# OUR COASTAL FUTURE FORUM

## Briefing Book

Trident Technical College Main Conference Center
North Charleston, SC

Friday, October 20 and Saturday, October 21, 2017

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*
*SC 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, SC*

**Spencer Wetmore**
*City Administrator,*
*City of Folly Beach, SC*

**Ricky Martin**
*Building and Zoning Administrator,*
*City of Georgetown, SC*

**Allison Hardin**
*Planner,*
*City of Myrtle Beach, SC*

**Kim Jones**
*Manager, Watershed*
*Management Division*
*Town of Bluffton, SC*

**Dan Ahern**
*Design Review Board Member,*
*City of Beaufort, SC*

### 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**
*South Carolina 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**
*South Carolina Department*
*of Natural Resources*

**April Turner**
*S.C. Sea Grant Consortium*

**Sarah Watson**
*S.C. Sea Grant Consortium*



Product no.: SCSGC-H-17-06

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.

This project would not have been possible without the project team, staff at the S.C. Sea Grant Consortium, and funding support provided by the Gulf Research Program of the National Academies of Sciences, Engineering, and Medicine under award number 200007353. This publication is a product of the S.C. Sea Grant Consortium. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Gulf Research Program or the National Academies of Sciences, Engineering, and Medicine, the S.C. Sea Grant Consortium, the State of South Carolina, and NOAA.

# Contents



**Figure A.1** Morris Island Lighthouse from the Lighthouse Inlet Hertitage Preserve. *Lee Bundrick, S.C. Sea Grant Consortium (July 2017)*
**Front and Back Cover Illustration** Tolers Cove, Sullivan's Island. *Lee Bundrick, S.C. Sea Grant Consortium (May 2017)*

# About Our Coastal Future Forum

The Our Coastal Future Forum is one part of a research project to determine the feasibility of using a deliberative democratic process 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 resources 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 managment 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 is a short discussion about topics including:

- Biodiversity, the vast range of coastal habitats, plants, and animals valued by South Carolinians
- Living marine resources, such as fish, marine mammals, and shellfish
- Healthy environments, important to biodiversity and our overall health
- Coastal mineral and energy resources, including sand that moves along our shore and blankets our beaches, offshore wind that can provide clean energy, and the potential for oil and gas production.

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.

# Forum Agenda

## Friday, October 20 (5:00pm – 8:30pm)

| Time | Activity | Speaker |
|---|---|---|
| **5:00** | Registration and buffet reception, provided | |
| **6:00** | Welcome and Introductions | Dr. Susan Lovelace, Dr. Justin Reedy, Dr. Matt Nowlin, Lee Bundrick, Stacey Weinstock, Chris Anderson, Barbara Brown |
| **6:45** | Weather, Climate, and Impacts<br>*Presentation and Questions* | Dr. Kirstin Dow |
| **8:00** | Format and Expectations for Saturday | |
| **8:30** | Adjourn for Evening | |

## Saturday, October 21 (8:00am – 4:30pm)

| Time | Activity | Speaker |
|---|---|---|
| **8:00** | Continental Breakfast, provided | |
| **8:30** | Biodiversity and Living Marine Resources,<br>*Presentations and Questions* | Dr. Paul Sandifer and Dr. Marcel Reichert |
| **9:45** | Break | |
| **9:55** | Small Group Discussions | |
| **11:45** | Lunch, provided | |
| **12:20** | Healthy Environments and Energy Resources<br>*Presentations and Questions* | Dr. Geoff Scott and Dr. Paul Gayes |
| **1:25** | Break | |
| **1:35** | Small Group Discussions | |
| **3:10** | Report Out from Small Groups and Large Group Discussion | Barbara Brown |
| **4:00** | Wrap-up | |
| **4:15** | Administrative Wrap-up, Final survey, paperwork for stipend, evaluation | |
| **4:45** | Adjourn | |

# 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, and riverine, near-shore, 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 is made up 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?

This is one 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.

**Figure A.2** Southernmost groin on Folly Beach. *Lee Bundrick, S.C. Sea Grant Consortium (Aug. 2017)*

# Our Coastal Weather and Climate

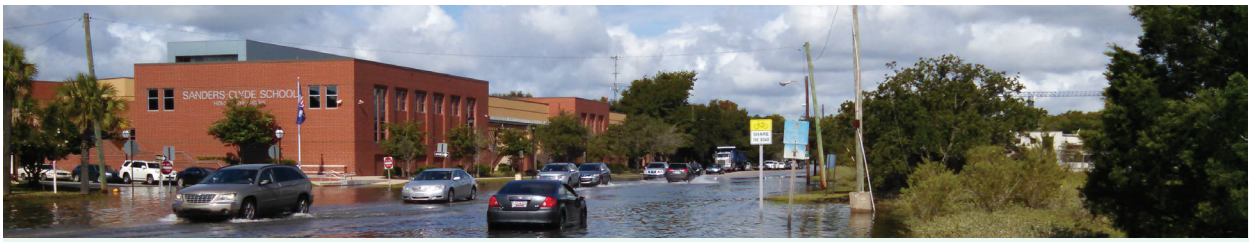


**Figure 1.1** "Blue Sky" tidal flooding during king tide. *Elizabeth Fly, S.C. Sea Grant Consortium (2014)*

## 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**).

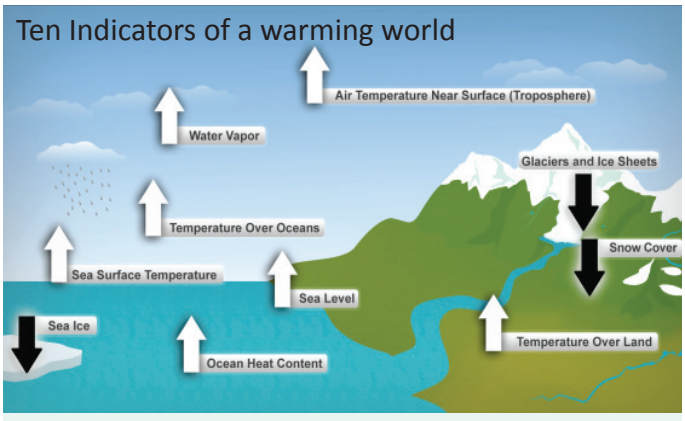


**Figure 1.2** Indicators of Global Warming. *National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center (NCDC). Based on data updated from Kennedy et al. 2010*

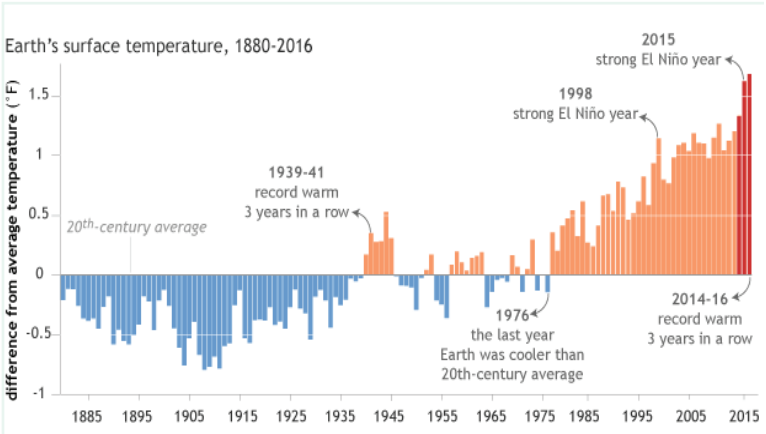


**Figure 1.3** Difference in Earth's surface temperature over time. *NOAA NCDC Climate at a Glance (September 2017)*

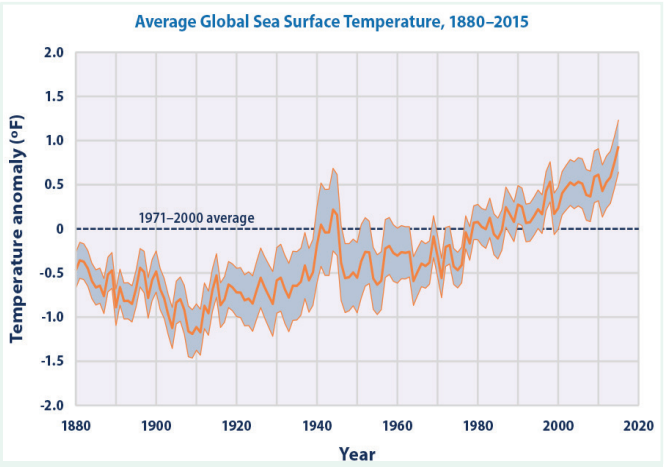


**Figure 1.4** Global sea surface average temperature anomalies from 1880 to 2020. *NOAA (2016)*

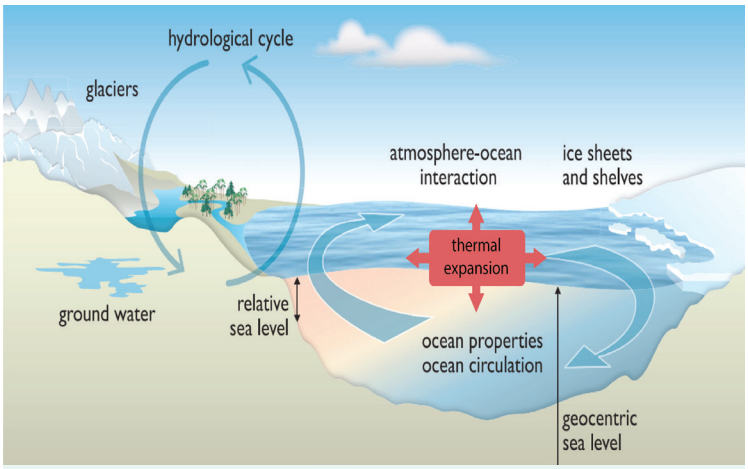


**Figure 1.5** How the Ocean Water Cycle is Changing. *National Climate Assessment with added content (2014)*

## *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.

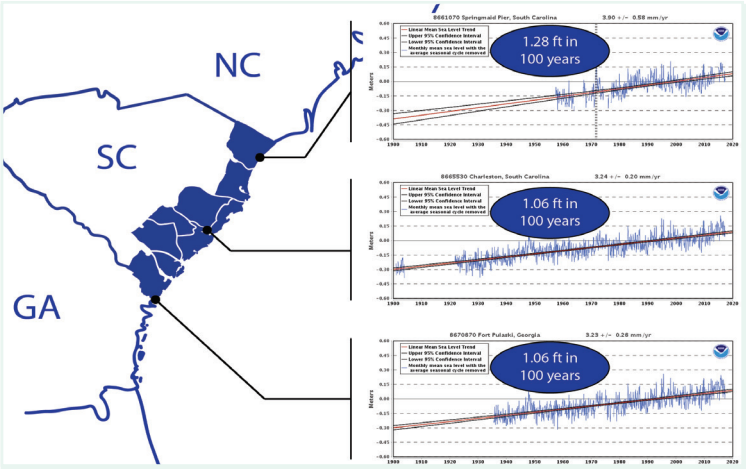


**Figure 1.6** Sea level rise measured by gauges located at Myrtle Beach, Charleston, and Savannah, Georgia. *Created using information from NOAA (2017)*

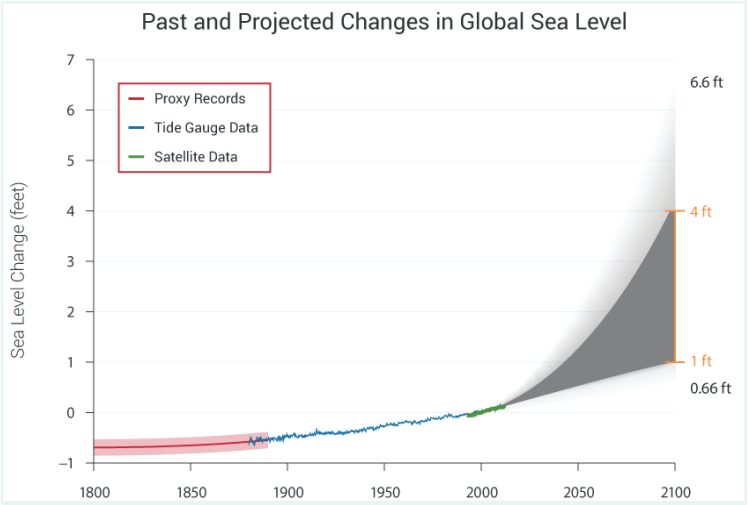


**Figure 1.7** Past record and future projection for sea level change. *National Climate Assessment (2014)*

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 increase. 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.

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 where drinking water is withdrawn. Saltwater

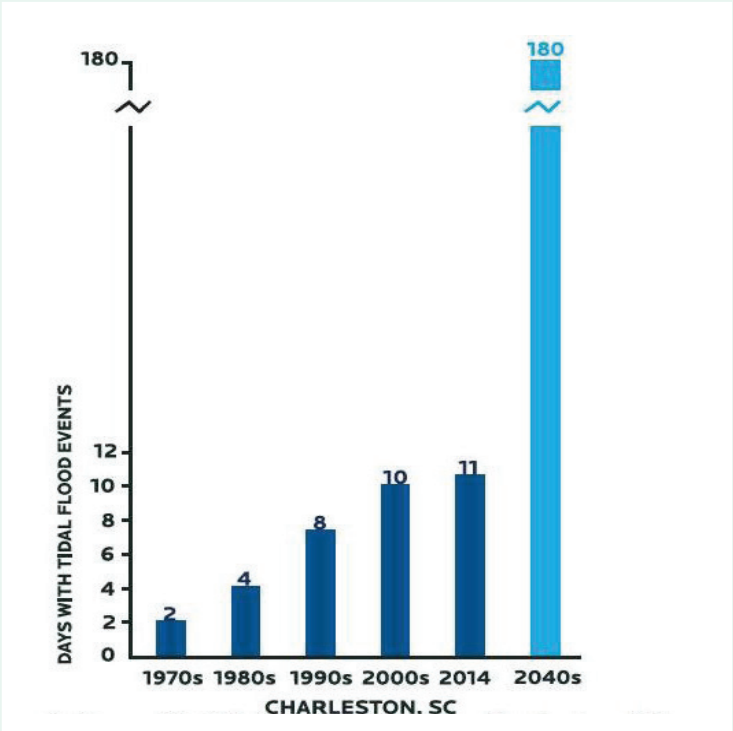


**Figure 1.9** Days per year with tidal flooding. *City of Charleston (2015)*

***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)*

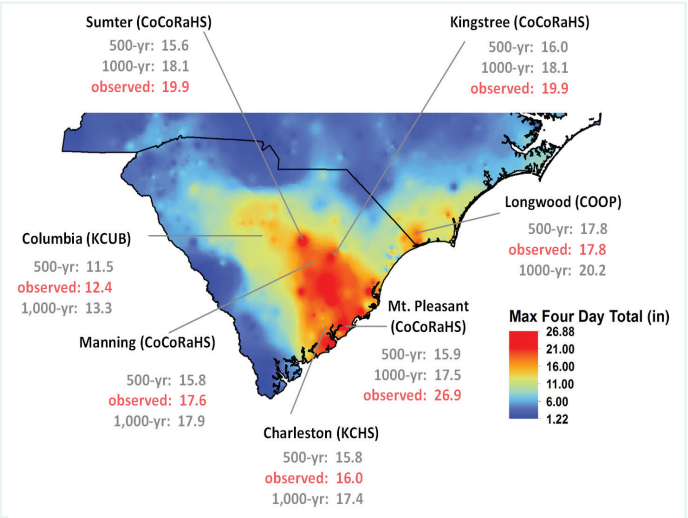


**Figure 1.11** Rainfall during the October 2015 extreme event. *Carolinas Integrated Sciences and Assessments (CISA) (2016)*

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 from 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.

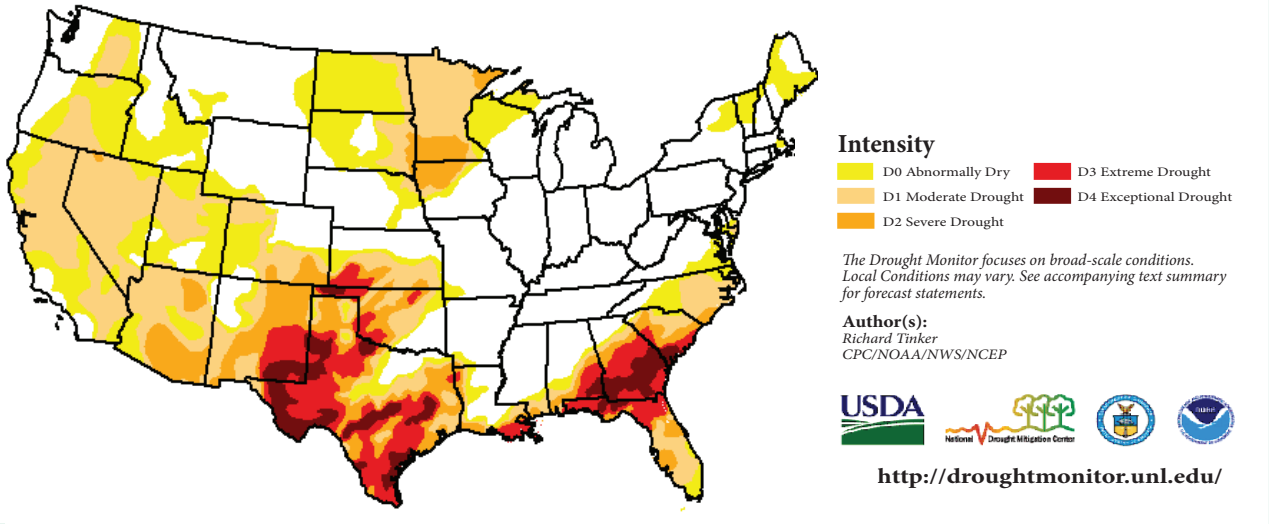


**Figure 1.12** U.S. Drought Monitor data for February 14, 2012. *National Drought Mitigation Center (2017)*

**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. 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

# 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, 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. Hospitals such as the Medical University of South Carolina (MUSC) recognized the potential benefits of green spaces and have 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. Uncarefully 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 problem by protecting


**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)*

natural wetland buffer zones 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 diverse set 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.

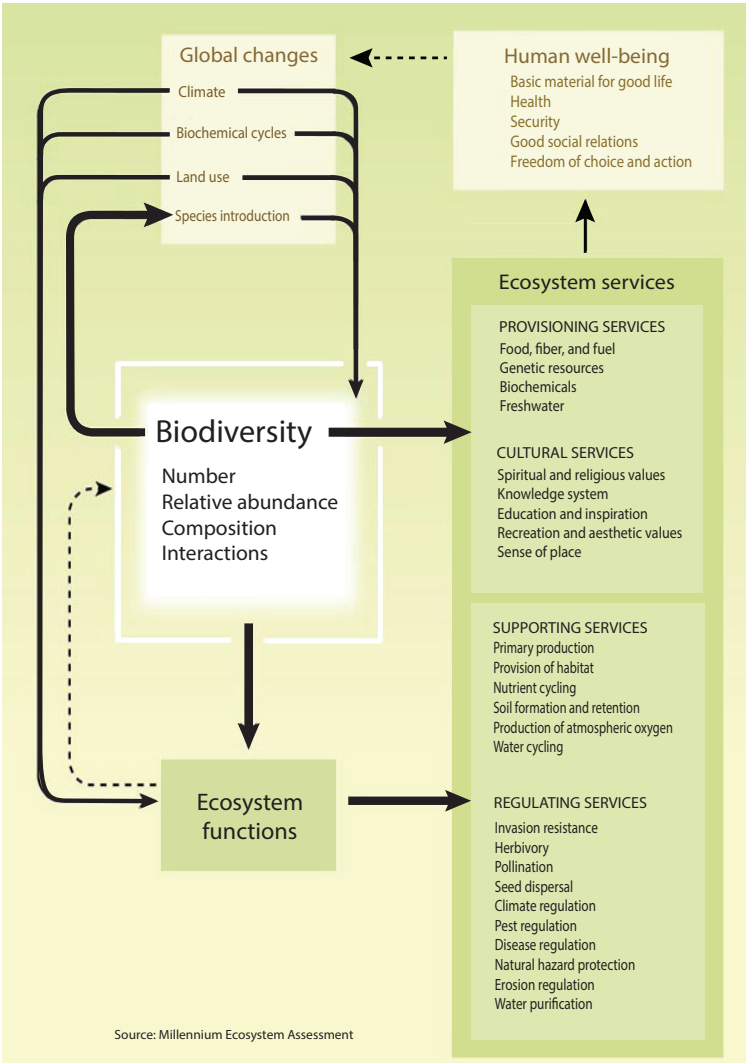


**Figure 2.2** Relationships between biodiversity, ecosystem services, and human well-being, including global changes that affect them. *Millennium Ecosystem Assessment Box 1.4 (2005)*

**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)*

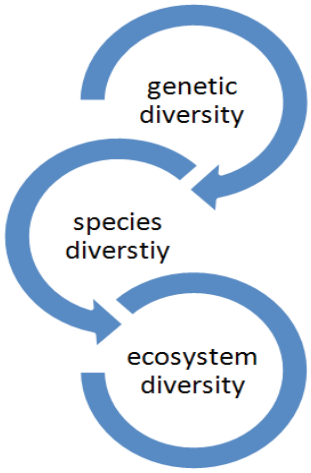


**Figure 2.4** Levels of diversity which contribute to overall biodiversity. Genetic diversity of species, the diversity of species within an ecosystem, and the diversity of ecosystems within the environment.

## 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, building oyster reefs, among other things

**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. Forestry Service. Cooperative program of the U.S. Forest Service that focuses on the stewardship of urban natural resources. Website: https://www.fs.fed.us/managing-land/urban-forests/ucf
- **SC WaterWays - Life Along the Salt Marsh: Protecting Tidal Creeks with Vegetative Buffers**. Clemson University. Website: http://bit.ly/2x2Owk0
- **Water quality monitoring volunteer program.** S.C. Oyster Restoration and Enhancement (SCORE) program. SCDNR. Website: http://score.dnr.sc.gov/deep.php?subject=5
- **Coastal Resilience Mapping Tool**. 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. https://coast.noaa.gov/digitalcoast/tools/coastalresilience.html
- **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/

# 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 about 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 or 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 storm water 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 water, 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 events 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 can be every bit as problematic as too much,

**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)*

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**).

Impacts of invasive species are second only to

**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)*

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 out-compete 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 Devlopment 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/

# Our Environmental Health

## How We Affect Environmental Health

Our coastal environment is changed by human activity. Likewise, human health and our activities are changed by the environment. That is why it is important to study and understand this interaction. How do our activities impact the health of the environment and how does that affect public health and the well-being of communities?

Sanitation and drainage systems have improved public health and the livability of urban areas. However, the pollution removed from these areas can accumulate elsewhere and cause ecological and public health issues. Pollution introduced into the environment also can cause stress to many different organisms and have a devastating impact on ecosystems.

Chemical pollutants such as pesticides, petroleum products, and heavy metals make it increasingly difficult for natural organisms to survive and maintain their role within an ecosystem. For example, of the 100 most commonly sold pesticides in S.C. and the southeastern U.S., more than 80 are used on turf grass in residential areas and golf courses. National monitoring programs have found adverse effects in aquatic life at 90% of sites in urban areas. Although most plants and animals can tolerate a certain level of pollution, a small increase in the concentration of pollutants can change the behavior of organisms and cause die-offs. Our biggest concern is the cumulative effects of these mixtures of chemical pollutants. In other words, what happens when you have small effects from many pollutants at the same time, and do these pollutants interact with each other in a way that make them more harmful?

The impacts of pollutants are magnified when there are also other stressors, such as extreme temperatures, changes in the acidity or salinity of water, loss of a food source, or introduction of high levels of artificial light, affect the system. Increasing acidity caused by some pollutants can increase the leeching of trace metals and other contaminants from the land, resulting in more pollution in aquatic ecosystems. Rising temperatures can be especially troublesome. Higher temperatures tend to make some chemicals more toxic. Pollutants that find their way into warming waters can accumulate in the muscles of fish and wildlife that we eat and eventually begin to affect us directly.

## Bioaccumulation and Biomagnification

An organism taking in pollutants more rapidly than it removes them can result in bioaccumulation (van der Hoop, 2013). The pollutants are stored in bodily tissues or the bloodstream and can reach toxic levels. Predators that consume these organisms end up with higher concentrations of pollutants in their bodies compared to their prey, an effect known as biomagnification. Through bioaccumulation, levels of contaminants in lower animals (e.g., fish, crabs) are transferred to higher animals known as apex predators (e.g., sharks, hawks, and humans) (**Figure 4.1**). A classic example of this was seen in the 1940s with the case of DDT and Brown Pelicans. DDT was a pesticide that was sprayed on agricultural crops and eventually ended up in streams and rivers due to stormwater runoff. As invertebrates were infected with DDT, it made its way up the food chain through the fish that ate the invertebrates and to the

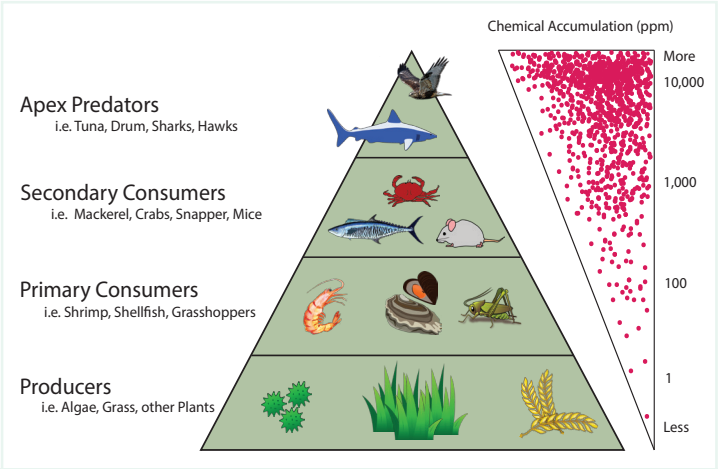


**Figure 4.1** Biomagnification of chemicals in relation to trophic levels. *Lee Bundrick, S.C. Sea Grant Consortium (2017)*

pelicans that ate the fish. As fish were the primary diet of pelicans, the amount of DDT in one bird was much higher than that of one fish. The DDT was biomagnified and caused the eggshells to become so weak that they were crushed under the weight of their mother. This biomagnification effect almost eliminated pelicans in many areas including South Carolina. In 1972 DDT was banned in the United States, and since then the pelican population has rebounded.

Biomagnification is also seen in humans as we are a top predator. These effects are studied to measure the accumulation of pollutants that can alter biological processes. For example, heavy metals such as mercury and lead accumulate in fish. Heavy metals have been shown to impact the nervous system of most animals, and consuming fish or shellfish that have accumulated heavy metals can also cause health issues for people, including impaired brain function and organ failure. This is particularly an issue in pregnant women and small children due to specialized metabolism during these critical windows of human development, and excessive exposure can lead to hyperactivity and learning disabilities. Many other pollutants — oil products, pesticides, fecal matter, high levels of nitrogen — that accumulate in the tissue of large animals can cause major health issues. However, consuming even the smallest organisms that accumulate toxins can potentially cause health issues as well.

**Figure 4.2** Plastic litter by walkway near Lockwood Boulevard in Charleston. *Lee Bundrick, S.C. Sea Grant Consortium (May 2017)*

## *Chemicals of Emerging Concern*

While the danger of chemicals found in pesticides and oil products has long been studied, other pollutants are emerging as concerns for public and environmental health. These include flame retardants, pharmaceuticals, personal care products, nanomaterials, and microplastics. Flame retardants are used in a variety of products including home furnishings, clothing, electronics, and firefighting chemicals, and are known to be toxic to aquatic life and humans.

Some pharmaceuticals and personal care products, such as ibuprofen and antibiotics, are simply dumped down household drains, but some pass through the human body and end up in wastewater systems. Caffeine passes through the body without being processed so often that it is used as a marker to measure wastewater contamination in the environment. For most chemical contaminants, the higher the concentration the greater the potential for harm to the environment, and lower levels are generally less harmful to the environment. Antibiotics are different though. Lower doses may actually enhance the development of antibiotic-resistant bacteria, which may cause illnesses associated with eating contaminated seafood or infections caused from being in the water.

Nanomaterials are tiny particles, 100,000 times smaller than the width of a hair. With recent improvements in magnification technology, nanomaterials increasingly are being used to improve a variety of manufactured products, including antibacterial soaps, industrial paints, sunscreens, and cosmetics. Some nanomaterials have been shown to cause heart and lung issues in industrial workers who occasionally breathe them in on the job, but studies are just getting started on the accumulation of nanomaterials in wildlife.

While there are no reliable estimates on

the amount of plastic litter entering coastal waters, 30 million U.S. tons of plastic waste were produced in the United States in 2008. Only 7.1% of that was recovered or recycled, with the remaining 92.9% ending up in the environment (**Figure 4.2**). Almost 80% of all plastic debris found in coastal environments originates from land-based pollution sources, including street litter washed or blown into nearby waterways, public littering, inadequately covered containers, sewage treatment and combined sewer overflows, fishing, and boats and ships offshore.

Microplastics are formed by the degradation of plastic packaging and other material in the environment into very small particles that may be bioaccumulated by shellfish and other marine species. Other pollutants may adsorb to the surfaces of these microplastic particles, resulting in additional exposure of legacy pollutants and other contaminants to living marine organisms in our coastal environments. All of the chemicals of emerging concern can find their way into aquatic environments and bioaccumulate in the tissues of animals and plants.

## Tougher Bacteria

Not only are we dealing with new chemical concerns, but our bacteria are becoming more resilient. Some bacteria that cause illnesses in humans are starting to become more resistant to antibiotics, resulting in less effective treatment and raising more health concerns. The increase in bacterial resistance to antibiotics will cause more health risks involved with recreation and eating food from coastal waterways.

One group of saltwater and brackish water pathogens in the genus *Vibrio* is becoming more resistant to antibiotics. *Vibrio* infections usually start in the small intestine, and those affected exhibit symptoms of diarrhea, vomiting, headaches, fever, and septic shock, which can lead to death. Someone can be easily infected with *Vibrio* by eating seafood from, or swimming with open wounds in, contaminated water.

Climate change can affect the resistance

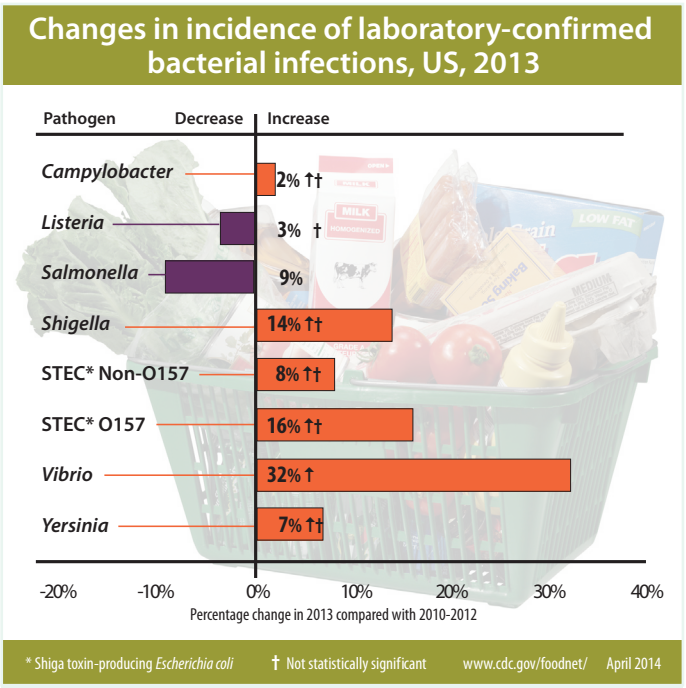


**Figure 4.3** Change in incidence of laboratory-confirmed bacterial infections. *Centers for Disease Control (2014)*

and prevalence of pathogens like *Vibrio*. For example, rising temperatures could result in the increase of plankton and algae that serve as aquatic hosts for *Vibrio*. A significant public health risk associated with global climate change and sea level rise is the presence of *Vibrio vulnificus* and *Vibrio parahaemolyticus* in coastal waters and seafood. *Vibrio vulnificus* annually causes more than 22 deaths per year, accounting for 85% of all deaths from consuming seafood in the U.S. *Vibrio parahaemolyticus* annually causes more than 6,000-8,000 cases but rarely causes deaths. In 2013 there was a substantial increase in the number of cases of *Vibrio* illness on the East Coast of the U.S. due to an outbreak associated with the consumption of shellfish. *Vibrio* illnesses from seafood consumption and wound infections in the U.S. have increased by 46% from 1996-2005. According to Centers for Disease Control, the annual incidence rate of *Vibrio* illnesses in 2013 increased by 32% compared to the annual incidence rates in 2010-2012 as shown in **Figure 4.3**.

Bacteria and the accumulation of harmful chemicals can be detrimental in and of themselves. However, other factors such as changes in salinity, acidity, and temperature of water can make these issues worse by

increasing absorption into organisms' tissues, particularly for fish and invertebrates species we consume as seafood. This makes the presence of pollutants far more dangerous in areas with higher temperatures and salinities and areas with very high or very low acidity levels. Altered salinity and temperatures in waters can also affect where bacteria like *Vibrio* are present and may enhance their virulence, ultimately affecting more people. Rising temperatures also increase the range of these bacteria and the ability of organic tissues to absorb pollutants.

As the number of antibiotic-resistant microbes and the levels of legacy pollutants remain and emerging chemical contaminants increase, the health of the environment will be impacted. The growing presence of harmful chemicals and bacteria such as *Vibrio* can cause coastal waters to become more dangerous to swim in and to use as a source of drinking water or food. Coupled with rising temperatures and sea level rise, these problems will become worse.

## What Can We Do?

**Develop programs that recycle and treat wastewater** for other uses, such as the ones implemented in California and Florida

**Design urban areas with less impervious surfaces** to reduce the impact of urban stormwater runoff

**Reduce the impact of pesticides** by limiting their usage and using **integrated pest management** (IPM) strategies, particularly in residential areas and golf courses

**Enhance recycling and trash collection** to prevent plastic from entering coastal environments

**Reduce the use of antibiotics in health care and agricultural industry**

**Encourage programs that properly dispose of unused pharmaceuticals** at retail pharmacies and hospitals

**Reduce the use of commercial and industrial products made with chemicals of emerging concern**

**Increase the monitoring and reporting of dangerous pathogens,** like *Vibrio,* in our environment

**Develop forecast models that predict effects of sea level rise on current coastal surface water drinking water reservoirs**

## Resources for More Information

- **Clemson's Carolina Clear Program**. Website: www.clemson.edu/carolinaclear
- **Centers for Disease Control.** Vibrio Species Causing Vibriosis. Website: https://www.cdc.gov/vibrio/index.html
- **California Expert Panels on Chemicals of Emerging Concern.** Report: http://www.waterboards.ca.gov/water_issues/programs/swamp/cec_aquatic/docs/cec_ecosystems_rpt.pdf
- **Integrated Pest Mangement.** USEPA. Website: https://www.epa.gov/managing-pests-schools/introduction-integrated-pest-management
- **NOAA Mussel Watch and National Status and Trend Programs.** Website**:** https://products.coastalscience.noaa.gov/collections/ltmonitoring/nsandt/default.aspx
- **SCDHEC Beach Guide**. GIS map with current swim advisories. Website: https://gis.dhec.sc.gov/beachaccess/
- **How to dispose of unused medicines**. U.S. Food and Drug Administration (USFDA). Website: https://www.fda.gov/ForConsumers/ConsumerUpdates/ucm101653.htm
- **Shellfish Monitoring Map.** Water quality classifications of shellfish growing areas. SCDHEC. Website: http://www.scdhec.gov/FoodSafety/ShellfishMonitoring/Map/
- **Breaking Down Plastic.** South Carolina Aquarium. Website: http://plastic.scaquarium.org/learn-more/

# Our Ocean Mineral and Energy Resources

## *Sand, Our Coastal Mineral Resource*

Coastal South Carolina's lovely sand beaches and coastal islands are perfect for outdoor adventures. Yet, while our beaches are a draw for South Carolina, they are constantly in flux. The sand that makes up our beaches is constantly shifting. It is driven by waves, currents, and wind, which change day to day and throughout each year. Sand moves along the coast with currents within the surf zone and may also be driven offshore and lost from the beach system, particularly during storms. Beach sand can move within tidal inlets for extended periods and episodically escape back onto the adjacent beaches. As a result, locally more sediment may be gained or lost from the beach resulting in accretion or erosion.  Overall, our beaches are losing sand and natural sources to replace that sand are limited.

This erosional process is worsened by rising sea levels and increased storm intensities which have been documented along our coastal counties. One way we have tried to remedy these disappearing beaches is through beach renourishment, in which sand from off shore, such as borrow pits or other areas, is brought to eroding beaches via pipes, barges, or dump trucks. For years, large and repeated efforts have sustained beaches in South Carolina. For example, the Army Corps of Engineers has regularly renourished Folly Beach. The most recent renourishment at Folly Beach cost $30 million.

**Figure 5.1** Eastern section of the Battery, a seawall in Charleston. *S.C. Sea Grant Consortium.*

The federal government covered 85% of the cost for the Folly Beach renourishment as mitigation for the construction of Charleston Harbor's three-mile long jetties in 1895. Anchored on each side of the harbor, the jetties prevent the natural movement of sand from the north down to Folly's shores. For other federal restoration, there is a 65% cost-share between local, state, and federal funding for renourishment projects. Acquiring funds and permits can be an arduous process. Keeping up with Mother Nature means some beachfront communities begin saving for the next renourishment as soon as the previous renourishment has finished. In addition, this strategy requires mining and transporting sand from outside the beach system. In many areas committed to nourishment, there is a limited sand resource close to the coast. This can be expected to cause competition and cost issues for many of our coastal communities in the future. In other areas, there may be an abundance of sediment nearby but it is located within tidal inlet deltas. Tidal inlets are complex, and changes within them can significantly affect the adjacent beaches, which occurred with the manipulation of the Charleston Harbor entrance.

## *Human Engineering*

Other tools for dealing with coastal erosion include manmade groins and sea walls. Groins are created to catch sand moving down the coast to protect beaches, but that means the areas south of groins are denied the sand. Groins are often wooden structures stretching out 75-100 feet into the ocean and dot many South Carolina beaches. The Charleston Harbor jetties serve as a giant groin. In addition to robbing Folly Beach of sand, the jetty has contributed to the extreme shifting of undeveloped Morris Island, once home base for an iconic lighthouse that is now surrounded by water.

While groins catch sand, sea walls are designed to create a barrier between property and the erosional power of storm waves and rising seas. The Battery (**Figure 5.1**) in the southeast region of

Charleston peninsula is the most famous South Carolina sea wall. South Carolina now places strict regulations on the construction of beachfront sea walls, though many were built before regulations were in place. Sea walls can prevent direct intrusion of saltwater, but they require constant maintenance.

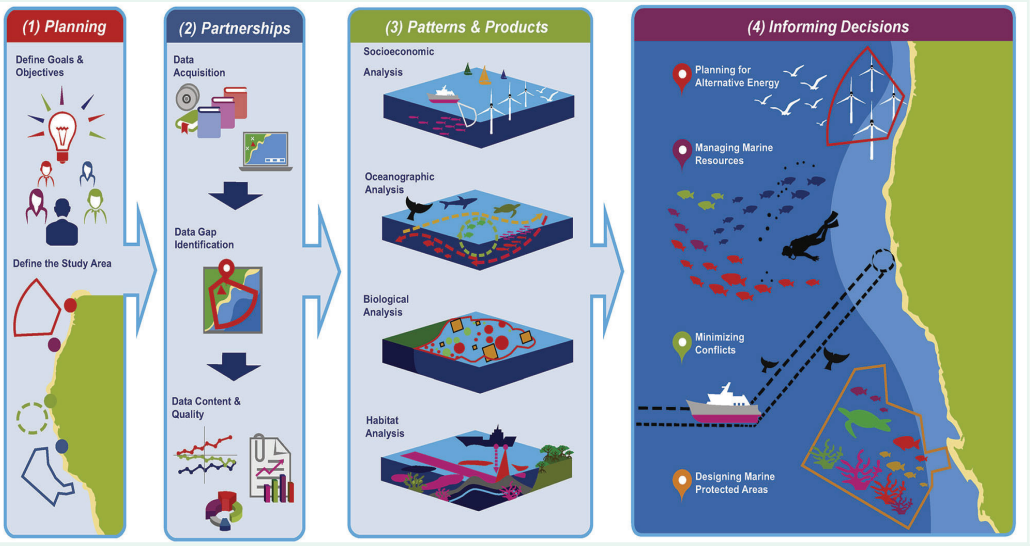


**Figure 5.2** The four-step Biogeographic Assessment Framework is often developed and used to support marine spatial planning, used in energy development decision-making. *NOAA NCCOS (2014)*

In terms of environmental impacts, sea walls have positives and negatives. They can decrease diverse habitat for plants and animals that live in marsh or sand, but they can increase habitat for animals such as barnacles and oysters that need hard substrates. They also tend to increase erosion at the ends of their structure, and beach sand can be scoured in front of sea walls impacted by heavy waves. So while human engineering can protect property and some animals, it can create problems elsewhere.

One option for combating rising sea levels and shifting coastline is to retreat. This means moving entire communities landward. In some areas of the floodplains in Mississippi and Louisiana, towns have picked up and moved inward. Yet, this could be a costly and problematic solution in South Carolina. Some of the most valuable homes and commercial buildings in the state are on beachfronts and along tidal waterfronts.

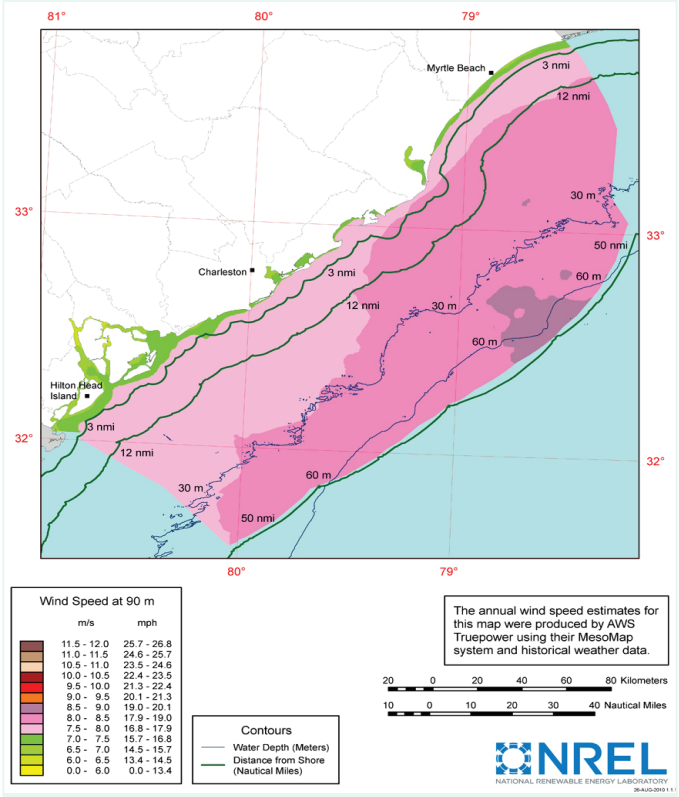


**Figure 5.3** Coastal Offshore Wind Speed in South Carolina at 90 meters; such charts are used to position wind farms. *WINDExchange, US Department of Energy (2017)*

In fact, South Carolinians have done the opposite of retreating. After Hurricane Hugo devastated thousands of homes along the coast in 1989, many were built back larger and, in some cases, closer to the water. As Charleston dealt with a record number of nuisance flooding days in 2016, construction crews worked on multiple new high-rise hotels on the city's historic peninsula.

## *Offshore Wind*

As the population increases, so does South Carolina's energy demands. New possible energy alternatives have arisen to help meet that growing demand. One such alternative is offshore wind power.

According to a report from the Clemson University Restoration Institute and Strom Thurmond Institute of Government and Public Affairs, a 1,000-megawatt offshore wind farm constructed between 2016 and 2025 would create an average of more than 3,800 jobs per year throughout the 10-year construction period. It would generate nearly $2 billion in wages and nearly $620 million in combined state and local government revenue.

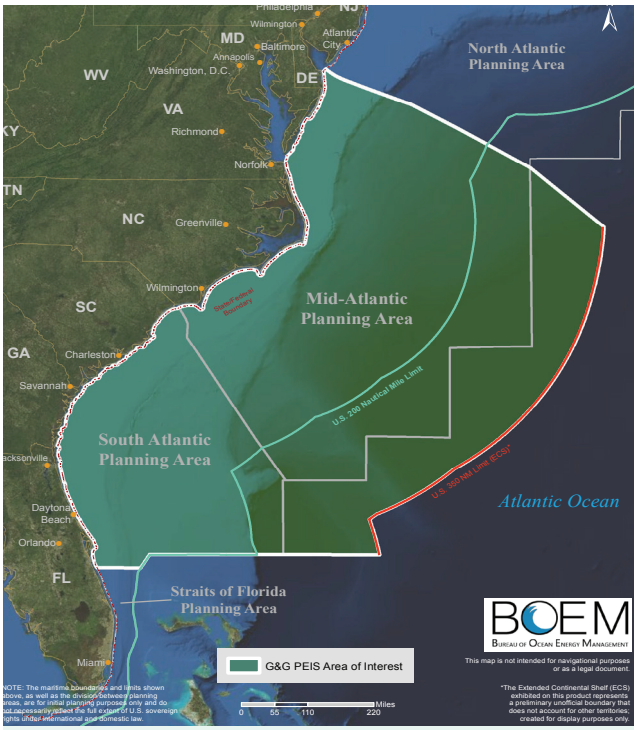


**Figure 5.4** Atlantic Outer Continental Shelf Geological and Geophysical Programmatic Environmental Impact Statement area of interest. *This is the area currently being used for energy development decision making. BOEM (2013)*

With energy-related manufacturers like General Electric, IMO Group, and Prysmian already in South Carolina, there is the potential to significantly expand the industrial base. The Clemson University Restoration Institute in North Charleston features a test facility for large wind turbines, and state-owned power company Santee Cooper operates a 2.4-kilowatt, land-based wind turbine at North Myrtle Beach. In 2008, legislators created the Wind Energy Production Farms Feasibility Study Committee. This led to studies on the regulatory challenges and the production potential for wind energy off South Carolina's coast. Currently some market barriers stand in the way of offshore wind development, but the S.C. General Assembly is seeking to change this.

Wind turbines have an additional benefit of putting the state on the forefront of wind energy. North Myrtle Beach has chosen to position itself as a major proponent of offshore wind energy to promote coastal tourism.

While wind energy may have benefits, it also has costs. The placement of wind turbines will have to be strategic because some people consider them a blemish on the horizon. **Figure 5.5** demonstrates the visibility of wind turbines from two miles to eight miles off the coast. They can have a substantial presence the closer they are to shore, dependent on clear weather. Additionally, they could have ecological impacts on birds, sea turtles, and other wildlife. This could also impact recreation and commercial fishing communities. However, these costs are all dependent on the location of wind farms. The Bureau of Ocean and Energy Management (BOEM) studies have determined areas for potential wind farm locations with the least impact on environment and recreation.

## *Offshore Drilling*

Another energy resource being considered in South Carolina is oil and gas. This topic has been contentious. In December 2016, President Obama imposed a federal moratorium on drilling in the Atlantic continental outer shelf, but President Trump announced plans in April 2017 to reverse that ban. While drilling could increase economic opportunity for South Carolina, an offshore accident leading to an oil spill could have large environmental and economic impacts.

To move forward with offshore drilling, more thorough estimations of oil deposits along the coast would have to be made. This requires seismic testing using air guns that shoot loud blasts of compressed air toward the ocean floor. The reflection of those sounds off the ocean floor help indicate the location of oil and gas beneath the surface.

The loud compressed air blasts can have negative impacts on sea creatures, especially marine mammals, such as whales and dolphins. These animals rely on sonar for communication and movement. To move forward with offshore

**Figure 5.5** Landscape simulation of wind turbines at mile intervals between 2-8 miles offshore. *Santee Cooper (2009)*

drilling, seismic testing would be necessary across the continental shelf.

If sizeable deposits of oil or gas were to be found off the coast, extracting them could bring oil refineries and jobs to the state, boosting the economy. South Carolina's manufacturing base and port in Charleston make South Carolina well-positioned to benefit economically from offshore drilling. An analysis by the University of Wyoming School of Energy Resources determined the benefits of offshore drilling outweigh the environmental costs by a 2-1 margin. Drilling opponents disagree with those findings, claiming the potential economic damage of an oil spill is much greater than the economic opportunity of the oil reserves off South Carolina.

Leaders in multiple coastal communities have come out against offshore drilling and seismic testing. Their reasons are two-fold. An oil spill would be detrimental to tourism, which relies on its pristine marshes and beaches. And the onshore infrastructure needed for an oil refinery would have negative environmental impacts. The commercial fishing industry also opposes seismic testing and drilling due to possible impacts on the fisheries. Offshore drilling is a complex issue, and many coastal communities remain firmly against oil and gas development.

## *What Can We Do?*

**Consider costs and benefits of continuing beach renourishment efforts**

**Use environmental engineering techniques** such as living shorelines to decrease erosion and protect shorelines

**Consider long-term strategies for responding to sea level rise** and increased flooding events in coastal communities, such as retreating

**Implement building codes for new construction to respond to sea level rise**, such as site elevation requirements

**Construct new and update old sea walls** to adapt to current and future sea level rise

**Weigh the costs and benefits of offshore wind,** particularly in northern SC area

**Weigh the costs and benefits of conducting seismic tests** to determine the extent of oil deposits in the Atlantic

## *Resources for More Information*

- **U.S. Department of Energy, Make Your Home Green document.** Website: http://www.energy.sc.gov/files/MakingYourHomeGreen.pdf
- **The Nature Conservancy, South Carolina: Goldbug Island Living Shoreline.** Website: https://www.nature.org/photos-and-video/video/south-carolina-goldbug-island-living-shoreline
- **Charleston Jetties, The Incidental Reef.** Pete Laurie**,** SCDNR. Website: http://www.dnr.sc.gov/magazine/articles/marapril2014/chasjetties.html
- **South Carolina Department of Health and Environmental Control, Interactive SC Beach Renourishment GIS Map**. Website: https://gis.dhec.sc.gov/renourishment/
- **British Petroleum. BP statistical review of world energy 2013**. Website: http://large.stanford.edu/courses/2013/ph240/lim1/docs/bpreview.pdf
- **Bureau of Ocean Energy Management (BOEM).** Website: https://www.boem.gov/South-Carolina/
- **South Carolina Department of Natural Resources. Comprehensive spatial database on SC's coastal resources. GIS Data Resources.** Website: http://www.dnr.sc.gov/GIS/gisenergy
- **South Carolina Energy Office.** Website: http://www.energy.sc.gov/

# Resources and References


Adams, Chris. "SC Already Feeling Climate Change Effects." The State Newspaper. McClatchy Washington Bureau. 06 May, 2014. Web Article. Link to article:http://www.thestate.com/news/local/article13852676.html

Anderson, P. D., Denslow, N. D., Drewes, J. E., Olivieri, A. W., Schlenk, D., Scott, G. I., & Snyder, S. A. Monitoring strategies for chemicals of emerging concern (CECs) in California's aquatic ecosystems—recommendations of a science advisory panel. Costa Mesa, CA: Southern California Coastal Water Research Project. 2012. Link to Article: http://bit.ly/2vnkQOV

Andrady, A., 2011. Microplastics in the marine environment. Marine Pollution Bulletin, 62(8), pp.1596– 1605.

Baker-Austin, C., J. V. McArthur, R. C. Tuckfield, M. Najarro, A. H. Lindell, J. Gooch and R. Stepanauskas. 2008. Antibiotic resistance in the shellfish pathogen Vibrio parahaemolyticus, isolated from the coastal water and sediment of Georgia and South Carolina, USA. Journal of Food Protection, Vol. 71, No. 12: 2552–2558.

Baker-Austin, C., Trinanes, J.A., Taylor, N.G.H., Hartnell, R.,Siitonen, A., Martinez-Urtaza, J., 2012. Emerging Vibrio risk at high latitudes in response to ocean warming. Nature Clim. Change, 73-77.

Baker-Austin, C., J. Trinanes, N. Gonzalez-Escalona, and J. Martinez-Urtaza. 2017. Non-Cholera Vibrios: The Microbial Barometer of Climate Change. Trends in Microbiology 25 (1): 76-84.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. "The value of estuarine and coastal ecosystem services." Ecological monographs 81.2 (2011): 169-193. Link to article: http://leopoldleadership.stanford.edu/sites/default/files/The_Value_of_Estuarine_and_Coastal_Ecosystem_Services_Barbier_et_al%202011.pdf

Bayer, Michael, Nancy Frank, and Jason Valerius. Becoming an urban planner: a guide to careers in planning and urban design. John Wiley & Sons, 2010. Link to book:http://bit.ly/2gNoyy3

Bell, B. G., Schellevis, F., Stobberingh, E., Goossens, H., & Pringle, M. "A systematic review and meta-analysis of the effects of antibiotic consumption on antibiotic resistance." BMC infectious diseases14.1 (2014): 13. Link to article:https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-14-13

Bisesi, M.l, Long, S., London, A., Harvey, C.H., and Collins, A.E.. "Definitions of Environmental Health." Definitions of Environmental Health | National Environmental Health Association: NEHA. Web. 13 July 2017. Link to article: https://www.neha.org/about-neha/definitions-environmental-health

Buerge, Ignaz J., et al. "Caffeine, an anthropogenic marker for wastewater contamination of surface waters." Environmental science & technology 37.4. (2003): 691-700. Link to article:http://pubs.acs.org/doi/abs/10.1021/es020125z?journalCode=esthag

Camargo, Julio A., and Álvaro Alonso. "Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment." Environment international 32.6 (2006): 831-849. Link to article: http://bit.ly/2vFC7SA

Camargo, Julio A., and Álvaro Alonso. "Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: a global assessment." Environment international 32.6 (2006): 831-849. Link to article:http://bit.ly/2vFC7SA

Cardinale, B. J.; Duffy, E.; Gonzalez, A.; Hooper, D.U.; Perrings, C.; Venail, P.; Narwani, A.; Mace, G.M:; Tilman, D.; Wardle, D.A.; Kinzig, A.P.; Daily, G.C.; Loreau, M.; Grace, J.B.; Larigauderie, A.; Srivastava, D. and Naeem, S. (2012) Biodiversity loss and its impact on humanity. Nature. Volume: 486, Number: 7401, pp 59-67. Link to article: http://pub.epsilon.slu.se/10240/7/wardle_d_etal_130415.pdf

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. "Nonpoint pollution of surface waters with phosphorus and nitrogen." Ecological applications 8.3 (1998): 559-568. Link to article: https://kuscholarworks.ku.edu/bitstream/handle/1808/16724/SmithVal_EA_8(3)559.pdf?sequence=1&isAllowed=y

Carter, L. M., J. W. Jones, L. Berry, V. Burkett, J. F. Murley, J. Obeysekera, P. J. Schramm, and D. Wear, 2014: Ch. 17: Southeast and the Caribbean. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 396-417. doi:10.7930/J0N-P22CB. Link to chapter: http://nca2014.globalchange.gov/report/regions/southeast

Ceballos, Gerardo, Paul R. Ehrlich, Anthony D. Barnosky, Andrés García, Robert M. Pringle, and Todd M. Palmer. "Accelerated modern human–induced species losses: Entering the sixth mass extinction." Science advances 1.5 (2015): e1400253. Link to article: http://advances.sciencemag.org/content/1/5/e1400253.full?con=&dom=pscau&src=syndication

Centers for Disease Control and Prevention (CDC). 2006. Preliminary FoodNet data on the incidence of infection with pathogens transmitted commonly through food-10 states, United States, 2005. MMWR Morb. Mortal. Wkly Rep. 55: 392–395.

Chapin Iii, F.S., Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E. and Mack, M.C. "Consequences of changing biodiversity." Nature 405.6783 (2000): 234-242. Link to article: http://www.nature.com/nature/journal/v405/n6783/full/405234a0.html

Coastal Conservation League. "South Carolina's Wind Energy Potential." Coastal Conservation League. Accessed July 2017. Web. Link: http://coastalconservationleague.org/projects/south-carolinas-offshore-wind-potential/

Daughton, Christian G. "Pharmaceuticals in the environment: Sources and their management." Comprehensive analytical chemistry 50 (2007): 1-58. Link to article:http://bit.ly/2uFMCrS

Daughton, Christian G., and Ilene S. Ruhoy. "Environmental footprint of pharmaceuticals: the significance of factors beyond direct excretion to sewers." Environmental toxicology and chemistry 28.12 (2009): 2495-2521. Link to article:http://onlinelibrary.wiley.com/doi/10.1897/08-382.1/full

Daughton, Christian G., and Thomas A. Ternes. "Pharmaceuticals and personal care products in the environment: agents of subtle change?" Environmental health perspectives 107.Suppl 6 (1999): 907. Link to article:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1566206/pdf/envhper00523-0087.pdf

DeLorenzo, M.E., Wallace, S.C., Danese, L.E. and Baird, T.D. "Temperature and salinity effects on the toxicity of common pesticides to the grass shrimp, Palaemonetes pugio." Journal of Environmental Science and Health, Part B 44.5 (2009): 455-460. Link to article:http://www.tandfonline.com/doi/full/10.1080/03601230902935121?scroll=top&needAccess=true see: abstract

Delorenzo, Marie E. "Impacts of climate change on the ecotoxicology of chemical contaminants in estuarine organisms." Current Zoology 61.4 (2015): 641-652. Link to article:https://academic.oup.com/cz/article-pdf/61/4/641/5103711/czoolo61-0641.pdf

DeLorenzo, Marie E., Geoffrey I. Scott, and Philippe E. Ross. "Toxicity of pesticides to aquatic microorganisms: a review." Environmental toxicology and chemistry 20.1 (2001): 84-98. Link to article: http://bit.ly/2uDI3yy

Díaz, S., J. Fargione, F. Stuart Chapin III, and D. Tilman "Biodiversity loss threatens human well-being." PLoS Biol 4.8 (2006): e277. Link to article: https://stuff.mit.edu/afs/athena.mit.edu/course/12/12.000/www/m2015/pdfgroup1.pdf

Eggert, J., Dye, C.J., Vincent, E., Parker, V., Daily, S.B., Pham, H., Watson, A.T., Summey, H. and Roy, T. "Effects of viewing a preferred nature image and hearing preferred music on engagement, agitation, and mental status in persons with dementia." SAGE open medicine 3 (2015): 2050312115602579. Link to article: http://journals.sagepub.com/doi/full/10.1177/2050312115602579

Fair, Richard J., and Yitzhak Tor. "Antibiotics and bacterial resistance in the 21st century." Perspectives in medicinal chemistry 6 (2014): 25. Link to article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4159373/

Fretwell, Sammy. "Climate Report Released by DNR." The State Newspaper. Politics & Government. 09 April, 2013. Web Article. Link to article:http://www.thestate.com/news/politics-government/article14425643.html

Gayes, Paul. "Update on Spatial Use Data to Inform Planning." South Carolina Offshore Renewable Energy Task Force. 16 May 2014. Presentation. Link: http://energy.sc.gov/files/Gayes%20Update%20BOEM%20SC%20Task%20Force.pdf

Gonzalez, Marianne T., and Marit Kirkevold. "Benefits of sensory garden and horticultural activities in dementia care: a modified scoping review." Journal of Clinical Nursing 23.19-20 (2014): 2698-2715. Link to article: http://bit.ly/2uMKeR7

Haines-Young, Roy, and Marion Potschin. "The links between biodiversity, ecosystem services and human well-being." Ecosystem Ecology: a new synthesis (2010): 110-139.Link to article: https://www.pik-potsdam.de/news/public-events/archiv/alter-net/former-ss/2009/10.09.2009/10.9.-haines-young/literature/haines-young-potschin_2009_bes_2.pdf

Hull, Peter. "S.C. Offshore Wind Farm Would Generate Thousands Of Jobs, Clemson Study Shows." Clemson University. Clemson Newsstand. 04 October 2012. Web Article. Link to article: http://newsstand.clemson.edu/mediarelations/sc-offshore-wind-farm-would-generate-thousands-of-jobs-clemson-study-shows/

Hunter, P. R. "Climate change and waterborne and vector-borne disease." Journal of applied microbiology 94.s1 (2003): 37-46. Link to article: http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2672.94.s1.5.x/full

Jiang, Bin, Chun-Yen Chang, and William C. Sullivan. "A dose of nature: Tree cover, stress reduction, and gender differences." Landscape and Urban Planning 132 (2014): 26-36. Link to article: https://www.fs.fed.us/nrs/pubs/jrnl/2014/nrs_2014_jiang_001.pdf

Jones, Melissa K., and James D. Oliver."Vibrio vulnificus: disease and pathogenesis." Infection and immunity 77.5 (2009): 1723-1733. Link to article: http://iai.asm.org/content/77/5/1723.full

Jones, Nicola. "How Climate Change Could Jam The World's Ocean Circulation." Yale E360. Yale School of Forestry and Environmental Studies, 6 Sept. 2016. Web. Link to article:http://e360.yale.edu/features/will_climate_change_jam_the_global_ocean_conveyor_belt

Katagi, Toshiyuki. "Bioconcentration, bioaccumulation, and metabolism of pesticides in aquatic organisms." Reviews of environmental contamination and toxicology. Springer New York, 2010. 1-132. Link to article:http://bit.ly/2gNsQFw see section 2.1.3.

Lacoue-Labarthe, Thomas, et al. "Effects of increased pCO2 and temperature on trace element (Ag, Cd and Zn) bioaccumulation in the eggs of the common cuttlefish, Sepia officinalis." Biogeosciences 6.11 (2009): 2561-2573. Link to article:https://hal.archives-ouvertes.fr/hal-00474436/file/Lacoue-Labarthe_et_al_2009_BG.pdf

Latimer, J. S., Hoffman, E. J., Hoffman, G., Fasching, J. L., & Quinn, J. G. "Sources of petroleum hydrocarbons in urban runoff." Water, Air, & Soil Pollution 52.1 (1990): 1-21. Link to article: http://bit.ly/2vFB5Gk

Lipp, E. K., Huq, A., and Colwell, R. R. "Effects of global climate on infectious disease: the cholera model." Clinical microbiology reviews 15.4 (2002): 757-770. Link to article: https://www.ncbi.nlm.nih.gov/pubmed/12364378

Lobitz, B., Beck, L., Huq, A., Wood, B., Fuchs, G., Faruque, A.S.G. and Colwell, R. "Climate and infectious disease: use of remote sensing for detection of Vibrio cholerae by indirect measurement". Proceedings of the National Academy of Science. 97, 1438–1443 (2010). Link to article: http://www.pnas.org/content/97/4/1438.full

Lockman, P. R., Mumper, R. J., Khan, M. A., & Allen, D. D. "Nanoparticle technology for drug delivery across the blood-brain barrier." Drug development and industrial pharmacy 28.1 (2002): 1-13. Link to article:https://sites.esm.psu.edu/~mcd18/dec10.pdf

Loreau, Michel, and Claire Mazancourt. "Biodiversity and ecosystem stability: a synthesis of underlying mechanisms." Ecology letters 16.s1 (2013): 106-115. Link to article: http://bit.ly/2vnJ63m

Lucas, Jake. "'Groundhog Day' — Lowcountry Mayors Restate Opposition To Offshore Drilling & Seismic Testing In Wake Of Trump Executive Order." Moultrie News [Charleston, SC]. 28 April 2017. Web Article. Link to article: http://bit.ly/2xUUQOZ

Magill, Bobby. "The Front Lines of Climate Change: Charleston's Struggle." Climate Central. 09 January 2014. Web Article. Link to article: http://www.climatecentral.org/news/the-front-lines-of-climate-change-charlestons-struggle-16934

National Oceanic and Atmospheric Administration Fisheries Office of Habitat Conservation. (2005). Ecosystem Services 101. NOAA. Web. Link to article: http://www.nmfs.noaa.gov/aboutus/contactus.html

Newton, A. E., Garrett, N., Stroika, S. G., Halpin, J. L., Turnsek, M., & Mody, R. K. "Notes from the field: increase in Vibrio parahaemolyticus infections associated with consumption of atlantic coast shellfish-2013." MMWR Morb Mortal Wkly Rep 63 (2014): 335-336. Link to article:https://www.cdc.gov/mmWr/preview/mmwrhtml/mm6315a6.htm

Palmer, Margaret, et al. "Ecology for a crowded planet." Science 304.5675 (2004): 1251-1252. Link to article: https://www.researchgate.net/profile/Clifford_Duke/publication/8540831_Ecological_Science_and_Sustainability_for_a_Crowded_Planet_21st_Century_Vision_and_Action_Plan_for_the_Ecological_Society_of_America/links/02bfe50fefbcc19621000000.pdf

Palumbi, Stephen R., Sandifer, Paul. et al. "Managing for ocean biodiversity to sustain marine ecosystem services." Frontiers in Ecology and the Environment 7.4 (2009): 204-211. Link to article: https://kuscholarworks.ku.edu/bitstream/handle/1808/13308/Fautin_Managing_for_ocean_biodiversity.pdf?sequence=1

Park, Seong-Hyun, and Richard H. Mattson. "Therapeutic influences of plants in hospital rooms on surgical recovery." HortScience 44.1 (2009): 102-105. Link to article: http://hortsci.ashspublications.org/content/44/1/102.full

Pascual, M., Rodó, X., Ellner, S.P., Colwell, R. and Bouma, M.J. (2000) Cholera dynamics and El-Niño-Southern Oscillation. Science 289, 1766–1769.

Peters, T.M., Elzey, S., Johnson, R., Park, H., Grassian, V.H., Maher, T. and O'Shaughnessy, P. "Airborne monitoring to distinguish engineered nanomaterials from incidental particles for environmental health and safety." Journal of occupational and environmental hygiene 6.2 (2008): 73-81. Link to article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4789272/

Peterson, Bo. "NOAA sets table for seismic testing offshore, including off South Carolina." Post and Courier. 05 June 2017. Web Article. Link to article: http://www.postandcourier.com/news/noaa-sets-table-for-seismic-testing-offshore-including-off-south/article_65a5ed56-49fb-11e7-b800-bffa5fb7e624.html

Randa, Mark A., Martin F. Polz, and Eelin Lim. "Effects of temperature and salinity on Vibrio vulnificus population dynamics as assessed by quantitative PCR." Applied and environmental microbiology 70.9 (2004): 5469-5476. Link to article: http://aem.asm.org/content/70/9/5469.full

Sandifer, Paul A., and Ariana E. Sutton-Grier. "Connecting stressors, ocean ecosystem services, and human health." Natural Resources Forum. Vol. 38. No. 3. 2014. Link to article: http://onlinelibrary.wiley.com/doi/10.1111/1477-8947.12047/abstract

Sandifer, Paul A., Ariana E. Sutton-Grier, and Bethney P. Ward. "Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation." Ecosystem Services 12 (2015): 1-15. Link to article: http://www.sciencedirect.com/science/article/pii/S2212041614001648

Santos, L. H., Araújo, A. N., Fachini, A., Pena, A., Delerue-Matos, C., & Montenegro, M. C. B. S. M. "Ecotoxicological aspects related to the presence of pharmaceuticals in the aquatic environment." Journal of hazardous materials 175.1 (2010): 45-95. Link to article: http://bit.ly/2vG2eZA

Scott, G .I., D.E. Porter, S. Norman, C. H. Scott, M. Uyaguari, K. A. Maruya, S. B. Weisberg, M. H.. Fulton, E. F. Wirth, J. Moore, P. L. Pennington, D. Schlenck, N. D. Denslow, G. Cobb. 2016. Antibiotics as CECs: An Overview of the Hazards Posed by Antibiotics and Antibiotic Resistance. Frontiers in Marine Science 3(24):1-24.

Scott, G. I., Fulton, M. H., Weisberg, S. B., Maruya, K. A., and Lauenstein, G. "Contaminants of Concern in the Marine Environment: The Need for New Monitoring and Assessment Strategies." J Mar Biol Oceanogr 1 1 (2012): 2. Link to article: http://bit.ly/2tujPqZ

Sharpley, A. N., Chapra, S. C., Wedepohl, R., Sims, J. T., Daniel, T. C., & Reddy, K. R. "Managing agricultural phosphorus for protection of surface waters: Issues and options." Journal of environmental quality 23.3 (1994): 437-451. Link to article: https://kuscholarworks.ku.edu/bitstream/handle/1808/16724/SmithVal_EA_8(3)559.pdf?sequence=1&isAllowed=y

South Carolina. "Climate Change: The Local Effects in Coastal South Carolina." South Carolina Sea Grant Consortium. 13 Aug. 2014. Web. Link:http://www.scseagrant.org/pdf_files/Climate-Fact-Sheet-8-13-2014.pdf

Speelmon, E.C., Checkley, W., Gilman, R.H., Patz, J., Caleron, M. and Manga, S. "Cholera incidence and El-Niño-related higher ambient temperature." Journal of the American Medical Association 283, 3072–3074. (2000)

State of South Carolina. "Climate Change Impacts To Natural Resources in South Carolina." South Carolina Department of Natural Resources. April 2013. Online Report. Link: http://www.dnr.sc.gov/pubs/CCINatResReport.pdf

State of South Carolina. "Comprehensive Spatial Database on SC's Coastal Resources and Uses." South Carolina Department of Natural Resources. Web. Link: http://www.dnr.sc.gov/GIS/gisenergy

Stone, W. W., R.J. Gilliom, and J.D. Martin 2014. An overview comparing results from 2 decades of monitoring of pesticides in the nation's streams and rivers, 1992-2001 and 2002-2011.U.S. Dept. of Interior, USGS, Scientific Investigation Report 2014-5154:23pp.

Swaddle, J.P., Francis, C.D., Barber, J.R., Cooper, C.B., Kyba, C.C., Dominoni, D.M., Shannon, G., Aschehoug, E., Goodwin, S.E., Kawahara, A.Y. and Luther, D. "A framework to assess evolutionary responses to anthropogenic light and sound." Trends in ecology & evolution 30.9 (2015): 550-560. Link to article: http://www.soundandlightecologyteam.colostate.edu/pdf/trendsecologyevolution2015.pdf

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. "Heavy metal toxicity and the environment." Molecular, clinical and environmental toxicology. Springer Basel, 2012. 133-164. Link to article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4144270/

Union of Concerned Scientists. "What South Carolinians Deserve to Know About Climate Change." UCS Publications. April 2013. Web Article. Link to Article: http://www.ucsusa.org/publications/got-science/2013/got-science-april-2013.html#.WUPwDesrJpi

United Nations. World Health Organization. "Cholera Vaccines: WHO Position Paper." Weekly Epidemiological Record: No. 13. 26 March, 2010. Web. July 2017. Link to article: http://www.who.int/wer/2010/wer8513.pdf

United States. "What Climate Change Means for South Carolina." United States Environmental Protection Agency. Washington, DC:USEPA. August 2016. Web. Link:https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-sc.pdf

United States. Centers for Disease Control and Prevention. "About NCEH." National Center for Environmental Health. CDC, Atlanta, GA. 31 Mar. 2016. Web. 13 July 2017. Link to article: https://www.cdc.gov/nceh/information/about.htm

United States. Centers for Disease Control and Prevention. "Cholera - Vibrio cholerae Infection" CDC. Atlanta, GA. 27 Oct. 2014. Web. July 2017. Link to article: https://www.cdc.gov/cholera/index.html

United States. Centers for Disease Control and Prevention. "Increase in Vibrio parahaemolyticus illnesses associated with consumption of shellfish from several Atlantic coast harvest areas, United States" CDC. Atlanta, GA. 2013. Web. July 2017. Link to article: https://www.cdc.gov/vibrio/investigations/vibriop-09-13/signs-symptoms.html

United States. Centers for Disease Control and Prevention. "Vibrio Species Causing Vibriosis" CDC. Atlanta, GA. 31 Mar. 2016. Web. July 2017. Link to article: https://www.cdc.gov/vibrio/faq.html

United States. Environmental Protection Agency. "Ibuprofen." Drinking Water Treatability Database. Washington, D.C.: USEPA, July, 2009. Web. Accessed July, 2017. Link to article:https://iaspub.epa.gov/tdb/pages/contaminant/contaminantOverview.do?contaminantId=10022

van den Bosch, Matilda Annerstedt, and Michael H. Depledge. "Healthy people with nature in mind." BMC Public Health 15.1 (2015): 1232.Link to article: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-015-2574-8

van der Hoop, Julie. "Bioamplication, Bioaccumulation, and Bioconcentration." Massachusetts Institute of Technology, Mercury Science and Policy. 17 January, 2013. Web. July, 2017. Link to article: http://mercurypolicy.scripts.mit.edu/blog/?p=499

Walsh, Roberta A. 1994. Uniola paniculata. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.fed.us/database/feis/plants/graminoid/unipan/all.html [July 2017].

Weinstein, J. E., H. Wertz, and A. Gray. 2014. Marine plastic debris: Assessing the hazards to larval oysters, Crassostrea virginica and grass shrimp, Palaemonetes pugio. Final Report SC Sea Grant Consortium.

Wickliffe, L.C. 2013. 2013. Pesticide Decision Making Tool. PhD Dissertation, Arnold School of Public Health, University of South Carolina: 174pp.

Wong, K. C., Brown, A. M., Luscombe, G. M., Wong, S. J., & Mendis, K. "Antibiotic use for Vibrio infections: important insights from surveillance data." BMC infectious diseases 15.1 (2015): 226. Link to article: https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-015-0959-z

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B., Lotze, H.K., Micheli, F., Palumbi, S.R. and Sala, E. "Impacts of biodiversity loss on ocean ecosystem services." science 314.5800 (2006): 787-790. Link to article: http://copa.acguanacaste.ac.cr:8080/bitstream/handle/11606/137/Impactos%20perdida%20biod%20marina.pdf?sequence=1&isAllowed=y

# OUR COASTAL FUTURE FORUM

Charleston, SC
October 20 and 21, 2017

College of Charleston
University of Oklahoma
South Carolina Sea Grant Consortium

***Total printing cost: $1,374.69*** ***Total number printed: 130*** ***Cost per unit: $10.57***