Tidal Creek Habitats

Sentinels of Coastal Health

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Photos/George Steele, George Riekerk, Anne Blair

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Preface

" Many have the attitude toward development that we once had toward smoking: sure it's bad, but it won't be a problem for me. "

Anna Quindlen's article, *Put 'Em in a Tree Museum*, 2004

Tidal creek ecosystems are the primary aquatic link between stormwater runoff from the land and ***estuaries***. Small tidal creeks begin in upland areas and drain into larger creeks forming a network. The creeks increase in size until they join a tidal river, sound, bay, or harbor that ultimately connect to the coastal ocean. The upper regions or headwaters of tidal creeks are "first responders" to stormwater runoff and are an important habitat for evaluating the impacts of coastal development on aquatic ecosystems.

Coastal development has a negative impact on tidal creeks and ultimately impacts public health and the quality of coastal living. When the amount of ***impervious cover*** from development, including roads, parking lots and roofs, in coastal watersheds exceeds 10-30 percent, the physical, chemical, and biological processes in tidal creeks are impaired and potential human uses of these important habitats decrease. Properties along the shores of developed tidal creeks become more vulnerable to flooding as impervious cover levels increase.

This booklet is based on a synthesis of over 15 years of research in tidal creek systems. It is designed to inform local and state decision-makers and citizens about the consequences of rapid, poorly planned coastal development on tidal creeks and coastal communities.

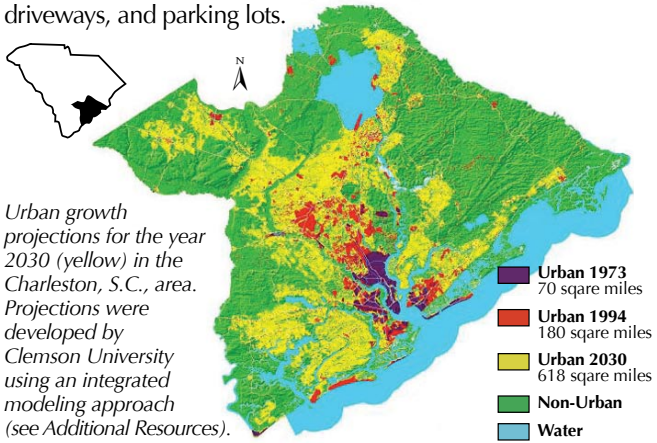
Photo/George Steele

Valuing Tidal Creeks

Our coastlines are alluring places for millions of people, residents and visitors alike. Currently, over 50 percent of the U.S. population lives along the coasts. With its mild climate and scenic vistas of tidal creeks and salt marshes, the Southeast is one of the fastest growing regions of the country. Historically, southeastern coastal development occurred on higher ground with deep water access. Lower elevation areas were sparsely developed because of their vulnerability to flooding, disease, and limited access to deep water. As more people have moved to the southeastern coast, the shores of low lying tidal creeks and salt marshes have become popular locations for building homes, resorts, and recreational facilities. Coastal resources annually contribute almost a trillion dollars to the U.S. economy. The Southeast is no exception with South Carolina's coastal economy accounting for $40 billion in economic output in 2000 and 25 percent of the state's employment growth.

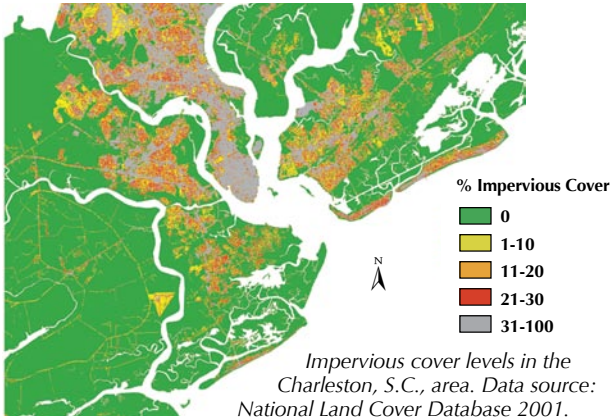
Coastal ***ecosystems*** also provide society with many goods and services including seafood, shipping routes, recreation, and waste treatment. These free goods and services are critical for sustaining coastal communities and their economies. For example, tidal creeks and salt marshes are important aquatic nurseries providing refuge and food for juvenile fish, shrimp, and crabs. Red drum, spotted sea trout, spot, croaker, white and brown shrimp, and blue crabs represent some of the economically important tidal creek inhabitants. Tidal creeks and salt marshes also protect adjacent lands from flooding and the scenic vistas they provide enhance property values and the quality of life of homeowners.

Regrettably, most current coastal development is proceeding in a manner that is costly and wasteful. For example, coastal growth in Charleston, S.C., is consuming forested and agricultural land at a rate six times greater than the growth of the human population. This pattern of development, called ***urban sprawl***, creates communities that are highly reliant upon automobile use. About 65 percent of the impervious cover in suburban areas is for infrastructure such as roads, driveways, and parking lots.



Urban growth projections for the year 2030 (yellow) in the Charleston, S.C., area. Projections were developed by Clemson University using an integrated modeling approach (see Additional Resources).

Large amounts of impervious cover in a watershed prevent the percolation of water into the soil and channels it quickly into tidal creeks. This runoff carries with it whatever pollutants are on the hard surfaces, including sediments, chemicals, bacteria, and viruses. These pollutants come from many hard-to-identify sources, called ***non-point sources***, and impair the health of tidal creeks. The chemicals accumulate in creek sediments and can reach levels that harm marine life in developed areas. Swimming in creeks with high levels of fecal bacteria or eating fish and shellfish from degraded creeks may adversely affect human health.



Impervious cover levels in the Charleston, S.C., area. Data source: National Land Cover Database 2001.

Local and state governments are responsible for approving almost every aspect of coastal development. As a result, public officials control coastal development. If these officials and the governments they represent support a sprawl-like growth pattern and do not conserve open space, the productivity, quality, beauty, and services of tidal creeks and other marine habitats will be impaired – possibly forever. More importantly, the quality of coastal living will not be sustained for future generations.

Tidal creeks as sentinels

Conceptually, sentinels provide early warning of unseen threats. When we think of sentinel species, the canary in the coal mine comes to mind. Canaries were used to give miners a warning that the air in mines contained lethal levels of toxic gases, providing the miners a chance to exit before they were harmed. Tidal creeks, particularly their headwater areas, serve a similar function for our coasts and provide the first evidence of the impact coastal development is having on marine ecosystems and human health and well-being. These headwater creeks are the primary aquatic link between land environments and estuaries and have limited capacity to dilute non-point source pollutants in runoff. Tidal creeks are, therefore, sentinel habitats that provide early warning of the degradation of coastal environments years to decades before system-wide impairment occurs.

Studying Tidal Creeks

Over the past decade, researchers have studied more than 40 creeks in South Carolina. Recently the research has been expanded into Georgia and North Carolina using sites in the National Estuarine Research Reserve System (NERRS) as representative undeveloped tidal creek habitat. Suburban and urban areas adjacent to NERRS sites were also sampled. In future years, researchers plan to include NERRS sites and adjacent developed areas in the Gulf of Mexico.

Primary Objectives

1. ***Identify*** and ***understand*** the effects of coastal development on tidal creek habitats.
2. ***Evaluate the benefits*** of using tidal creeks as a sentinel habitat for monitoring and assessment activities.
3. ***Obtain information*** and ***develop tools*** to forecast the impacts of coastal development on tidal creek habitats.
4. ***Develop a conceptual model*** linking coastal development, tidal creek environmental quality, and human uses to alternative management actions.
5. ***Identify*** ways to reduce development impacts on valued resources and human uses.

Measurements

To accomplish their objectives, tidal creek researchers measured the following parameters for each creek and the associated watershed.

1. ***Development and land-use patterns*** including impervious cover levels.
2. ***Water and sediment quality*** including nutrients, pathogen indicators, and chemical contaminants.
3. ***The kinds and abundance of aquatic life*** including valued species like fish and shrimp as well as their prey.
4. ***Human uses*** including the potential to harvest shellfish.

Photo/George Riekerk

8 *Stressors*

Coastal development and related population growth are the major ***stressors*** identified for tidal creek habitats. Coastal development stress is measured using human population density, land cover, and the amount of impervious cover in a watershed. Forested watersheds have less than 10 percent impervious cover and a population density of less than 4 people per acre. In contrast, suburban watersheds average about 30 percent impervious cover and have a population density of about 25 people per acre. Industrial watersheds have low population densities (less than 10 people per acre) compared to urban watersheds (greater than 40 people per acre); however, they have similar impervious cover levels (greater than 50 percent). In Charleston, S.C., the amount of impervious cover increased by about 10 percent between 1992 and 1999 in suburban watersheds. This trend is expected to continue in the future for much of the state and region.

Observed change from a forested watershed in 1994 to a suburban watershed in 1999.

Aerial photos provided by S.C. Department of Natural Resources.

Environmental Exposures

Coastal development creates two types of pollution: point source (originating from a discharge pipe) and non-point source (everything else). State and federal laws effectively control the amount and quality of pollution originating from point-source discharges. Non-point source pollution, called stormwater runoff, originates from many different sources including impervious surfaces, lawns, parks, and golf courses. Because non-point source pollution originates from diffuse sources, it is difficult to control. When the amount of impervious cover in a tidal creek watershed exceeds 10 to 20 percent, measurable increases in the volume and rate of stormwater runoff occur, resulting in impaired water quality, excessive amounts of harmful chemicals in sediments, and increases in pathogens in water and shellfish.

Increased stormwater runoff

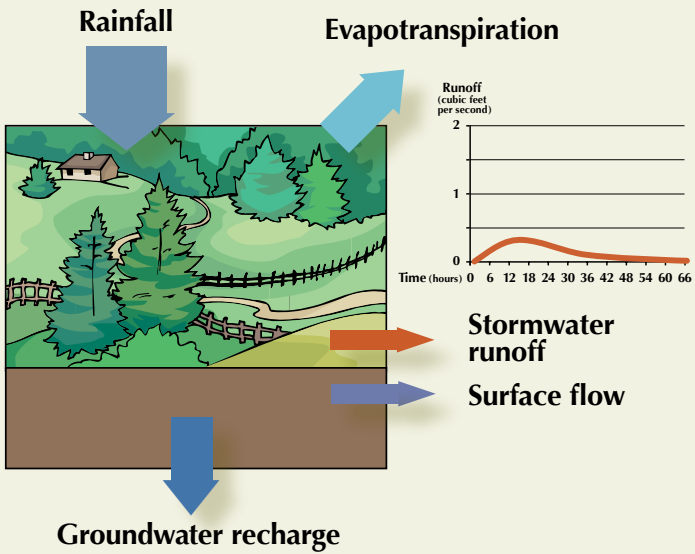
Stormwater runoff is episodic or "flashy" with increasing levels of impervious cover. For instance, a one-acre parking lot produces 16 times the runoff as a one-acre meadow. Vegetated environments reduce the amount and rate of runoff and improve water quality by allowing runoff to percolate into the soil. In the soil, natural processes trap and transform pollutants into harmless decay products. In forested settings, only about 10 to 20 percent of the rain that falls on the watershed enters tidal creeks as stormwater runoff. In suburban and urban areas, 15 to 75 percent of rain that falls on the watershed enters the creek.

Highly variable water quality

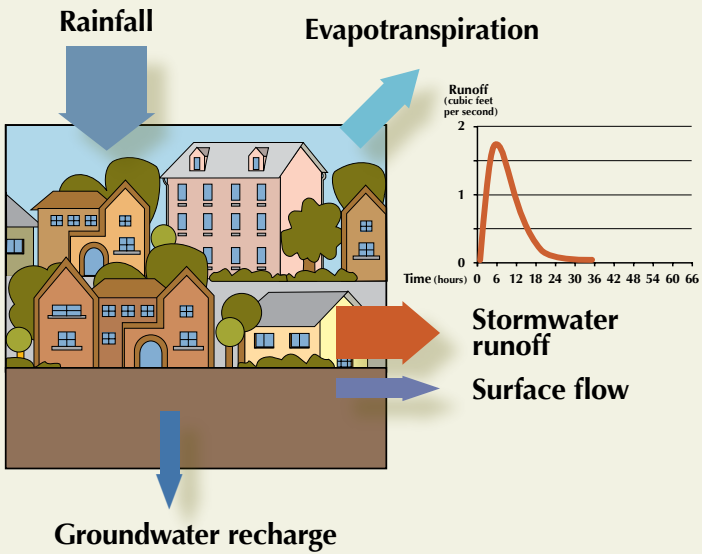
The episodic runoff occurring in suburban and urban areas causes large fluctuations in water quality, creating poor nursery habitat for sensitive juvenile fish, shrimp, and crabs. As a result, these organisms are frequently not as abundant and may not develop normally in creeks with impaired water quality. Nutrients, such as nitrogen, which are abundant in runoff from suburban lawns and golf courses, are also more abundant in suburban and urban creeks in comparison to forested creeks. Excessive levels of nutrients can result in noxious and harmful algal blooms and decreases in dissolved oxygen levels.

Increased chemical contaminants in sediments

Chemical pollutants in creek sediments provide an integrated measure of the chemicals that occur in the water over many years. The amount and kinds of chemical pollutants in sediments also provide an indication of the amount of chemical pollutants that may accumulate



Forested Watershed



Developed Watershed

Visual representation of the differences in the volume and rate of stormwater runoff between an undeveloped forested watershed and a developed urban environment. The magnitude of the differences is represented by the size of the arrows as well as the height and width of the peaks in the graphs.

in seafood. The chemicals found in tidal creek sediments include substances that are harmful to marine animals as well as chemicals that are a risk to human health should they occur in seafood. In general, the levels of sediment chemicals are slightly higher in suburban creeks than in forested creeks. However, sediment trace metal concentrations (copper, cadmium, lead, zinc, and mercury) are 2 to 10 times higher in urban creeks than in suburban and forested creeks. Urban creeks also have substantially higher organic contaminants, including products from automobile exhausts, such as ***Polycyclic Aromatic Hydrocarbons*** (PAHs). The chemical contamination of creek sediments increases in a predictable manner as the amount of impervious cover in the watershed increases.

Tidal creek sediments were also tested for Polybrominated Diethyl Ethers (PBDEs) which are used as flame retardants in clothing, furniture, tires, and building materials. Although these chemicals have been developed to protect us, they escape from the products in which they are placed and accumulate in the environment. Once in the environment PBDEs are a threat to marine life and humans. PBDEs occur in the sediments of urban and a few suburban creeks but do not occur in forested creeks.

Similarly, pharmaceuticals have been developed to treat human and animal diseases. Unfortunately, we do not fully utilize the drugs we take, and sewage treatment facilities and septic systems are not designed to remove pharmaceuticals or their decay products from wastewater before it is released into creeks and rivers. People often dispose of excess pharmaceuticals by flushing them into wastewater systems. Once released into the environment pharmaceuticals can harm marine life. A potentially important consequence of excessive release of antibiotics is an increase in the abundance of antibiotic resistant bacteria in the environment. Antibiotic resistant bacteria, as well as trace levels of pharmaceuticals, are found in tidal creeks as well as in some shellfish.

Indicators of human pathogens

Fecal coliform bacteria are found in the digestive tracts of warm-blooded animals including mammals and birds as well as some cold-blooded animals. These bacteria are used as indicators of the presence of pathogens in the environment.

Humans typically ingest pathogens from eating contaminated shellfish and by ingesting contaminated water during swimming. Most states close shellfish grounds to harvesting when the number of fecal coliform bacteria exceeds about 50 colony forming units (CFU) per

"Almost one-third of South Carolina shellfish harvesting areas are closed because the consumption of oysters from these areas could pose health risks."

Webster et al., 2004

100 ml of water, and water contact recreation is generally prohibited when fecal coliform levels exceed about 400 CFU per 100 ml of water.

The level of fecal coliform contamination increases when the amount of impervious cover in tidal creek watersheds increases. Most of the creeks, including many undeveloped forested creeks, do not meet the fecal coliform standard for shellfish harvesting or swimming. The source of most of the fecal coliform contamination at forested sites is wildlife. The high fecal coliform levels in suburban areas are most likely due to pets and wildlife. Extremely high fecal coliform levels in urban creeks are from multiple sources, including human sewage. Because many human diseases originate from pathogens associated with domestic animals and wildlife, consumption of seafood or swimming in water containing large numbers of fecal bacteria represents a human health risk.

Biological Responses

Tidal creeks and their associated salt marshes are important nursery habitats for juvenile fish, shrimp, and crabs. Organisms living in tidal creeks respond to increases in pollution associated with coastal development in a variety of ways. The abundance of pollution-sensitive animals, such as edible shrimp and important food items in the diets of fish, decline as impervious cover levels in watersheds increase. Impairment to marine life is most severe when impervious cover levels exceed 20-30 percent. Pollution-tolerant worms are very abundant in urban creeks and accumulate high levels of contaminants in their bodies which may be transferred to the fish and shellfish that eat them. Highly developed urban creeks also have simple food webs, low abundances of edible marine life, and are poor nursery habitats.

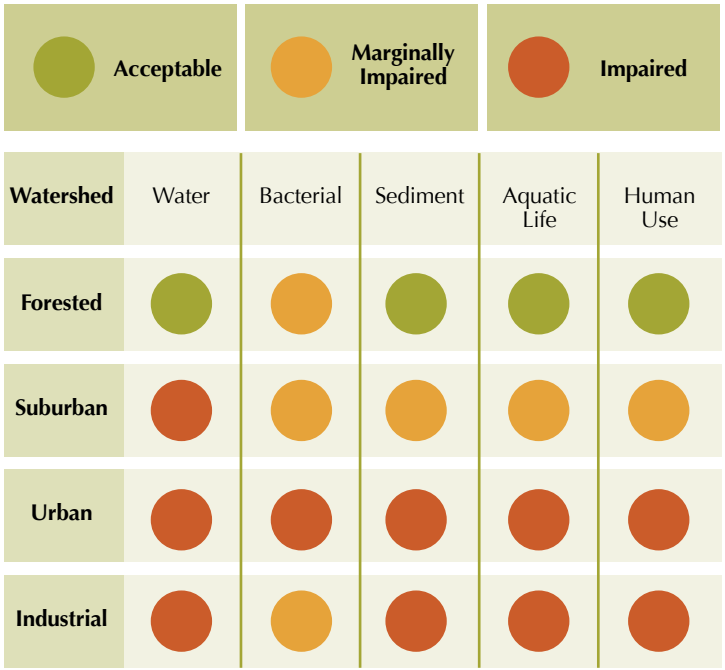
A number of pollution tolerant worms are found in higher numbers in developed creeks. Photo/John Weinstein

White and brown shrimp rely on tidal creek nursery habitats. Photo/George Riekerk

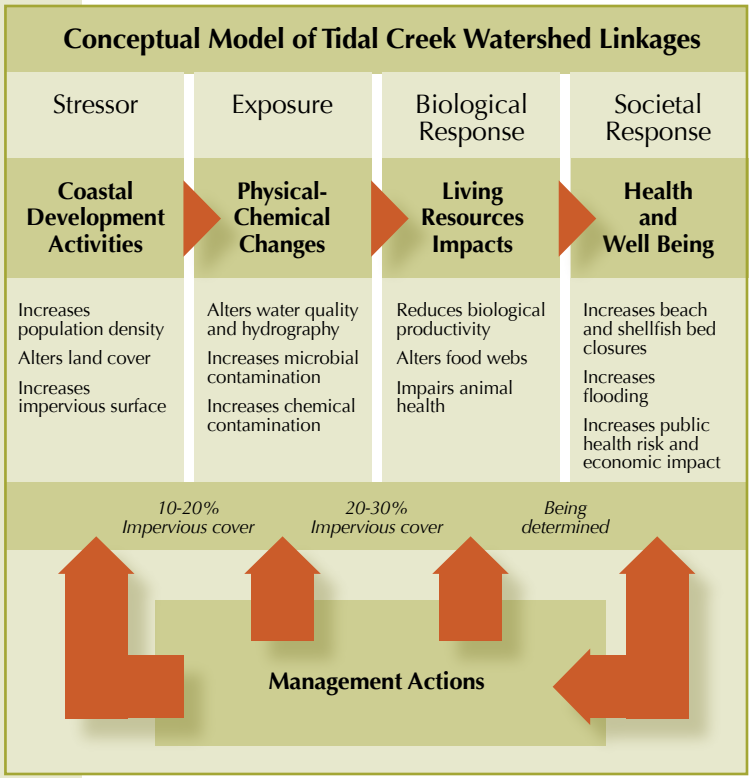
Societal Responses

As impervious cover levels and coastal development increase, human uses of tidal creek habitats decrease, adversely affecting the quality of coastal living. These changes ultimately impact the attitudes and values society places on coastal environments. For example, degradation of tidal creek water quality decreases seafood harvesting opportunities and the recreational use of these beautiful and accessible habitats. Almost none of the developed creeks studied support shellfish harvesting and most suburban and urban creeks do not meet the water quality criteria for recreational use. In addition, higher levels of impervious cover increase the vulnerability of adjacent land to flooding after large rain events. This episodic flooding adversely affects traffic infrastructure and homeowners. Correction of flooding problems will be at a substantial economic cost to coastal communities because they will require modifications to stormwater infrastructure. Increases in homeowner insurance costs and decreases in property values are likely consequences over the long term.

Tidal Creek Habitat Report Card



14 Relating Data to a Conceptual Model



A conceptual ecosystem model is a visual representation of the relationships between an environmental stressor (coastal development) and the physical, chemical, and biological components and processes that make up an ecosystem, including humans. The adjacent diagram is a conceptual model that identifies the important connections and relationships between:

- coastal development and population growth,
- physical and chemical changes including water quality,
- biological responses of fish and shellfish, and
- societal responses such as not allowing humans to harvest the shellfish.

This model provides planners and decision-makers a tool for understanding how alternative management actions may affect the goods and services society wants to preserve and sustain in tidal creeks.

Conclusions

In conclusion, tidal creeks, particularly the headwater portions, provide early warning of the impacts from coastal development on estuaries. The message derived from recent studies of tidal creeks is straightforward: The types and levels of watershed development greatly influence the amount of stormwater runoff and pollution that is released into coastal waters. Poorly planned or sprawling development patterns that create large amounts of impervious cover adversely affect the biological integrity and human uses and benefits derived from tidal creek habitats. The following impacts have been documented:

- **Episodic or "flashy" runoff** indicates the extent to which natural creek flow has been altered.
- **Increased amounts of chemicals in sediments** indicate the extent of chemical contamination and the degree to which seafood may be contaminated.
- **Increased pathogen levels** indicate the degree to which swimming and shellfish harvesting opportunities have been impaired.
- **Changes in the kinds and abundance of food web organisms** indicate the degree to which creeks can no longer support the production of fish and shellfish.
- **Decreased abundance of harvestable shrimp** indicates the degree to which nursery grounds have been harmed.
- **Increased vulnerability of headwater creeks to flooding** indicates potential property depreciation and lessened quality of life in coastal communities.

16 Recommendations

A concerted public education effort will foster and encourage permanent protection of watersheds and the important goods and services they provide society. The best strategy for conserving tidal creek environmental quality is planning for development at a variety of scales, including regional, watershed, community, and site level, with the goal of minimizing the amount of stormwater runoff and maximizing the quality of runoff.

Regionally, infrastructure planning and zoning are the most effective approaches for determining where new development should occur; however, zoning and ordinances only protect the land until the next Land-Use Plan or until a new municipal official is elected.

Recommendations at the municipality and county scale

- ***Purchasing Development Rights*** (PDR) programs and land conservation easements to provide permanent land protection.
- Encouraging or requiring alternative and mixed-use designs that maximize street and community connectivity, protect open space, and minimize vehicle use.

Recommendations at the watershed or neighborhood planning scale

- Planning development activities that:
  - limit alterations to freshwater inflows into tidal creeks,
  - minimize the amount of impervious surface,
  - require naturally vegetated buffers, and
  - maximize the amount of vegetated open space.
- Preparing and publishing guidelines and standards for development that prevent pollution from entering valuable tidal creek and marsh habitats.
- Creating a land conservation ethic that encourages stewardship of tidal creeks and marshes.
- Evaluating development on a watershed basis.
- Limiting the amount and kind of pollutants released into tidal creeks.
- Establishing permanent land trusts for critical habitats within tidal creek watersheds.
- Considering implementing an impervious cover trading program similar to air pollution trading.
- Periodically monitoring and assessing the status and trends of tidal creeks and reporting their condition to the public.

Recommendations at the site or homeowner scale

- Minimizing the amount of new impervious cover that is created on one's property.
- Using pervious alternatives such as porous concrete and pavers.
- Directing surface water runoff into ***swales*** and ***vegetated buffers*** to trap pollutants and increase infiltration, allowing slower movement of stormwater to creeks.
- Maintaining naturally vegetated open spaces and buffers to decrease the amount and rate of runoff.
- Designing and implementing bioretention cells, rain gardens, and/or constructed wetlands to provide added treatment of stormwater.
- Following label directions when applying fertilizers and pesticides as well as properly storing and disposing of these hazardous household products.
- Disposing of trash properly and recycling when possible.
- Picking up and properly disposing of pet wastes (pooper scooper programs).

Sprawling development through the years

"Depressing, brutal, ugly, unhealthy, and spiritually degrading."

James Kunstler 1944

"Sprawl is bad aesthetics; it is bad economics. Five acres is being made to do the work of one, and do it poorly. This is bad for the farmers, it is bad for the communities, it is bad for industry, it is bad for utilities, it is bad for recreational groups, it is even bad for the developers."

William Whyte 1958

"…a form of urbanization distinguished by leapfrog patterns of development, commercial strips, low density, separated land uses, automobile dominance and a minimum of public open space."

Oliver Gillham 2002

"Sprawl is a costly and wasteful form of development that unnecessarily degrades natural systems, adversely affects human safety and health, and is not economically sustainable. Sprawl represents a poor quality of life."

Fred Holland 2007

Additional Resources

Points of Contact

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Many organizations support programs that provide information about the impacts of development on coastal environments and communities. The following entities provide information related to protecting and studying tidal creeks.

The **Hollings Marine Laboratory** (HML) is one of NOAA's five National Centers for Coastal Ocean Science (NCCOS) and is a partnership among the South Carolina Department of Natural Resources, Medical University of South Carolina, National Oceanic and Atmospheric Administration, the National Institute of Standards and Technology, and the College of Charleston. The tidal creeks conceptual model serves as an integrative framework for environmental and public health research at the laboratory. For more information, visit HML at www.hml.noaa.gov or call 843.762.8811.

The **Oceans and Human Health Initiative** (OHHI) seeks to improve our understanding and management of the coasts to enhance benefits to human health and reduce public health risks. This is achieved by developing new methods and approaches to identify and characterize chemical and microbial threats to marine ecosystems and human health as well as to evaluate the health responses of marine organisms and ecosystems to stress. For more information, visit www.eol.ucar.edu/projects/ohhi.

The **Center for Coastal Environmental Health and Biomolecular Research** (CCEHBR) is also one of NCCOS's five national centers and conducts interdisciplinary research to resolve issues related to coastal ecosystem health, environ-mental quality, and related public health impacts. Visit CCEHBR at www.chbr.noaa.gov.

The **South Carolina Sea Grant Consortium** (SCSGC) is a science-based state agency that seeks to enhance the practical use and conservation of South Carolina's coastal and marine resources through research, education, and extension programs. Contact the SCSGC for a homeowner's water-quality guide, *Coast-A-Syst,* for information about the S.C. Nonpoint Education or Municipal Officials (SCNEMO) program. Visit the SCSGC at www.scseagrant.org.

The **South Carolina Department of Natural Resources** (SCDNR) is a state agency that is an advocate for and steward of the state's natural resources by regulating fishing, boating, and hunting. Visit SCDNR at www.dnr.sc.gov.

The **South Carolina Department of Health and Environmental Control's Office of Ocean and Coastal Resource Management** (SCDHEC-OCRM) is a state agency that is responsible for protecting South Carolina's coastal environment while promoting responsible development

along the state's coast. Visit SCDHEC-OCRM at www.scdhec.gov/environment/ocrm.

The **South Atlantic Bight Land Use-Coastal Ecosystem Study** (LU-CES) was an interdisciplinary S.C. Sea Grant research program designed to understand the effects of changing land-use patterns on coastal resources. Visit LU-CES at www.lu-ces.org.

The **Urbanization and Southeastern Estuarine Systems** (USES) **Project** was a study that assessed and modeled the effects of urban development on small, high salinity estuaries on the southeastern coast of the United States. Visit USES at www.urbanestuary.org.

The **Growth Projection Study** was a modeling effort by Clemson University's Strom Thurmond Institute of Government and Public Affairs to predict the future urban growth in the Charleston area. The predictions were based on an integrated GIS model. It is not expected that real growth will exactly follow the predicted patterns. Visit www.strom.clemson.edu/teams/dctech/urban.html for additional information.

The **National Estuarine Research Reserve System** (NERRS) is a network of protected areas established for long-term research, education, and stewardship. For more information, visit NERRS at www.nerrs.noaa.gov.

An **Ocean Blueprint for the 21st Century** is a 2004 report by the U.S. Commission on Ocean Policy which provides recommendations for a new national policy for the ocean. Visit www.oceancommission.gov to review the document.

Photo/ George Steele

Photo/ George Steele

20 Glossary

Ecosystems are systems formed by complex communities of organisms and their physical environment. Tidal creeks research includes humans as part of the coastal ecosystem.

Estuaries are diverse, semi-enclosed coastal bodies of water where seawater and freshwater mix.

Fecal coliform bacteria are a collection of microorganisms that live in the intestines of humans and other warm- and cold-blooded animals. High fecal coliform concentrations can indicate the presence of harmful viruses and bacteria.

Impervious cover is the percentage or ratio of impervious surfaces such as roofs, roads, parking lots, and other hard materials that water cannot penetrate, relative to the total land area.

Photo/ George Steele

Land cover is the nature of the surface of a watershed which includes forests, suburban and urban areas, rivers and lakes, and wetlands. There are two primary methods for obtaining information on land cover: field surveys and analysis of remotely sensed images of the landscape.

Non-point source pollution cannot be traced to a specific source but comes from multiple generalized sources, such as residential developments, farmlands, stormwater ponds, and parking lots that drain from watersheds into the receiving water bodies.

Polycyclic aromatic hydrocarbons (PAHs) are carcinogenic chemicals that are formed when fossil fuels are not completely combusted.

Purchase of development rights (PDR) programs channel development from rural areas into already developed areas by using public funds to purchase the development rights for rural properties in perpetuity.

Stressors are agents that cause stress to an organism, population, or ecosystem.

Swales are engineered drainage areas that are low, narrow tracts of land which allow water to percolate into the ground as they convey water to a receiving water body.

Photo/ April Turner

Tidal creeks connect uplands and marshes to larger estuarine and coastal water bodies.

Photo/ George Riekerk

Urban sprawl is the spreading out of development into rural lands in a manner where residents tend to live in single-family homes and commute by automobile to work.

Vegetated buffers are areas covered in vegetation generally occurring between the development and a water body. The vegetation slows down stormwater runoff, promotes groundwater recharge, and filters pollutants.

Photo/ SCDHEC-OCRM

Watersheds are the land area surrounding a particular water body – streams, rivers, ponds, and lakes – into which runoff drains. Watershed boundaries are generally based on elevation.

Photo/Anne Blair

Hollings Marine Laboratory

Sea Grant
S.C. Sea Grant Consortium

DNR

Oceans & Human Health Initiative

SCSGC-G-08-04