OUR COASTAL FUTURE FORUM

Environmental Health in a Changing Climate

COLLEGE of CHARLESTON

Sea Grant
S.C. Sea Grant Consortium

The UNIVERSITY of OKLAHOMA

Principal Investigators

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

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

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

Editors

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

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

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

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

Expert Scientist Presenters

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

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

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

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

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

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

Coastal Advisory Group

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

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

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

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

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

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

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

Facilitators

Barbara Brown
President,
Citizens Center for Public Life

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

Blaik Keppler
S.C. Department
of Natural Resources

Michelle LaRocco
University of South Carolina

Susannah Sheldon
S.C. Sea Grant Consortium

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

Jessica Tipton
S.C. Department
of Natural Resources

April Turner
S.C. Sea Grant Consortium

Sarah Watson
S.C. Sea Grant Consortium

Sea Grant
S.C. Sea Grant Consortium

Product no.: SCSGC-H-18-06

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.

Front Cover: Estuarine marsh. *Lee Bundrick, S.C. Sea Grant Consortium (August 2017)*
Back Cover: Sunset near Sullivan's Island. *Lee Bundrick, S.C. Sea Grant Consortium (May 2017)*

Contents

About Our Coastal Future Forum

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

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

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

Topics for Discussion

The great challenges to society's management of natural resources in coastal South Carolina include increasing population and changing weather and climate. Over the course of the forum we will be discussing a few 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 section about our environmental health.

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

Introduction

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

Our Changing Coast

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

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

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

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

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

Natural Resources and the Economy

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

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

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

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

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

Our Coastal Weather and Climate

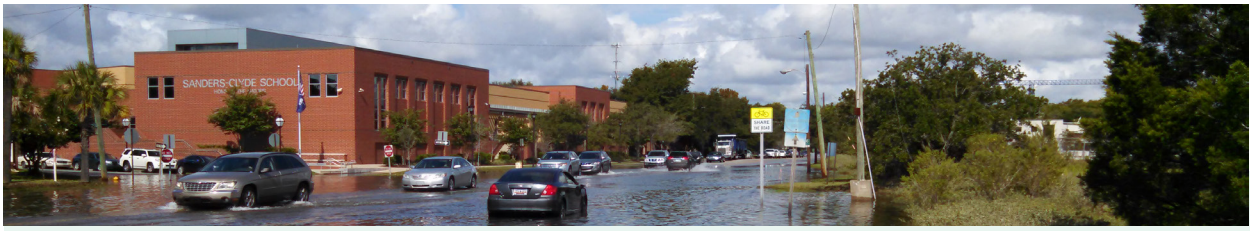

Figure 1.1 "Blue Sky" tidal flooding during King Tide. *Elizabeth Fly, S.C. Sea Grant Consortium (2014)*

Changing Weather and Climate: Impacts in South Carolina

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

Global Warming

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

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

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

Changes in Sea Level

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

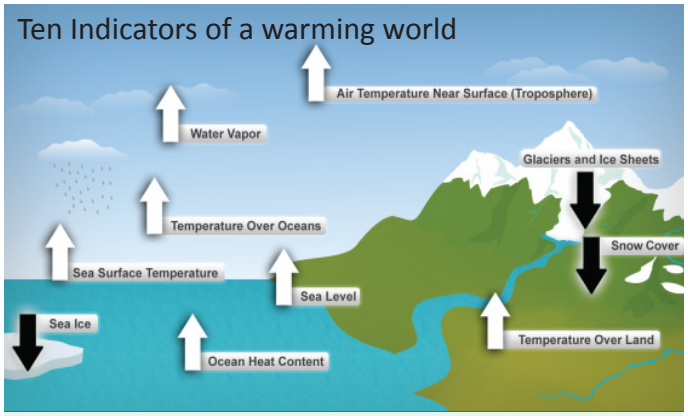

Figure 1.2 Indicators of Global Warming. *National Oceanic and Atmospheric Administration (NOAA) National Climate Data Center (NCDC). Based on data updated from Kennedy et al. 2010*

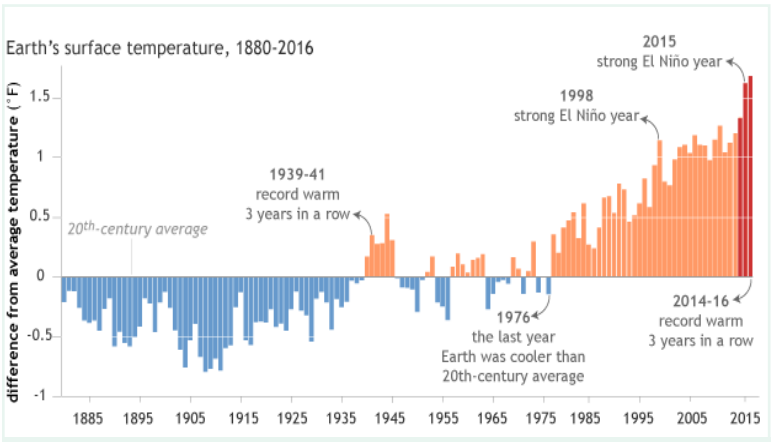

Figure 1.3 Difference in Earth's surface temperature over time. *NOAA NCDC Climate at a Glance (September 2017)*

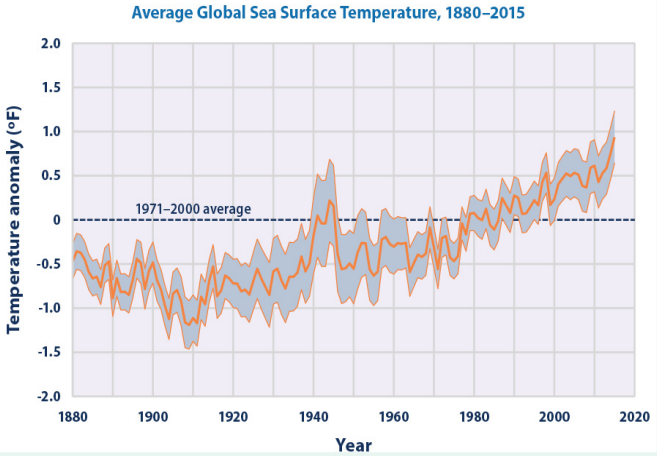

Figure 1.4 Global sea surface average temperature anomalies from 1880 to 2020. *NOAA (2016)*

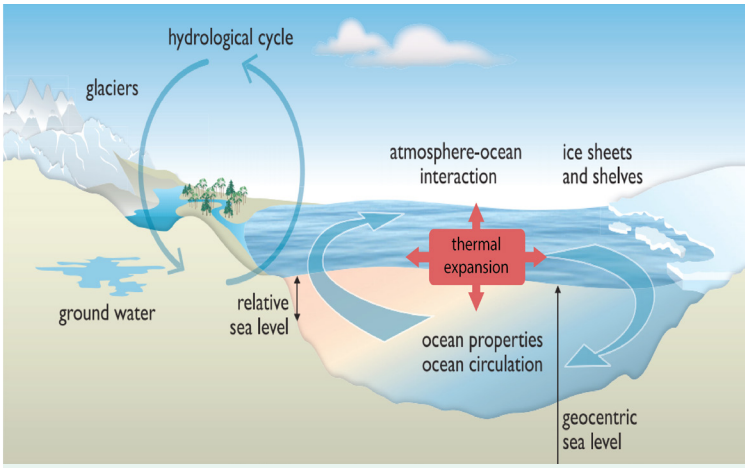

Figure 1.5 How the Ocean Water Cycle is Changing. *National Climate Assessment with added content (2014)*

So What Does This Mean for the South Carolina Coast?

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

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

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

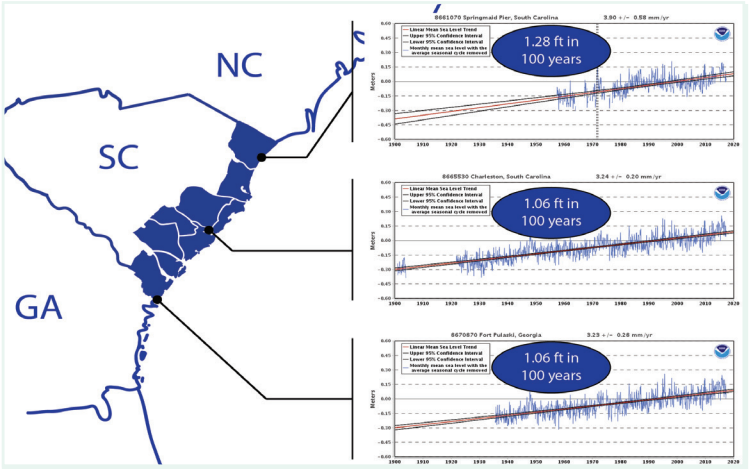

Figure 1.6 Sea level rise measured by gauges located at Myrtle Beach, Charleston, and Savannah, Georgia. *Created using information from NOAA (2017)*

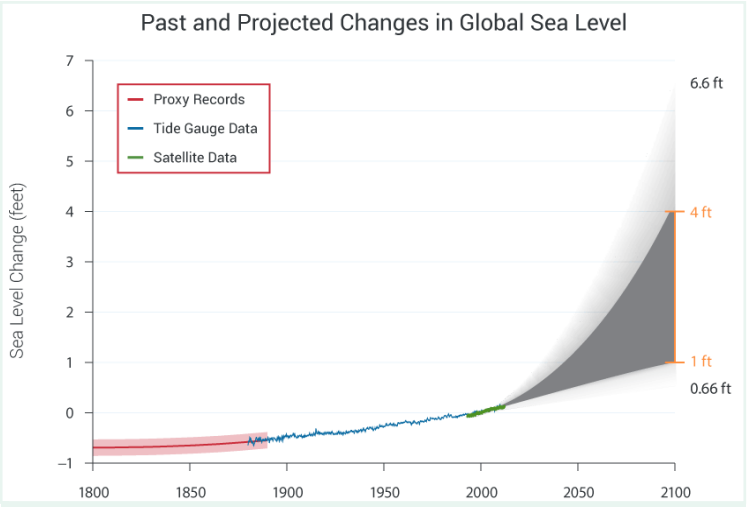

Figure 1.7 Past record and future projection for sea level change. *National Climate Assessment (2014)*

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

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

Coastal Flooding

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

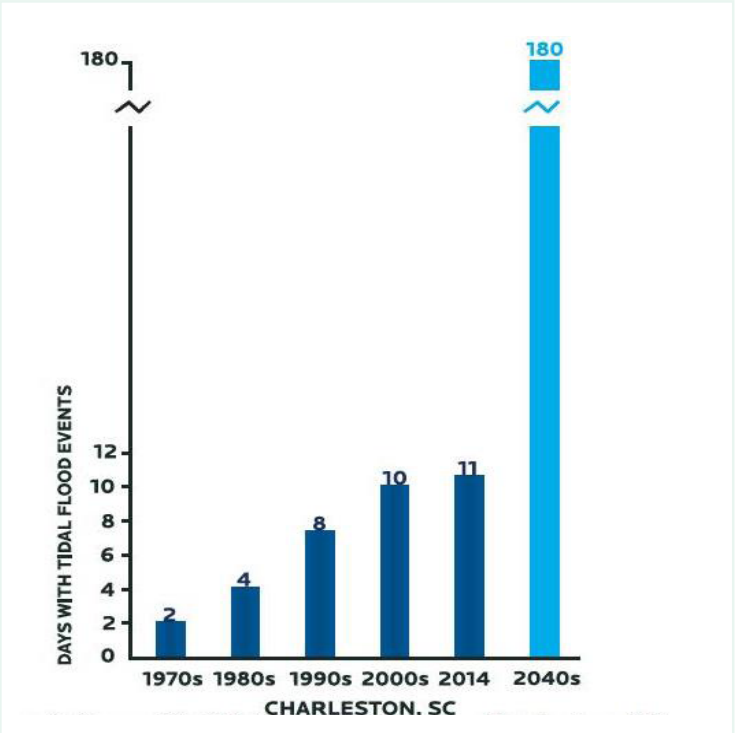

Figure 1.9 Days per year with tidal flooding. *City of Charleston (2015)*

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

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

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

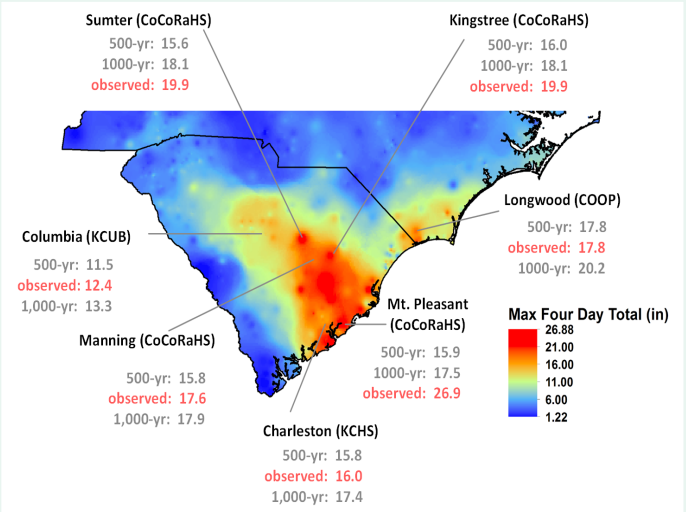

Figure 1.11 Rainfall during the October 2015 extreme event. *Carolinas Integrated Sciences and Assessments (CISA) (2016)*

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

Extreme Rainfall

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

Drought

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

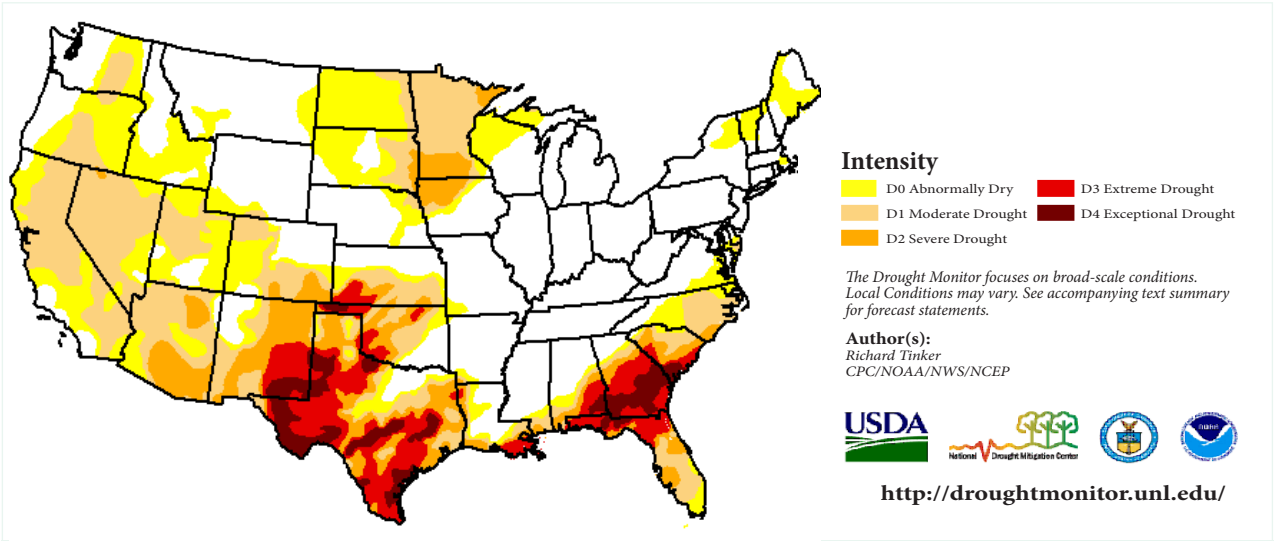

Figure 1.12 U.S. Drought Monitor data for February 14, 2012. *National Drought Mitigation Center (2017)*

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

What Can We Do?

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

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

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

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

Reduce development in high-risk flooding areas

Introduce desalination facilities that turn saltwater into drinking water

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

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

Resources for More Information

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

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

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. The 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 makes 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. 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 pelicans that ate the fish. As fish were the

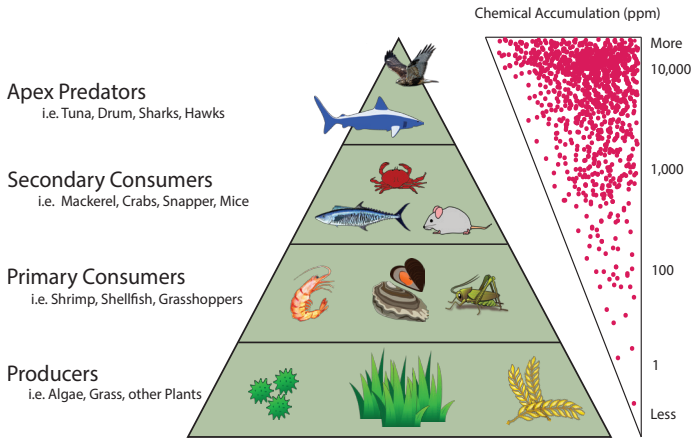

Figure 4.1 Biomagnification of chemicals in relation to trophic levels. *Lee Bundrick, S.C. Sea Grant Consortium (2017)*

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

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

can cause major health issues. However, consuming even the smallest organisms that accumulate toxins can potentially cause health issues as well.

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 (Weinstein et al., 2014) (**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

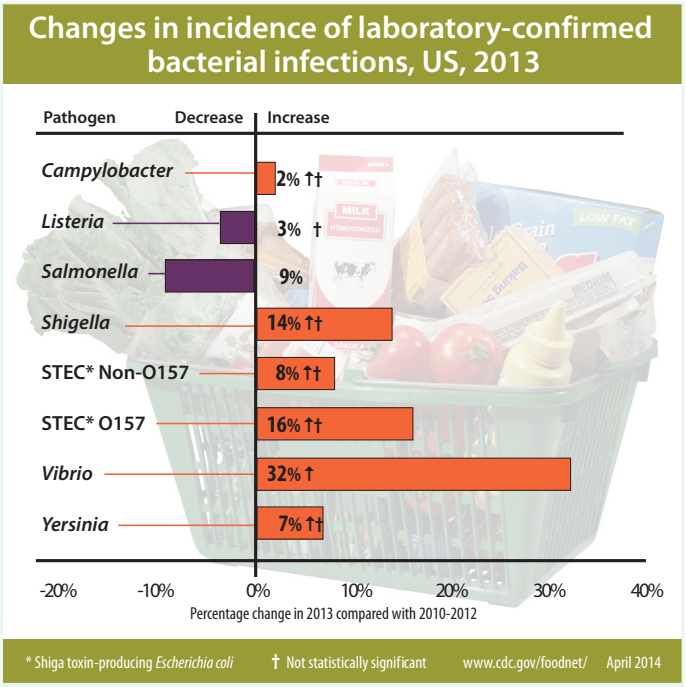

Figure 4.3 Change in incidence of laboratory-confirmed bacterial infections. *Centers for Disease Control (2014)*

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 invertebrate 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 industries

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 Management.** 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/
- **S.C. Sea Grant Consortium.** *Coastal Heritage,* The Global Plastic Breakdown. Website: http://www.scseagrant.org/Content/?cid=732
- **Breaking Down Plastic.** South Carolina Aquarium. Website: http://plastic.scaquarium.org/learn-more/

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

Resources and References

Adams, Chris (2014). SC already feeling climate change effects. *The (Columbia) State*. McClatchy Washington Bureau. 06 May, 2014. Web 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. (2012). 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. http://bit.ly/2vnkQOV

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

Baker-Austin, C., McArthur, J. V., Tuckfield, R. C., Najarro, M., Lindell, A. H., Gooch, J., & Stepanauskas, R. (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., Hartnell, R., Siitonen, A., & Martinez-Urtaza, J. (2013). Emerging Vibrio risk at high latitudes in response to ocean warming. *Nature Climate Change*, 3(1), 73-77.

Baker-Austin, C., J. Trinanes, N. Gonzalez-Escalona, and J. Martinez-Urtaza (2016). Non-Cholera Vibrios: The microbial barometer of climate change. *Trends in Microbiology* 25.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81(2), 169-193. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/10-1510.1

Bayer, M., Frank, N. and Valerius, J. (2010). *Becoming an urban planner: a guide to careers in planning and urban design.* John Wiley & Sons. http://bit.ly/2gNoyy3

Bell, B. G., Schellevis, F., Stobberingh, E., Goossens, H., & Pringle, M. (2014). A systematic review and meta-analysis of the effects of antibiotic consumption on antibiotic resistance. *BMC Infectious Diseases*, 14(1), 13. 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. (2017). Definitions of Environmental Health. National Environmental Health Association: NEHA. 13 July 2017. https://www.neha.org/about-neha/definitions-environmental-health

Buerge, I. J., Poiger, T., Müller, M. D., & Buser, H. R. (2003). Caffeine, an anthropogenic marker for wastewater contamination of surface waters. *Environmental Science & Technology*, 37(4), 691-700. http://pubs.acs.org/doi/abs/10.1021/es020125z?journalCode=esthag

Camargo, J. A., & Alonso, Á. (2006). Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. *Environment International*, 32(6), 831-849. http://bit.ly/2vFC7SA

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D., Wardle, D.A. and Kinzig, A.P., Daily, G.C., Loreau, M., Grace, J.B., Larigauderie, A., Srivastava, D., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486(7401), 59-67. 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. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, 8(3), 559-568. https://kuscholarworks.ku.edu/bitstream/handle/1808/16724/SmithVal_EA_8(3)559.pdf?sequence=1&isAllowed=y

Carter, L. M., Jones, J. W., Berry, L., Burkett, V., Murley, J. F., Obeysekera, J., Schramm, P. J., and Wear, D. (2014). Southeast and the Caribbean. Climate Change Impacts in the United States: The Third National Climate Assessment. http://nca2014.globalchange.gov/report/regions/southeast

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015). Accelerated modern human–induced species losses: Entering the sixth mass extinction. *Science Advances*, 1(5), e1400253. 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. *Morbidity and Mortality Weekly Report*. 55: 392–395. https://www.cdc.gov/mmwr/preview/mmwrhtml/mm5514a2.htm

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. (2000). Consequences of changing biodiversity. *Nature*, 405(6783), 234-242. http://www.nature.com/nature/journal/v405/n6783/full/405234a0.html

Coastal Conservation League. South Carolina's wind energy potential. Coastal Conservation League. July 2017. http://coastalconservationleague.org/projects/south-carolinas-offshore-wind-potential/

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

Daughton, C. G., & Ruhoy, I. S. (2009). Environmental footprint of pharmaceuticals: the significance of factors beyond direct excretion to sewers. *Environmental Toxicology and Chemistry*, 28(12), 2495-2521. http://onlinelibrary.wiley.com/doi/10.1897/08-382.1/full

Daughton, C. G., & Ternes, T. A. (1999). Pharmaceuticals and personal care products in the environment: agents of subtle change? *Environmental Health Perspectives*, 107 (Suppl 6), 907. 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. (2009). 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), 455-460. https://www.ncbi.nlm.nih.gov/pubmed/20183050

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

DeLorenzo, M. E., Scott, G. I., and Ross, P.E. (2001). Toxicity of pesticides to aquatic microorganisms: a review. *Environmental Toxicology and Chemistry* 20(1), 84-98. http://bit.ly/2uDl3yy

Díaz, S., Fargione, J., Chapin III, F.S., and Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS Biology* 4 (8), e277. 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. (2015). 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, 2050312115602579. 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. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4159373/

Fretwell, Sammy (2013). Climate report released by DNR. *The (Columbia) State*. Politics & Government. 09 April, 2013. http://www.thestate.com/news/politics-government/article14425643.html

Gayes, Paul (2014). Update on spatial use data to inform planning. South Carolina Offshore Renewable Energy Task Force. 16 May 2014. Presentation. http://energy.sc.gov/files/Gayes%20Update%20BOEM%20SC%20Task%20Force.pdf

Gonzalez, M.T., and Kirkevold, M. (2014). Benefits of sensory garden and horticultural activities in dementia care: A modified scoping review. *Journal of Clinical Nursing*, 23(19-20), 2698-2715. https://www.ncbi.nlm.nih.gov/pubmed/24128125 https://www.ncbi.nlm.nih.gov/pubmed/24128125

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. Ecosystem Ecology: a new synthesis, *BES Ecological Reviews Series*, 110-139. 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. (2012). S.C. offshore wind farm would generate thousands of jobs, Clemson study shows. Clemson University. Clemson Newsstand. 04 October 2012. http://newsstand.clemson.edu/mediarelations/sc-offshore-wind-farm-would-generate-thousands-of-jobs-clemson-study-shows/

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

Jiang, B., Chang, C. Y., & Sullivan, W. C. (2014). A dose of nature: Tree cover, stress reduction, and gender differences. *Landscape and Urban Planning*, 132, 26-36. https://www.fs.fed.us/nrs/pubs/jrnl/2014/nrs_2014_jiang_001.pdf

Jones, M. K., and Oliver, J. D. (2009). Vibrio vulnificus: Disease and pathogenesis. *Infection and Immunity* 77(5), 1723-1733. http://iai.asm.org/content/77/5/1723.full

Jones, Nicola. (2016). How climate change could jam the world's ocean circulation. Yale E360. Yale School of Forestry and Environmental Studies, 6 Sept. 2016. Web. http://e360.yale.edu/features/will_climate_change_jam_the_global_ocean_conveyor_belt

Katagi, Toshiyuki (2010). Bioconcentration, bioaccumulation, and metabolism of pesticides in aquatic organisms. *Reviews of Environmental Contamination and Toxicology*. Springer New York. 1-132. https://link.springer.com/chapter/10.1007/978-1-4419-1440-8_1 See section 2.1.3.

Lacoue-Labarthe, T., Martin, S., Oberhänsli, F., Teyssié, J. L., Markich, S., Jeffree, R., & Bustamante, P. (2009). 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), 2561-2573. 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. (1990). Sources of petroleum hydrocarbons in urban runoff. *Water, Air, & Soil Pollution*, 52(1), 1-21. http://bit.ly/2vFB5Gk

Lipp, E. K., Huq, A., and Colwell, R. R. (2002). Effects of global climate on infectious disease: the cholera model. *Clinical Microbiology Reviews* 15(4), 757-770. 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. (2010). 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. http://www.pnas.org/content/97/4/1438.full

Lockman, P. R., Mumper, R. J., Khan, M. A., & Allen, D. D. (2002). Nanoparticle technology for drug delivery across the blood-brain barrier. *Drug Development and Industrial Pharmacy* 28(1), 1-13. https://sites.esm.psu.edu/~mcd18/dec10.pdf

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

Lucas, Jake. (2017) Groundhog Day — Lowcountry mayors restate opposition to offshore drilling & seismic testing in wake of Trump executive order. *Moultrie News* [Charleston, SC]. 28 April 2017. http://bit.ly/2xUUQOZ

Magill, Bobby (2014). The front lines of climate change: Charleston's struggle. Climate Central. 09 January 2014. Web 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. http://www.nmfs.noaa.gov/aboutus/contactus.html

Newton, A. E., Garrett, N., Stroika, S. G., Halpin, J. L., Turnsek, M., & Mody, R. K. (2014). Notes from the field: Increase in *Vibrio parahaemolyticus* infections associated with consumption of Atlantic coast shellfish-2013. *Morbidity and Mortality Weekly Report* 63, 335-336. https://www.cdc.gov/mmWr/preview/mmwrhtml/mm6315a6.htm

Palmer, M., Bernhardt, E., Chornesky, E., Collins, S., Dobson, A., Duke, C., Gold, B., Jacobson, R., Kingsland, S., Kranz, R. and Mappin, M. (2004). Ecology for a crowded planet. *Science*, 304(5675), 1251-1252. 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, S.R., Sandifer, P.A., Allan, J.D., Beck, M.W., Fautin, D.G., Fogarty, M.J., Halpern, B.S., Incze, L.S., Leong, J.A., Norse, E. and Stachowicz, J.J. (2009). Managing for ocean biodiversity to sustain marine ecosystem services. *Frontiers in Ecology and the Environment*, 7(4), 204-211. 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. 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. (2008). Airborne monitoring to distinguish engineered nanomaterials from incidental particles for environmental health and safety. *Journal of Occupational and Environmental Hygiene*, 6(2), 73-81. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4789272/

Peterson, Bo. (2017). NOAA sets table for seismic testing offshore, including off South Carolina. (Charleston) *Post and Courier*. 05 June 2017. http://www.postandcourier.com/news/noaa-sets-table-for-seismic-testing-offshore-including-off-south/article_65a5ed56-49fb-11e7-b800-bffa5fb7e624.html

Randa, M. A., Polz, M. F., & Lim, E. (2004). Effects of temperature and salinity on Vibrio vulnificus population dynamics as assessed by quantitative PCR. *Applied and Environmental Microbiology*, 70(9), 5469-5476. http://aem.asm.org/content/70/9/5469.full

Sandifer, P. A., & Sutton-Grier, A. E. (2014, August). Connecting stressors, ocean ecosystem services, and human health. *Natural Resources Forum* Vol. 38, No. 3, pp. 157-167. http://onlinelibrary.wiley.com/doi/10.1111/1477-8947.12047/abstract

Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services*, 12, 1-15. 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. (2010). Ecotoxicological aspects related to the presence of pharmaceuticals in the aquatic environment. Journal of Hazardous Materials 175(1), 45-95. 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., & Lauenstein, G. (2012). Contaminants of concern in the marine environment: The need for new monitoring and assessment strategies. *Journal of Marine Biology & Oceanography*, 1, 1, 2. http://bit.ly/2tujPqZ

Sharpley, A. N., Chapra, S. C., Wedepohl, R., Sims, J. T., Daniel, T. C., & Reddy, K. R. (1994) Managing agricultural phosphorus for protection of surface waters: Issues and options. *Journal of Environmental Quality*, 23(3), 437-451. https://kuscholarworks.ku.edu/bitstream/handle/1808/16724/SmithVal_EA_8(3)559.pdf?sequence=1&isAllowed=y

South Carolina Sea Grant Consortium (2014). Climate Change: The local effects in coastal South Carolina. South Carolina Sea Grant Consortium. 13 Aug. 2014. Web. 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. (2000) Cholera incidence and El-Niño-related higher ambient temperature. *Journal of the American Medical Association*, 283, 3072–3074.

South Carolina Department of Natural Resources. (2013) Climate change impacts to natural resources in South Carolina. South Carolina Department of Natural Resources. April 2013. Online Report. http://www.dnr.sc.gov/pubs/CCINatResReport.pdf

South Carolina Department of Natural Resources. Comprehensive spatial database on SC's coastal resources and uses. South Carolina Department of Natural Resources. Web. http://www.dnr.sc.gov/GIS/gisenergy

Stone, W. W., Gilliom, R. J., and Martin, J. D. (2014). An overview comparing results from two decades of monitoring for pesticides in the nation's streams and rivers, 1992-2001 and 2002-2011. U.S. Dept. of Interior, US Geological Survey, 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. (2015). A framework to assess evolutionary responses to anthropogenic light and sound. *Trends in Ecology & Evolution* 30(9), 550-560. http://www.soundandlightecologyteam.colostate.edu/pdf/trendsecologyevolution2015.pdf

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. *Molecular, Clinical and Environmental Toxicology*. 133-164. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4144270/

Union of Concerned Scientists (2013). What South Carolinians deserve to know about climate change. Union of Concerned Scientists Publications. April 2013. Web article. http://www.ucsusa.org/publications/got-science/2013/got-science-april-2013.html#.WUPwDesrJpi

United Nations. World Health Organization (2010). Cholera Vaccines: WHO position paper. *Weekly Epidemiological Record*, No. 13., 26 March, 2010. Web. July 2017. http://www.who.int/wer/2010/wer8513.pdf

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

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

United States Centers for Disease Control and Prevention (2014). Cholera - *Vibrio cholerae* infection. CDC. Atlanta, GA. 27 Oct. 2014. Web. July 2017. https://www.cdc.gov/cholera/index.html

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

United States Centers for Disease Control and Prevention. (March 2016) *Vibrio* Species Causing Vibriosis. CDC. Atlanta, GA. Web. July 2017. https://www.cdc.gov/vibrio/faq.html

United States Environmental Protection Agency (July 2009). Ibuprofen. Drinking water treatability database. Washington, D.C.: USEPA. Web. Accessed July, 2017. https://iaspub.epa.gov/tdb/pages/contaminant/contaminantOverview.do?contaminantId=10022

van den Bosch, Matilda Annerstedt, and Michael H. Depledge. (2015). Healthy people with nature in mind. *BMC Public Health* 15(1), 1232. https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-015-2574-8

van der Hoop, Julie (2013). Bioamplication, bioaccumulation, bioconcentration. Massachusetts Institute of Technology, Mercury Science and Policy. Web. July, 2017. http://mercurypolicy.scripts.mit.edu/blog/?p=499

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

Weinstein, J. E., Wertz, H, and Gray, A. (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). 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. (2015). Antibiotic use for *Vibrio* infections: Important insights from surveillance data. *BMC Infectious Diseases* 15(1), 226. 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. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science* 314(5800), 787-790. http://copa.acguanacaste.ac.cr:8080/bitstream/handle/11606/137/Impactos%20perdida%20biod%20marina.pdf?sequence=1&isAllowed=y

Total printing cost: $344.83 ***Total number printed: 40*** ***Cost per unit: $8.62***