling nesting, and incidence of nest predation were all related to annual variation in wetland conditions, with greater overall population productivity in years characterized as being wet. Analysis of long-term wood duck nesting patterns on the SRS demonstrate that the start of the breeding season has gradually shifted to earlier in the year, with dates of first nests each year advancing by about a month from the early 1970s through the mid-1990s. This shift to earlier nesting by wood ducks was associated with a winter warming trend over time. Wood ducks advance their nesting dates by being able to meet the energetic demands for reproduction earlier in the year. Currently, for wood ducks on the SRS and elsewhere in the southern U.S., there are recognized advantages to nesting earlier each year, including the laying of larger clutches of eggs, increased opportunity for producing two broods in a single season, and respite from certain predators that become active later in the season. Continued rapid climate change, however, makes their future less certain.

Appendix 3: List of Participants

September 13, 2012 – Charleston, SC

Daniel B. Ahern
Beaufort County Stormwater Utility
102 Industrial Village Road, Bldg. #3
Beaufort, SC 29906
Phone: 843.255.2805
Email: dahern@bcgov.net

Dennis Allen
USC Baruch Marine Field
Laboratory, Hobcaw Barony on
Hwy 17 N
Georgetown, SC 29440
Phone: 843.904.9025
Email: dallen@belle.baruch.sc.edu

Wendy B. Allen
North Inlet - Winyah Bay National
Estuarine Research Reserve
USC Baruch Marine Lab
PO Box 1630
Georgetown, SC 29442
Phone: 843.904.9026
Email: wendy@belle.baruch.sc.edu

Devendra M. Amatya
USDA Forest Service
Center for Forested Wetlands Research
3734 Highway 402
Cordesville, SC 29434
Phone: 843.336.5612
Email: damatya@fs.fed.us

Hakim Bayyoud
Beaufort County P.O. Box 333
Port Royal, SC 29935
Phone: 843 255.2071
Email: hbayyoud@bcgov.net

Frank E. Blume
SC Seafood Alliance (SCSA)
815 Savannah Highway, Suite 204
Charleston, SC 29407
Phone: 843.556.2520
Email: scarolinaseafood@knology.net

Amanda Brennan
Carolinas Integrated Sciences
& Assessments (CISA)
Department of Geography
University of South Carolina
Columbia, SC 29208
Phone: 803.777.6875
Email: abrennan@sc.edu

Joy Brown
The Nature Conservancy
1417 Stuart Engals Boulevard, Suite 100
Mount Pleasant, SC 29464
Phone: 843.937.8807, ext. 35
Email: joy_brown@tnc.org

Sara A. Brown
US Army Corps of Engineers
Charleston District
69A Hagood Avenue
Charleston, SC 29403
Phone: 843.329.8150
Email: Sara.A.Brown@usace.army.mil

Michael Childress
Clemson University132 Long Hall - Clemson
University Clemson, SC 29634-0314
Phone: 864.656.6198
Email: mchildr@clemson.edu

Arpita Choudhury
Association of Fish and Wildlife Agencies
444 North Capitol Street NW, Suite 725
Washington, DC 20001
Phone: 202.624.5853
Email: achoudhury@fishwildlife.org

Mark Collins
Phone: 843.762.3530
markryancollins@gmail.com

Paul Conrads
US Geological Survey
Stephenson Center, Suite 129
720 Gracern Road
Columbia, SC 29210
Phone: 803.750.6140
Email: pconrads@usgs.gov

Rusty Day
National Institute of Standards and Technology
Hollings Marine Laboratory
331 Fort Johnson Rd
Charleston, SC 29412
Phone: 843.762.8904
Email: russell.day@nist.gov

Susan Dunham
SC Emergency Management Division GIS
2779 Fish Hatchery Road
West Columbia, SC 29172
Phone: 803. 737.8588
Email: sdunham@emd.sc.gov

Stephanie Fauver (Kemerer)
Human Dimensions Program
NOAA Coastal Services Center
2234 S Hobson Avenue
Charleston, SC 29405
Phone: 843.740.1287
Email: stephanie.fauver@noaa.gov

Dianne Greenfield
Baruch Institute for Marine and Coastal Science
Hollings Marine Laboratory
331 Fort Johnson Rd.
Charleston, SC 29412
Phone: 843.725.4823
Email: dgreenfield@belle.baruch.sc.edu

Jane Griess
U.S. Fish and Wildlife Service
Savannah National Wildlife Refuge
694 Beech Hill Lane
Hardeeville, SC 29927
Phone: 843.784.9911
Email: jane_griess@fws.gov

Cynthia Hall
Department of Geology
College of Charleston
202 Calhoun Street, Suite 224B
Charleston, SC 29424
Phone: 843.953.7852
Email: hallcr@cofc.edu

Jay Herrington
U. S. Fish and Wildlife Service
176 Croghan Spur Road, Suite 200
Charleston, South Carolina 29407
Phone: 843.727.4707, ext. 212
Email: Jay_Herrington@fws.gov

Amanda Hill
U.S. Fish and Wildlife Service
176 Croghan Spur Road, Suite 200
Charleston, SC 29407
Phone: 843.727.4707 ext. 303
Email: amanda_hill@fws.gov

Robin R. Humphreys
Department of Geology and Environmental Geosciences
College of Charleston
Room 243 NSCB
66 George Street
Charleston, SC 29424
Phone: 843.953.7424
Email: humphreysr@cofc.edu

Peter Keller
U.S. Fish and Wildlife Service Arkansas National Wildlife Refuge Complex
P.O. Box 100
Austwell, TX 77950
Phone:
Email: peter_keller@fws.gov

Robert E. Klink
Beaufort County
4 Hobonny Place
Hilton Head, SC 29926
Phone: 843.255.9420
Email: reknmk@hargray.com

Eric Krueger
The Nature Conservancy
1417 Stuart Englas Blvd.
Mt. Pleasant, SC 29464
Email: ekrueger@tnc.org

Sarah Latshaw
SCDHEC-OCRM
1362 McMillan Ave., Suite 400
Charleston, South Carolina 29405
Phone: 843.953.9237
Email: latshasa@dhec.sc.gov

Jarrod Loerzel
College of Charleston
Email: jlloerze@g.cofc.edu

Diane Lauritsen
Commissioner, Mt. Pleasant Waterworks
705 Bradburn Drive
Mount Pleasant, SC 29464
Phone: 843.822.0822
Email: ddlauritsen@comcast.com

Ginger Ogburn Matthews
Baruch Marine Field Laboratory
PO Box 1630
Georgetown, SC 29442
Phone: 843.904.9032
Email: ginger@belle.baruch.sc.edu

Malcolm Meaburn
NOAA National Ocean Service
Retired

Tom McCoy
U.S. Fish and Wildlife Service
SC Ecological Services Field Office
176 Croghan Spur Road, Suite 200
Charleston, SC 29407
Phone: 843.727.4707, ext. 227
Email: thomas_mccoy@fws.gov

Mark Messersmith
Planning and Environmental Branch
US Army Corps of Engineers
Charleston District
69A Hagood Ave
Charleston, SC 29403
Phone: 843. 329.8162
Email: mark.j.messersmith@usace.army.mil

Eddie Mills
Nemours Wildlife Foundation
161 Nemours Plantation Road
Yemassee, SC 29445
Phone: 843.986.2568
Email: emills@nemourswildlife.org

Barbara Neale
SCDHEC-OCRM
1362 McMillan Ave., Suite 400
Charleston, South Carolina 29405
Phone: 843.953.0245
Email: nealeb@dhec.sc.gov

Raye Nilius
SC Lowcountry Refuges Complex
5801 Highway 17 North
Awendaw, SC 29429
Ernest F. Hollings ACE Basin, Cape Romain, Santee, and Waccamaw National Wildlife Refuges
Phone: 843.928.3264
Email: raye_nilius@fws.gov

Craig Plante
Grice Marine Laboratory
205 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9187
Email: plantec@cofc.edu

Robert D. Podolsky
Grice Marine Laboratory
205 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9186
Email: podolskyr@cofc.edu

Margaret Ptacek
Clemson University
College of Agriculture, Forestry and Life Sciences
Clemson, SC 29634
Phone: 864.656.6964
Email: mptacek@clemson.edu

Mark A. Purcell
Manager, EFH ACE Basin NWR
8675 Willtown Road
P.O. Box 848
Hollywood, SC 29449
Phone: 843.889.3084
Email: Mark_Purcell@fws.gov

Nicole M. Rankin
U.S. Fish and Wildlife Service
National Wildlife Refuge System
Inventory and Monitoring Network
5801 Highway 17 North
Awendaw, SC 29429
Phone: 843. 928.3264 ext. 211
Email: nicole_rankin@fws.gov

Will Salters
SC DHEC-OCRM
1362 McMillan Ave., Suite 400
Charleston, South Carolina 29405
Phone: 843.953.0258
Email: salterwg@dhec.sc.gov

Geoff Scott
NOAA Center for Environmental Health and Biomolecular Research
219 Fort Johnson Road
Charleston, SC 29412
Phone: 843.762.8508
Email: geoff.scott@noaa.gov

Erik Smith
North Inlet-Winyah Bay National Estuarine Research Reserve
Baruch Marine Field Laboratory
PO Box 1630
Georgetown SC 29442
Phone: 843.904.9035, ext. 235
Email: erik@belle.baruch.sc.edu

Charles Tucker
ACE Basin

Bethney Ward
NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405
Phone: 843.740.1282
Email: bethney.ward@noaa.gov

David Whitaker
Marine Resources Division
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843. 953.9392
Email: whitakerd@dnr.sc.gov

Jessica C. Whitehead
South Carolina Sea Grant Consortium/
North Carolina Sea Grant/
Carolinas Integrated Sciences &
Assessments (CISA)
287 Meeting Street
Charleston, SC 29401
Phone: 843.953.2090
Email: jessica.whitehead@scseagrant.org

Ernie Wiggers
Nemours Wildlife Foundation
161 Nemours Plantation Road
Yemassee, SC 29445
Phone: 843.986.2568
Email: ewiggers@nemourswildlife.org

Pace Wilber
HCD Atlantic Branch
NOAA Fisheries Service
219 Ft Johnson Road
Charleston, SC 29412
Phone: 843.762.8601
Email: Pace.Wilber@noaa.gov

Carolee Williams
City of Charleston
Planning, Preservation & Sustainability
75 Calhoun Street
Charleston, SC 29401
Phone: 843.724.3776
Email: williamsc@charleston.sc.gov

Andy Yasinsac
SC Chapter, Sierra Club
236 Loch Drive
Columbia, SC 29201
Phone: 803.731.5282
Email: yasinsaa@yahoo.com

SCDNR Staff

Ivetta Abramyan
State Climate Office of South Carolina
1000 Assembly Street
Columbia, SC 29201
Email: abramyani@dnr.sc.gov

Blaik P. Keppler
ACE Basin Coastal Training Program
217 Ft. Johnson Road
Charleston SC 29412
Phone: 843.953.9024
Email: kepplerb@dnr.sc.gov

Steve Arnott
Marine Resources
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9794
Email: arnotts@dnr.sc.gov

John Leffler
Marine Resources Research Institute
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843. 953.3903
Email: lefflerj@dnr.sc.gov

Robert Boyles
Marine Resources Division
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9304
Email: boylesr@dnr.sc.gov

Phil Maier
Marine Resources
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9001
Email: pmaier@dnr.sc.gov

Mike Denson
Marine Resources Research Institute
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9834
Email: densonm@dnr.sc.gov

Hope Mizzell
State Climate Office of South Carolina
1000 Assembly Street
Columbia, SC 29201
Phone: 803.734.9568
Email: mizzellh@dnr.sc.gov

Amanda C. Fornal
ACE Basin National Estuarine Research Reserve
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9225
Email: fornala@dnr.sc.gov

Sarah Goldman
Marine Resources Monitoring, Assessment
and Prediction Program
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843. 953.3256
Email: goldmans@dnr.sc.gov

Julie Holling
Heritage Trust
1000 Assembly Street
Columbia, SC 29201
Phone: 803.734.3917
Email: hollingj@dnr.sc.gov

Bob Perry
Office of Environmental Programs
1000 Assembly Street
Columbia, SC 29201
Phone: 803.734.3766
Email: perryb@dnr.sc.gov

Ken Rentiers
Land, Water and Conservation Division
1000 Assembly Street
Columbia, SC 29201
Phone: 803.734.9035
Email: rentiersk@dnr.sc.gov

Jonathan Richardson
Marine Resources Research Institute
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843. 953.9093
Email: RichardsonJ@dnr.sc.gov

Denise M. Sanger
Marine Resources Research Institute
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9074
Email: sangerd@dnr.sc.gov

Derrell Shipes
Wildlife & Freshwater Fisheries
1000 Assembly Street
Columbia, SC 29201
Phone: 803.734.3938
Email: derrells@dnr.sc.gov

Al Segars
ACE Basin National Estuarine Research Reserve
16 Coastal Seafood Road
St. Helena Island, SC 29920
Phone: 843. 252.4244
Email: segarsa@dnr.sc.gov

Saundra Upchurch
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843. 953.9223
Email: upchurchs@dnr.sc.gov

Michelle Willis
Marine Resources Division
217 Fort Johnson Road
Charleston, SC 29412
Phone: 843.953.9054
Email: willisc@dnr.sc.gov

October 24, 2012 – Columbia, SC

Steve Bennett
119 Northman Drive
Columbia, SC 29210
Phone: 803-731-0002
Email: steveb0989@gmail.com

Amanda Brennan
Carolinas Integrated Sciences & Assessments
USC Department of Geography
709 Bull Street
Columbia, SC 29208
Phone: 803-777-6875
Email: abrennan@sc.edu

Steve de Kozlowski
Congaree Riverkeeper
207 Canterfield Road
Columbia, SC 29212
Phone: 803-600-7528
Email: sdekoz2@gmail.com

Richard (Rick) DeVoe
SC Sea Grant Consortium
287 Meeting Street
Charleston, SC 29401
Phone: 843-953-2078
Email: rick.devoe@scseagrant.org

John Farley
WIS-TV
1111 Bull Street
Columbia, SC 29201
Phone: 408-515-9443
Email: jfarley@wistv.com

Eric Fleming
USDA – NRCS
1835 Assembly Street, Rm.950
Columbia, SC 29201
Phone: 803-765-5683
Email: eric.fleming@sc.usda.gov

Wayne Grooms
Lexington County Soil & Water Conservation District
1312 Alpine Drive
West Columbia, SC 29169
Phone: 803-960-0754 (cell)
Email: waynemgrooms@gmail.com

Mary Taylor Haque, ASLA
114 Srode Circle
Clemson, SC 29631
Phone: 864-654-2643
Email: mhaque@clemson.edu

Frank Henning
Congaree National Park
100 National Park Road
Hopkins, SC, 29061
Phone: 803-776-4396/803-647-3963
Email: frankphenning@gmail.com

Mel Jenkins
Environmentalists, Inc.
3324 Montgomery Avenue
Columbia, SC 29205
Phone: 803-603-4351
Email: greenpalmetto@yahoo.com

Robert Kennamer
Savannah River Ecology Laboratory
P O Drawer E Aiken, SC 29802
Phone: 803-725-0387
Email: rkennamer@srel.edu

Michael Kruk
ERT, Inc.
151 Patton Ave. Asheville, NC 28801
Phone: 828-271-4095
Email: michael.kruk@noaa.gov

Gwendolyn F. Littlejohn
Blackville Community Development Corp.
PO Box 295
Blackville, SC 29817
Phone: 803-284-2196
Email: gl4816@gmail.com

Jennifer Majors
Environmental Discovery Center
1110 Ben Gause Road
Coward, SC 29530
Phone: 843-389-0550
Email: jmajors@florenceco.org

Steven McNulty
Eastern Forest Environmental Threat Assessment Center
USDA Forest Service
920 Main Campus Drive
Raleigh, NC 27695
Phone: 919-515-9489
Email: steve_mcnulty@ncsu.edu

Bill Melven
Lexington County Soil & Water Conservation District
123 Park Road
Lexington, SC 29072
Phone: 359-3165, Ext.3
Email: bill.melven@sc.nacdnet.net

Aashka Patel
University of South Carolina
230 Pendleton St., Apt 4B, Columbia SC 29201
Phone: 803-457-6911
Email: aashkajp@gmail.com

Dwayne E. Porter
Department of Environmental Health Sciences
Arnold School of Public Health and the Baruch Institute
University of South Carolina
Columbia, SC 29201
Phone: 803-777-4615
Email: porter@sc.edu

Laurie Reid
SC Forestry Commission
5500 Broad River Road
Columbia, SC 29212
Phone: 803-896-8820
Email: lreid@forestry.state.sc.us

S. Samadi (Vidya)
CISA
SC Department of Geography
709 Bull Street
Columbia, SC 29208
Phone: 803-346-9273
Email: SAMADI@mailbox.sc.edu

William Schmitz
Southeast Regional Climate Center
Saunders Hall Campus Box 3220
Chapel Hill, NC 27599
Phone: 919-843-9721
Email: wschmitz@email.unc.edu

David Scott
Savannah River Ecology Lab
PO Drawer E Bldg. 737-A, SRS
Aiken, SC 29802
Phone: 803-725-5747
Email: scott@srel.edu

Geoff Scott
Center for Coastal Environmental Health
and Biomolecular Research
NOAA's National Ocean Service
National Center for Coastal Ocean Science
219 Fort Johnson Road
Charleston, SC 29412
Phone: 843-762-8508
Email: Geoff.Scott@noaa.gov

Hart Scott
University of South Carolina
2107 Harper Street
Newberry, S.C. 29108
Phone: 803-860-0333 or 803-276-8484
Email: scottch@email.sc.edu

David C. Shelley
Congaree National Park
100 National Park Road
Hopkins, SC, 29061
Phone: 803-647-3966
Email: david_shelley@nps.gov

Kenneth Stone
USDA-ARS
2611 West Lucas Street
Florence, SC 29501
Phone: 843-669-5203 x 111
Email: ken.stone@ars.usda.gov

Fred Taylor
Lexington County Soil & Water
Conservation District
PO Box 294
Gilbert, SC 29054
Phone: 803-898-4241
Email: taylorfj@dhec.sc.gov

Dan Tufford
University of South Carolina
Department of Biological Sciences
715 Sumter Street
Columbia, SC
Phone: 803-777-3292
Email: tufford@sc.edu

Leonard Vaughan
National Weather Service
2909 Aviation Way
W. Columbia, 29170
Phone: 803- 822-8038
Email: Leonard.Vaughan@noaa.gov

Ethel Washington
Blackville Community Development Corp.
1417 Legion Road
Blackville, SC 29817
Phone: 803-671-2197
Email: ethelwshngtn@yahoo.com

Allen Weber (retired)
Savannah River National Laboratory
820 Jackson Ave.
North Augusta, SC 29841
Phone: 803-278-2781
Email: weber.allen@gmail.com

David Werth
Savannah River National Laboratory
SRS, Bldg. 773-A, Rm. 1012
Aiken, SC 29808
Phone: 803-725-3717
Email: david.werth@srnl.doe.gov

Norman Whitaker
Central Midlands Council of Governments
236 Stoneridge Drive
Columbia, SC 29210
Phone: 803-744-5128
Email: nwhitaker@cmcog.org

SCDNR STAFF

Ivetta Abramyan
State Climate Office of South Carolina
1000 Assembly Street
Columbia, SC 29201
Email: abramyani@dnr.sc.gov

Kathy Boyle
Heritage Trust
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-4032
Email: boylek@dnr.sc.gov

Marc Cribb
Land, Water and Conservation Division
Conservation Districts
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-6367
Email: cribbm@dnr.sc.gov

Kay Daniels
Heritage Trust
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-3893
Email: danielsK@dnr.sc.gov

Scott Harder
Land, Water and Conservation Division
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-4764
Email: harders@dnr.sc.gov

Julie Holling
Heritage Trust
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-3917
Email: hollingj@dnr.sc.gov

Hope Mizzell
State Climate Office of South Carolina
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-9568
Email: mizzellh@dnr.sc.gov

Bob Perry
Office of Environmental Programs
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-3766
Email: perryb@dnr.sc.gov

Bert Pittman
Heritage Trust
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-3920
Email: pittmanb@dnr.sc.gov

Lynn Quattro
Wildlife & Freshwater Fisheries
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-9094
Email: quattrol@dnr.sc.gov

Mark Scott
Wildlife & Freshwater Fisheries
311 Natural Resources Drive
Clemson, SC 29631
Phone: 864-654-6346, Ext. 14
Email: scottm@dnr.sc.gov

Derrell Shipes
Wildlife & Freshwater Fisheries
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-3938
Email: derrells@dnr.sc.gov

December 5, 2012 – Greenville, SC

Jeffery S. Allen
Strom Thurmond Institute of Government and Public Affairs
South Carolina Water Resources Center
Clemson University
Clemson, SC 29634-0125
Phone: 864-656-0228
Email: jeff@sti.clemson.edu

Kyle Barrett
School of Agricultural, Forest, and Environmental Sciences
261 Lehotsky Hall
Clemson University
Clemson, SC 29634
Phone: 334-663-6813
Email: rbarre2@clemson.edu

Jennifer Barrington
Anderson Regional Joint Water System
998 Hungers Trail
Anderson, SC 29625
Phone: 864-332-6532
Email: jbarrington@arjwater.com

Garrett Bedenbaugh
WACH Fox Columbia
1400 Pickens Street
Columbia, SC 29201
Phone: 803-251-4920
Email: gbedenbaugh@wach.com

Herb Burnham
Lake Hartwell Association
103 Andrea Point
Anderson, SC 29625
Phone: 864-202-5204
Email: herbburnham@bellsouth.net

Rob Carey
Regional Dynamics & Economic Modeling Laboratory
Clemson University
Clemson, SC 29634-0125
Phone: 864-656-0228
Email: carey2@clemson.edu

Mike Caston
SJWD Water District
P.O. Box 607
Lyman, SC 29365
Email: mcaston@sjwd.com

Dennis Chastain
SC Drought Response Committee
5699 Highway 11
Pickens, SC 29671
Phone: 864-878-7455, 864- 395-1522
Email: dchas@aol.com

Jane Chastain
5699 Highway 11
Pickens, SC 29671
Phone: 864-878-7455, 864- 395-1522
Email: dchas@aol.com

Lori Dickes
South Carolina Water Resources Center
Clemson University
Clemson, SC 29634-0125
Phone: 864-656-0228
Email: lorid@.clemson.edu

Kirsten Lackstrom
Carolinas Integrated Sciences and Assessments (CISA)
Department of Geography
University of South Carolina
Columbia, SC 29208
Phone: 803-777-3463
Email: Lackstro@mailbox.sc.edu

Linda Rimer
US Environmental Protection Agency
Research Triangle Park
Durham, NC 27711
Phone: 919-541-0785
Email: rimer.linda@epa.gov

Kirsten Robertson
Greenville County Soil & Water Conservation District
301 University Ridge, Suite 4800
Greenville, SC 29601
Phone: 864-467-2755
Email: kirobertson@greenvillecounty.org

David Shelley
Congaree National Park
100 National Park Road
Hopkins, SC 29061
Phone: 803-647-3966
Email: david_shelley@nps.gov

Chris Starker
Upstate Forever
507 Pettigru Street
Greenville, SC 29601
Phone: 864-250-0500
Email: cstarker@upstateforever.org

Mitch Turner
SJWD Water District
P.O. Box 607
Lyman, SC 29365
Phone: 864-439-4423
Email: mturner@sjwd.com

John Tomko
National Weather Service
1549 GSP Drive
Greer, SC 29651
Phone: 864-848-1332
Email: John.tomko@noaa.gov

John Westcott
Spartanburg Water
175 N. Liberty Street
Spartanburg, SC 29306
Phone: 864-580-5685
Email: jwestcott@spartanburgwater.org

Doug Young
Chickasaw Point Property Owner's Association
105 Eagle Court
Westminster, SC 29693
Phone: 864-247-3900
Email: dgyoung@bellsouth.net

SCDNR Staff

Ivetta Abramyan
State Climate Office of South Carolina
1000 Assembly Street
Columbia, SC 29201
Email: abramyani@dnr.sc.gov

Scott Harder
Land, Water and Conservation Division
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-4764
Email: harders@dnr.sc.gov

Julie Holling
Heritage Trust
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-3917
Email: hollingj@dnr.sc.gov

Hope Mizzell
State Climate Office of South Carolina
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-9568
Email: mizzellh@dnr.sc.gov

Lynn Quattro
Wildlife & Freshwater Fisheries
1000 Assembly Street
Columbia, SC 29201
Phone: 803-734-9094
Email: quattrol@dnr.sc.gov

Mark Scott
Wildlife & Freshwater Fisheries
311 Natural Resources Drive
Clemson, SC 29631
Phone: 864-654-6346, Ext. 14
Email: scottm@dnr.sc.gov

Johnny Stowe
Heritage Preserve Manager
Clemson University Sandhill Research and
Education Center
P.O. Box 23205
Columbia, SC 29224
Phone: 803-419-9374
Email: stowej@dnr.sc.gov


Workshop Photos