OUR COASTAL FUTURE FORUM

Biodiversity in a Changing Climate

COLLEGE of CHARLESTON 1770

Sea Grant
S.C. Sea Grant Consortium

The UNIVERSITY of OKLAHOMA

Principal Investigators

Susan Lovelace, PhD
Assistant Director,
Extension and Development
S.C. Sea Grant Consortium

Matt Nowlin, PhD
Assistant Professor,
Department of Political Science
College of Charleston

Justin Reedy, PhD
Professor,
Department of Communication
University of Oklahoma

Editors

Lee Bundrick
Graduate Assistant,
S.C. Sea Grant Consortium
College of Charleston

Stacey Weinstock
Graduate Assistant,
S.C. Sea Grant Consortium
College of Charleston

Joey Holleman
Science Writer,
S.C. Sea Grant Consortium

Susan Ferris Hill
Director of Communications,
S.C. Sea Grant Consortium

Expert Scientist Presenters

Kirstin Dow, PhD
Professor,
Department of Geography
University of South Carolina

Paul Gayes, PhD
Director, School of Coastal and
Marine Systems Science
Coastal Carolina University

Marcel Reichert, PhD
Senior Scientist, Marine Resources
Research Institute
S.C. Department of Natural Resources

Paul Sandifer, PhD
Director, Center for Coastal
Environmental and Human Health
College of Charleston

Geoff Scott, PhD
Chair, Department of
Environmental Health Sciences
University of South Carolina

Elizabeth Fly, PhD
Formerly of S.C. Sea Grant
Consortium and Carolina Integrated
Sciences and Assessments (CISA)

Coastal Advisory Group

Emily Cedzo
Program Director,
Air, Water, and Public Health
Coastal Conservation League

Kelly Mezzapelle
Planner,
City of Myrtle Beach, S.C.

Spencer Wetmore
City Administrator,
City of Folly Beach, S.C.

Ricky Martin
Building and Zoning Administrator,
City of Georgetown, S.C.

Allison Hardin
Planner,
City of Myrtle Beach, S.C.

Kim Jones
Manager, Watershed
Management Division
Town of Bluffton, S.C.

Dan Ahern
Design Review Board Member,
City of Beaufort, S.C.

Facilitators

Barbara Brown
President,
Citizens Center for Public Life

Bob Kahle, PhD
Joseph P. Riley Jr. Center for
Livable Communities
College of Charleston

Blaik Keppler
S.C. Department
of Natural Resources

Michelle LaRocco
University of South Carolina

Susannah Sheldon
S.C. Sea Grant Consortium

Kendra Stewart, PhD
Joseph P. Riley Jr. Center for Livable
Communities
College of Charleston

Jessica Tipton
S.C. Department
of Natural Resources

April Turner
S.C. Sea Grant Consortium

Sarah Watson
S.C. Sea Grant Consortium

Sea Grant
S.C. Sea Grant Consortium

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The S.C. Sea Grant Consortium generates and provides science-based information to enhance the practical use and conservation of coastal and marine resources that foster a sustainable economy and environment for the state of South Carolina and its citizens. The Consortium provides mechanisms by which many interests can come together to identify, discuss, study, and share information about our coastal and ocean environment and its economic, environmental, and socio-economic importance to the state. We do this through partnerships, and we recognize that the value of working with partners from all sectors is critical to our success.

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Front Cover: Oyster harvester in Clark Sound, James Island. *Alex Braud (February 2018)*
Back Cover: Sunset near Sullivan's Island. *Lee Bundrick, S.C. Sea Grant Consortium (May 2017)*

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About Our Coastal Future Forum

The Our Coastal Future Forum is one part of a research project to determine the feasibility of using a process of deliberative democracy in coastal resources decision-making, particularly when it comes to issues associated with climate change and increasing population. Our objectives are to:

- Assess the effectiveness of small group engagement of residents, local and state natural resource decision-makers, civic and non-governmental organization leaders, county and municipal staff and officials, and business leaders in deliberating on current issues in coastal planning and management.
- Prioritize issues and tasks associated with climate resilience, including biodiversity, living marine resources, environmental health, and mineral and energy resources in an inclusive process.

The outcomes of the forum will be shared with residents, community leaders, and natural resource decision-makers through a report, the project website, and presentations at local conferences. We hope that our forum participants will learn more about planning for the coastal future of our residents, visitors, and natural resources, and that they will share what they learn with their neighbors and friends.

Topics for Discussion

The great challenges to society's management of natural resources in coastal South Carolina include increasing population and changing weather and climate. Over the course of the forum we will be discussing four topics important to the people who live here. Since changes in weather and climate impact each area, this booklet begins with an overview of our changing weather and climate and the potential impacts. Then there are sections about biodiversity and our living marine resources.

After each section, you will find links to scientific resources that inform each discussion, additional resources, and steps others have considered to solve problems. We hope you will bring all of your ideas to the forum for discussion.

Introduction

South Carolina's coast is one of the state's most valuable assets. The coastal plain is divided into five watersheds – Pee Dee, Santee, Edisto, Salkehatchie, and Savannah. Through each of these watersheds, rivers mighty and meandering bring nutrients and sediments from the state's interior, some stretching to the mountains. Rain falling in each watershed finds its way through creeks, into the rivers, and eventually to our coastal cities and towns.

Our Changing Coast

Our coast is made up of a complex natural network of uplands, rivers, wetlands, beaches, creeks, and barrier islands. The network supports a diverse range of ecosystem types and coastal and marine species. It also serves as the natural resource foundation for the needs of our growing coastal population.

Our coastal areas are often divided into three regions: The "Grand Strand," which includes Horry and Georgetown counties; the Berkeley-Charleston-Dorchester county region, which includes the Charleston metropolitan area and rural communities; and the "Lowcountry," which includes Colleton, Beaufort, and Jasper counties. Each of these are growing in population and development. People are increasingly drawn to the South Carolina coast and enjoy the often-pleasant climate and overall high quality of life while taking advantage of the opportunities provided by the state's natural and cultural resources. More than 28 percent of the state's 4.83 million residents live in the eight coastal counties. From 1970 to 2010, the population of the eight coastal South Carolina counties increased by 130 percent, third highest among the 31 coastal and Great Lakes states nationwide. The coastal S.C. population, which was 530,260 in 1970, is expected to top 2 million by 2025 (S.C. Sea Grant Consortium Strategic Plan FY2018-FY2021). In addition, more than 20 million tourists visit coastal South Carolina each year. Indeed, during this decade, Charleston, S.C. has been identified multiple times by *Condé Nast Traveler* as the number one tourist destination in the United States, and in 2015, number one in the world.

"In the spring our rivers fill up with migrating fish moving into fresh-water rivers and creeks to lay their eggs according to the primal urges of heredity. The shad surrender egg sacs that gourmet restaurants prize as one of the great delicacies of the sea, and huge cobia provide steaks for the grills of lowcountry people. Men and women throw their cast-nets with gestures of infinite beauty, and they can fill their freezers with shrimp for a half season on a good night. The osprey dive for mullet in golf-course lagoons and chase bald eagles away from their nests."

- Pat Conroy, Forward in "State of the Heart: South Carolina Writers on the Places They Love," 2013.

Population growth and increasing tourism are placing greater pressure on the state's natural resources and coastal infrastructure, especially at the ever-widening margins of our urbanized areas. Where we put people and how we accommodate their needs for critical infrastructure, transportation, jobs, and quality of life are questions facing decision-makers along the South Carolina coast and inland, and indeed across the whole southeastern U.S.

Natural Resources and the Economy

The economy of coastal South Carolina is also changing. Although it represents a decreasing portion of the state's economy, the commercial fishing industry (fish, oysters, clams, shrimp, and crabs) remains an important component of our local waterfronts, coastal economies, and way of life. South Carolina's shellfish aquaculture industry consists of established clam growers

and new oyster farmers, a sector that doubled its number of businesses in 2016. Recreational fishing and boating make an ever-larger contribution to the state's economy. According to S.C. Department of Natural Resources (SCDNR), the annual impact of marine recreational fishing in the state exceeds $590 million. As of June 30, 2015, more than 2,964,343 individual saltwater stamps/licenses have been sold to recreational anglers since the state began issuing licenses in 1992. In addition, tourism is now a $19 billion industry, with the eight coastal counties accounting for approximately 60 percent of that total and supporting more than 62,000 jobs. The Port of Charleston is one of the busiest and fastest growing container ports on the East and Gulf coasts. Other expanding sectors include manufacturing (Boeing, Daimler, Volvo), tech (Blackbaud), pharmaceutical development and manufacturing, and health care, especially for the growing retirement communities. Although some of these may depend on raw resources shipped into our state, the people who work in these industries depend on our natural resources for clean air, clean water, and commercial and recreational opportunities.

How do we accommodate new residents and visitors who come and go? And how do we do so while maintaining the environmental, cultural, and historical resource qualities that we enjoy and that continue to draw people here? How do we continue to adapt to sea level rise and a warming climate so that our communities remain strong and resilient now and into the future?

These are some of the reasons we are hosting the Our Coastal Future Forum. During this event, we want to have a thoughtful discussion on natural resources topics to provide decision-makers with the perspectives of our communities. We wish to identify priority areas and actions that will support the well-being of our residents and visitors alike through protection of the natural resources on which we all depend.

Southernmost groin on Folly Beach. *Lee Bundrick, S.C. Sea Grant Consortium (August 2017)*

Our Coastal Weather and Climate

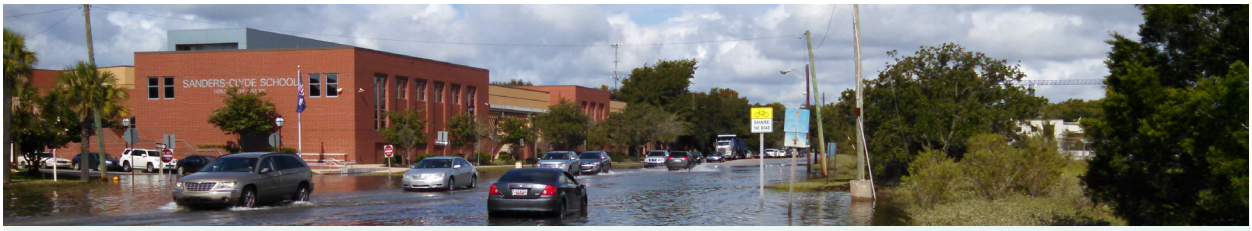

Figure 1.1 "Blue Sky" tidal flooding during King Tide. *Elizabeth Fly, S.C. Sea Grant Consortium (2014)*

Changing Weather and Climate: Impacts in South Carolina

Have you noticed the changes in our weather patterns? We seem to have longer dry periods, and the rain all seems to come at once. Flowers are blooming earlier, and we have home-grown tomatoes at Christmas. The television local morning news regularly warns us to expect road closures due to extreme high tides (**Figure 1.1**). These are weather impacts of our changing climate. The term climate refers to long-term patterns that impact short-term weather events such as heavy rains, record high temperatures, and droughts.

Global Warming

Overall our world is warming. This is determined by measuring changes in air and sea temperatures, humidity, and glacier, snow, and ice cover (**Figure 1.2**). Viewing these measures over time, it is clear our global climate is warming, affecting many of our local weather patterns.

The chart at the bottom right (**Figure 1.3**) uses zero as the baseline average of global surface temperatures between 1880 and 2016. Each year is different. However, despite variability year to year, we see an overall trend from temperatures below the baseline before the 1940s to well above it by the 1990s. In fact, we see record high years in 1998, 2005, 2010, 2014, and 2015, with 2016 being the warmest year on record.

Ocean temperatures are also rising. The graph on the next page (**Figure 1.4**) shows the change in sea surface temperatures from a baseline average between years 1971-2000. The trend is increasing globally. The temperatures have been consistently higher during the last 30 years than any other time since reliable records began being kept in 1880.

Changes in Sea Level

The heat from the atmosphere is absorbed by the oceans. When water heats up, the molecules get bigger. This is called thermal expansion, and it is one cause for sea level rise. Additionally, the heat causes glaciers and ice on land to melt, adding more water to the ocean. The changing temperatures also interfere with the hydrological cycle, the pattern of water movement from land to atmosphere and back again, and, in many cases, cause a change in rain patterns (**Figure 1.5**).

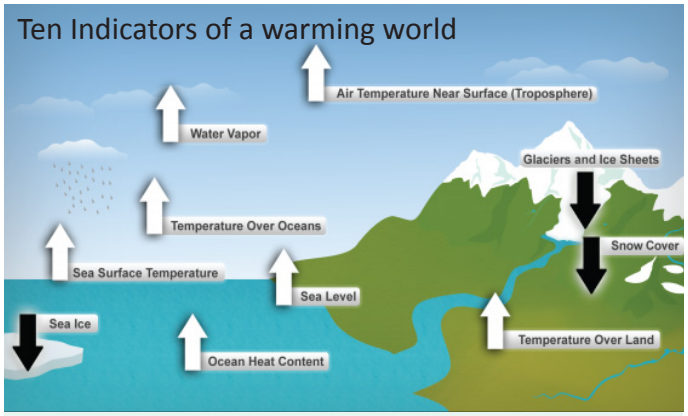

Figure 1.2 Indicators of Global Warming. *National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center (NCDC). Based on data updated from Kennedy et al. 2010*

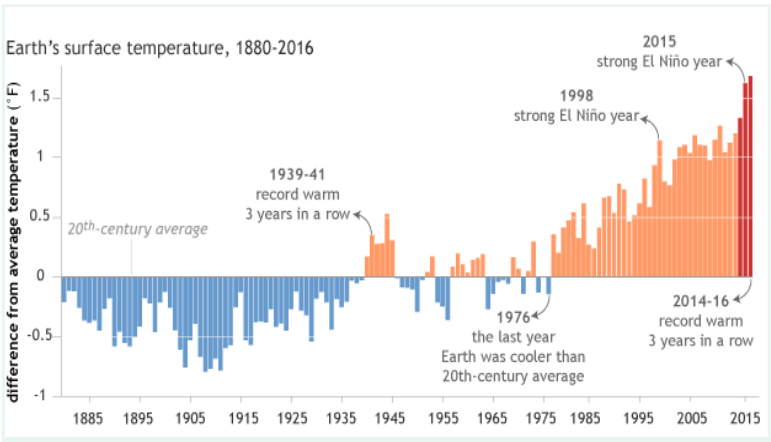

Figure 1.3 Difference in Earth's surface temperature over time. *NOAA NCDC Climate at a Glance (September 2017)*

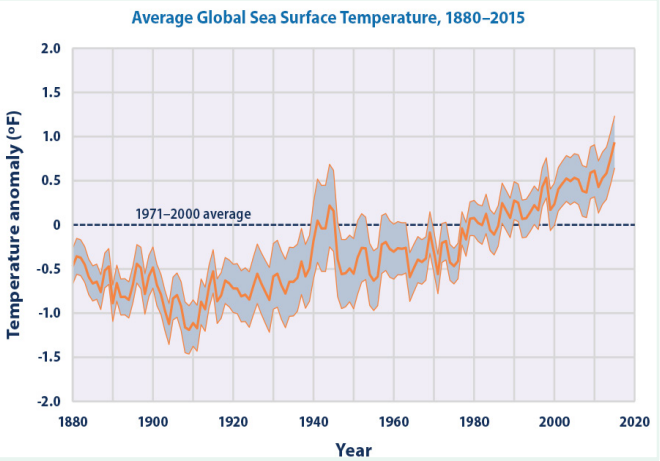

Figure 1.4 Global sea surface average temperature anomalies from 1880 to 2020. *NOAA (2016)*

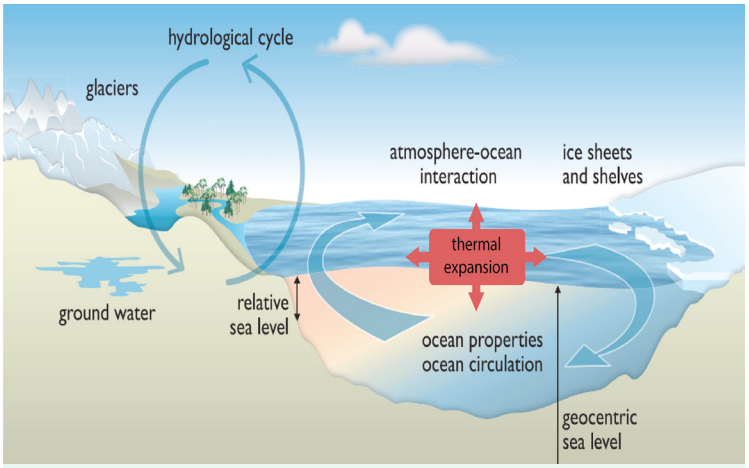

Figure 1.5 How the Ocean Water Cycle is Changing. *National Climate Assessment with added content (2014)*

So What Does This Mean for the South Carolina Coast?

Air temperatures in South Carolina are increasing. Temperatures here have increased about a half a degree (0.5 degree F) since 1900. The number of record high temperatures is also increasing. For instance, in Columbia, 10 days exceeded 100 degrees in 2015 and 16 days exceeded 100 degrees in 2016. For comparison, the average number of days above 100 degrees between 1953 and 1983 was only slightly more than two. There are also increases in night-time temperatures and fewer days below freezing since the 1990s, which have an impact on agricultural and native plants. With higher temperatures, there is also an increased risk of health issues for vulnerable populations, such as the young and the elderly.

Sea level rise increases the erosion along our coast and flooding in our streets. Many factors control how sea level rises locally, including land sinking or rising, sea level change, topography, and wind patterns. For those reasons, the amount of sea level rise has varied even along South Carolina's coast (**Figure 1.6**).

However, in the future the rate is expected to increase. The projection, shown in **Figure 1.7**, shows sea level is expected to rise 1 to 4 feet by 2100. The differences in projections are largely due to the rate of CO_2 increase (the greenhouse gas that acts as a warm blanket around earth) and the amount of ice melting on land, lakes, and sea. As we better understand how much ice is melting and how quickly the world reduces greenhouse gases, the gap in projections should go down.

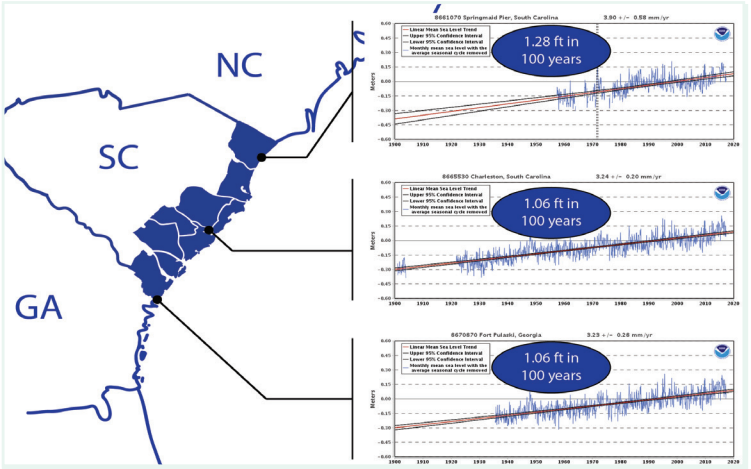

Figure 1.6 Sea level rise measured by gauges located at Myrtle Beach, Charleston, and Savannah, Georgia. *Created using information from NOAA (2017)*

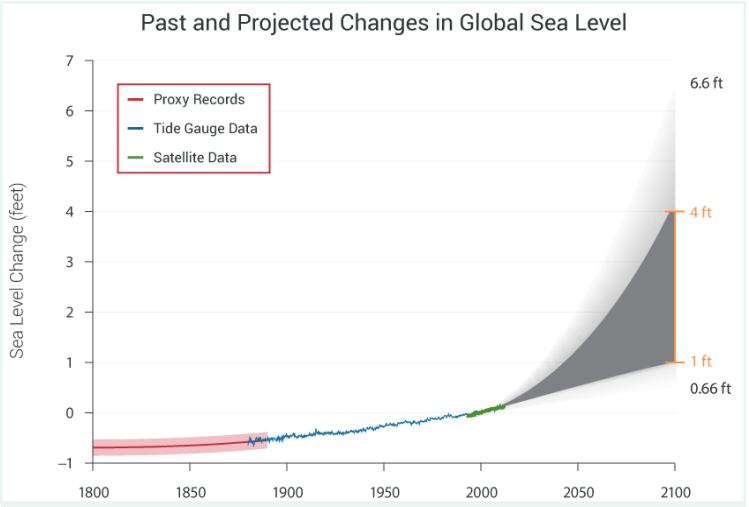

Figure 1.7 Past record and future projection for sea level change. *National Climate Assessment (2014)*

It is important to note that although there are a range of possibilities, planners can now use this information to make safety and economic decisions for communities. Using what is called "no regrets" planning, communities can

consider different scenarios of sea level rise when siting development and creating new development standards. In other words, if the expected life-span of a structure is short or the risk is low, such as a homeowner's dock or a snack bar on the beach, then a low estimate can be used. If sea level rises faster, there is little safety or economic risk for the decision. For development that has long-term consequences, the higher estimate for sea level rise is used. For example, the building of a sewage treatment plant or a high-rise housing unit would have a high risk to safety and large economic risk if flooded or damaged. "No-regrets" refers to the level of risk society is willing to accept.

Coastal Flooding

The coast of S.C. experiences regular tidal flooding in streets, school yards, residential properties, and businesses. During full moon or new moon periods, or if strong winds push ocean waters our way, high tide washes into our communities (**Figure 1.8**). As sea level rises, the number of days with extreme high tides increases. During the 1980s such flooding occurred about four times a year. From 2000 through 2014, the annual average hovered around 10 days of flooding. In 2016, Charleston dealt with a record 50 days of tidal flooding. By the 2040s, Charleston is forecast to experience 180 days per year of nuisance tidal flooding and impassable roads (**Figure 1.9**). If it happens to rain during these high tides, the stormwater has no place to go, and thus there will be more flood water.

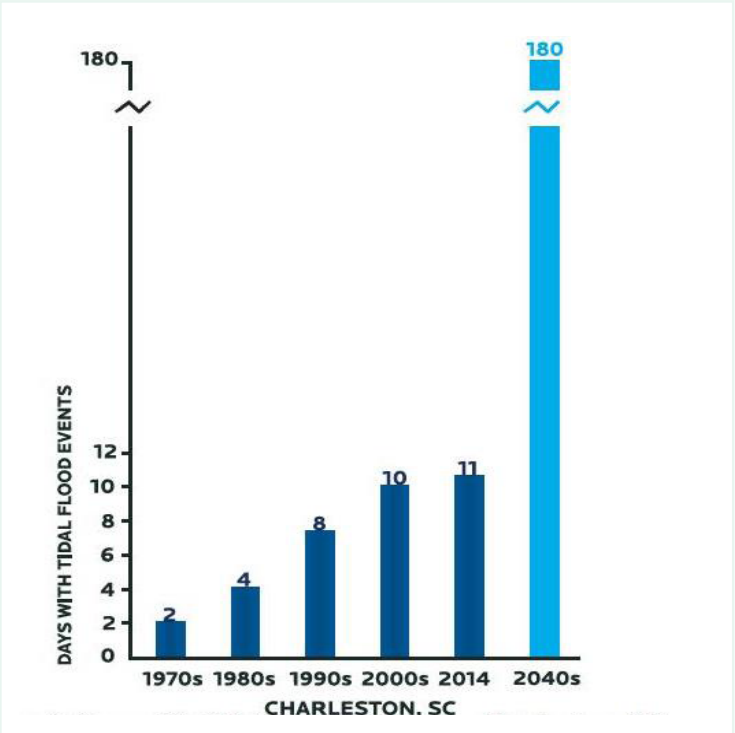

Figure 1.9 Days per year with tidal flooding. *City of Charleston (2015)*

Sea level rise is also a factor in the amount of destruction caused by storm surge during hurricanes and other coastal storms. The higher the tide, the farther inland ocean water travels with the storm surge, increasing the amount of land and structures in danger (**Figure 1.10**). Saltwater pushed inland due to sea level rise also threatens fresh water in rivers and aquifers. Coastal cities rely on fresh river water for their drinking water supplies. Aquifers are our natural freshwater storage areas underground. Many people have deep water wells for drinking and shallower wells for irrigation. As sea level rises, more saltwater travels up rivers and into areas

Figure 1.8 Tide reaching into downtown Charleston street. *Elizabeth Fly, S.C. Sea Grant Consortium (2014)*

Figure 1.10 Tidal flooding along waterfront in Beaufort, S.C. *Jeramie Stanley as reported to King Tide Report (October 27, 2015)*

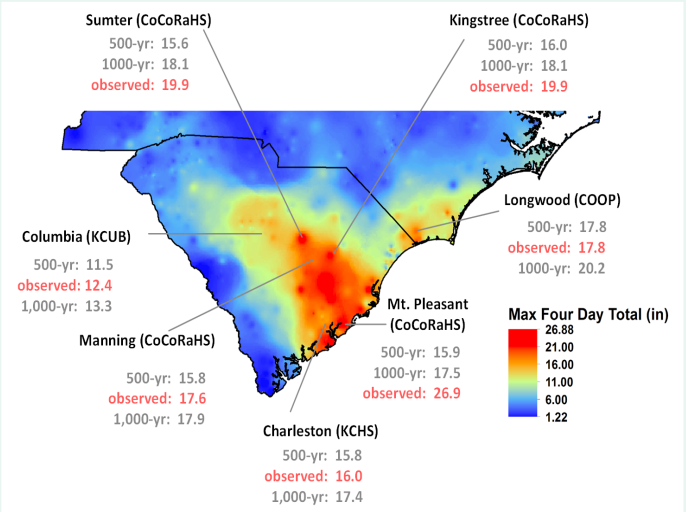

Figure 1.11 Rainfall during the October 2015 extreme event. *Carolinas Integrated Sciences and Assessments (CISA) (2016)*

where drinking water is withdrawn. Saltwater can intrude into the aquifers. Not only does this change local ecosystems, but it also has potential health and economic impacts. Some impacts include public utilities that provide water to residents and for emergency backup services. Drilling deeper wells or finding additional sources of freshwater may be necessary. Other options may include desalination for drinking water. The cost of moving water treatment plants and pipes is challenging. We have built houses, roads, and other infrastructure in the path of a rising sea, all of which may have to be modified or relocated in the future.

Extreme Rainfall

Extreme rains like those we saw in the fall of 2015 and 2016 can cause devastating flooding. CoCoRaHS, a national volunteer precipitation monitoring network, allows scientists to collect data all over the state during these sorts of events. The map in **Figure 1.11** shows the maximum rainfall totals that fell over a four-day period (Oct. 2-5, 2015). The data was obtained from CoCoRaHS sites and weather stations. The 500-year and 1,000-year maximum rainfall projections are based on historical records. They indicate there is a 0.2 percent chance of 15.9 inches of rain, or 0.1 percent chance of 17.5 inches, in a four-day period in Mount Pleasant in any year. Mount Pleasant was slammed with 26.9 inches, or worse than a 1,000-year rainfall. Most of the hardest hit areas were closer to 500-year rainfall during the 2015 storm. Many of the same areas experienced 500-year rainfall the following October as Hurricane Matthew churned offshore.

Drought

With the changes in weather patterns, the Southeast can expect more extreme dry periods as well. With this comes drought. Although the rains of 2015 and 2016 soaked the coastal counties, this was a relief from a long period of off-and-on drought. From July 2010 through October 2015, at least one coastal county was considered in constant drought conditions by the S.C. Drought Response Committee. During 2012, most of our coastal area was in extreme drought (**Figure 1.12**). This means less freshwater flowing down rivers and into our groundwater, allowing saltwater to travel farther up rivers and ultimately into our aquifers. Too little water can be as challenging as too much.

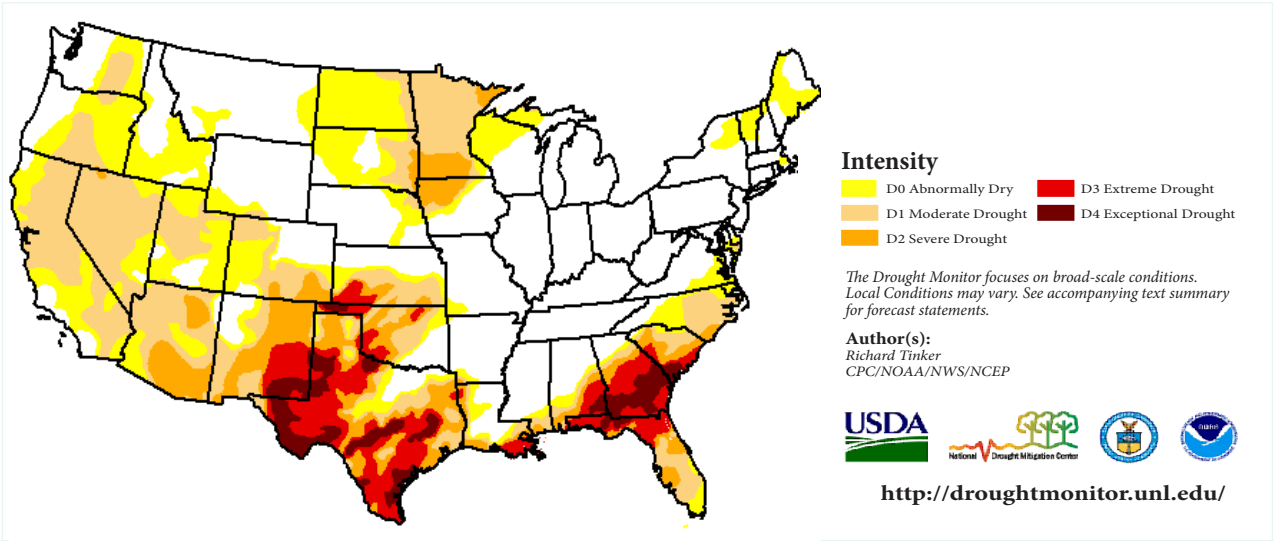

Figure 1.12 U.S. Drought Monitor data for February 14, 2012. *National Drought Mitigation Center (2017)*

Figure 1.13 Folly Beach, Lighthouse Inlet Heritage Preserve. *Lee Bundrick, S.C. Sea Grant Consortium (July 2017)*

What Can We Do?

Help collect climate data for CoCoRaHS, Community Collaborative Rain, Hail, and Snow network, a community-based network of citizen scientists who report rain, hail, and snow measurements using low-cost materials

Report to MyCoast: South Carolina, a S.C. Department of Health and Environmental Control (SCDHEC) resource to collect and analyze pictures and data to assess hazards and to enhance awareness among decision-makers and stakeholders

Develop strategies for the community to respond to different scenarios of sea level rise

Update current infrastructure (e.g. roads, bridges, seawalls) to respond to the effects of climate change

Reduce development in high-risk flooding areas

Introduce desalination facilities that turn saltwater into drinking water

Conserve groundwater from aquifers and preserve natural waterways for sustainable usage of water resources

Respond to drought conditions that are met with heavy, but infrequent, rainfall events

Resources for More Information

- **CoCoRaHS** for mapping precipitation. Website: https://www.cocorahs.org/
- **MyCoast: South Carolina**. SCDHEC. Website: https://mycoast.org/sc
- **South Carolina tides and currents, data and maps.** NOAA. Website: https://tidesandcurrents.noaa.gov/map/index.shtml?region=South%20Carolina
- **King Tides and Climate Change**. **U.S. Environmental Protection Agency (USEPA).** Website: https://www.epa.gov/cre/king-tides-and-climate-change
- **City of Charleston Sea Level Rise Strategy.** Report. Website: http://www.charleston-sc.gov/DocumentCenter/View/10089
- **Beaufort and Port Royal Sea Level Rise Task Force**. Website with link to their final report: https://bprsealevelrise.wordpress.com/
- **SeaRise.** South Carolina Aquarium. Website: https://searise.scaquarium.org/
- **Hazard Vulnerability Assessment Tool**. SCDHEC. Website: http://www.scdhec.gov/HomeAndEnvironment/Docs/HVA_Tool_Info%20(GSAA)%20(1).pdf
- **Coastal Flood Exposure Map**. NOAA. Website: https://coast.noaa.gov/floodexposure/#/splash

The complete Briefing Book for the Our Coastal Future Forum can be found at the link below
http://www.scseagrant.org/pdf_files/OCFF-Briefing-Book-Updated.pdf

Our Biodiversity

Nature provides us with ecosystems that make life on Earth possible and offer physical and psychological benefits for humans. Direct benefits include products (such as lumber, food, and water), recreation, and beauty. Indirect benefits include the regulation of our environment (such as clean air and water) and the regeneration of our resources (such as pollination and nutrient cycles). Together these are called ecosystem services.

Biodiversity

An environment with a variety of life and habitats is considered biodiverse, and biodiversity has a positive impact on people. Whenever biodiversity is reduced, the supply and delivery of ecosystem services is also reduced. For example, less diverse estuaries lead to fewer healthy oyster beds which lead to greater erosion of shores.

The loss of ecosystem services can also result in the weakening of economic prosperity in nearby communities, such as a loss in tourism and declining property values. Other impacts could include an increase in health risks that affect humans and animals caused by chemical contaminants, organisms that carry infectious diseases, and toxins produced by harmful algal blooms.

Research indicates that people exposed to biodiverse areas such as green spaces, natural areas, and coastal environments are healthier physically and psychologically. Views of nature can improve the postoperative healing rates of patients and improve the outlook of patients with dementia. The Medical University of South Carolina (MUSC) recognized the potential benefits of green spaces and has increased the amount of vegetation on its grounds (**Figure 2.1**). The MUSC Institute of Psychiatry runs a horticulture therapy program where patients can spend time working in a healing garden planting vegetables and flowers.

How nature, biodiversity, and coastal environments benefit human health and well-being is only beginning to be understood. As we gain a better understanding of the mechanisms, health care providers can improve their use of nature as treatment for patients with a range of needs, both mental and physical.

Human Impacts

Rapid changes in coastal ecosystems caused by unintentional consequences of increased development and climate change can also have a potentially damaging impact on human health and well-being (**Figure 2.2**). Development of wetlands takes away their ability to perform services such as holding water after a storm or filtering stormwater runoff that carries contaminants. Carelessly placed development can add to the contamination problem by introducing sewage from septic tanks, fertilizers, pesticides, and street debris into wetland habitats. The S.C. Department of Health and Environmental Control's (SCDHEC) Division of Ocean and Coastal Resource Management (OCRM) addresses this issue by protecting natural wetland buffer zones

Figure 2.1 Green space at the Medical University of South Carolina near the Drug Discovery Building and the MUSC Library. Simulated natural settings like this can provide therapeutic benefits for patients. *S.C. Sea Grant Consortium (2017)*

through its policies that restrict the removal of vegetation from areas along tidal marshlands and natural wetlands.

Biodiversity contributes not only to ecosystem services provided by organisms but also to the speed of recovery of communities to shocks, defined in this sense as a sudden change or impact. Major environmental shocks like hurricanes (**Figure 2.3**), excessive cold or heat, oil spills, and chemical contamination can cause the environment to fall out of balance. Ecosystem services, provided through a wide range of biologically diverse organisms including animals, plants, and bacteria, contribute to the quick recovery and stabilization of the ecosystem. Some examples of ecosystem services are the filtering of flood water through aquatic plants and nutrient cycling, and also the general breakdown of chemical contaminants by bacteria and plants. Biodiverse habitats adapt more readily to changing environmental conditions.

Although ecosystems are resilient and can recover from many environmental shocks, the increasing number, intensity, and frequent repetition of these shocks, including those caused by increased human activity, can reduce the ability of the ecosystem to recover over time, potentially leading to irreparable damage and loss of ecosystem services. Loss of species and genetic diversity may also result in the loss of scientific discoveries, such as natural chemicals to fight cancer. For example, we harvest many species for biomedical purposes, including deep-sea sponges for medicines and horseshoe crab blood that allows us to detect contamination in medicines.

While the links between biodiversity and long-term marine and coastal health are not fully understood, preserving biodiversity could be one important way to maintain the integrity of our ecosystems, coastal resilience, and critical ecosystem services. The loss of biodiversity and ecosystem services can prove to be devastating to communities on the coast and elsewhere around the globe. It is important to address issues surrounding the loss of biodiversity and ecosystem services before they are lost forever.

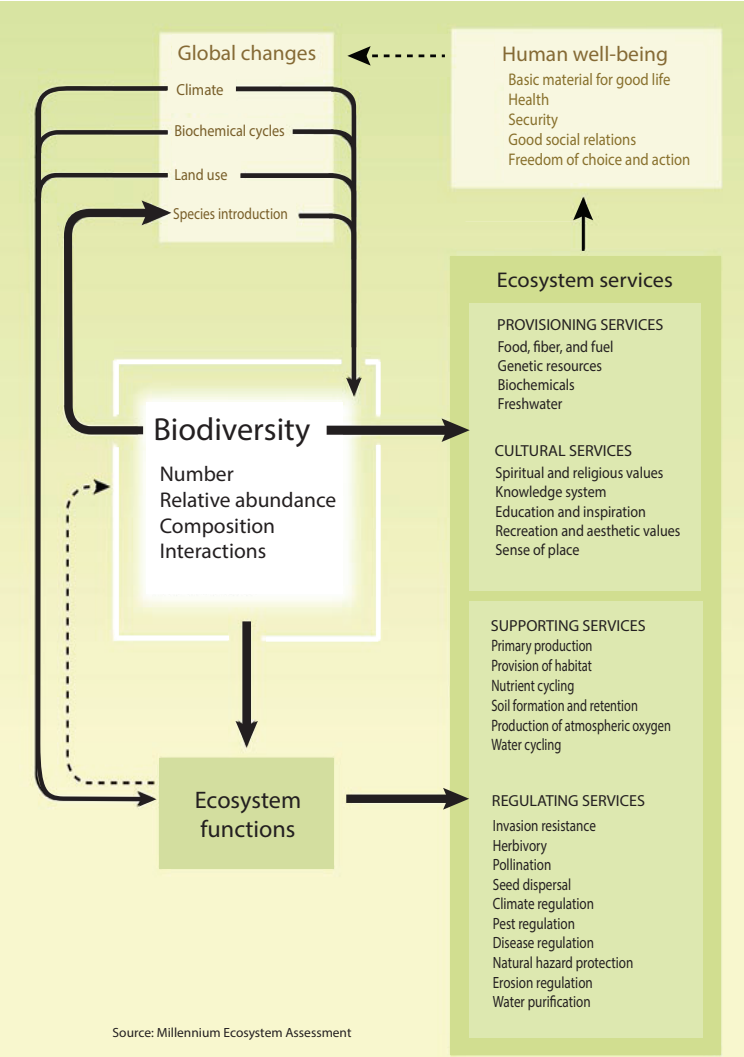

Figure 2.2 Relationships between biodiversity, ecosystem services, and human well-being, including global changes that affect them. *Millennium Ecosystem Assessment Box 1.4 (2005)*

Figure 2.3 Air-conditioning unit sits on S.C. Highway 174 on top of a layer of sand deposited by Hurricane Matthew. Edisto Beach, S.C. *National Weather Service, NOAA (2016)*

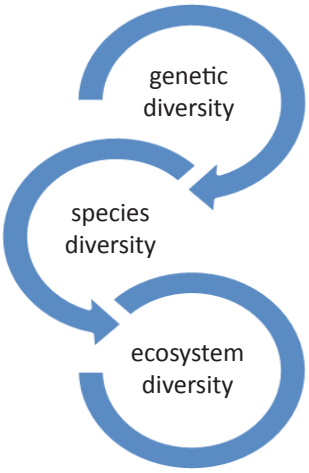

Figure 2.4 Levels of diversity which contribute to overall biodiversity. Genetic diversity of species, the diversity of species within an ecosystem, and the diversity of ecosystems within the environment.

What Can We Do?

Preserve natural green spaces like forests and marshland from further development to encourage biodiversity and community resilience

Encourage use of "Green Infrastructure" (e.g. rain gardens, green roofs, urban forests) to mitigate issues relating to stormwater runoff

Renourish and protect marshland by planting marshland grasses and building oyster reefs

Consider the options of placing conservation easements on properties bordering marshland habitat

Limit the harvesting of resources in waterways to promote biodiversity in marine habitats and stimulate species population growth

Implement sustainable landscape designs into new developments with native plants to limit the use of irrigation, fertilizers, and pesticides

Protect trees and vegetation near and inside dunes to increase the communities' resilience to extreme weather events

Construct buildings in the community that minimize their environmental impact

Resources for More Information

- **Private Lands Conservation.** The Nature Conservancy. Information on how to reserve private land for conservation efforts. Website: https://www.nature.org/about-us/private-lands-conservation/
- **Urban and Community Forestry Program**. U.S. Forest Service. Cooperative program that focuses on the stewardship of urban natural resources. Website: https://www.fs.fed.us/managing-land/urban-forests/ucf
- **S.C. WaterWays - Life Along the Salt Marsh: Protecting Tidal Creeks with Vegetative Buffers**. Clemson University. Website: http://bit.ly/2x2Owk0
- **Water quality monitoring and restoration volunteer program.** S.C. Oyster Restoration and Enhancement (SCORE) program. SCDNR. Website: http://score.dnr.sc.gov/deep.php?subject=5
- **Coastal Resilience Mapping Portal**. NOAA Office for Coastal Management**.** Interactive web tool helps users visualize future flood risks and the ecological, social, and economic impacts from sea level rise and storm surge. Website: https://coast.noaa.gov/digitalcoast/tools/
- **LEED (Leadership in Energy and Environmental Design) Certification** by the U.S. Green Building Council for sustainable achievement in building construction. Website: https://new.usgbc.org/leed
- **Designing Our Future: Sustainable Landscapes.** American Society of Landscape Architects. Website: https://www.asla.org/sustainablelandscapes/about.html
- **Green Infrastructure.** USEPA. Website: https://www.epa.gov/green-infrastructure/what-green-infrastructure
- **Current Coastal Zone Management laws and regulations.** SCDHEC-OCRM. Website: http://www.scdhec.gov/Agency/RegulationsAndUpdates/LawsAndRegulations/Coastal/

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Our Living Marine Resources

South Carolinians cherish our ocean, coastal lands, water, marshes, and animals that live there. From fishing to dolphin watching, our living marine resources are an important part of our cultural heritage. Our main seafood harvests include oysters, crabs, shrimp, mussels, and fish. These creatures, as well as dolphins, sea turtles, and many bird species, make homes in our marshes and coastal waters. Our abundant seafood is key to our booming tourism industry, helping spark our growing reputation as a culinary destination.

South Carolina also boasts a large and healthy natural environment, with a variety of beaches, barrier islands, and marshes. The saltwater marshes and barrier islands along the coast are important, both ecologically and economically. Tourists want to visit them, and so do many other creatures. The marshes provide breeding grounds and nurseries for various species of fish, turtles, and birds, while barrier islands provide nesting grounds for sea turtles and shorebirds.

Coastal Habitat

Importantly, these natural landscapes act as barriers against major weather events. Barrier islands provide protection from ocean storm winds and surge, reducing inland property damage. Wetlands contribute to natural flood mitigation by absorbing and filtering water runoff. All of these natural resources are under pressure from climate change and human impact.

Rising sea levels have been documented across coastal South Carolina, with scientists predicting from one to four feet of sea level rise in the next century **(Figure 1.7, page 4)**. The King Tides experienced during full and new moon periods today will be the everyday high tides of tomorrow. As sea level rises, the lowest dry lands will be submerged and become either tidal wetlands or open water. To some extent, wetlands can keep pace with a slowly rising sea. But in many coastal areas in the Southeast, wetlands will convert to open water.

Saltwater marshes are some of our most susceptible ecological habitats, impacted by human development as well as rising seas. Sea walls and groins have indirect effects, often worsening erosion. Coastal development increases impervious surfaces, including roofs, roads, and sidewalks, that prevent rainwater from seeping into the ground. This increased stormwater runoff along with saltwater from rising sea levels could affect coastal habitats, threatening many important shellfish species that live in estuarine waters.

Stormwater

More runoff increases the possibility of hypoxic events, the depletion of dissolved oxygen, in our coastal waters. Like humans, aquatic and marine organisms need oxygen to breathe. Hypoxic events are typically linked to the buildup of nutrients from chemicals, like those in fertilizer, pet and wildlife waste, and other materials that run off during storms. Algae grows in large quantities as a result of excess nutrients and then is consumed by bacteria that use the oxygen in the water. An example of such an event was seen in Long Bay in Horry County in 2004 and 2009 where hypoxia led to large-scale fish kills (**Figure 3.1**).

Humans can mitigate these occurrences by limiting fertilizer use and reducing storm runoff. Until other solutions are found, runoff will continue to increase as our population rises and the coast continues to develop.

Earlier we touched on the issue of drought and extreme rain. We learned that too little rain

Figure 3.1 Fish killed as a result of hypoxic water conditions caused by algal blooms. *NOAA (2017)*

Figure 3.2 Posted sign in the Lighthouse Inlet Heritage Preserve, Folly Beach, S.C. for an American Oystercatcher nesting area. Shellfish declines hurt Oystercatcher populations. *Lee Bundrick, S.C. Sea Grant Consortium (2017)*

can be every bit as problematic as too much, particularly as it affects the balance of salt and fresh water, also known as salinity. One particular impact is that increased periods of drought can lead to increased salinity in estuaries and hinder important fisheries. For example, blue crabs are more vulnerable to diseases in high salinity waters. Moreover, increased salinity can have varying impacts on our marine species as much as decreased salinity due to excessive runoff.

Coastal Ocean Habitats and Species

Changing climate is also affecting our oceans. Changing temperature and the increasing level of acidity in ocean water impact reefs and fisheries. As temperatures change, we see many species move. Southern fish species are now caught farther north of their typical ranges. Recreational anglers and commercial fishermen are already shifting what they catch. Mangrove trees from tropical regions are moving north to subtropical areas. As sea level rises, coastal marshes are shifting inland, trying to keep up with the changing environment. Movement of marshes inland can also erode nearby land and put homes and other development at risk. Sea level may be rising faster than many habitats can move. In the case of saltmarsh, the coastal marsh may drown and the nursery habitat it provides could be lost.

Rising ocean temperatures increase the rate at which carbon dioxide (CO_2) is absorbed into the ocean. While this removes the greenhouse gas from the atmosphere, as CO_2 is absorbed by ocean and coastal waters, it increases the acidity. Ocean acidification may have huge impacts on coral reef species. While South Carolina does not have local shallow reefs, many of our economically important fish, including grouper, sea bass, and snapper, live on deeper reefs off the coast. These reefs could be impacted by acidification and thus habitat for commercial fish species may be lost.

In some parts of the United States, acidification is beginning to impact shellfish by affecting the composition of their shells. While we are still studying the effects, acidification combined with hypoxia may be detrimental to local shellfish and organisms that depend on them for survival (**Figure 3.2**).

Invasive Species

In South Carolina, an increase in the number and diversity of non-native invasive plant and animal species has been documented in terrestrial, freshwater, and marine habitats. Some of these species may have been released accidentally or by well-meaning residents, but others are likely migrating northward from more tropical climates in response to warming temperatures and changes in rainfall, among other environmental factors. Regardless of how they become established, these species can impact native animals and their habitats. They may outcompete native species for food and other resources (**Figure 3.3**).

Figure 3.3 Feral hogs are a prevalent invasive species that damages wetland habitats of endangered species and compete with other species for resources. *S.C. Department of Natural Resources (2015)*

Figure 3.4 Non-native invasive lionfish. *James Morris, NOAA (2005)*

Impacts of invasive species are second only to habitat loss in causing the significant decline of both endangered and common species. The current environmental, economic, and health costs of invasive species exceeds $138 billion per year in the United States, with $1.2 billion being spent on combating invasive species in 2006 alone (SCDNR, 2013). That total does not include the numerous hours and dollars spent at regional, state, and private levels to combat invasive species.

In the U.S., most invasive species are plants, reptiles, freshwater fish, and crustaceans. In coastal South Carolina, most invasive species are marine plants and crustaceans. One prolific invasive fish species wreaking havoc in the coastal waters of South Carolina is the red lionfish (**Figure 3.4**). The lionfish is native to the Indo-Pacific and was introduced into the Atlantic and Caribbean basins by humans in the early 1980s. It has colonized the entire Caribbean region as well as the Atlantic coast, including deep waters off South Carolina. These fish outcompete other important commercial fish for resources, and they devour juvenile snapper, grouper, and most other fish species. They thrive in warm waters. As temperatures warm, we will likely see a rising trend in the occurrence of other invasive species.

What Can We Do?

Limit the amount of impervious surfaces and/or increase green infrastructure to mitigate issues surrounding stormwater runoff

Limit our use of fertilizers, especially those with high phosphorus and nitrogen concentrations that promote the growth of algae

Implement land use policies that acknowledge landward migration of nature due to sea level rise

Stop the introduction and spread of invasive species in coastal habitats

Participate in the fisheries policy process by attending South Atlantic Fishery Management Council public hearings and meetings on fishing limits, regulations, and marine protected areas

Support organizations involved with monitoring water quality and promoting coastal conservation efforts

Resources for More Information

- **Low Impact Development in Coastal South Carolina: A Planning and Design Guide.** S.C. Sea Grant Consortium. Website: http://www.scseagrant.org/pdf_files/LID-in-Coastal-SC-low-res.pdf
- **National Invasive Species Information Center, State Information for South Carolina**. U.S. Department of Agriculture (USDA). Website: https://www.invasivespeciesinfo.gov/unitedstates/sc.shtml
- **Sea Level Rise Viewer interactive map.** NOAA. Website: https://coast.noaa.gov/slr/
- **South Atlantic Fishery Management Council**. Website: www.safmc.net
- **REEF.** Nonprofit organization of divers and marine enthusiasts committed to ocean conservation. Website: www.reef.org
- **Conservation at South Carolina Aquarium.** Website: http://scaquarium.org/conservation/
- **Aquatic Nuisance Species Program.** SCDNR. Website: http://www.dnr.sc.gov/water/envaff/aquatic/

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