Coastal Resilience Assessment of the Charleston Harbor Watershed

NFWF

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Table of Contents

Abstract

The Charleston Harbor Watershed Coastal Resilience Assessment focuses on identifying areas of open space where the implementation of restoration or conservation actions could build human community resilience and fish and wildlife habitat in the face of increasing storms and flooding impacts. The study is important to the area around Charleston, South Carolina because it was established on a low-lying peninsula between the Ashley and Cooper Rivers that has experienced flooding since its founding in 1670. In recent years, the area has experienced extensive damage to human assets from episodic and chronic flooding events.

This assessment combines human community assets, threats, stressors, and fish and wildlife habitat spatial data in a unique decision support tool to identify Resilience Hubs, which are defined as large area of contiguous land that could help protect human communities from storm impacts while also providing important habitat to fish and wildlife if appropriate conservation or restoration actions are taken to preserve them in their current state. The Hubs were scored based on a Community Vulnerability Index that represents the location of human assets and their exposure to flooding events combined with Fish and Wildlife Richness Index that represents the number of fish and wildlife habitats in a given area. Local stakeholders and experts were critical to the assessment process by working with the project team to identify priority fish and wildlife species in the watershed and provide data sets and project ideas that have potential to build human community resilience and fish and wildlife habitat within the Charleston Harbor Watershed.

As part of the assessment process, 30 resilience-related project ideas were submitted through the stakeholder engagement process, of which three are described in detailed case studies in this report. The case studies illustrate how proposed actions could benefit fish and wildlife habitat and human communities that face coastal resilience challenges such as storm surge during extreme weather events.

The products of the assessment process include this report, the Coastal Resilience Evaluation and Siting Tool (CREST) interactive online map viewer, and a Geographic Information System-based decision support tool pre-loaded with assessment datasets. These products provide opportunities for a variety of users, such as land use, emergency management, fish and wildlife, and green infrastructure planners to explore vulnerability and resilience opportunities in the watershed. The products can also be used to guide funding and resources into project development within high scoring Resilience Hubs, which represent areas where human communities are exposed to the greatest flooding threats and where there is sufficient habitat to support fish and wildlife. The decision support tool also allows users to manipulate the community vulnerability and fish and wildlife datasets to identify areas of value based on their own objectives.

Executive Summary

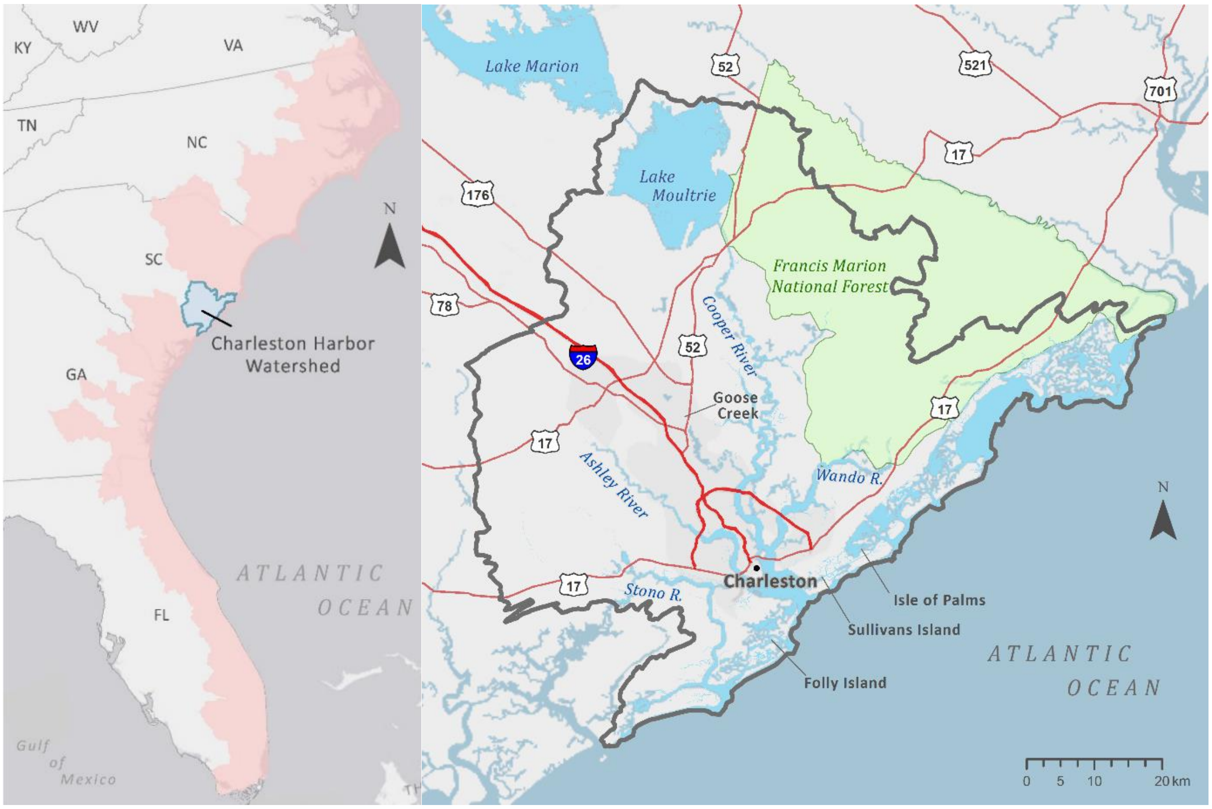
In response to increasing frequency and intensity of coastal storm events, the National Fish and Wildlife Foundation (NFWF) is committed to supporting programs and projects that improve community resilience by reducing communities' vulnerability to these coastal storms, sea-level rise, and flooding through strengthening natural ecosystems and the fish and wildlife habitat they provide. NFWF commissioned NatureServe to conduct coastal resilience assessments that identify areas ideal for implementation of conservation or restoration projects (Narayan et al. 2017) that improve both human community resilience and fish and wildlife habitat before devastating events occur and impact the surrounding community. The assessments were developed in partnership with the National Oceanic and Atmospheric Administration and UNC Asheville's National Environmental Modeling Analysis Center, and in consultation with the U.S. Army Corps of Engineers.

Coastal Resilience Assessments have been conducted at two scales: 1) at a regional level, covering five coastal regions that incorporate all coastal watersheds of the conterminous U.S., and 2) at the local watershed level, targeting eight coastal watersheds. Each of the eight Targeted Watershed Assessments nest within these broader Regional Assessment and provide the opportunity to incorporate local data and knowledge into the larger coastal assessment model.

This assessment focuses on the Charleston Harbor Watershed. By assessing this region's human community assets, threats, stressors and fish and wildlife habitat, this Targeted Watershed Assessment aims to identify opportunities on the landscape to implement restoration or conservation projects that provide benefits to human community resilience and fish and wildlife habitat, ensuring maximum impact of conservation and resilience-related investment.

Charleston Harbor Watershed

The Charleston Harbor Watershed includes the city of Charleston, South Carolina. Charleston was established on a low peninsula between the Ashley and Cooper Rivers, and many of the adjacent communities are also situated in areas that are relatively low elevation (see figure below). The highest point within the City of Charleston's lower peninsula is 18 feet, with most of the lower peninsula at 10 feet (Kana et al. 1984). Significant sections of the city are built on fill near sea level, so flooding has been a part of the city's (and adjacent watershed's) history since its founding in 1670. Some of the most extensive flooding has occurred in recent years, both from episodic and chronic events, extensively damaging human assets. The area considered in this assessment includes three sub-basins adjacent to Charleston Harbor.



Location and boundary of the Charleston Harbor Watershed study area. *The map on the left shows the watershed in the context of the South Atlantic Coast Regional Assessment area (pink). In the map on the right, the study area, composed of three sub-basins surrounding Charleston Harbor, is shown with the dark gray outline.*

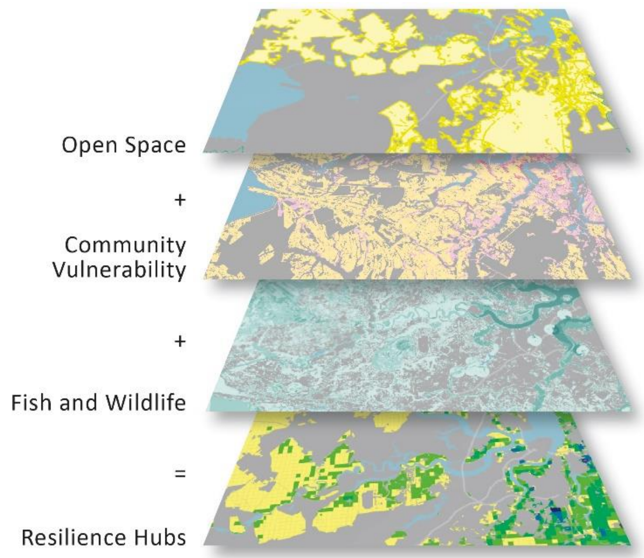
Assessment Objectives

The objectives of this assessment were to:

1. Identify Resilience Hubs or areas on the landscape where implementation of conservation actions will have maximum benefit for human community resilience and fish and wildlife habitat.
2. Account for threats from both coastal and inland storm events.
3. Create contiguous and standardized data sets across the study area.
4. Use local knowledge, data sources, and previously completed studies and plans to customize the Regional Assessment model for this smaller study area.
5. Identify projects in the watershed that have a demonstrated need and local support.
6. Make the products of the assessment broadly available to facilitate integration of resilience planning in a variety of land, resource management, and hazard planning activities.

Assessment Approach

The assessment approach was focused on identifying and evaluating Resilience Hubs, areas of open space and contiguous habitat that can potentially provide mutual resilience benefits to human community assets (HCAs) and fish and wildlife. This assessment was conducted primarily through Geographic Information System (GIS) analyses using existing datasets created by federal, state and local agencies, non-profits, universities, and others. Three categories of data were used as the primary inputs to the assessment: Open Space (protected lands or unprotected privately owned lands), Human Community Vulnerability, and Fish and Wildlife Species and Habitats.



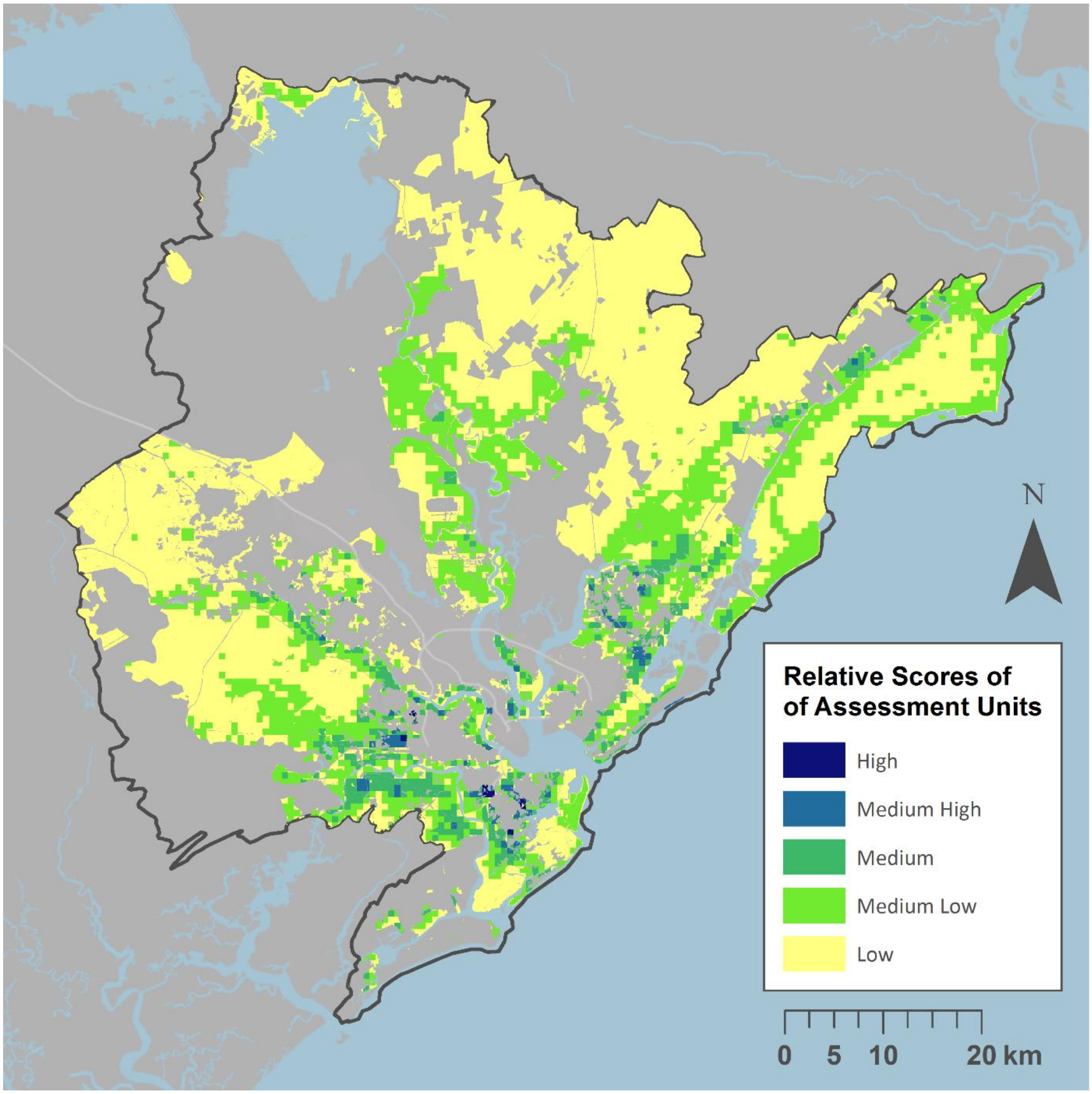
***Left**: **Diagram of the overall approach of this assessment.** Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas in proximity to HCAs with high vulnerability **and** high fish and wildlife richness are mapped as Resilience Hubs where efforts to preserve or increase resilience to threats are well-justified. From the set of all such Hubs, those scoring highest by these measures represent priority areas for undertaking resilience projects.*

Results

Resilience Hubs

Resilience Hubs are large tracts of contiguous land that, based on the analyses, provide opportunities to increase protection to human communities from storm impacts while also providing important habitat for fish and wildlife. Hubs mapped in the Regional Assessment were evaluated using the Human Community Vulnerability Index and Fish and Wildlife Richness Index. In the map below:

- Parcels in **dark blue** were scored higher because they contain or are near highly vulnerable human population and infrastructure *and* support a diversity of fish and wildlife habitats. It is within or near these higher scoring parcels that restoration projects may be most likely to achieve multiple benefits for human community resilience and fish and wildlife.
- Parcels in **yellow** are scored lower because they are either not proximate to concentrations of HCAs or have low value for the fish and wildlife elements addressed in this assessment.



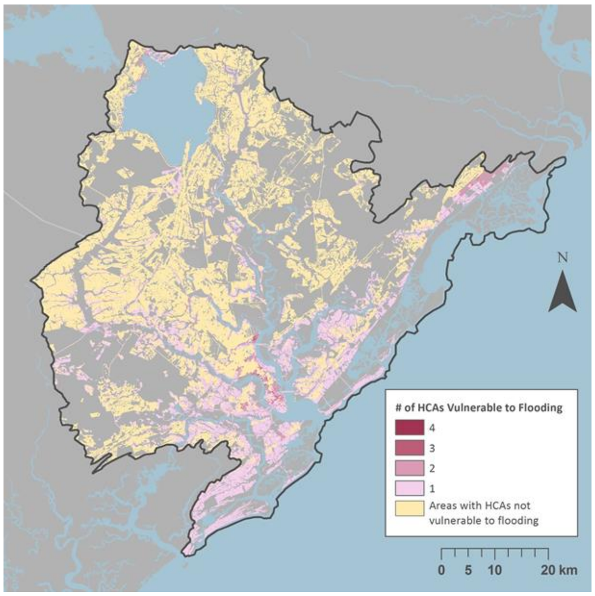
Resilience Hubs assessment unit relative scores for the Charleston Harbor Watershed*. Assessment units are 100-acres grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieve both community resilience and fish and wildlife benefits. Gray areas are outside of Hubs.*

Community Vulnerability

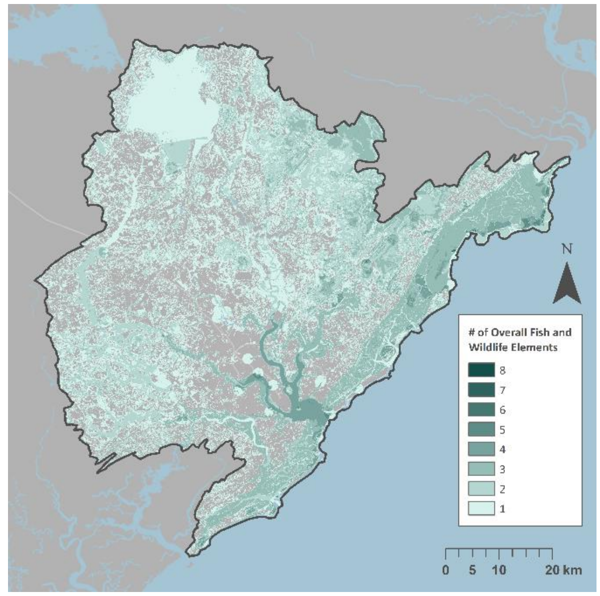
The Community Vulnerability Index (see map below) accounts for approximately half of the scoring of the Resilience Hubs. This index communicates threats to human community assets wherever they occur as well as concentrated areas of threat. Vulnerability is highest in the immediate coastal areas where there are concentrations of populations and infrastructure exposed to most flooding threats. Areas of vulnerability farther inland are largely due to precipitation-caused flooding threats (flood zones and flat areas with poorly draining soils) and not sea-level rise or storm surge.

Fish and Wildlife

A total of 21 unique habitats, species, and species aggregations (referred to in this report as 'fish and wildlife elements' or simply 'elements') were included in this analysis. A Richness Index (see below) represents the concentration of fish and wildlife elements in each location.



Community Vulnerability Index for the Charleston Harbor Watershed*. Pink to red shades indicate the number of Human Community Assets (HCAs) exposed to flooding related threats. Tan areas indicate areas of low to no impact from the flooding threats. Gray areas within the project boundary have no mapped HCAs.*



Richness of fish and wildlife elements in the Charleston Harbor Watershed*. Green shades indicate the number of elements found in a location. Gray areas within the project boundary have no mapped fish or wildlife elements considered in this assessment.*

Resilience Projects

Plans and ideas were gathered from stakeholders for projects that could increase human community resiliency *and* provide fish and wildlife benefits but require funding to implement. The projects were collected to identify conservation and restoration need in the study area and to analyze the utility of the assessment to provide additional information on potential project benefits. The projects span a range of types including resilience planning, conservation of habitats, and habitat restoration. A complete list of projects can be found in Appendix 6. Several project sites were visited before selecting three case studies presented later in this report:

- Case Study 1: Long Branch Creek – Restoring Ecosystem Services to Improve Flood Resilience
- Case Study 2: Crab Traps to Oyster Reefs
- Case Study 3: Sea Island Wetland Restoration

Assessment Products

A rich toolbox of products was generated by this assessment and different audiences will find unique value in each of the tools.

Products from this effort can be obtained from www.nfwf.org/coastalresilience/Pages/regional-coastal-resilience-assessment.aspx and include:

- Final reports for the Charleston Harbor Watershed, other local Targeted Watershed Assessments, and the Regional Assessment.
- Coastal Resilience Evaluation and Siting Tool (CREST), an online map viewer and project site evaluation tool that allows stakeholders access to key map products. CREST is available at resilientcoasts.org.
- The GIS data inputs and outputs can be downloaded and used most readily in the Esri ArcGIS platform. Though not required to access or use these data, this project is also enabled with the NatureServe Vista™ planning software which can be obtained at www.natureserve.org/vista. Vista™ can support additional customization, assessment, and planning functions.

Products may be used to:

1. Assist funders and agencies to identify where to make investments in conservation and restoration practices to achieve maximum benefits for human community resilience and fish and wildlife.
2. Inform community decisions about where and what actions to take to improve resilience and how actions may also provide benefits to fish and wildlife.
3. Distinguish between and locate different flooding threats that exist on the landscape
4. Identify vulnerable community assets and the threats they face
5. Identify areas that are particularly rich in fish and wildlife species and habitats
6. Understand the condition of fish and wildlife where they are exposed to environmental stressors and how that condition may be impacted by flooding threats.
7. Inform hazard planning to reduce and avoid exposure to flooding threats.
8. Jump start additional assessments and planning using the decision support system.

Introduction

Background

Coastal communities throughout the United States face serious current and future threats from natural events, and these events are predicted to intensify over the short and long term (Bender et al. 2010). Many of these events (e.g., intense hurricanes, extreme flooding) have the potential to devastate both human communities and fish and wildlife, which has been seen in recent years with Hurricanes Florence and Michael (2018); Irma, Harvey, and Maria (2017); Hurricanes Matthew and Hermine and severe storms in coastal LA and Texas (2016).

The National Fish and Wildlife Foundation (NFWF) is committed to supporting programs and projects that improve resilience by reducing communities' vulnerability to these coastal storms, sea-level rise, and flooding events through strengthening natural ecosystems and the fish and wildlife habitat they provide. NFWF's experience in administering a competitive grant program in the wake of Hurricane Sandy (2012), revealed the clear need for thorough coastal resilience assessments to be completed prior to devastating events and that these assessments should include both human community resilience and fish and wildlife benefits to allow grant making to achieve multiple goals. In response, NFWF has developed a Regional Assessment that includes all coastal areas of the contiguous U.S., in addition to Targeted Watershed Assessments in select locations. This will allow for strategic investments to be made in restoration projects today to not only protect communities in the future, but also to benefit fish and wildlife. When events do strike, data and analyses will be readily available for NFWF and other organizations to make informed investment decisions and respond rapidly for maximum impact.

Regional Assessment

Developed through a separate but similar effort, the Regional Assessment (Dobson et al. 2019) explored resilience in five geographic regions of the conterminous United States (**Figure 1**) and aimed to identify areas where habitat restoration, installation of natural and nature-based features (U.S. Army Corps of Engineers 2015), and other such projects that could be implemented to achieve maximum benefit for human community resilience, fish and wildlife populations, and their habitats. The analysis conducted for the Regional Assessment identified Resilience Hubs that represent large areas of contiguous habitat that may provide both protection to the human communities and assets in and around them and support significant fish and wildlife habitat. Enhancing, expanding, restoring, and/or connecting these areas would allow for more effective and cost-efficient implementation of projects that enhance resilience.

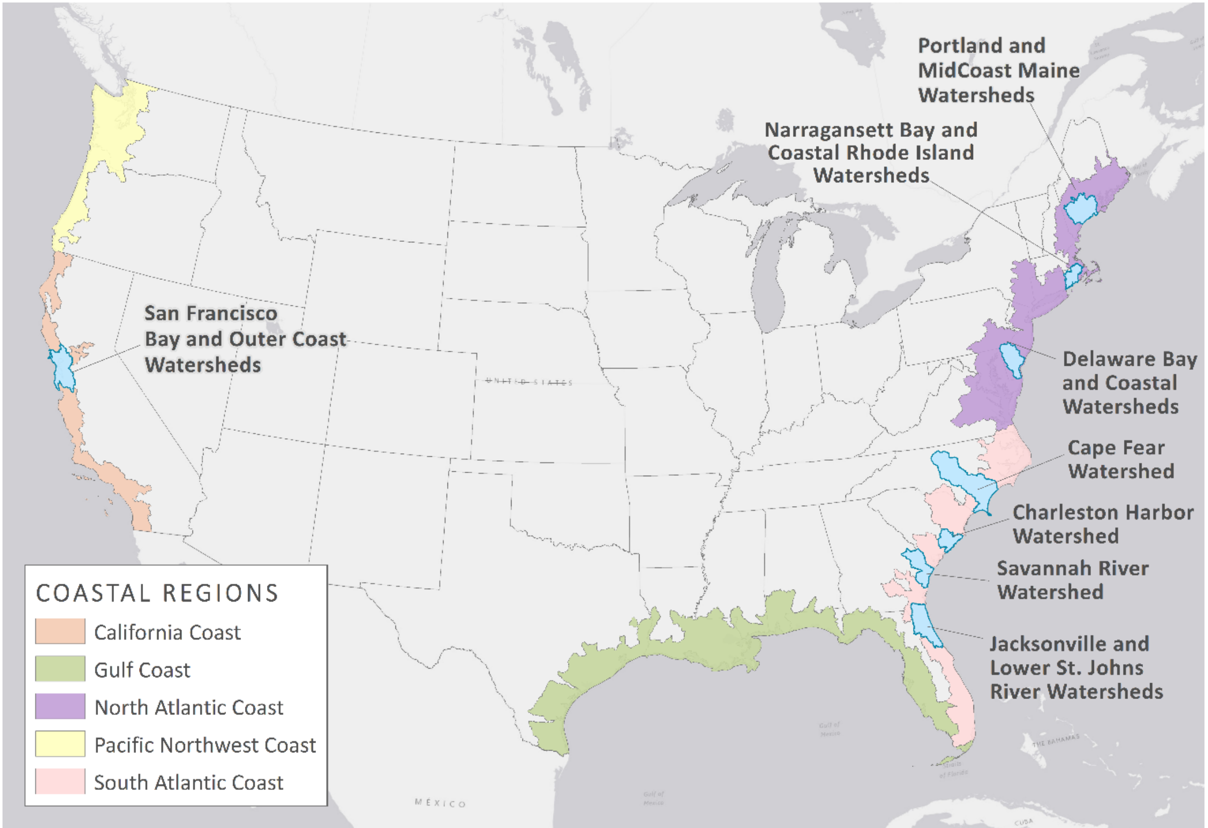


Figure 1. Map showing study areas for the Regional and Targeted Watershed Assessments. *The broad Regional Assessment included five coastal regions. High resolution resilience assessments were carried out in eight coastal Targeted Watershed Assessment study areas (in blue); the Cape Fear Watershed was conducted first as a pilot. The Targeted Watershed Assessments were informed in part by the Regional Assessment.*

Targeted Watershed Assessments

Eight smaller areas were identified for additional, in-depth study in order to build upon the concepts developed in the Regional Assessment while allowing for more detailed local data to be incorporated for a truly customized assessment (**Figure 1**). These areas were selected due to their location relative to large population centers and proximity to significant areas of open space that if restored could not only benefit fish and wildlife, but also human community resilience.

Resilience Hubs

In a model used by both the Regional and Targeted Watershed Assessments, areas of open space are identified and analyzed in terms of human community vulnerability and fish and wildlife richness to inform where projects may be ideally sited for restoration or conservation. The Regional Assessment is designed to do this on a larger scale and use only nationally available datasets, whereas the Targeted Watershed Assessments include more state and local, often higher-resolution datasets.

The Regional Assessment created contiguous and standardized datasets, maps and analyses for U.S. coastlines to support coastal resilience assessment planning, project siting, and implementation at a state, regional, or national scale. This ensures planning agencies and other professionals can compare "apples to apples" across the landscape. Unlike previous studies that quantified impacts to only a thin strip of coastline, the Regional Assessment looks at the full extent of coastal watersheds to analyze the potential impacts of both coastal and inland storm events to include every sub-basin that drains to the sea, and in some places, a sub-basin or two beyond that where they are particularly low lying or tidally influenced.

Targeted Watershed Assessment Objectives

The Regional Assessment was an important first step in the development of the assessment model and ensuring standardization of datasets across U.S. coastal watersheds. Targeted Watershed Assessments such as the one described in this report complemented these assessments by: 1) using finer scale, local data—particularly with regard to fish and wildlife, 2) involving local stakeholders in providing expertise and sourcing important information necessary for understanding more detailed patterns and local context, and 3) identifying projects in the watershed that have a demonstrated need and local support. Three of those projects are presented as case studies.

Assessment Products

The following products from this effort can be obtained from www.nfwf.org/coastalresilience/Pages/regional-coastal-resilience-assessment.aspx

1. This report (and reports from the other Targeted Watersheds), which includes:
    a. Detailed methodology
    b. Resilience Hub map
    c. Community Vulnerability Map
    d. Fish and Wildlife Richness Map
    e. Case studies on three select projects
    f. List of projects submitted by stakeholders in the watershed
2. The Coastal Resilience Evaluation and Siting Tool (CREST), an online map viewer and project site evaluation tool that allows stakeholders access to key map products. CREST is available at resilientcoasts.org.
3. A zipped file that contains all of the Geographic Information System (GIS) data used in this assessment in the form of an ArcMap project (.mxd) with all associated data inputs and outputs (subject to any data security limitations) including many intermediary and secondary products that are available for download in CREST at resilientcoasts.org/#Download. Though not required to access or use these data, this ArcMap project was designed for use with NatureServe Vista™ planning software (Vista DSS, an extension to ArcGIS), which can be obtained for no charge at www.natureserve.org/vista.

Application of the Assessment

This Targeted Watershed Assessment is a tool to identify potential project sites that can most efficiently increase both fish and wildlife and human community resilience. The insights and products generated can be used by practitioners such as planners, state agency personnel, conservation officials, non-profit staff, community organizations, and others to focus their resources and guide funding decisions to improve a community's resilience in the face of future coastal threats while also benefiting fish and wildlife.

The results and decision support system can inform many future planning activities and are most appropriately used for landscape planning purposes rather than for site-level regulatory decisions. **This is neither an engineering-level assessment of individual Human Community Assets (HCAs) to more precisely gauge risk to individual areas or structures, nor a detailed ecological or species population viability analysis for fish and wildlife elements to estimate current or future viability.**

Charleston Harbor Watershed

The Charleston Harbor Watershed study area is centered around the city of Charleston, South Carolina. Charleston and a constellation of suburban towns surround Charleston Harbor, all extend inland along the Ashley and Cooper Rivers. The regional population of the Charleston Metropolitan Statistical Area as of 2010 was 648,090 residents (S.C. Department of Employment and Workforce 2019). The region has a strong economy from the Port of Charleston, tourism, military installations, medical facilities, manufacturing, and information technology. The port is ranked 8th in the U.S. in terms of cargo value[1]. The Charleston Harbor Watershed project area, located on the central coast of South Carolina, is shown in **Figure 2.**

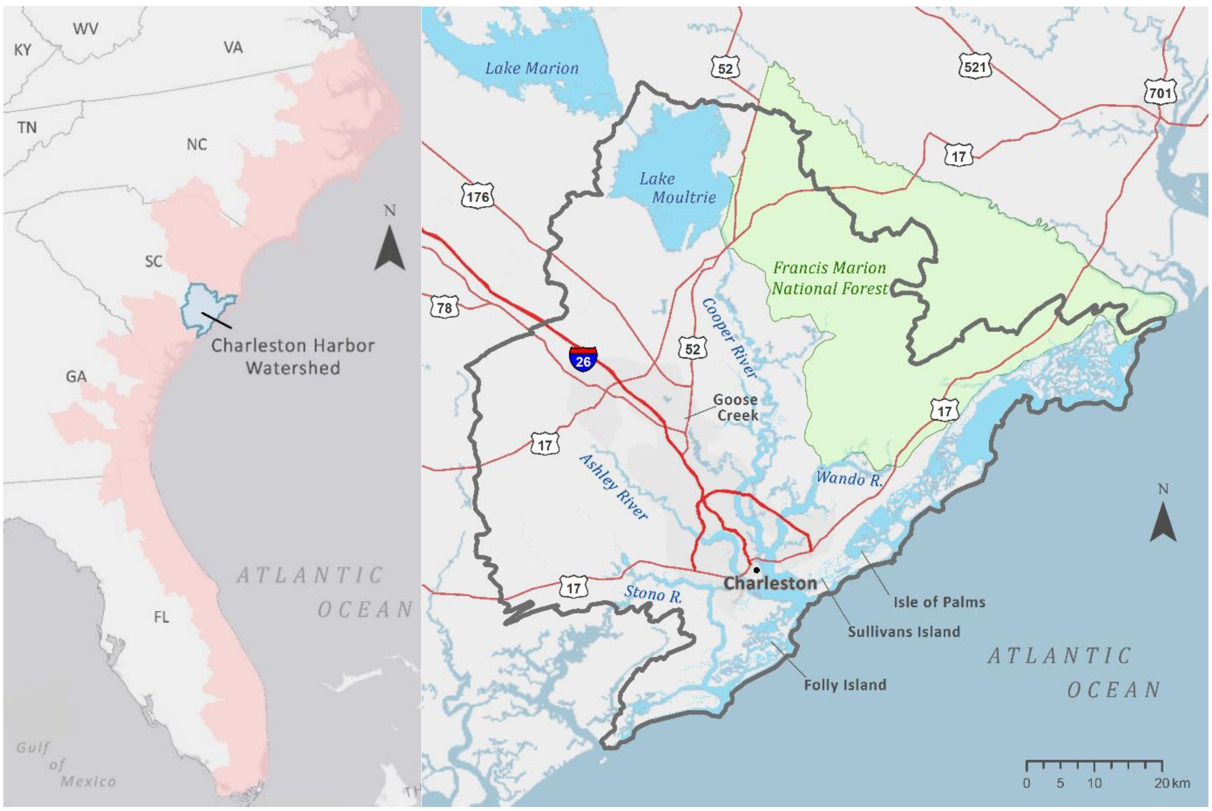


Figure 2. Location and boundary of the Charleston Harbor Watershed study area. *The map on the left shows the watershed in the context of the South Atlantic Coast Regional Assessment area (pink). In the map on the right, the study area, composed of three sub-basins surrounding Charleston Harbor, is shown with the dark gray outline.*

The boundary of the watershed follows those of the three United States Geological Survey (USGS) level four hydrological units[2] adjacent to Charleston Harbor. The dominant watershed feature is Charleston Harbor, formed by the confluence of the Ashley, Cooper, and Wando Rivers. Originating in

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[1] According to South Carolina Ports 2017 data. http://www.scspa.com/about/statistics/cargo-value/

[2] Also referred to as 'subbasins' or 'HUC8 units' (in reference to the 8-digit unique codes used to identify each such unit at this level in the national Watershed Boundary Dataset (USGS & USDA 2013)). See the publication at this link for further details: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_021581.pdf.

the coastal plain, both the Ashley and Wando Rivers—and their associated sub-basins—are particularly susceptible to coastal flooding-related threats such as morphological and vegetation community transformation and salinization. The Cooper, though historically originating in the coastal plain, was connected to the Santee River by a canal in the late 18th century and currently is fed with water from the Santee (originating in the Southern Appalachians) through dams on Lake Moultrie and Lake Marion. The lower sections of the Cooper and Wando Rivers are dredged and contain a federal channel for the Port of Charleston, which is also dredged on a periodic basis.

At the coastal edge of the watershed are extensive tidal salt marshes bounded by a chain of barrier islands. Bulls Bay and a complex of marsh and tidal creeks dominate the northern coast, an area rich in fish and wildlife and the location of the Cape Romain National Wildlife Refuge. This rich complex of tidal habitats supports relatively high densities of shrimp, crabs, and bivalves as well as iconic birds such as great blue herons and snowy egrets. Northern inland areas are forested wetlands and pine uplands (originally longleaf pine) supporting red-cockaded woodpeckers and migrating Kirtland's warblers. The southern inland areas, originally forested swamp and uplands, were cleared for agriculture including indigo, rice, and cotton starting in the 1600s.

Historic Impacts from Flooding

Flooding has been part of the region's history since its founding. The city itself was established on a peninsula between the Ashley and Cooper Rivers and is surrounded by low lying areas. The highest point within the City of Charleston's peninsula is just 18 feet (Kana et al. 1984), with significant sections of the city built on fill near sea level. Some of the most extensive flooding has occurred in recent years, both from episodic and chronic events, extensively damaging human assets.

- In October 2015, a rainfall event dumped 11.5 inches of rain in a 24-hour period at the Charleston International Airport, and over 20 inches over a three-day period. This was the most ever recorded in Charleston history. At the same time the high tide was 1.5 feet higher than average, which flooded coastal areas and limited the drainage of flood waters from the rainfall event. Officials blocked the entrance to the entire Charleston peninsula for most of a two-day period. Stores along King Street, the main commercial and tourism district on the peninsula, were flooded, leading to significant lost revenue to the tourism industry.
- Over the course of 2015 there were 37 king tides (exceptionally high tides), which represents a 25% increase over normal levels. This increase in the frequency of king tides has led to predictions that by 2045, there may be as many as 180 king tide events each year in Charleston (Harrison & Kooistra 2017). This would cause tidal flooding in the city every other day on average.
- In 2016, Hurricane Matthew produced 11 to 12 inches of rain over a two-day period with tidal surges three feet above normal. Floodwaters once again ravaged many of the lowest lying areas within the peninsula and throughout the region, including City Market in downtown Charleston.
- Hurricane Irma, in 2017, produced surge levels four feet higher than average water levels and was among the worst hurricanes in Charleston history, which includes Hurricane Hugo in 1989. Irma's storm surge was eight inches higher than that of Hurricane Matthew. According to

news reports, 111 roads across the city were closed due to either flooding or downed trees (Waters, 2017).

These same weather events affected fish and wildlife habitat with inundated beaches, extensive coastal and riparian erosion, submerged marshes, lower salinity, degraded water quality, and extensive flooding of upland forests and savannas.

The City of Charleston and the surrounding communities are actively involved in addressing the increased depth, frequency, and extent of flooding. In recognition of the severity of this issue, the Charleston Resilience Network (http://www.charlestonresilience.net/) was created as a volunteer-based effort composed of public and private sector stakeholder organizations within the metropolitan area that have a collective interest in the resilience of communities and critical infrastructure to episodic natural disasters and chronic coastal hazards. On behalf of the Charleston Resilience Network, South Carolina Sea Grant Consortium received a National Oceanic and Atmospheric Administration (NOAA) Regional Coastal Resilience Grant of over half a million dollars for community resilience and recovery efforts in 2016 to share science-based information, educate stakeholders, and promote resilience-related planning and decisions. The active regional resilience community provided substantial expertise for this Targeted Watershed Assessment. In addition, the City of Charleston released a Sea Level Rise strategy in 2015 (City of Charleston 2015).

Methods Overview

This overview is intended to provide the reader with sufficient information to understand the results. Details on methods are provided in the appendices as referenced in each section below to provide deeper understanding and/or aid in the use of the available Vista decision support system (Vista DSS).

Overall Approach

The overall approach aims to identify Resilience Hubs, places where investments made in conservation or restoration may have the greatest benefit for both human community resilience and fish and wildlife (**Figure 3**). Identifying these areas can support resilience planning by informing the siting and designing of resilience projects. This assessment was conducted primarily through GIS analyses using existing datasets created by federal, state and local agencies, non-profits, universities, and others. Three categories of data were used as the primary inputs to the project: Open Space (protected land or unprotected privately owned lands), Human Community Vulnerability, and Fish and Wildlife Species and Habitats. Bringing these data together generated many useful assessments, which culminated in the mapping and scoring of Resilience Hubs.

The use of a publicly-available decision support system (NatureServe Vista™) to conduct the Targeted Watershed Assessments provides a useful vehicle for delivering the full set of inputs, interim products, and key results to users in a way that allows them to update the results with new information and customize the assessments with additional considerations such as additional Human Community Assets (HCAs) and fish and wildlife elements. Details on the components of the approach are described below and supported by Appendices 2-5.

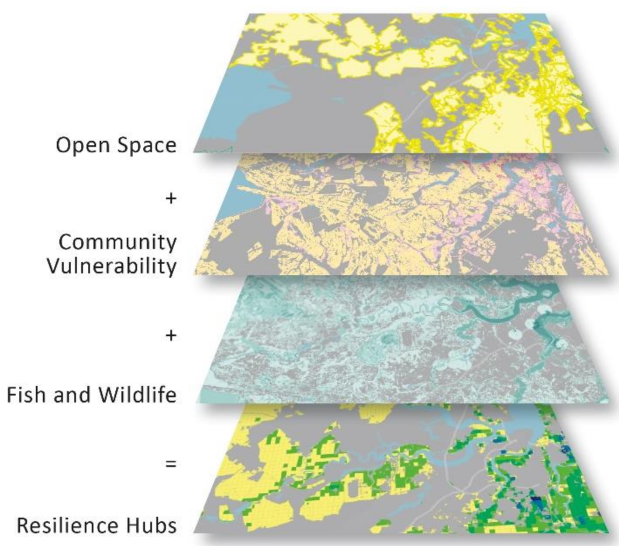


Figure 3. Diagram of the overall approach of this assessment. *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas with high HCA vulnerability and high fish and wildlife richness are mapped as Resilience Hubs where efforts to preserve or increase resilience to threats are well-justified. From the set of all such Hubs, those scoring highest by these measures represent priority areas for undertaking resilience projects. Diagram represents generic region and is only intended to illustrate methods.*

Stakeholder Participation

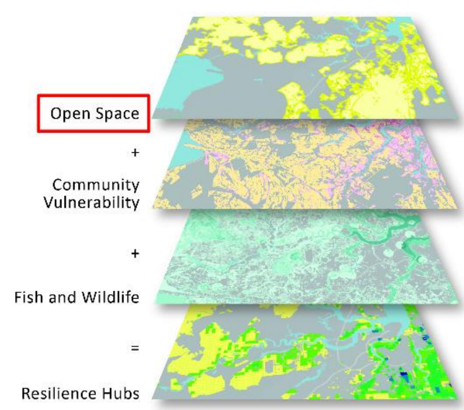
A fundamental part of this Targeted Watershed Assessment was to engage and work with individual and organizational stakeholders and partners within the Charleston Harbor Watershed. Stakeholder involvement can improve the quality of decisions and policy—especially in the context of complex environmental and social challenges (Elliott 2016, Reed 2008). The stakeholder engagement process for the Charleston Harbor Watershed was designed to address four goals: 1) inform a wide array of stakeholders in the watershed of this assessment, its objectives and potential utility, and opportunities to contribute to it; 2) inform the selection of fish and wildlife habitats and species, and their stressors; 3) identify and access the best existing local data to supplement regional and national data to be used in the spatial assessments; and 4) catalog proposed resilience project plans and ideas.

In addition to the overall Coastal Resilience Assessment Technical and Steering Committees that helped to guide the Targeted Watershed Assessment goals and deliverables and provide feedback at key points in the process (such as reviewing the fish and wildlife habitat layers, resilience project sites for site visits, and final case studies), a Charleston Harbor Watershed Committee was formed consisting of local experts from NOAA, the South Atlantic Landscape Conservation Cooperative (LCC), South Carolina Department of Natural Resources, South Carolina Aquarium, South Carolina Sea Grant, South Carolina Department of Health & Environmental Control, U.S. Army Corps of Engineers, and NFWF. This committee helped to identify relevant stakeholders to engage, determine times and places of stakeholder workshops, and compile the initial fish and wildlife element list and associated data. Specific individual and institutional roles and contributions are listed in the 'Acknowledgements' section.

Over 35 participants including federal and state agency representatives, NGO staff, local elected officials and municipal staff, and citizens representing their communities were engaged in the stakeholder process through web meetings, in-person workshops, and follow-up activities such as site visits to proposed resilience project sites. Additional details on key stakeholder inputs, details about the stakeholder process, and the committee structure that guided the assessment can be found in Appendix 1.

Components of the Assessment

For each component described below, an inset of **Figure 3** above is repeated, identifying in red outline the component being described in relation to the other three components.



Open Space

Large contiguous areas of habitat may provide mutual resilience benefits to HCAs and fish and wildlife elements, especially with the implementation of resilience projects. Identifying these areas of open space serves as a first step in identifying high value Resilience Hubs where prospective conservation and restoration projects could contribute to resilience and benefit fish and wildlife. The method for scoring the value of the Hubs using results from the watershed assessments is further described below.

Mapping Open Space

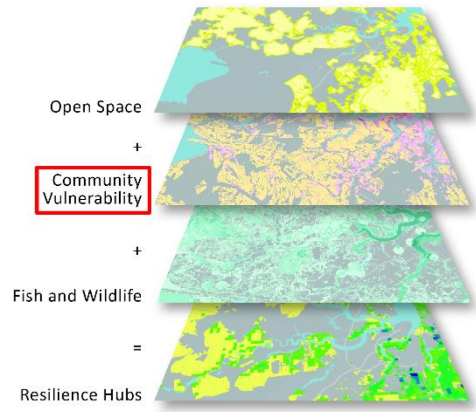
The process of delineating open space is described in the Regional Assessment (Dobson et al. 2019) and incorporates:

1. Protected areas, which are defined as lands that are part of the USGS Protected Areas Database of the United States (PAD-US).
2. Unprotected privately owned lands with contiguous habitat, as identified from the USGS National Land Cover Database (NLCD). The open space areas were further processed to remove impervious surfaces and deep marine areas. Within the Regional Assessment methodology, these areas were also analyzed using a community exposure index to highlight areas of higher exposure and areas that are near or adjacent to communities.

Once open space areas were identified in the Regional Assessment, those open spaces within the target watershed were further refined as follows:

1. Protected areas were augmented with local The Nature Conservancy (TNC) data on protected properties. All protected area polygons were intersected with the Resilience Hubs as identified in the Regional Assessment to distinguish protected from unprotected areas.
2. Hubs with shorelines (rivers or coastal) were supplemented with the National Hydrography Dataset (NHD) to include waters within a 50-meter buffer to add nearshore habitat areas that could provide locations for aquatic resilience projects such as oyster reefs or marsh protection/restoration.
3. Impervious surfaces were deleted from the Hubs using the National Land Cover Database (Homer et al. 2011) and Topologically Integrated Geographic Encoding and Referencing (TIGER) roads data (U.S. Census 2016). The removed areas might be protected but have pavement or structures in place that would limit restoration actions.
4. Tracts that were less than five acres (mostly slivers resulting after deleting impervious surfaces and splitting polygons) were removed from consideration. For the purposes of this assessment, areas under this threshold were assumed to have significantly less potential for improving community resilience or supporting fish and wildlife in meaningful, measurable terms.

Community Vulnerability



Assessing community vulnerability is a process of examining where and how assets within a community may be impacted by flooding threats. Understanding where people and infrastructure are most exposed and vulnerable to threats can help communities assess where they are most at risk, and where actions may need to be taken to increase resilience.

Human Community Asset Weighted Richness Index

For the purposes of this assessment, Human Community Assets (HCAs) data were selected to represent: 1) critical infrastructure and facilities essential for community recovery post-storm event, 2) areas of dense human population, and 3) socially vulnerable populations. They are not intended to be comprehensive; for example, not all roads are included and instead focus on storm escape routes. The Regional Assessment identified a suite of HCAs that were used in this Targeted Watershed assessment. The selected HCAs are defined below (see also the Regional Assessment Report [Dobson et al. 2019]). **Table 1** provides further breakdown of the HCAs as represented in the spatial assessment and the importance weightings derived from the Regional Assessment. **Table 2** provides additional detail on the critical facilities category and sources of data.

Human Community Asset categories are defined as follows:

Critical Facilities. Schools, hospitals, nursing homes, and fire and police stations are just a few of the types of facilities included as critical facilities. These services are considered critical in the operation of other community infrastructure types, such as residences, commercial, industrial, and public properties that themselves are not HCAs in this assessment. Critical facilities were drawn from the National Structures Dataset and include (see **Table 2** for additional detail):

- Schools or educational facilities (class 730) (often used as shelters during disasters)
- Emergency Response and Law Enforcement facilities (class 740)
- Health and Medical facilities (class 800)
- Government and military facilities (class 830)

Critical Infrastructure. A variety of additional infrastructure is included that may help communities with emergency evacuation, building economic resilience, and identifying infrastructure (e.g., dams) that may require more extensive and long-term planning and permitting (**Table 2**). Other critical infrastructure includes airport runways, primary transportation routes, ports, refineries, hazardous chemical facilities, power plants, etc. Coastal infrastructure is expected to be increasingly at risk due to major inundation from storm surge and sea level rise. Infrastructure that was considered an important economic asset was also included, such as fishing ports.

Population Density. This category was included because denser populations in high-threat areas will lead to more people being exposed to flooding threats. Density was calculated by Census Block for each region based on the 2010 Census.

Social Vulnerability. Social vulnerability varies geographically in coastal areas where there are large socioeconomic disparities. This input is meant to indicate a community's ability to respond to and cope with the effects of hazards, which is important to consider because more disadvantaged households are typically found in more threatened areas of cities, putting them more at risk to flooding, disease, and other chronic stresses. The input considers certain demographic criteria such as minority populations, low-income, high school completion rate, linguistic isolation, and percent of population below five or over 64 years of age. To account for regional differences and remove any unnecessary bias in the modeling, the source data were processed with a quintile distribution with the Weighted Linear Combination method to rank social vulnerability using a weight value range of 0-5 by Census Block Group at the national level.

Table 1. Human Community Assets included in the assessment and their importance weightings.

Human Community Assets	Description	Adjusted Weight
Critical Facilities	Facilities (i.e., schools, hospitals, fire/police stations) providing services that are critical in the operation of a community.	1
Critical Infrastructure (Rank 1)	**Low** spatial concentration of infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.).	0.2
Critical Infrastructure (Rank 2)	**Medium** spatial concentration of infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.).	0.4
Critical Infrastructure (Rank 3)	**High** spatial concentration of infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.)	0.6
Social Vulnerability	Resilience of communities when confronted by external stresses on human health, stresses such as natural or human-caused disasters, or disease outbreaks.	0.2
Population Density (Rank 1)	***Low*** total density calculated by Census Block for each region based on the 2010 Census.	0.2
Population Density (Rank 2)	***Low-medium*** total density calculated by Census Block for each region based on the 2010 Census.	0.4
Population Density (Rank 3)	***Medium*** total density calculated by Census Block for each region based on the 2010 Census.	0.6
Population Density (Rank 4)	***Medium-high*** total density calculated by Census Block for each region based on the 2010 Census.	0.8
Population Density (Rank 5)	***High*** total density calculated by Census Block for each region based on the 2010 Census.	1

Table 2. Critical infrastructure categories and sources of data.

Critical Infrastructure Category	Data Source
Ports	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later)
Power plants	EIA-860, Annual Electric Generator Report, EIA-860M, Monthly Update to the Annual Electric Generator Report and EIA-923, Power Plant Operations Report (2016 or later)
Wastewater treatment facilities	USGS National Structures Dataset File GDB 10.1 or later
Railroads	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later)
Airport runways	National Transportation Atlas Database (2015 or later)
National Highway Planning Network	National Transportation Atlas Database v11.09 (2015) or later; on behalf of the Federal Highway Administration
Evacuation routes	Homeland Security: Homeland Infrastructure Foundation Level Data (2007 or later)
Major dams	USDOT/Bureau of Statistics NTAD (2015 or later)
Petroleum terminals and refineries	EIA-815, "Monthly Bulk Terminal and Blender" Report; *Refineries*: EIA-820 Refinery Capacity Report (2015 or later)
Natural gas terminals and processing plants	EIA, Federal Energy Regulatory Commission, and U.S. Dept. of Transportation; *Processing Plants*: EIA-757, Natural Gas Processing Plant Survey (2015 or later)
National Bridge Inventory	Federal Highway Administration, NBI v.7, NTAD (2015 or later)
Hazardous facilities & sites	EPA Facility Registry Service (2016 or later)

The HCA weighted richness index expresses values based on the number of HCAs present in a location and their importance weights. The HCAs were combined in the Vista DSS using its Conservation Value Summary function[3] by first assigning a weighting factor that approximated the ranked weights used in the Regional Assessment (see Error! Reference source not found.**1**). For the purposes of the Targeted W atershed Assessment, the weights used in the Regional Assessments (1=lowest importance, 5= highest) were adjusted to a 0-1 scale (1=0.2, 2=0.4, 3=0.6, 4=0.8, 5=1). Next, the HCAs were overlaid, and their adjusted weights summed for each pixel.

Flooding Threats

Flooding threats were used to assess Community Vulnerability (described below) and Fish and Wildlife Vulnerability (described later). The flooding threats used in the Targeted Watershed Assessment are summarized below and illustrated in **Figure 4**. Additional details and assumptions in their use in the vulnerability assessments is provided in Appendix 2.

- Storm surge (with values of 1-5, which are based on hurricane categories 1-5)

[3] A Conservation Value Summary is a surface of mapped values that are the output of a Vista DSS overlay function that allows for a wide range of calculations based on element layers and user-specified attributes. Examples include richness (the number of overlapping elements at a location) and weighted richness where, for example, a simple richness index is modified by the modeled condition of elements.

- Flood zones (100 and 500-year floodplains and flood-ways)
- Sea level rise (one foot was used to correspond with an approximate 20-30-year planning time frame)
- Flood prone areas (flat topography with poorly draining soils)
- Moderate to high erosion potential
- Subsidence

Figure 4. Flooding threats used to assess community vulnerability. *SLR = sea level rise.*

The flooding threats used in the Targeted Watershed Assessments differed slightly from those used in the Regional Assessment. Specifically, the Threats Index used in the Regional Assessment was generated using an ordinal combination method and is presented in the Results section of this report for illustration purposes. Unlike the Targeted Watershed Assessments, all inputs used in the Regional Assessment were ranked on a 0-5 scale, representing the risk of impact (not the degree of impact) and included a five-foot sea level rise change. See the Regional Assessment report for more details on methods (Dobson et al. 2019). In this Targeted Watershed Assessment, a one-foot sea level rise change was used.

Community Vulnerability Assessment

Unlike the Regional Assessments, this Targeted Watershed Assessment went beyond assessing exposure (which examines which, if any, threats an HCA overlaps with and may include intensity of the threat at different levels of storm surge) by assessing vulnerability to threats. Assessing vulnerability includes consideration of the sensitivity of an HCA to the threat it is exposed to, and its adaptive capacity to recover from the impact of that threat (IPCC 2007). Therefore, in this assessment the coexistence of a threat with an HCA does not necessarily equate to vulnerability. The method for assessing vulnerability of HCAs is illustrated in **Figure 5** and details are provided in Appendix 2 and Appendix 3. The basic steps, implemented through the Vista DSS and illustrated in **Figure 5** are:

1. Intersect HCAs with the flooding threats
2. Apply the HCA vulnerability model
3. Generate individual HCA vulnerability maps
4. Sum the results across all HCAs to develop the Community Vulnerability Index. This provides a sum of the number of vulnerable HCAs for every location.

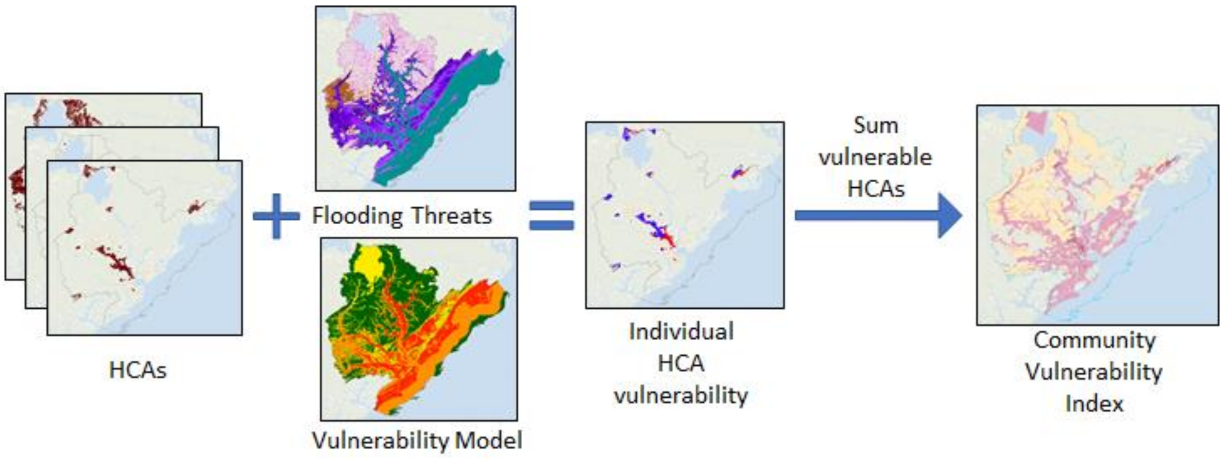
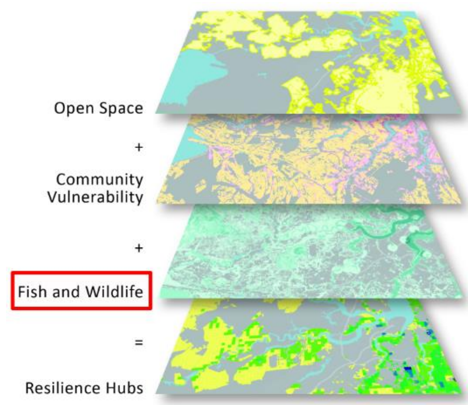


Figure 5. Community vulnerability assessment process. *Human Community Assets (HCAs) are intersected with the flooding threats, a vulnerability model is applied, and individual HCA results are summed to create the Community Vulnerability Index.*

Fish and Wildlife



The Regional Assessment only used those fish and wildlife data that were available nationwide. While this allowed for consistent data coverage over the entire study area, nationwide fish and wildlife data are very coarse. Therefore, the Targeted Watershed Assessment used local data when available, which facilitated a more accurate and higher resolution fish and wildlife analysis.

To better understand where high value areas of fish, wildlife, and associated habitat exist in the region, several analyses were conducted focused on mappable fish and wildlife species, habitats, and other related features of conservation significance (referred to in this report as "fish and wildlife "elements" or simply "elements"). This section of the report focuses on the fish and wildlife element selection process, and the development of conservation value indices. Specifically, two indices were calculated to inform the Resilience Hubs characterization and scoring used in the Targeted Watershed Assessment (see section below): 1) a Fish and Wildlife Richness Index, and 2) a Fish and Wildlife Condition-Weighted Index. Though not used directly in the hub prioritization, a Fish and Wildlife Vulnerability Index was also conducted and is likely to be of significant interest to stakeholders wanting to extend or further explore coastal resilience and fish and wildlife vulnerability. The Fish and Wildlife Vulnerability Index is described in Appendix 4.

Selection of Fish and Wildlife Elements

To facilitate the identification of areas in the watershed important for fish and wildlife conservation, restoration, and resilience, a set of mapped fish and wildlife elements of interest was first established. This was achieved via the following steps:

1. Establishment of an initial list of fish and wildlife elements based on explicit criteria (see below);
2. Review and refinement of this list based on extensive consultation with a diverse set of local experts and other stakeholders;
3. Identification and evaluation of relevant and appropriate spatial data to represent each element; and
4. Finalization of the element set based on input from local experts, the Watershed Committee, and other stakeholders.

For step one, national and local experts applied several criteria to establish an initial set of target fish and wildlife species, species groups, species habitat segments (e.g., migratory, breeding, or rearing habitat), or broad habitat units of significance occurring in this watershed. For inclusion, elements had to: 1) satisfy at least one of the inclusion criteria listed below, and 2) be mappable via relevant and available spatial data of sufficient coverage and accuracy to fairly represent the element (as determined by expert review).

For inclusion, elements must meet one or more of the following criteria:

- A NOAA Trust Resource[4]
- A formally recognized at-risk species based on its inclusion in one of the following categories at the time of this assessment including:
    - A species listed as 'endangered', 'threatened', or 'candidate' under the provisions of Endangered Species Act (ESA)[5]
    - A species with a NatureServe global imperilment rank of G1, G2, or G3[6]
    - A species with a NatureServe state imperilment rank of S1, S2, or S3
    - A State Species of Greatest Conservation Need (SGCN) as recorded in current State Wildlife Action Plans
- A distinctive ecological system or species congregation area that represents habitat important to at-risk species and/or species of significance to stakeholders in the region. Examples might include heron rookeries that represent important wading bird habitat or tidal marsh representing shrimp nursery areas and diamondback terrapin habitat; or
- A species or population of commercial, recreational, or iconic importance in the watershed. This includes:

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[4] NOAA trust resources are living marine resources that include: Commercial and recreational fishery resources (marine fish and shellfish and their habitats); Anadromous species (fish, such as salmon and striped bass, that spawn in freshwater and then migrate to the sea); Endangered and threatened marine species and their habitats; marine mammals, turtles, and their habitats; Marshes, mangroves, seagrass beds, coral reefs, and other coastal habitats; and Resources associated with National Marine Sanctuaries and National Estuarine Research Reserves (NOAA 2015).

[5] These categories are established by the **US Endangered Species Act of 1973, as amended through the 100th Congress**. (United States Government 1988) (See this factsheet for further explanation: https://www.fws.gov/endangered/esa-library/pdf/ESA_basics.pdf)

[6] These categories, used throughout the Americas are documented in the publication **NatureServe Conservation Status Assessments: Methodology for Assigning Ranks (Faber-Langendoen et al. 2012)** (Available here: http://www.natureserve.org/sites/default/files/publications/files/natureserveconservationstatusmethodology_jun12_0.pdf)

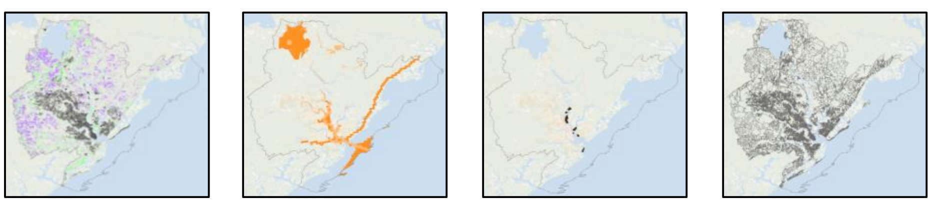
- Fish or wildlife species or populations of significant commercial value,
- Fish or wildlife-related features that confer resilience to biodiversity or human assets (such as oyster beds which have high economic significance as a fishery component and/or play a valuable role in coastal resilience by virtue of their physical structure which in many cases mitigates destructive wave action and storm surge impacts),
- Fish or wildlife populations or wildlife habitat-related features that provide unique recreational opportunities (such as Atlantic Beach and Dune habitat that provides key habitat while also providing recreational opportunities for visitors), and/or
- Iconic species that define the watershed and/or distinguish it from other geographies and represent species that have conservation support.

Elements were organized into the following broad categories: NOAA Trust Resources, At-Risk Species and Multi-species Aggregations, Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species, Fish or Wildlife-related Areas of Key Economic, Cultural or Recreational Significance, and Cross-cutting Elements.

Stressors

Current fish and wildlife stressors were identified during stakeholder workshops and available data were identified to represent each. These stressors include land use and infrastructure, roads, dredging material placement areas, and water quality (**Figure 6**). The complete list, descriptions, and data sources for fish and wildlife stressors included in this assessment are presented in Appendix 2.

The response of the fish and wildlife elements to these stressors results in a calculation of current condition as described further in the Fish and Wildlife Vulnerability Assessment section and in Appendix 2 and Appendix 3. The individual fish and wildlife element condition scores are then added together for each location to create the Fish and Wildlife Condition-Weighted Richness Index.



Land Uses | Water Quality | Dredge Materials | Roads

Figure 6. Fish and wildlife stressors used to model current habitat condition.

Fish and Wildlife Indices

The Fish and Wildlife Richness Index results from a simple overlay and sum of the number of elements occurring in each location. The method for generating the Richness Index is illustrated in **Figure 7** and was conducted using the Conservation Value Summary function in the Vista DSS.

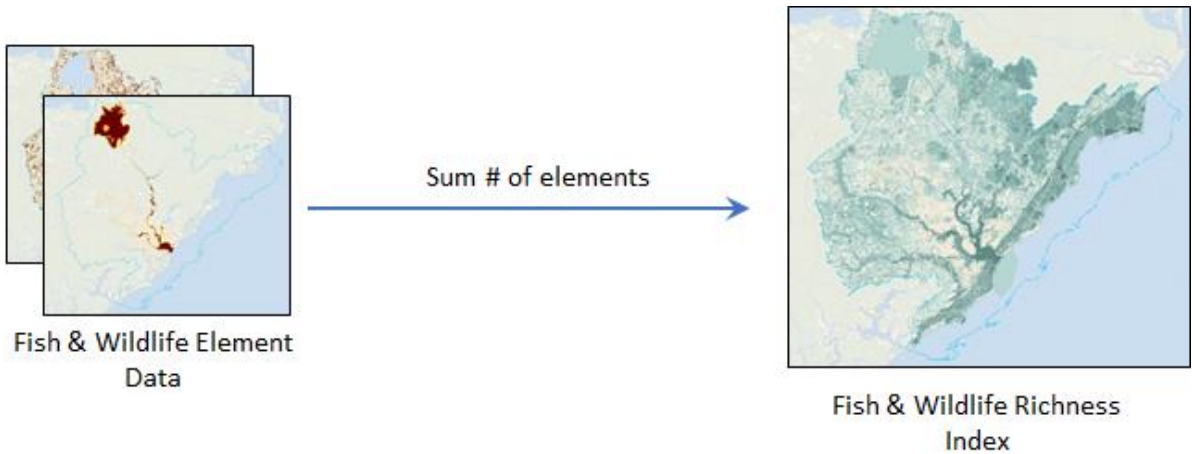


Figure 7. Method for generating the Fish and Wildlife Richness Index. *All elements are overlaid and the sum of elements occurring in a location is calculated.*

Condition-Weighted Fish and Wildlife Richness Index

The Condition Weighted Fish and Wildlife Richness Index is a sum of the condition scores for each fish and wildlife element at a location. While the richness index described above conveys the value of a location as a factor of how many fish and wildlife elements occur there, this index modifies the value to consider the current condition of the elements. Condition scores are generated as an intermediate step in a vulnerability assessment modeling process described in Appendix 4. The method is illustrated in **Figure 8.** It consists of the following steps which are further described in Appendix 2 and Appendix 3.

1. Intersect fish and wildlife elements with the fish and wildlife stressors.
2. Apply the relevant element vulnerability models (see Appendix 3 for parameters and assumptions).
3. Generate individual element condition maps.
4. Sum the condition scores of each element in each pixel to calculate the Index.

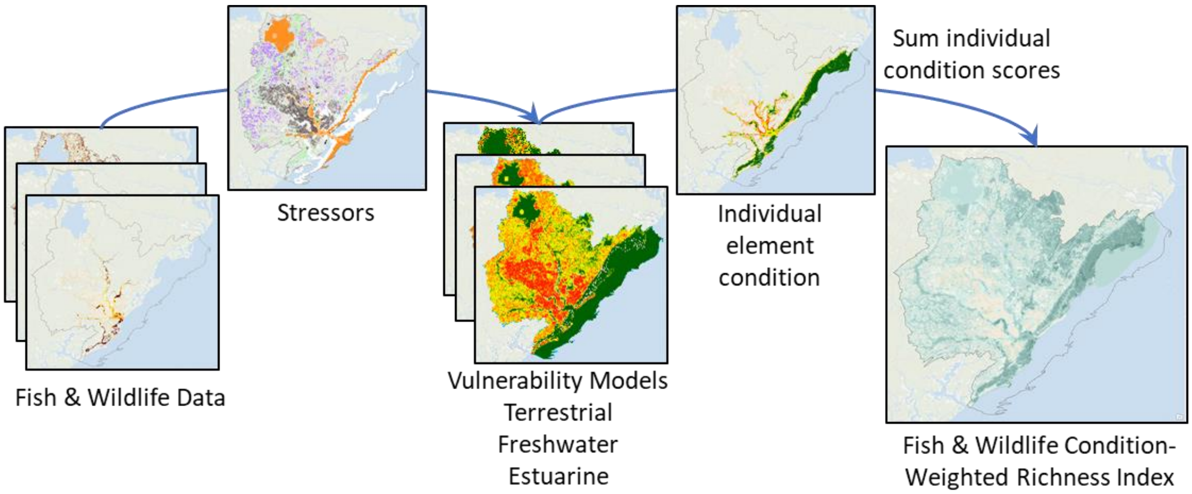
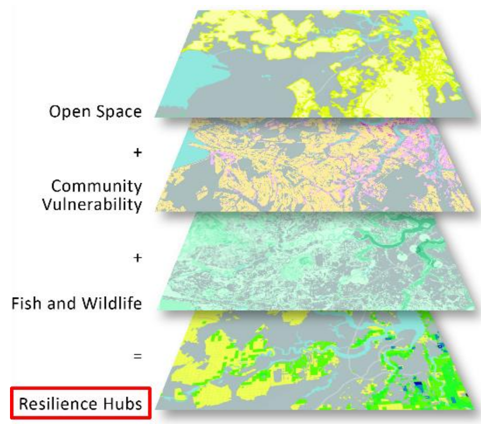


Figure 8. Method for generating the Fish and Wildlife Condition-Weighted Richness Index. *Fish and wildlife elements are intersected with stressors, the vulnerability model is applied, and individual element condition results are summed.*

Resilience Hub Characterization and Scoring



Once open space areas were delineated as described above, they were segmented into assessment units. Assessment units are approximately 100-acre subdivisions of the Resilience Hubs to facilitate scoring and understanding of how resilience values differ across the Hubs. Hubs were subdivided by first intersecting the protected areas (USGS GAP 2016) polygons; then remaining polygons larger than 100 acres were segmented by a 100-acre fishnet grid. This provided a relatively uniform size for the assessment units and, therefore, more consistency in scoring (i.e., a very large unit does not accrue a higher value than much smaller units because it contains more fish and wildlife elements as a factor of its size). The 100-acre assessment units provide a reasonable size for distinguishing differences in value across the watershed and directing those developing resilience project proposals to appropriately-sized areas.

Each assessment unit was then assigned a value (using the formula below) for their potential to provide mutual community resilience and fish and wildlife benefits. The scores range from 0.0-1.0 with 1.0 being the highest or most desirable value for the resilience objectives. The methods are illustrated by **Figure 9**.

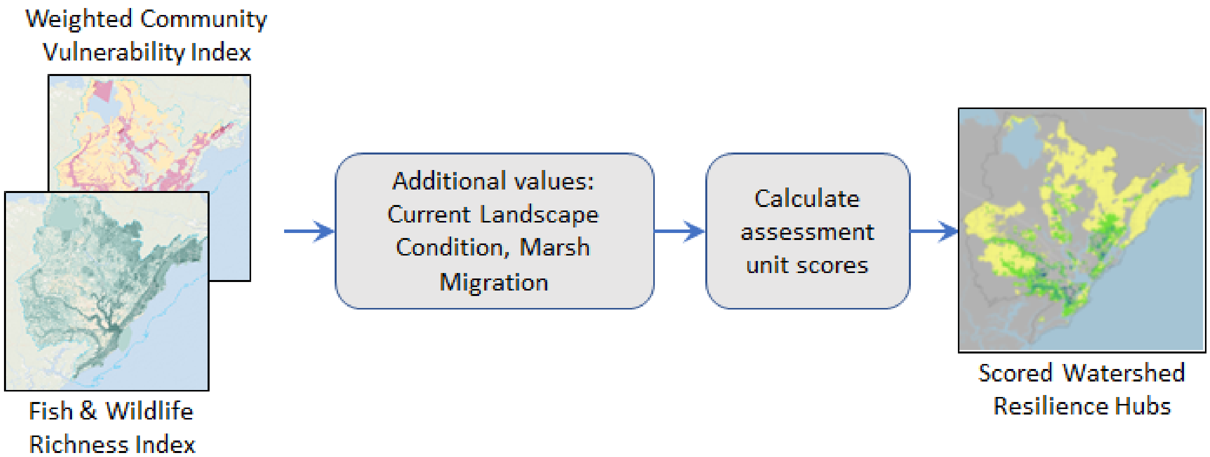


Figure 9. Method for scoring watershed Resilience Hubs. *Resilience Hub assessment units were scored based on their community resilience and fish and wildlife.*

The attributes used in the scoring, their rationale, and specific values assigned to each assessment unit are:

- **Weighted Community Vulnerability**: The weighted richness of HCAs with vulnerability to flooding threats falling within each assessment unit. This is a combination of the Community Vulnerability Index and HCA Weighted Richness Index. This attribute was used as a strong attractor of resilience projects to increase resilience to HCAs modeled to be vulnerable. The index has a value of zero if the HCA Flooding Threats Exposure Index is zero, otherwise it is the value from the HCA Weighted Richness. Focal statistics were used to summarize this combined map using a 1km radius and these results were summed to each assessment unit using zonal statistics. This is an intermediate product used only to score Resilience Hubs and therefore not depicted in the Results section.
- **Fish and Wildlife Richness Index**: The number of fish and wildlife elements falling within each assessment unit. This attribute was used to increase the value of areas that could benefit more fish and wildlife elements relative to places with fewer elements.
- **Future Marsh Migration Index**: This attribute is based on NOAA's three-foot sea level rise marsh migration models (NOAA 2018). The rationale is that areas modeled to support future marsh habitat will be able to provide ongoing fish and wildlife value with at least three-feet of sea level rise. While changes (e.g., one foot of sea level rise) may not occur until well into the future, conservation and restoration of these areas should begin now to prepare for future changes. Areas were assigned a one (1) if the assessment unit was projected to have estuarine marshes.
- **Restorability Index:** This attribute is based on the current condition as modeled from the existing fish and wildlife stressors as well as its protection status. scores the value of an assessment unit based on the average.
    - The protected areas assessment units are of interest for ***restoration*** to improve the viability of elements within them (as they are already protected from conversion to more intensive uses). Therefore, they were scored as:

        - 1 (high priority) if the elements are in moderate condition (score > 0.3 and < 0.7) and can be improved through significant restoration action,
        - 0.5 (medium priority) if the elements are currently in good condition (score > 0.7), requiring no to little restoration, or
        - 0 (low priority) for low condition (score < 0.3), considered to have lower prospects/higher cost for successful restoration.
    - Private open space areas would benefit from both conservation and restoration and/or protection. Therefore, they were scored as:
        - 1 (high priority) for all moderate to good conditions (score > 0.3), or
        - 0 (low priority) for low condition (score < 0.3), considered to have lower prospects/higher cost for successful restoration and would hold little conservation value.

A final score was calculated for each hub using the above indices. A higher score indicates a higher value. The algorithm used to combine the indices values is:

$$((C/\max(C)) * 4) + (((F/\max(F)) + M) * R)$$

Where: *C* is the Weighted Community Vulnerability
F is the Fish and Wildlife Richness Index
M is the Future Marsh Migration Index and
R is the Restorability Index

The score multipliers in the algorithm emphasize the relative importance of vulnerable HCAs in/near the hub assessment units and restorability of habitat. While the scoring emphasized the objectives of this Targeted Watershed Assessment, the component values from the indices in the assessment units are contained in the Resilience Hubs GIS map and can be used to support other objectives. For example, those most interested in protecting HCAs will be interested in hub areas with highest community vulnerability scores. Similarly, those most interested in fish and wildlife conservation and restoration can likewise find areas to support that objective.

Resilience Projects

Location data and descriptive information about resilience project plans and ideas were gathered from stakeholders (see Stakeholder and Partner Engagement methods and Appendix 1). It is hoped that this list of projects can help match conservation and resilience need to appropriate funding sources and interested implementers. While an extensive outreach effort was conducted to identify relevant projects, it is possible that, at the time of this assessment, additional relevant project plans and ideas existed but were not submitted or otherwise brought to the attention of the project team.

The submitted projects were reviewed for relevance to the assessment objectives, focusing on their ability to provide mutual benefits for community resilience and fish and wildlife. Relevant projects with sufficient ancillary information—including their location and geographic extent—were retained for further evaluation and consideration. Each project was evaluated for the following attributes.

- Calculated size in acres: The size in acres of the polygon representing the project area. Alternatively, submitters could enter an estimated size if project boundaries had not been developed.
- Alignment with NOAA's mission, programs, and priorities
- Alignment with USACE's mission, programs, and priorities
- Addressing stressors and threats mapped in the project polygon
- Project addresses the main threats: Assessed by comparing the list of threats to the proposed actions of the project
- Project proximity to a resilience hub: A Yes/No indicator for whether the project falls within one kilometer (0.62 miles) of any Resilience Hub
- Community Vulnerability Index: The average value of the regional Community Vulnerability Index for the project polygon
- Number of HCAs found within the project polygon
- List of the HCAs mapped within the project polygon
- Number and percentage of the HCAs within the project polygon that are designated non-viable in the Coastal Threats scenario evaluation
- Number of fish and wildlife elements found within the project polygon
- List of the fish and wildlife elements mapped within the project polygon
- Number and percentage of the fish and wildlife elements vulnerable to flooding threats

This information was used to select a subset of projects for site visits and case studies (see Results section). The complete list of projects submitted is presented in Appendix 7.

Site Visits

Five projects were selected for site visits of which three were developed into the case studies found in the Results section. A spreadsheet containing information on all projects provided by the proponents and corresponding indices calculated using the above steps was provided to NFWF. The Technical and Steering Committees analyzed the project information to identify projects most appropriate for site visits. Once selected, site visits were scheduled with project proponents. Watershed and Technical Committee members were invited to participate.

Site visits were conducted by representatives from NOAA, NFWF, and NatureServe. For each site visit, the assessment team spent two to four hours taking photos and compiling answers to a set of questions meant to increase understanding of the project's potential benefits and implementation challenges. Information gathered from the site visits was used to select three projects to be used as the focus for detailed case studies (see Case Studies section below).

Results

This section portrays the key set of products primarily focused on the resulting Resilience Hubs and key indices. Many map and tabular products were generated for this Targeted Watershed Assessment. In addition to this report, key results may be viewed in the Coastal Resilience Evaluation and Siting Tool (CREST), which is an interactive online mapping tool that includes results for the Regional Assessment and each of the eight Targeted Watersheds (available at resilientcoasts.org). CREST can also be used to download data including the Charleston Harbor Watershed NatureServe Vista decision support project, which includes the input data and useful intermediate products that can be updated and customized. Prior to using these results for any decisions, please see the limitations described in the Conclusions section.

Flooding Threats

The effects of the flooding threats on the vulnerability of Human Community Assets (HCAs) and fish and wildlife elements are treated individually in the assessment model (see Appendix 2); therefore, a separate threats index was not generated. An analog to a threats index can be found in Appendix 2, which contains the results of four models of how wildlife stressors and flooding threats may cumulatively impact the condition of HCAs, terrestrial wildlife, freshwater fish and wildlife, and estuarine fish and wildlife. The Threat Index generated in the Regional Assessment is provided below (**Figure 10**) to illustrate the accumulation of flooding threats across the Charleston Harbor Watershed. The Threats Index used in the Regional Assessment is a combination of the number and probability of occurrence of the flooding threats in each location (see Dobson et al. 2019 for more information).

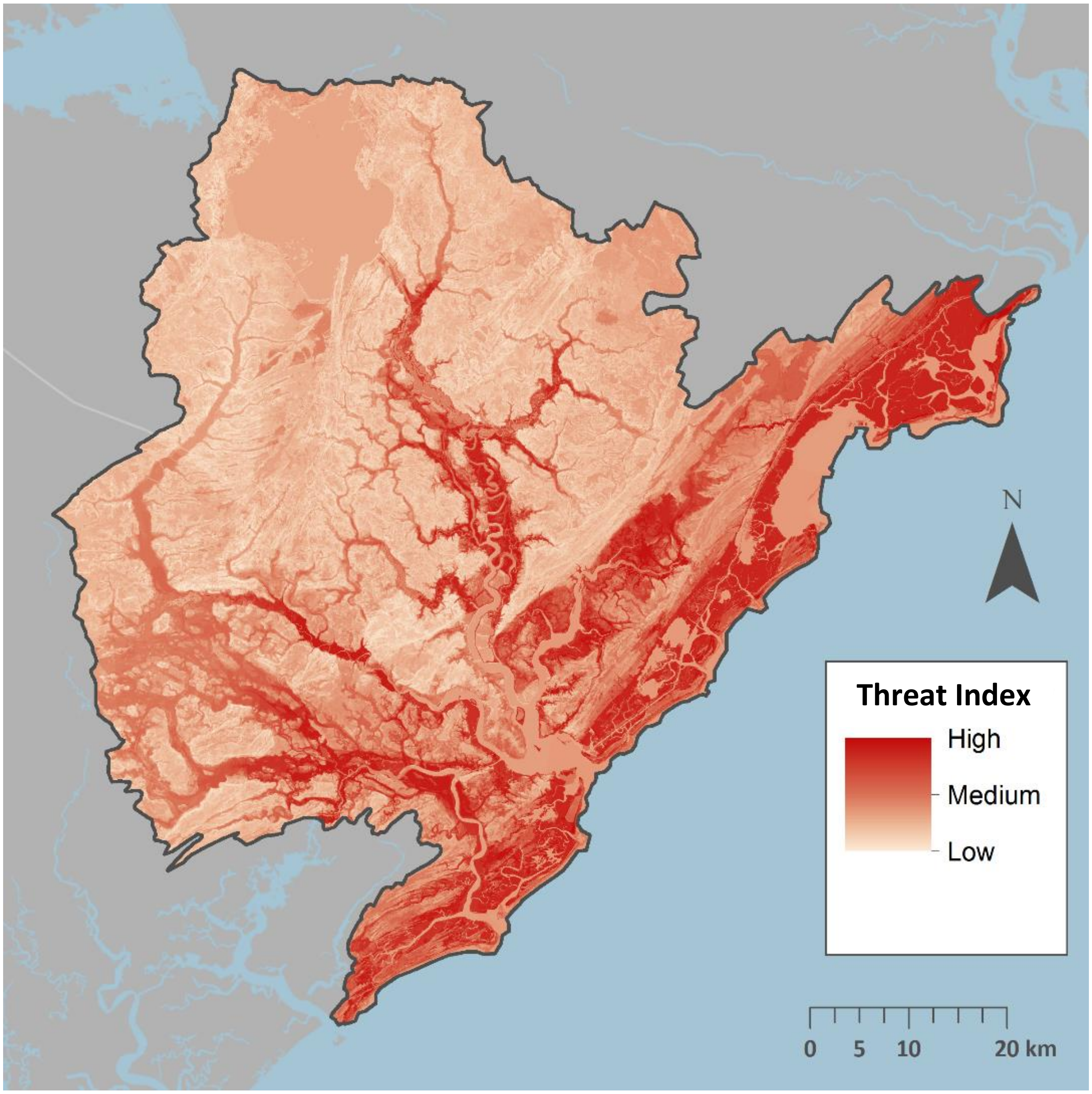


Figure 10. Weighted Threat Index for the Charleston Harbor Watershed. *Map shows the number of overlapping threats modified by a weighting based on their probability of occurrence.*

Suggested Uses

Understanding which threats occur in a location can inform whether action needs to be taken, whether proposed actions can mitigate all threats anticipated for an area, and what measures would be most appropriate to mitigate threats if mitigation is even feasible.

Human Community Assets

HCA Weighted Richness Index

This index indicates areas of HCA concentrations (**Figure 11**). Darker shades can be an indication of overlapping HCAs, higher or lower importance weightings, or both.

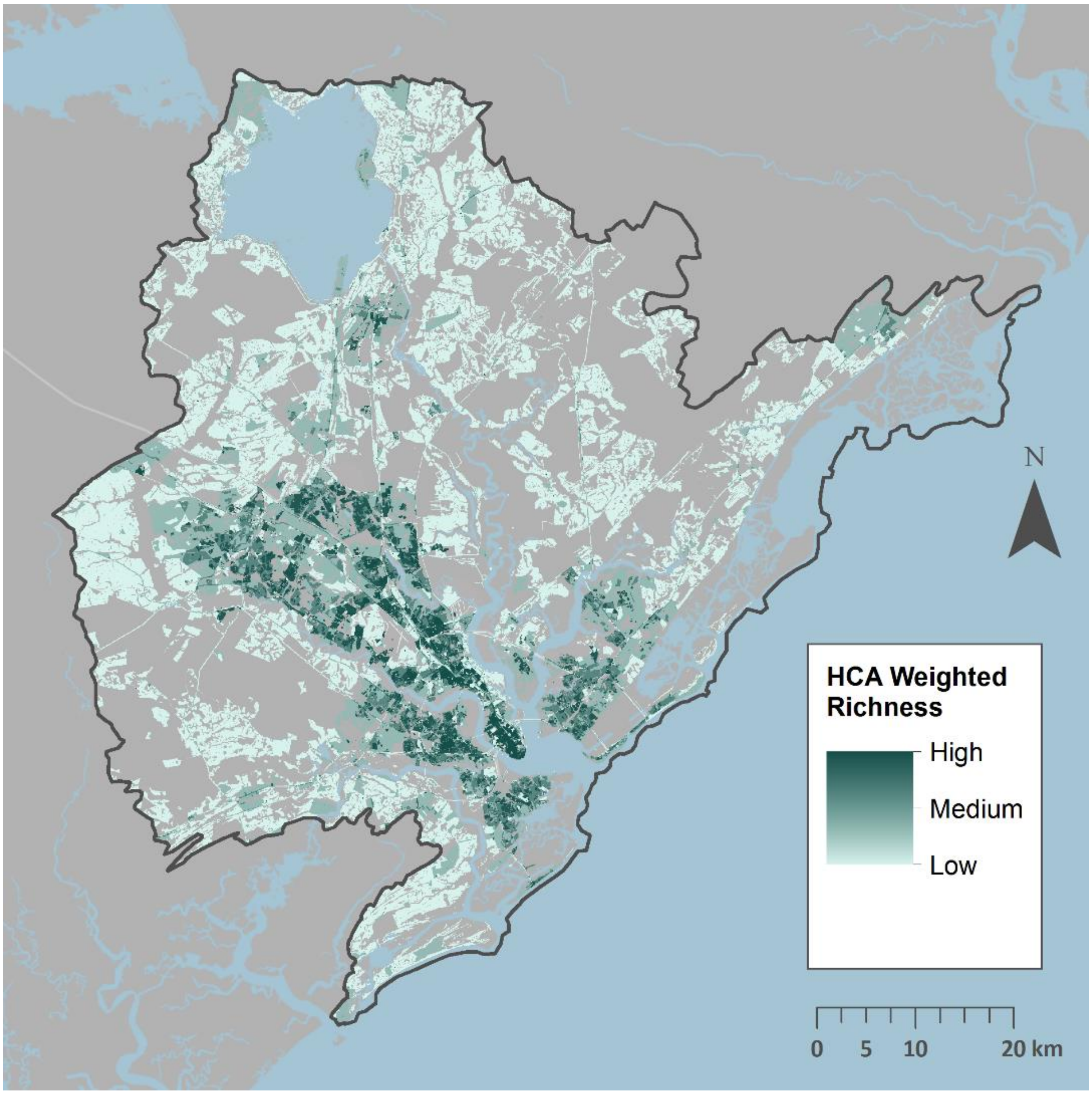


Figure 11. Human Community Asset (HCA) Weighted Richness Index for the Charleston Harbor Watershed. *Darker shades indicate higher value based on the number and importance weightings of HCAs in each location. Gray areas within the project boundary represent areas with no mapped HCAs.*

Community Vulnerability Index

This assessment evaluated the vulnerability of the HCAs to flooding threats. The score of any location in the index is based on the number of vulnerable HCAs at that location (**Figure 12**).

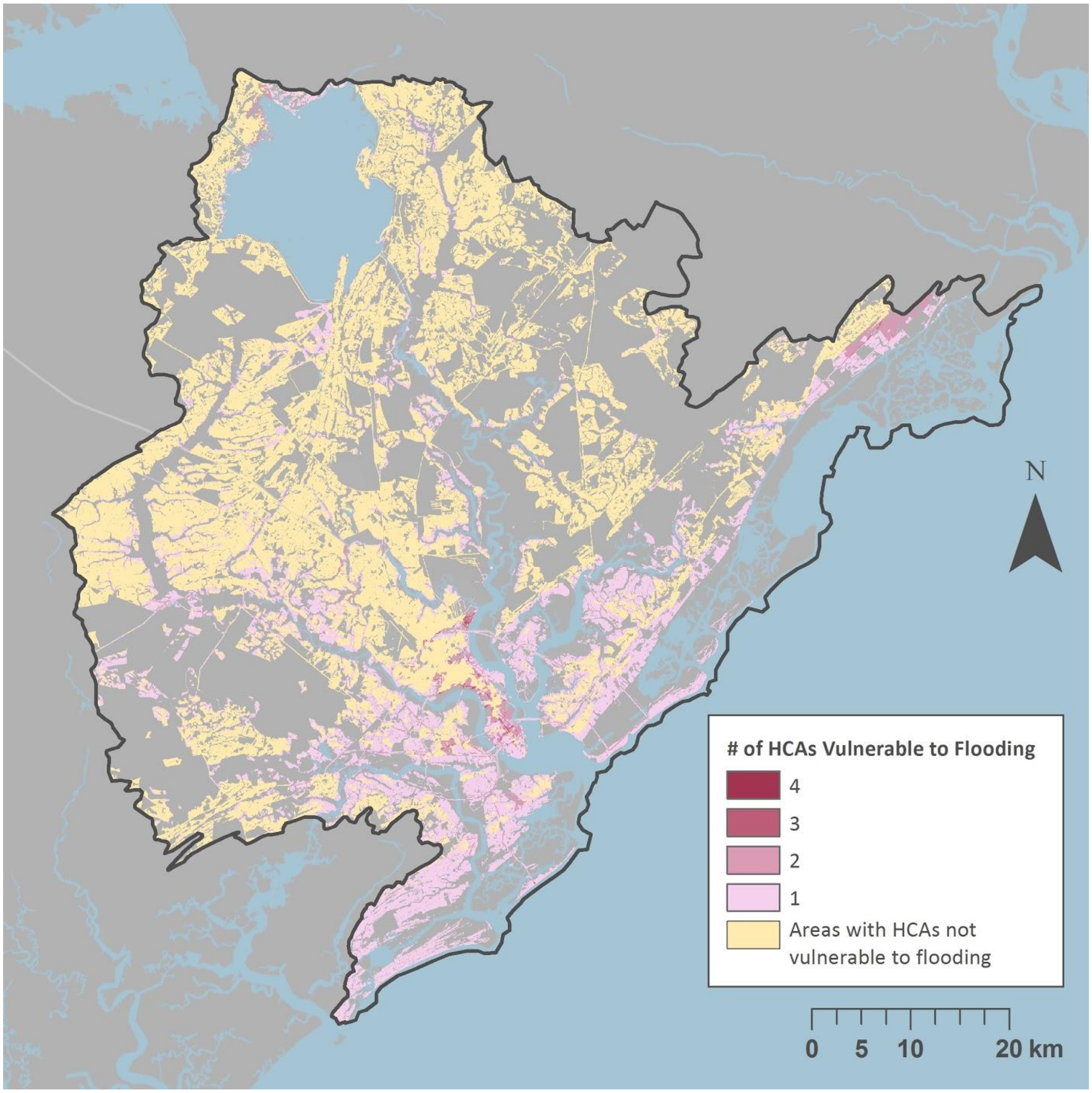


Figure 12. Community Vulnerability Index for the Charleston Harbor Watershed. *Pink to red shades indicate the number of Human Community Assets (HCAs) exposed to flooding related threats. Tan areas indicate areas of low to no impact from the flooding threats. Gray within the project boundary represents areas with no mapped HCAs.*

Vulnerability is highest in the immediate coastal areas where there are concentrations of HCAs exposed to the largest number of overlapping threats. Areas of vulnerability farther inland are largely due to precipitation-caused flooding threats (flood zones and flat areas with poorly draining soils). The Charleston peninsula is a hot spot of vulnerability based on the high concentration of HCAs and the large number of overlapping flooding threats to which they are exposed. Smaller communities such as McClellanville, northeast from Charleston along the coast, also represents local concentrations of vulnerable HCAs. This result is validated by McClellanville's history of hurricane effects, especially the high-level of impact to the community from Hurricane Hugo in 1989. The coast along this watershed contains extensive beaches and wetlands that currently provide some buffering from storms; however, the adjacency of the Intracoastal Waterway may introduce additional challenges to mitigating flooding threats. Building beaches and wetlands may provide a resilience-building opportunity.

Suggested Uses

The HCA Weighted Richness Index can focus planning efforts by directing planners to the areas with concentrations of highest weighted assets or those most important to rebuilding or responding to threats. The Community Vulnerability Index communicates threat to human community assets wherever they occur as well as concentrated areas of threat. Therefore, it can support the intended objectives of siting and designing resilience projects to reduce threats to HCAs. It can also support coastal hazard/emergency management and land use planning to proactively address risks by understanding threatened assets, areas, and types of threats.

Fish and Wildlife Value Indices

Fish and wildlife indices are overlays or combinations of the fish and wildlife elements intended to express value based on where the elements are mapped.

Richness of Fish and Wildlife Elements

This index (**Figure 13**) represents the number of elements that overlap in any location. It conveys value through the concept that areas with more elements (darker green shades) will provide more opportunities for conserving/restoring fish and wildlife than areas with a low number of elements (lighter green shades).

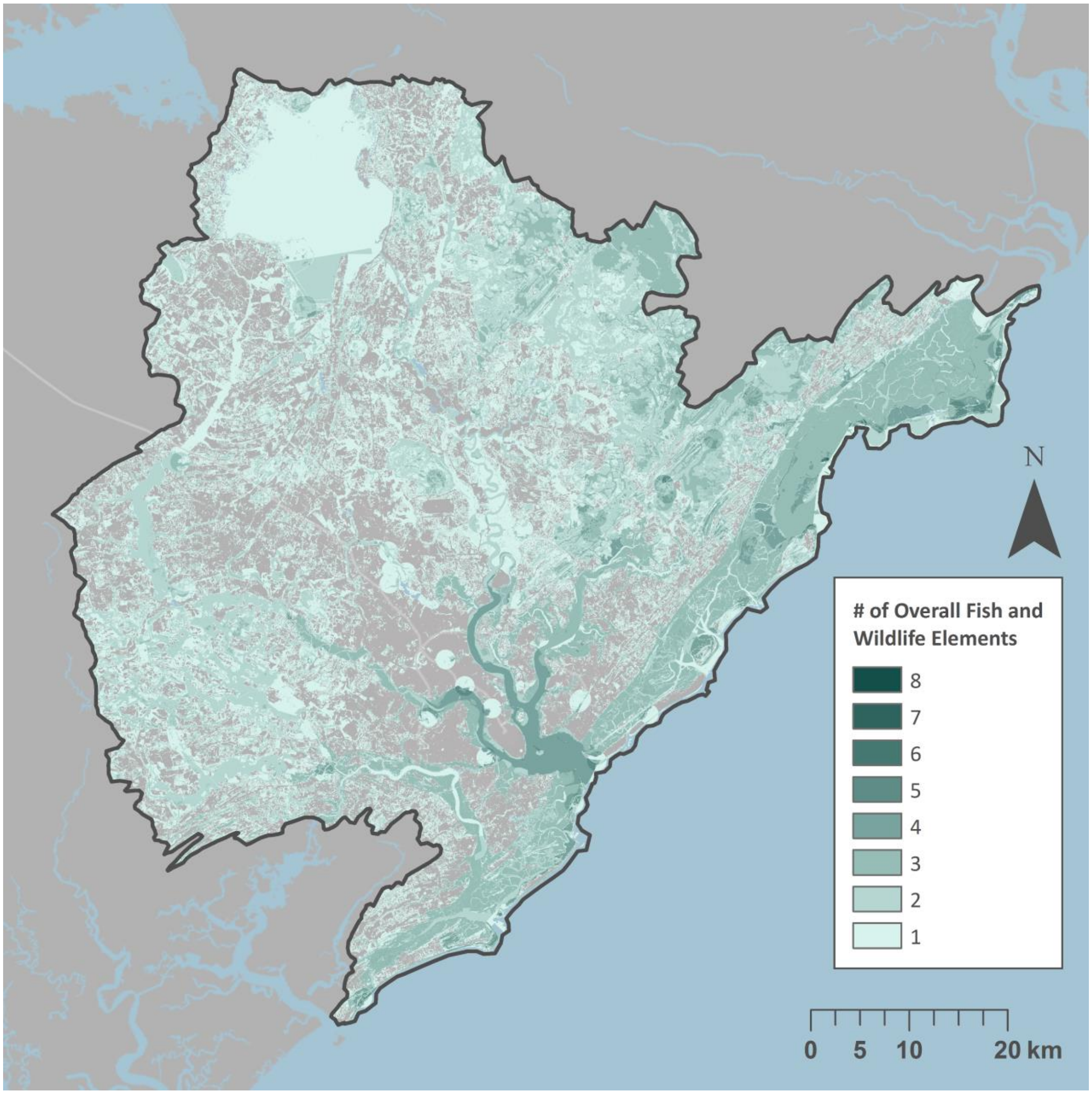


Figure 13. Richness of fish and wildlife elements in the Charleston Harbor Watershed. *Green shades indicate the number of elements found in a location. Gray areas within the project boundary have no mapped fish and wildlife elements considered in this assessment.*

Condition-weighted Richness of Fish and Wildlife Elements

The Fish and Wildlife Condition-weighted Richness Index (**Figure 14**) modifies the richness map above by incorporating the modeled condition of elements that overlap in any location. This analysis used a sum of the condition scores of all elements overlapping in a pixel. It conveys value through the concept that areas with more elements of higher condition are important to conserve, while areas with moderate scores may provide opportunities for restoration. Areas of low scores either have few elements or the elements present are in poor condition and therefore, may not represent the highest priorities for future projects with a goal of maximizing fish and wildlife benefits.

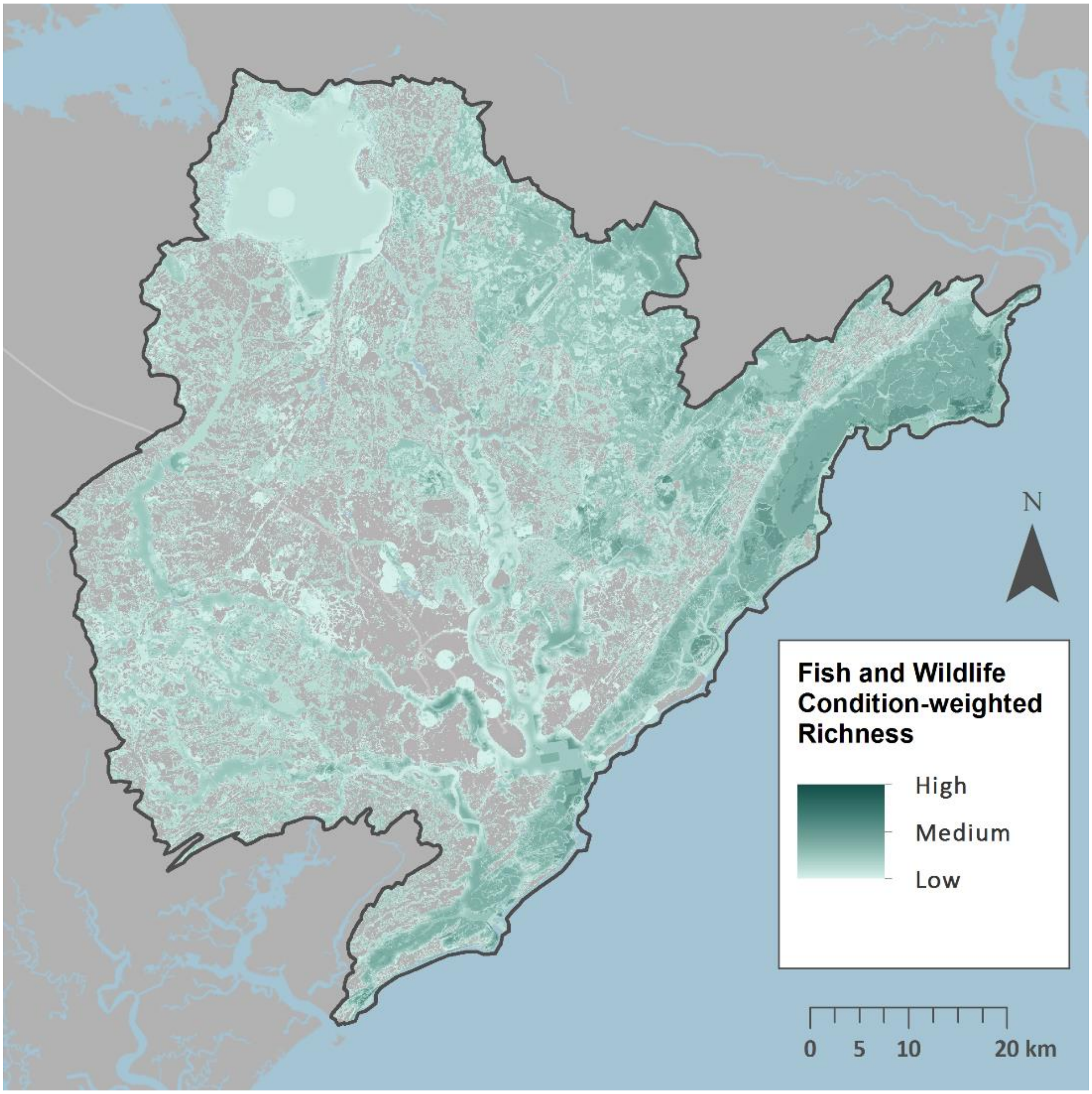


Figure 14. Fish and Wildlife Condition-weighted Richness Index results for the Charleston Harbor Watershed*. Green shades indicate the added condition scores of the elements found in a location, with a maximum value of one per element. Grey areas within the project boundary signify areas with no mapped fish and wildlife elements.*

Richness and condition are currently highest in the immediate coastal areas and in the Francis Marion National Forest that occupies a large portion of the northeastern side of the study area. When viewed at the full extent of the watershed, the differences between the richness and condition-weighted richness indices appear subtle, but significant differences can be seen in the harbor and in the rivers around Charleston where the water quality data and/or modeled water quality data reduce the condition-weighted richness index value (**Figure 14**) compared to the richness index (**Figure 13**). While in the Francis Marion National Forest, the richness index shows moderate value due to having fewer mapped fish and wildlife elements, the condition-weighted richness index shows higher values due to the higher modeled condition of the elements.

Suggested Uses

The primary use of these indices, besides informing the scoring of Hubs and resilience project attributes, is to support fish and wildlife conservation decisions (subject to the limitation that these indices only apply to the elements selected for this assessment). Richness informs areas to target larger numbers of elements. Conversely, the condition-weighted index adds information as to whether a location is amenable to simple protection efforts because it is already in good condition, or if a location may benefit from restoration because its condition and/or function is impaired or less than pristine.

Resilience Hubs

Resilience Hubs are areas of opportunity for conservation actions, such as resilience projects, that have the potential for providing mutual benefits for HCAs and fish and wildlife elements.

The Hubs incorporate community vulnerability and wildlife value, and therefore, they can be an important input to planning for more resilient land use, emergency management, and green infrastructure. As an integrative product, the Resilience Hubs also serve as a vehicle for collaborative planning and action among different agencies and/organizations. Such collaborative approaches can leverage multiple resources to achieve more objectives with significantly greater benefits than uncoordinated actions.

Resilience Hubs are based on undeveloped open spaces of protected or unprotected privately owned lands and waters (**Figure 15**) that are in proximity to concentrations of vulnerable HCAs. These open space areas were segmented into distinct Resilience Hubs based on the Regional Assessment (Dobson et al. 2019). For this Targeted Watershed Assessment, Hubs were further segmented into assessment units (100-acre areas) and scored as explained in the Methods Overview. Scores convey value based on project objectives for siting resilience projects with mutual benefits for HCAs and fish and wildlife. Scoring the assessment units is important because value is not uniform across a Hub; it changes based on proximity to vulnerable HCAs and richness of fish and wildlife elements.

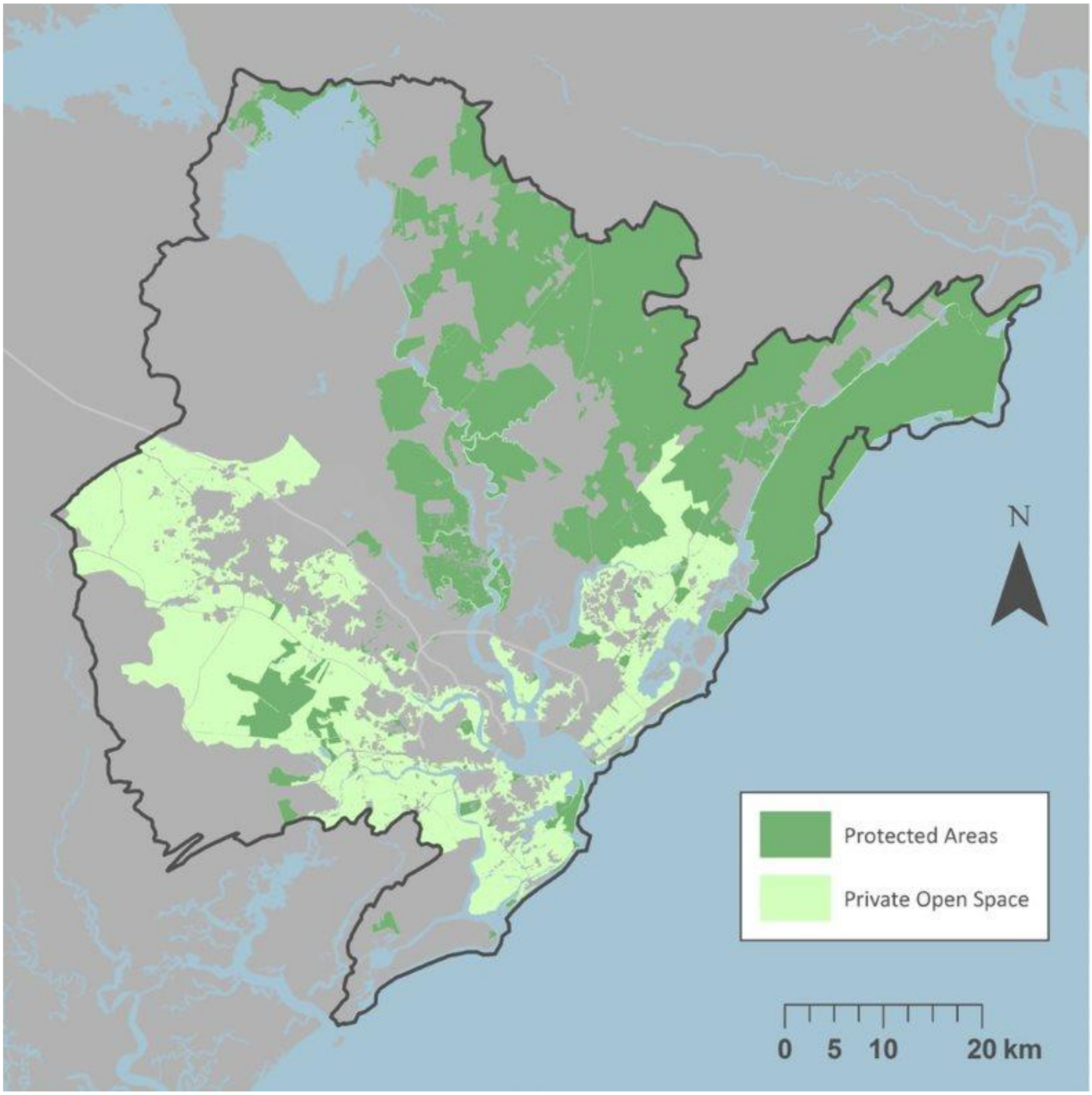


Figure 15. Undeveloped protected areas and unprotected privately owned areas of open space in the Charleston Harbor Watershed. *Map displays the distribution these areas within Resilience Hubs identified in the study area and therefore does not include all such areas within the study area.*

By design, Resilience Hubs occur where concentrations of vulnerable HCAs are proximate to open space areas. The size of a Hub does not equate to importance and instead is a factor of available open space near HCA concentrations (see **Figure 16** with assessment unit scoring). Identifying which portions of Hubs are already protected determines what actions may be most suitable. Expanding, restoring the condition of, or increasing connectivity between protected areas can increase resilience in these areas. Unprotected sites, if in good condition, may only need added protection to ensure long-term resilience benefits. In places where conditions are impaired, restoration is often the most appropriate path to increase resilience.

Resilience Hubs Assessment Unit Scores

The scoring of the assessment units of the Resilience Hubs, as described in the Methods Overview, was intended to convey the differing values for providing resilience and fish and wildlife benefits within the Hubs. In total, 10,567 assessment units were analyzed and scored within the Charleston Harbor Watershed. Highest scoring assessment units, in dark blue, are located nearest concentrations of vulnerable HCAs, whereas areas that have little benefit to human community resilience or benefit to fish and wildlife are in yellow (**Figure 16**).

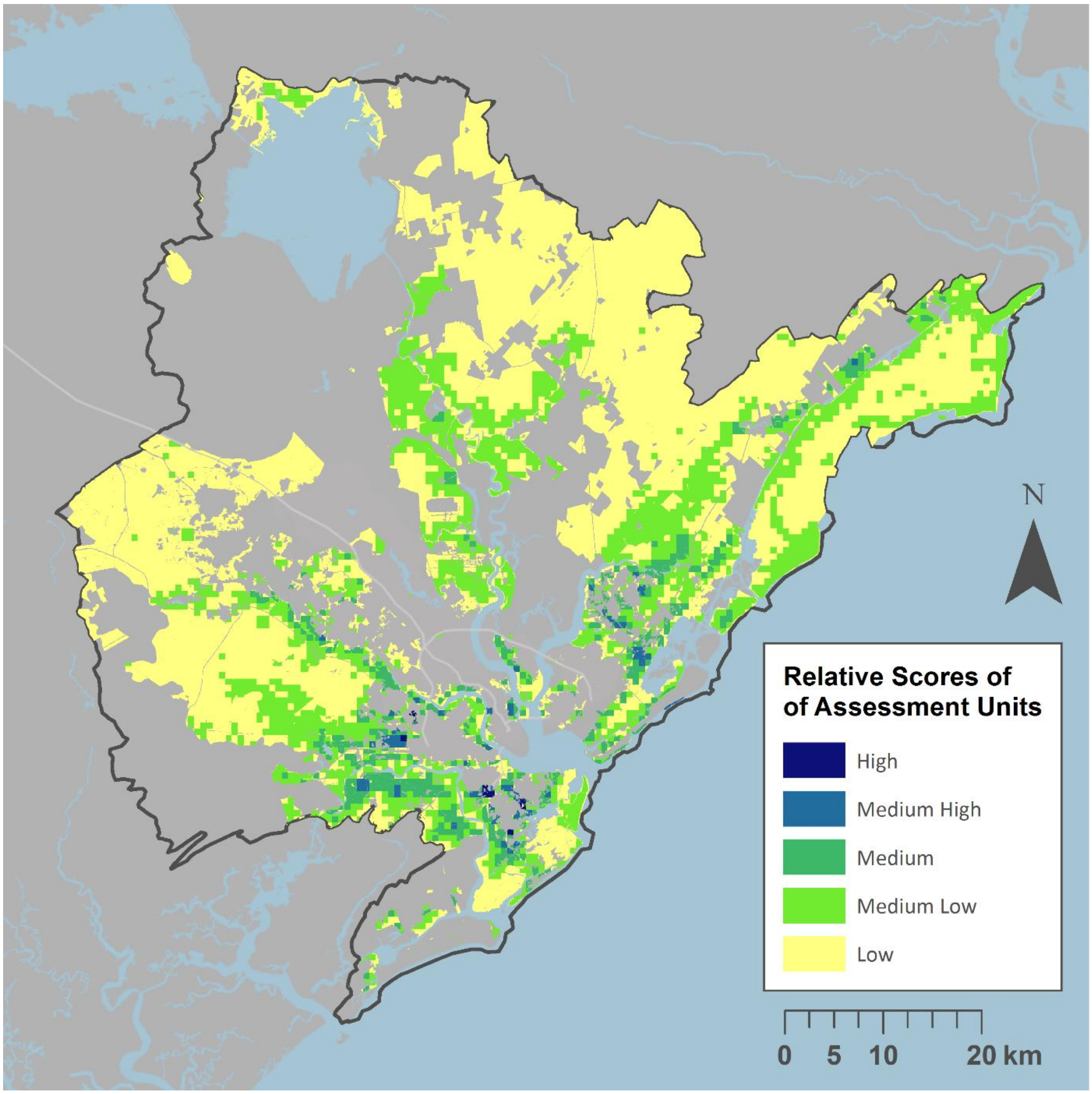


Figure 16. Resilience Hubs assessment unit relative scores for the Charleston Harbor Watershed*. Assessment units are 100-acre grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieve both community resilience and fish and wildlife benefits. Gray areas are outside of Hubs.*

The highest scoring portions of the Resilience Hubs cluster in and around the greater Charleston metro area where there are concentrations of vulnerable HCAs. There are notable exceptions; for example, the beach and dune strip on Isle of Palms (due east of the harbor mouth) contains one of the smallest Hubs, but one of the highest scoring because it offers protection to the adjacent community, contains valuable habitat (including future habitat under SLR), and is subject to nearly all of the flooding threats analyzed. Its moderate to low condition score and lack of protected status make it a good candidate for securing protection and conducting restoration to address the many paths that cut through the dunes. Three high scoring areas of Resilience Hubs are featured below and are associated with the case study resilience projects.

Suggested Uses

The Resilience Hubs map for the Charleston Harbor Watershed incorporate many of the key analyses described herein and therefore can inform many uses. The most direct use, as described in the project objectives, is to inform design and siting of, and investment in, resilience projects in areas where they can contribute to community resilience and benefit fish and wildlife. In addition to siting or evaluating the potential benefits of projects, decisions about what type of actions would be most appropriate given the community context, fish and wildlife present, and threats can be supported. This can be done by reviewing the scoring attributes found in the Hubs GIS map, and/or viewing the map in the context of other outputs such as the Community Vulnerability Index. While the scoring emphasizes areas providing mutual benefits, the individual inputs can assist users in identifying areas of value based on other objectives, such as focusing only on community resilience needs or areas that maximize fish and wildlife benefits.

Resilience Hubs Example Areas

Three of the highest scoring areas of the Resilience Hubs are characterized below to illustrate how the assessment identified potentially valuable places for resilience projects. Note that these results were provided to illustrate how the model scores a location and are not field validated. Additionally, they do not attempt to suggest specific actions that should be taken to increase resilience.

Long Branch Creek Resilience Hub Area Example

This hub area scored highly for resilience potential because as a densely populated area located within a tidal marsh, the location has the potential to benefit both human assets and fish and wildlife (**Figure 17**). Furthermore, sine this area was modeled to be a site for marsh migration, it is likely to retain at least a portion of these benefits under a three-foot sea level rise scenario. This hub is already in good condition as modeled under current fish and wildlife stressors, but condition would likely improve further with the hydrologic flow restoration work proposed in the Long Branch Creek resilience project (see case studies section). In addition, this site could benefit from additional protection through land acquisition or easement acquisition since it is not currently protected. Many of the actions proposed in the Long Branch Creek case study have the potential to help address flooding threats (storm surge, future sea level rise, and/or high rainfall events), while also improving habitat for key fish and wildlife species (see Long Branch Creek case study featured in this report for more information).

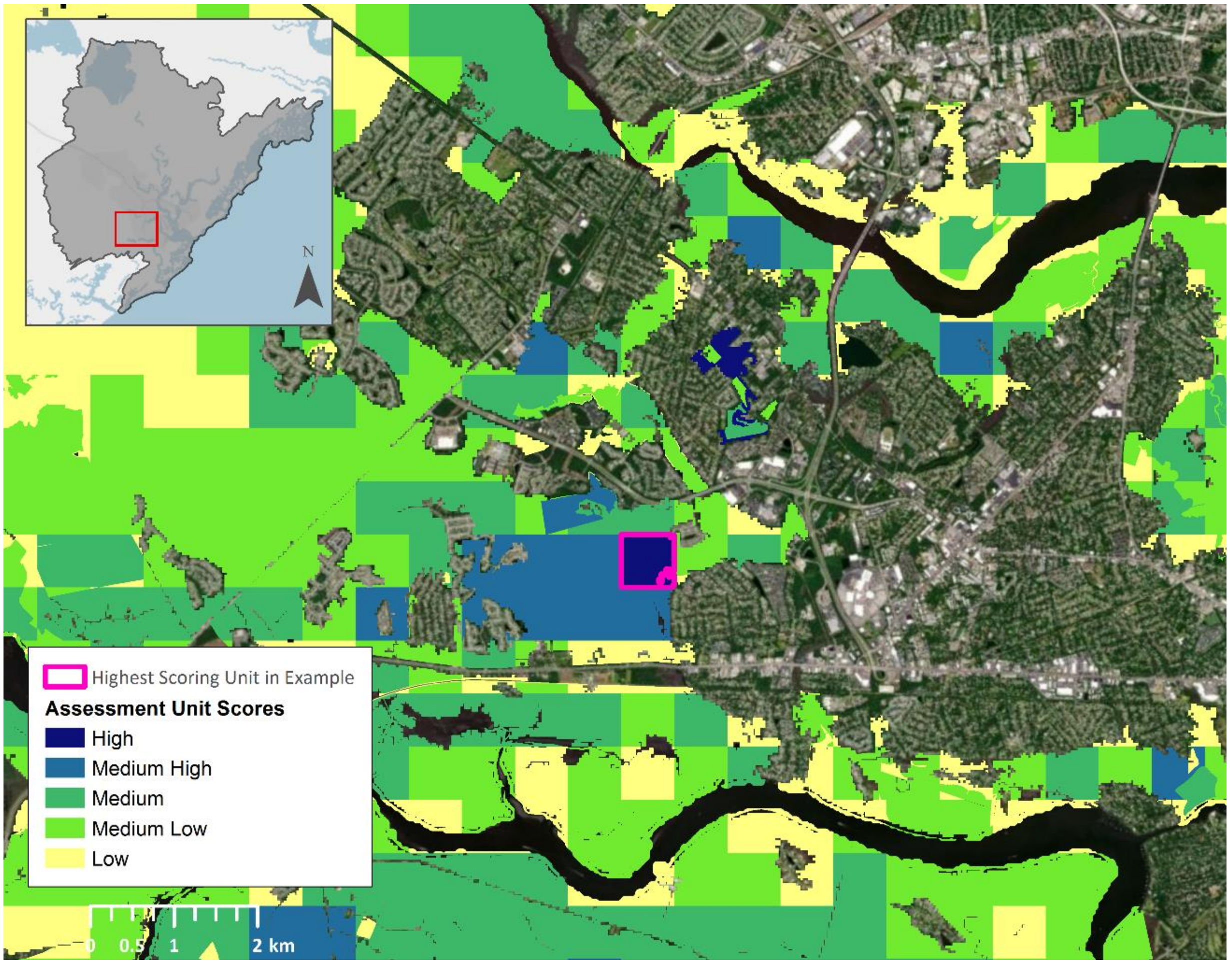


***Figure 17**. **Long Branch Creek Resilience Hub area example.** The yellow-blue shaded areas are the scored Resilience Hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Forested Wetlands (non-tidal)
- Open Pine
- Interior Live Oak Maritime Forest
- Freshwater Emergent Wetlands
- Marsh and Fish Habitat
- Snapper Grouper Essential Fish Habitat
- Tidal Swamp

HCA elements in or near assessment unit:

- Critical Infrastructure Rank 1 (Glen McConnell Parkway)
- Population Density Ranks 2, 3, 4, and 5. Especially Rank 2.

Table 3. Attributes used to calculate the final score for the Long Branch Creek Resilience Hub assessment unit example*. The values for each scoring attribute and the final score correspond to the hub assessment unit outlined in pink in* ***Figure 17****. See the Methods section for additional details on each scoring attribute.*

Description of Scoring Attributes	Score
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	8
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with 1 meaning high vulnerability. SD 0.09, Mean 0.04)	0.83 (very high)
Restorability Index	1 (good candidate for protection)
Average Condition (1= current very high condition)	0.67 (moderate)
Final score	**5.0 (rank #4 out of 10,567 units)**

James Island Resilience Hub Area Example

James Island is a large, low-lying, densely populated island to the south of the Charleston peninsula. The hub is a priority because its location is near areas of high population density and high priority fish and wildlife habitats downstream (such as oyster reefs and tidal marsh that support nursery habitat for important fish and shellfish species). Therefore, any work in this hub has the potential to benefit both human assets and fish and wildlife. This hub is in relatively poor current condition as modeled under current fish and wildlife stressors, so nature-based resilience projects could help improve the condition through improved water quality and tidal flow. In addition, this hub site could benefit from additional protection through land acquisition or easement acquisition since it is not currently protected.

The resilience hub assessment units near the Sea Island resilience project case study (**Figure 18**) scored very highly due to fish and wildlife richness, marsh migration areas, human asset vulnerability, and restorability. Within the case study footprint, a channelized ditch/creek flows into a tidal marsh, all surrounded by housing, parkland, a community center, and other key features. The ditch/channelized creek is the focus of the case study since changes in the creek that would widen the channel could reduce upstream flooding to the park and adjacent houses, in addition to improving water quality downstream as the freshwater hits tidal brackish marsh.

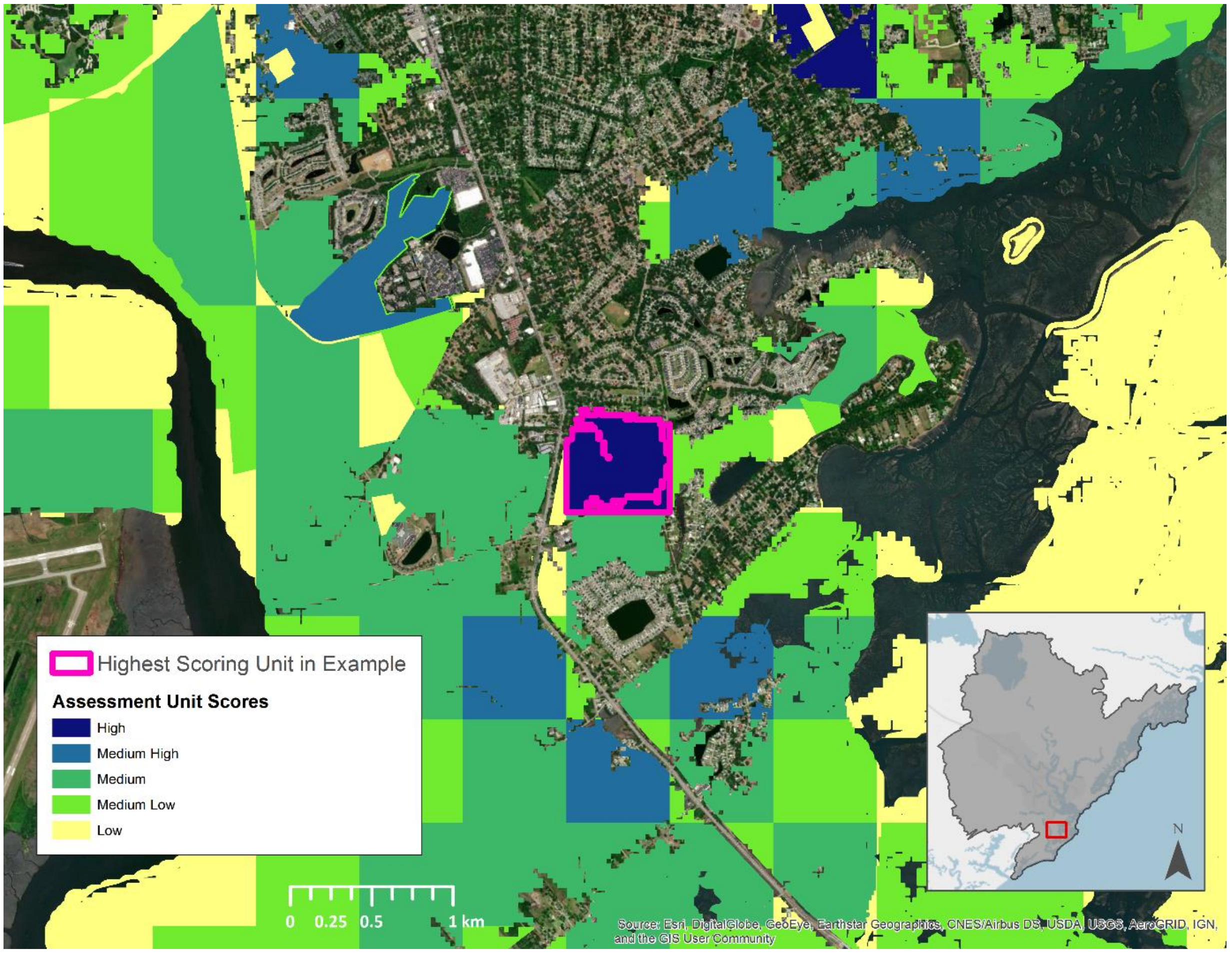


Figure 18. James Island Wetland Restoration Hub area example. *The yellow-blue shaded areas are the scored resilience hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Forested Wetlands (non-tidal)
- Interior Live Oak Maritime Forest
- Marsh and Tidal Creek (including open water)
- Tidal Swamp
- Wading Bird and Ally Colonies

HCA elements in or near assessment unit:

- Highway 171 near Riverland
- Population Density Ranks 1, 2, 3, 4, and 5.

Table 4. Attributes used to calculate the final score for the James Island Wetland Restoration Resilience Hub assessment unit example. *The values for each scoring attribute and the final score correspond to the hub assessment unit outlined in pink in Figure 18. See the Methods section for additional details on each scoring attribute.*

Description of Scoring Attributes	Score
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	5
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with 1 meaning high vulnerability. SD 0.09, Mean 0.04)	1.0 (very high)
Restorability Index	1 (highly restorable)
Average Condition (1= current very high condition)	0.69 (moderately high)
Final score	**5.4 (rank #1 out of 10,567 units)**

West Ashley Resilience Hub Area Example

West Ashley is a densely populated area just to the west of the Charleston peninsula (on the opposite bank of the Ashley River; **Figure 19**). Much of this area is low-lying and adjacent to tidal marshes and/or tidal river areas. The example hub assessment unit in this area scored highly (Oyster Beds and Reef) because it is near key human community assets and high priority fish and wildlife habitats (in particular tidal marsh, oyster reefs, and essential fish habitat for shrimp, snapper and grouper). This hub is in relatively poor current condition as modeled under current fish and wildlife stressors, so nature-based resilience projects could help improve the condition through restoration of key habitats. Given that most of the overall hub is unprotected, land acquisition and/or the establishment of one or more easements would likely be effective actions for increasing resilience.

This area is adjacent to several locations that are part of a proposed Crab Traps to Oyster Reefs project (one of our three resilience projects described in the Case Studies section of this report). In that project, the repurposed crab traps would be installed in the tidal area offshore of West Ashley and would serve as habitat for oysters—potentially helping reduce wave action that can erode banks near high population areas (see Case Study 2: Crab Traps to Oyster Reefs for more information).

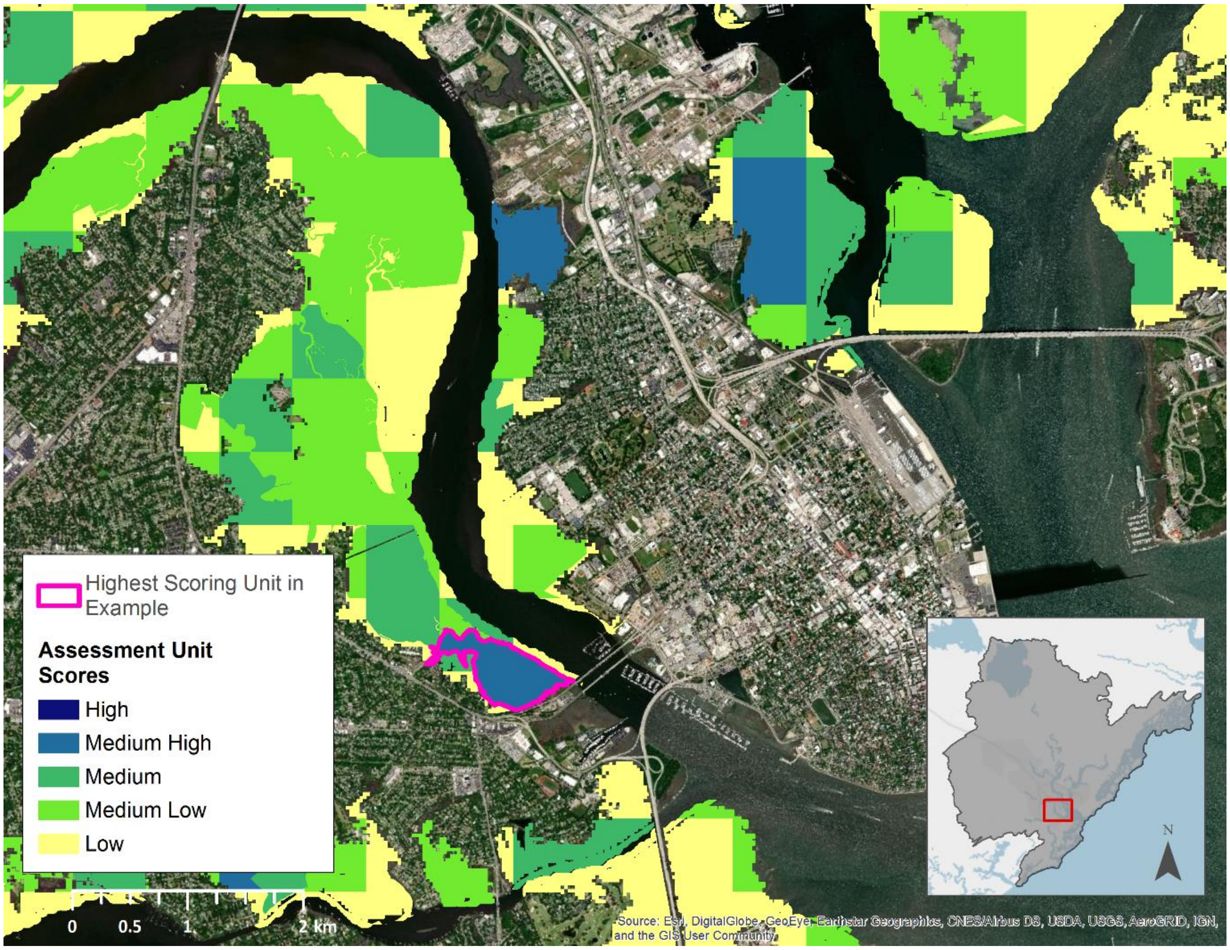


Figure 19. Assessment units in and around the West Ashley Resilience Hub. *The yellow-blue shaded areas are the scored resilience hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- G1-G3 or S1-S3 but not Threatened and Endangered Terrestrial
- Interior Live Oak Maritime Forest
- Important Riverine Systems
- Diadromous Fish Habitat
- Marsh and Tidal Creek (including open water)
- Shrimp Essential Fish Habitat
- Snapper Grouper Essential Fish Habitat
- Tidal Swamp
- Oyster Beds and Reefs

HCA elements in or near assessment unit:

- Critical Infrastructure (Savannah Hwy, St Andrews Blvd, Ashley River Memorial Bridge)
- Critical Facilities (Blessed Sacrament School, St. Andrew's School of Math and Science)

- Environmental Justice Area
- Pop Dens Ranks 2, 3, 4, 5

Table 5. Attributes used to calculate the final score for the Crab Traps to Oyster Reefs Resilience Hub assessment unit example. *The values for each scoring attribute and the final score correspond to the hub assessment unit outlined in pink in **Figure 19**. See the Methods section for additional details on each scoring attribute.*

Description of Scoring Attributes	Score
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	9
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with 1 meaning high vulnerability. SD 0.09, Mean 0.04)	0.55 (moderate)
Restorability Index	1 (highly restorable)
Average Condition (1= current very high condition)	0.50 (moderate)
Final score	**3.96 (moderately high, Rank # 17 out of 10,567 units)**

Fish and Wildlife Elements

The final list of elements explicitly represented in the Charleston Harbor Watershed analysis is shown in **Table 6**, with a brief description of each element's conservation significance, information about data sources used to represent their distributions, and data sources used. See Appendix 5 for a more detailed description of data sources that were and were not used in this assessment.

Table 6. Final list of elements used in the Charleston Harbor Watershed assessment.

Fish/Wildlife Element	Description/Significance
NOAA Trust Resources	
Diadromous fish habitat	Includes shortnose and Atlantic sturgeon migration, foraging, rearing, and spawning grounds/hotspots as well as other diadromous fish.
Important riverine systems	Includes key habitat for red drum, some coastal shark species, and other important fish species that utilize lower parts of river systems.
Important shark habitat	Reflects the key role of Bull's Bay in shark nursery habitat.
Marshes and tidal creeks	Extremely important nursery areas for many fish species (including NOAA trust resources).
Oysters beds/reefs	An iconic and commercially important habitat that also harbors habitat for numerous key species.
Snapper/grouper essential fish habitat	These fish represent key game/commercial fish in coastal waters.
Shrimp essential fish habitat	Shrimp are important economically and as part of coastal benthic communities.

Fish/Wildlife Element	Description/Significance
At-Risk Species and Multi-species Aggregations	
Federally listed Threatened or Endangered Terrestrial Species	This is an aggregate layer composed of element occurrences[7] of federally listed species. Specifically, it includes occurrence information for: American alligator, Bachman's warbler, black rail, flatwoods salamander (Frosted), gopher tortoise, piping plover, red knot, red-cockaded woodpecker, and wood stork. Detailed information including level of endangerment are provided in Appendix 5.
Terrestrial Species listed by NatureServe and the South Carolina Natural Heritage Program as imperiled, rare, uncommon, or endangered at the global or state level	This is an aggregate layer composed of element occurrences of the following species: Southern hognose snake, Southeastern bat (*Myotis*), island glass lizard, gopher frog, Bachman's sparrow, mimic glass lizard, eastern tiger salamander, Wilson's plover, star-nosed mole, eastern diamondback rattlesnake, American swallow-tailed kite, bald eagle, loggerhead shrike, eastern coral snake, eastern woodrat, Florida green water snake, brown pelican, pine snake (gopher snake), Florida pine snake, dwarf siren, black skimmer, yellow-throated warbler, least tern, common tern, black bear, yellow-throated vireo, wood thrush, and prothonotary warbler. Detailed information including specific ranks are provided in Appendix 5.
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Forested Wetlands (non-tidal) and Non-tidal Creek stretches	These areas provide important breeding habitat for a large number of high priority migratory and resident bird species.
Tidal hardwood swamp forest (with and without cypress)	This is a key habitat type with high biodiversity and provides key ecosystem services related to water quality and buffering between important aquatic fish/wildlife and adjacent upland land uses that might detrimentally affect water quality (like row crop agriculture or housing).
Freshwater emergent wetlands	In addition to their own ecological uniqueness, these areas provide habitat for a different suite of bird, reptile, and amphibian species than forested wetlands.
Cypress swamps and domes - potential habitat	These areas are of high value to key neotropical migrants and other bird species.
Beach and dune habitat	These areas include open sandy coastal expanses that provide habitat for a large set of high priority wildlife species.
Barrier island live oak hammock forest and scrub	These iconic and ecologically important communities in the Charleston area barrier islands buffer communities from winds and storm surge and provide habitat for a variety of species. This target includes newer scrub habitat and older, fully developed maritime live oak forest (A globally very imperiled (G2) community**.**
Interior live oak maritime forest	These forests provide habitat for the iconic live oak tree as well as wildlife species that are dependent upon live oak maritime forest (neotropical migrants, eastern diamondback rattlesnakes).

[7] An **Element Occurrence** (EO) is an area of land and/or water in which a species or ecological community is, or was, present. Species EOs referenced here represent the full occupied habitat (or previously occupied habitat) that contributes, or potentially contributes, to the persistence of the species at that location.

Fish/Wildlife Element	Description/Significance
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Open pine habitat	This system includes areas predominantly dominated by longleaf pine and/or slash pine and maintained by fire or other disturbances that mimic fire. This habitat is unique to the coastal plain and adjacent ecoregions in the Southeast and contains many endemic or near-endemic wildlife species.
Wading bird and ally colonies	These focused congregation areas are vulnerable to subtle changes that could impact annual colonies, forcing them into substandard areas.
Shorebird nesting hotspots	These areas represent nesting concentrations of seabirds and shorebirds. A separate SCDNR publication highlights Castle Pinckney and Crab Bank, both included in this target, as particularly important nesting areas at the state level.
Sea turtle nesting hotspots	Sea turtle nesting hotpots in the Charleston area are of global importance for sea turtle species, especially for loggerheads.
Cross-cutting Elements	
Continental and Global Important Bird Areas	Areas of key importance for bird species.

Resilience Projects Portfolio

A portfolio of resilience projects within the Charleston Harbor Watershed was compiled from plans and other project documents submitted by stakeholders (**Table 7**). A total of 30 projects were submitted for this watershed. Beyond a review of project documents, projects were further evaluated using several data layers created in the GIS assessments.

Through the process of reviewing resilience projects, visiting sites, and meeting with key stakeholders in the region about resilience project ideas, several themes emerged.

1. Agency, NGO, and extension staff in this region have a great deal of capacity to implement coastal resilience projects where funding is available.
2. Project leaders recognize the need to engage neighbors and community stakeholders upfront in planning and decision-making for projects that directly affect their areas of interest to ensure there is initial and ongoing support for long-term projects.
3. Citizens in the region are particularly aware of both short-term and long-term threats due to the history of high impact hurricanes (Hugo, Joaquin, Matthew, Irma, etc.) and king tide effects, so there is substantial evidence of political will to support projects that can minimize impacts to human communities while providing benefits to the fish and wildlife resources that define the Lowcountry of South Carolina.

Table 7. Summary of resilience-related projects identified for the Charleston Harbor Watershed study area. *Table shows the implementation stage of each project at the time of compilation.*

Project Type	**Project Phase**				
	Conceptual	**Planning Complete**	**Design Complete**	**Ready to Implement**	**Total**
Beach or dune restoration	1		1		2
Community resilience planning	1	1		1	3
Conservation BMPs	4				4
Marine debris removal	1				1
Flooding mitigation	1				1
Living shoreline	10			1	11
Oyster reefs	3	1		1	5
Riparian and floodplain restoration	1				1
Wetlands restored/enhanced				2	2
Totals	**22**	**2**	**1**	**5**	**30**

As can be seen in **Figure 20**, the submitted resilience projects are primarily clustered along the immediate coastal section of the study area and around the city of Charleston. Projects were submitted by a wide range of stakeholders—from emergency management personnel to local NGO staff to state and federal agency representatives. Locally-based NGOs and local municipalities submitted seven project ideas, demonstrating that the stakeholder engagement process was effective in attracting project ideas from local stakeholders. There were 16 submissions from federal agencies and seven from state agencies. Project sizes ranged from small living shoreline installations of less than one acre up to approximately 700 acres for the restoration project at Long Branch Creek.

Sixteen submitted projects are focused on installation of living shorelines or oyster reef restoration/creation, with the dual goals of improving fish/wildlife habitat while reducing future shoreline erosion. Other submitted projects ranged from creation of fine-scale vulnerability assessments to wetland restoration, best management practices development, beach/dune restoration, and marine debris removal projects. A full list of these submitted projects and summary information about each is in Appendix 6.

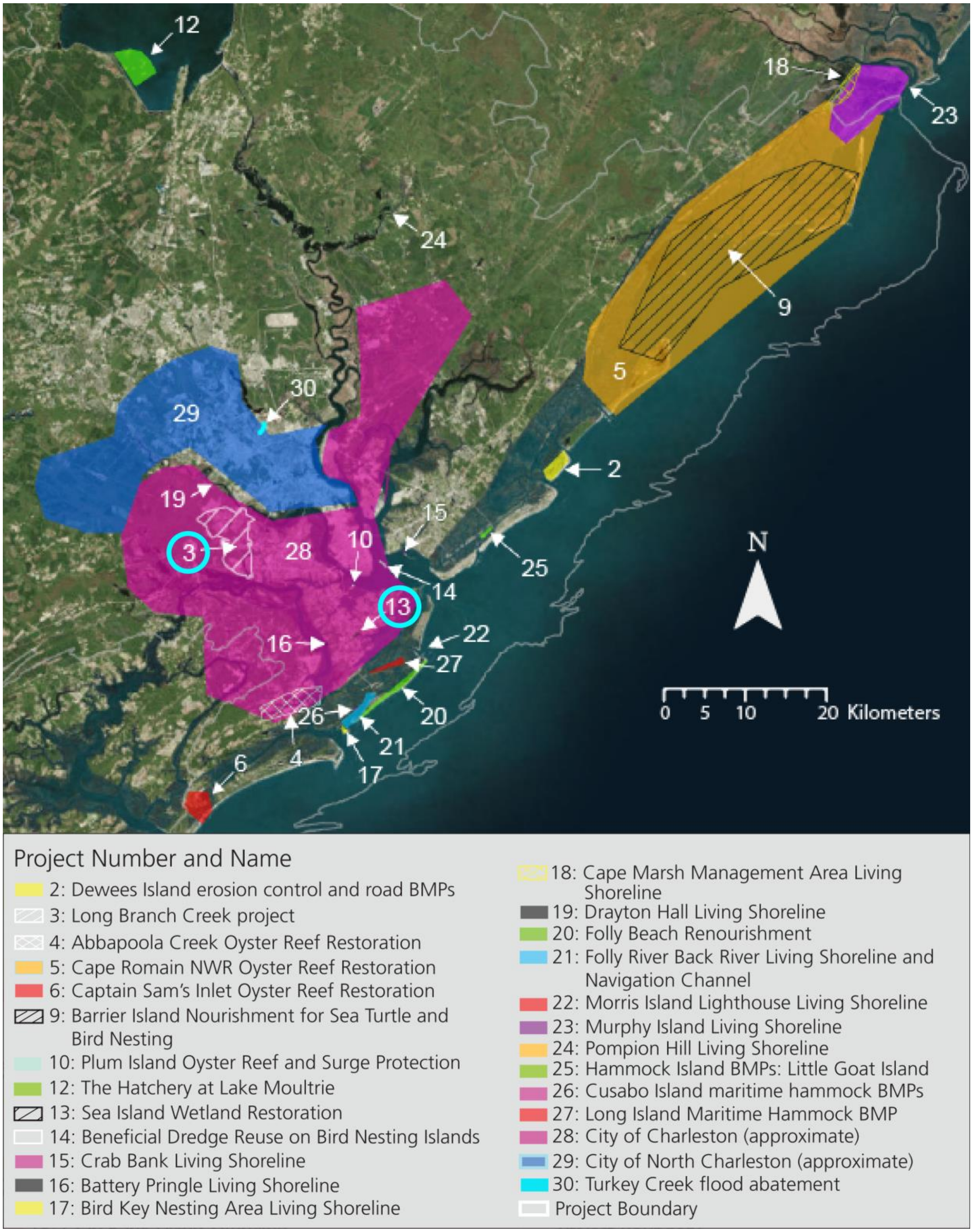


Figure 20. Map showing the boundaries of resilience projects compiled for the Charleston Harbor Watershed. *Projects #3 and #13 for which detailed case studies were developed are indicated with a blue circle around the project number. A third case study was also developed for project #8 but because of its distributed spatial nature, it is not indicated on this map. Projects #1, #7, and #11 are also not pictured due to their large size. See Appendix 6,* ***Table A6-1*** *for a full list of projects.*

Suggested Uses

The resilience projects database (Appendix 6) provides the names, project boundaries, and summary information about projects that were identified by stakeholders as those that could potentially increase human community resilience and/or enhance fish and wildlife habitat. These projects could potentially be implemented rapidly to recover from a flooding event, a high intensity tropical storm, or proactively improve resilience before the next major event.

Case Studies

The three case studies that follow illustrate how proposed resilience projects may benefit fish and wildlife habitat and human communities faced with coastal resilience challenges such as storm surge during extreme weather events. The case studies described for the Charleston Harbor Watershed share some interesting traits with one another:

- All projects will have high visibility during and after implementation due to their proximity to neighborhoods and/or areas used frequently by fishermen and/or boaters.
- Each of the projects has the potential to reduce flooding and/or storm surge effects to adjacent human assets such as homes, schools, hospitals, and places of business.
- Each project has an outreach component to involve interested individuals in the community in planning and/or implementation of the project, potentially leading to greater long-term success through ongoing community support and excitement about the projects.
- All projects have potential benefits for fish nursery areas for key species that support recreational and commercial endeavors in the region.

The three case studies are good examples of the types of projects proposed in the watershed that could potentially benefit both human assets and fish and wildlife populations facing increasing coastal threats.

Case Study 1: Long Branch Creek: Restoring Ecosystem Services to Improve Flood Resilience

Figure CS1-1. View of part of the marsh that would benefit from restoration of fish and wildlife habitat on Long Branch Creek.

Project Overview

Location: West Ashley/Charleston, SC

Date Visited: Nov. 20, 2017

Contact: Dr. Susan Lovelace, SC Sea Grant Consortium

Long Branch Creek is a large, tidally-influenced creek in the West Ashley area of Charleston, South Carolina (**Figure CS1-1** shows image of marsh and **Figure CS1-2** shows map overview). The creek and tidal basin contain numerous historic rice dikes/berms that bisect the wetlands with undersized culverts and tide gates that restrict water flow resulting in poor hydraulic function and frequent flooding on local roads and in neighborhoods and commercial areas. This proposed project includes engineering, construction, education, and planning efforts to address flooding issues in the community while also improving fish and wildlife habitat and was identified in NOAA's Habitat Blueprint as a priority for habitat restoration. Project leaders plan to improve hydraulic function of the system by removing tide gates, improving culverts, restoring salt marsh and oyster bed habitat, and involving stakeholders in community resilience planning.

More specifically, the project will:

- Positively impact more than 700 acres of marsh habitat and adjacent developed areas, which exist in low-lying areas surrounding the marsh.

- Document/determine tidal hydrology throughout the system to improve flow without exacerbating flooding.
- Create and begin implementation of a plan to improve hydraulic function and remove physical alterations such as culverts and tide gates to improve flow in the system.
- Engage residents and creek users, through "Creek Cafés," an outreach program designed for stakeholders to learn about the creek, its hydrology, sea level rise, and other flooding threats.
- Engage residents and creek users to take part in community oyster reef construction and salt marsh planting and support of the Seeds to Shorelines program in which schoolchildren grow smooth cordgrass (*Spartina alterniflora*) from seed in their classrooms with the help and engagement of project partners.

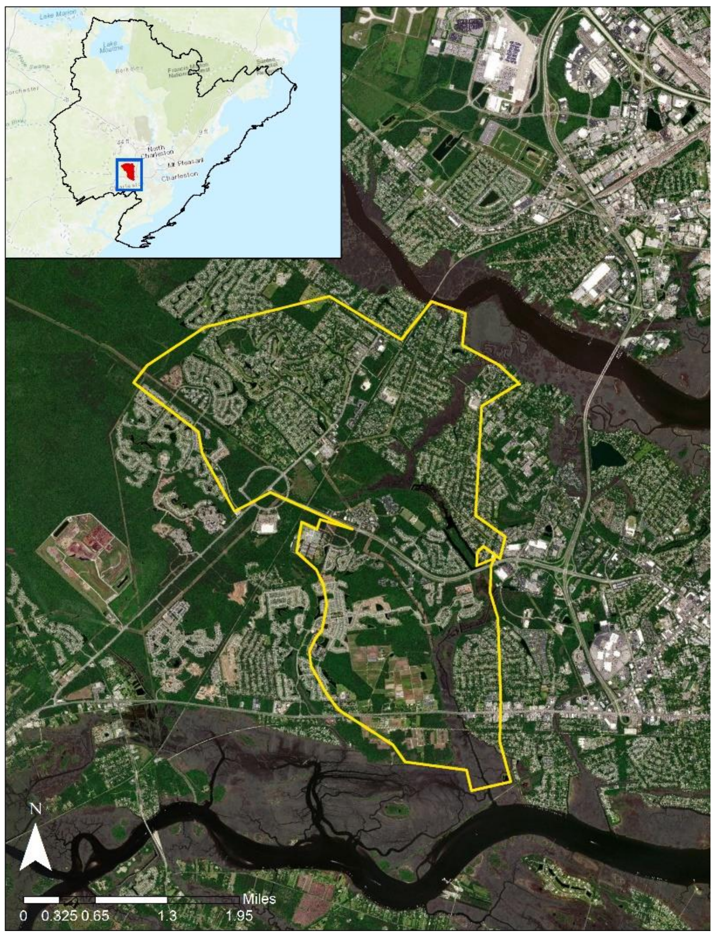


Figure CS1-2. Approximate project area (yellow boundary). *The north and south sections of the area are bisected by a road that is not considered part of the project area. Adjacent areas of human development are evident in the imagery. A subset of these locations is appropriate for crab trap reef installation.*

Estimated Cost of the Project

Total project costs are estimated to be over $821,000 for the first phase. For more detailed numbers, please contact the project sponsor, Dr. Susan Lovelace at the SC Sea Grant Consortium.

Stressors and Threats

This site has a high concentration of existing stressors and flooding threats to both fish and wildlife and human community assets (HCAs). Within the project area, existing stressors include development such as roads that bisect important habitat, medium to high density housing, and intense agriculture and silviculture (**Table CS1-1** contains a list of stressors and flooding threats). Fish and wildlife and HCAs are also vulnerable to future threats including sea level rise, storm surge, highly erodible soils, high potential for subsidence, and more frequent flooding. In particular, the low-lying populated areas adjacent to Long Branch Creek are likely to see more flooding in the future as sea level rise progresses.

Table CS1-1. Stressors and flooding threats identified in and near the project site.

Existing Stressors
Local Neighborhood and Connecting Roads
Secondary Roads
Dirt/Private Road/Culverts
Railroads, Bridges/Culverts
Low Density Housing (Rural)
High/Medium Density Housing
Developed Open Spaces
Intense Agriculture
Silviculture - Intensive
Ruderal (maintained pasture, old field)
Flooding Threats
100 Year Floodplain
1 Foot - Sea Level Rise
Storm Surge (Categories 1-5)
Flat & Poorly or Very Poorly Drained
Flat & Somewhat Poorly Drained
Frequent Flooded Spaces
High Erodibility
High Subsidence

Human Community Assets

This site and the surrounding area contain a high concentration of important HCAs including areas of high population density, critical infrastructure, key roads, the major Bon Secours St. Francis Hospital and associated clinics, and several schools (**Table CS1-3**). **Figure CS1-3** shows areas where there are high concentrations of HCAs that are vulnerable to the threats listed above. Within this area, flooding risk is highest for among very densely populated low-lying areas with key roads that bisect the marsh. Therefore, these assets are expected to benefit from a resilience project that reduces flooding risk.

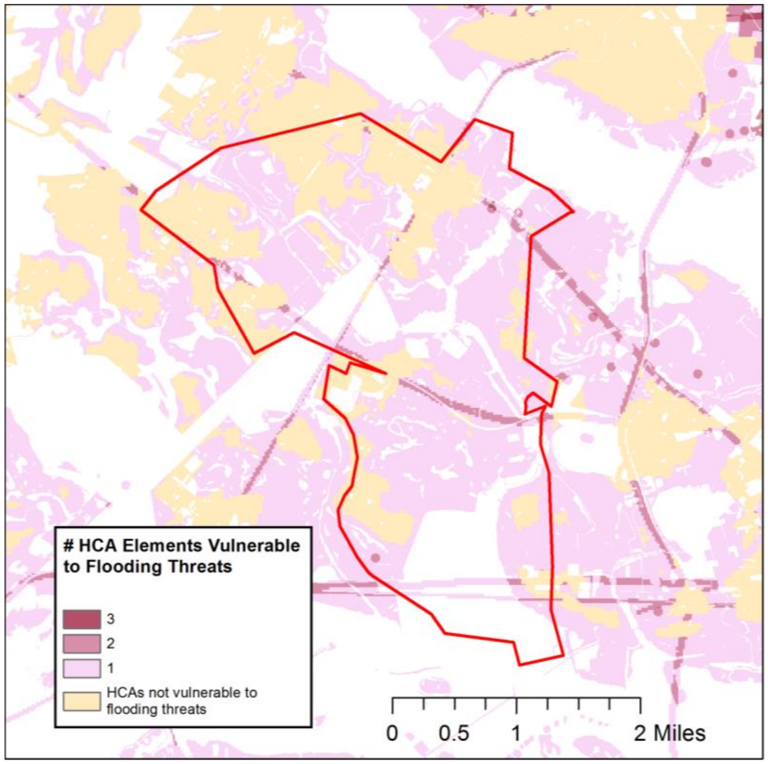


Figure CS1-3. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements) within and around the Long Branch Creek project. Tan color indicates areas with HCAs that are not categorized as vulnerable for the purposes of this assessment.*

Table CS1-2. Human Community Assets identified within the project boundary.

Categories of Human Assets Identified within Project Boundary
Densely populated areas
Critical infrastructure
Evacuation Route/Highways
Railroad (hazardous transport route)
Highways
Mapped Community/Human Assets within Project Boundary
Critical facilities
Springfield Elementary School
Charleston Christian School
Saint Andrews Fire Department Station 3
Saint Andrews Fire Department Station 2
West Ashley High School
C.E. Williams Middle Creative Arts Elementary School
Charleston SDA School
Physicians Eye Surgery Center

Fish and Wildlife

This site contains current and/or potential habitat for priority fish and wildlife species, including many species highly valued by regional stakeholders (**Table CS1-3**). In addition, restoration activities on site have the potential to positively impact species beyond the project boundary since many restoration benefits may be realized downstream and upstream of the project, such as those species that only spend a portion of their lifecycle within the site boundary (e.g., shrimp and snapper/grouper species).

Table CS1-3. Fish and wildlife habitats and example species for each habitat that potentially occur in the project area. *

Fish/Wildlife Habitat *	Species of Interest to Stakeholders that may be Represented by these Habitat Types **
Shrimp Essential Fish Habitat	Penaeid shrimp, summer flounder, blue crab
Diadromous Fish Habitat	Atlantic sturgeon, blueback herring, American shad
Important Riverine Systems	Red drum
Open Pine	Eastern diamondback rattlesnake, gopher frog
Interior Live Oak Maritime Forest	Prothonotary warbler
Freshwater Emergent Wetlands	Black rail
Marsh and Tidal Creek (including open water)	Black rail, sea sparrow, oystercatcher
Forested Wetlands (non-tidal)	Wood duck, Swainson’s warbler
Cypress Swamp Soils	American alligator
Tidal Swamp	Wood stork, black rail, American bittern
Snapper Grouper Essential Habitat	Snapper, grouper, shark nursery habitat
Oyster Beds/Reefs	Eastern oyster, blue crab
Wading Bird and Ally Colonies	Great blue heron, snowy egret, wood stork
G1-G3/S1-S3	Pine snake, least tern

**Based on modeled data (some of these habitats may not actually exist in the project boundary area or may be potential habitat if the habitat were improved or historic occurrences)*

*** Not meant to be an exhaustive list of all species that benefit from this habitat, but instead contains some example species that are likely represented by this layer of information and identified by stakeholders as priority species in the watershed.*

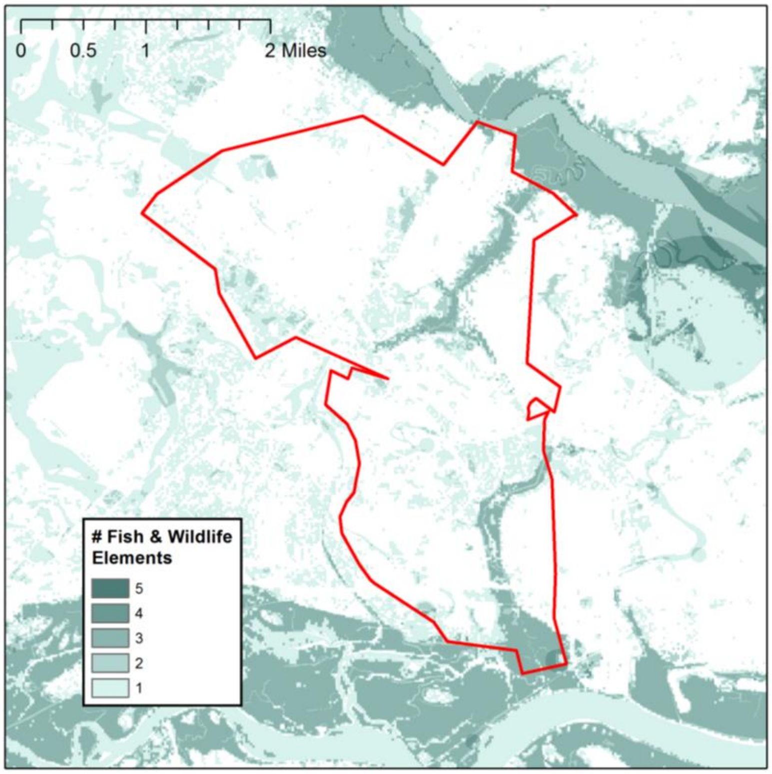


Figure CS1-4. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements richness (darker green signifies a higher number of elements co-occurring in the same place). Red outline is the project boundary.*

Expected Project Impact

If implemented, this project would establish important oyster reef structure and increase community buy-in for the implementation of additional resilience projects, paving the way to further improve oyster reef structure and tidal marshes while helping to reduce vulnerability to flooding of nearby homes during extreme storm events.

Oyster reef restoration would increase habitat for oysters and the species that benefit from the structure that reefs provide. Marsh restoration would increase tidal marsh area and potentially improve water quality, erosion control, and blue crab and shrimp nursery habitat. Marsh restoration would also increase opportunities for residents to enjoy crabbing and fishing and improved habitat for commercially important species (especially oysters) both on and off site.

Public engagement through pre-project meetings would provide important community buy-in and ownership so that the project goals could be met as part of a collaborative approach. In addition, the proposed educational “Creek Cafés” would be aimed at increasing the understanding changing environmental conditions and local hydrologic relationships among the public and provide public participation in the development of scenarios to be tested for hydrological improvements. In addition, the Seeds to Shorelines program would help students learn about science, stewardship, and habitat restoration.

Case Study 2: Crab Traps to Oyster Reefs

Project Overview

Location: Region wide

Date Visited: Nov. 20, 2017

Contact: Dr. Peter Kingsley-Smith, SC Department of Natural Resources

The Crab Traps to Oyster Reefs program uses abandoned crab traps to create new and thriving oyster reef habitat (**Figure CS2-1**). Program staff collect old traps from the public, commercial fishermen, and those found in the marsh. They close their openings so that turtles and other large organisms do not become trapped inside and coat the traps in concrete to stimulate oyster spat recruitment. The large surface area and structure of the traps allows them to be placed in softer sediments where denser bags of shell may sink.

Potential locations for this project are scattered throughout the study area (**Figure CS2- 2**). This project achieves multiple goals: removing marine debris, keeping waste out of landfill, and creating oyster reefs, all while potentially preventing erosion in adjacent areas through wave attenuation. In turn, oysters populating the artificial reefs filter feed, thus improving surrounding water quality.

Figure CS2-1. Crab Traps to Oyster Reefs Project. *Shellfish Research Section of South Carolina Department of Natural Resources building a crab trap reef with the help of Clemson University student volunteers (site is at South Fenwick Island, SC).*

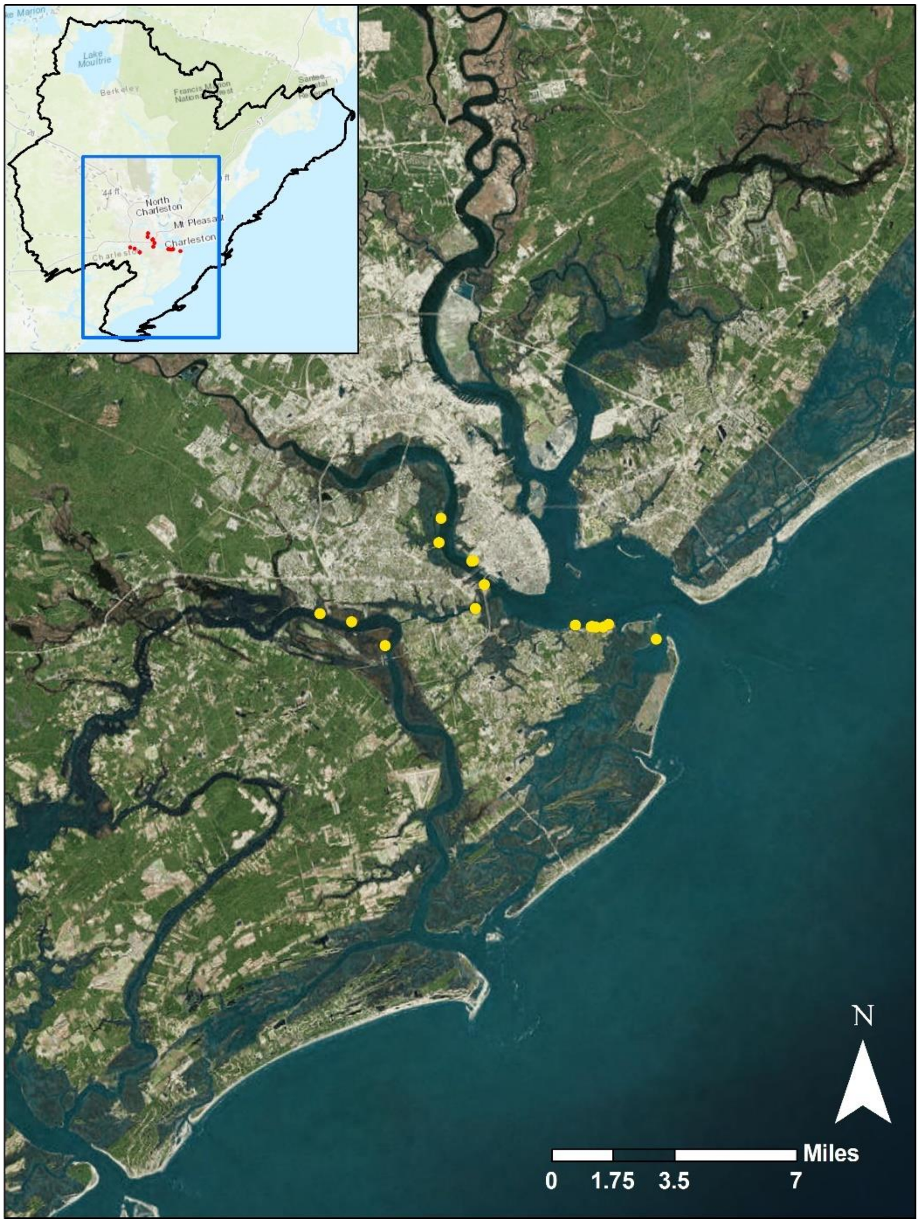


Figure CS2-2. Aerial view of project area showing potential crab trap-based oyster bed restoration sites.

Estimated Cost of the Project

Costs range from roughly $2,000-3,000 per installation, where a typical installation ranges from 15 – 45 linear meters (50 – 150 feet) of oyster reef. This cost does not include post-construction monitoring, which varies considerably among sites based on the specific project needs. For more detailed numbers, please contact Peter Kingsley-Smith at South Carolina Department of Natural Resource (SCDNR).

Stressors and Threats

The potential project sites contain a high concentration of existing and future threats to human communities and fish and wildlife habitat condition. Existing threats to fish and wildlife habitats in the tidal areas include low/moderate water quality, dredge material placement areas, and roads, bridges, and culverts that bisect important habitat. There are also several threats on adjacent upland areas that could affect the project sites, including developed areas such as high/medium density housing, intensive silviculture and agriculture, etc. (**Table CS2-1** lists threats in and near the site and **Figure CS2-3** depicts areas that are vulnerable to these threats). In addition, fish and wildlife habitat are vulnerable to future threats including sea level rise, high levels of subsidence, erosion, storm surge, and more frequent flooding.

Table CS2-1. Stressors and flooding threats identified in and near the project site.

Existing Stressors
Local Neighborhood and Connecting Roads
Secondary Roads
Railroads, Bridges/Culverts
Low Density Housing (Rural)
High/Medium Density Housing
Developed Open Spaces
Intense Agriculture
Silviculture - Intensive
Ruderal (maintained pasture, old field)
Water Quality - Low/Moderate
Dredged Soil Sites
Flooding Threats
100 Year Floodplain
1 Foot - Sea Level Rise
Storm Surge (categories 1-5)
Frequent Flooded Spaces
Occasional Flooded Soils
Flat & Poorly or Very Poorly Drained
Flat & Somewhat Poorly Drained
Very High Erodibility
High Erodibility
Very High Subsidence
High Subsidence

Human Community Assets

New oyster reef sites could prevent erosion and thus increase the resilience of several key assets. The site visited to inform this case study is particularly vulnerable to erosion caused by wakes from boats and by storm events. Other sites throughout the project area have similar profiles (**Figure CS2-3** shows vulnerable HCAs in relation to potential future project sites).

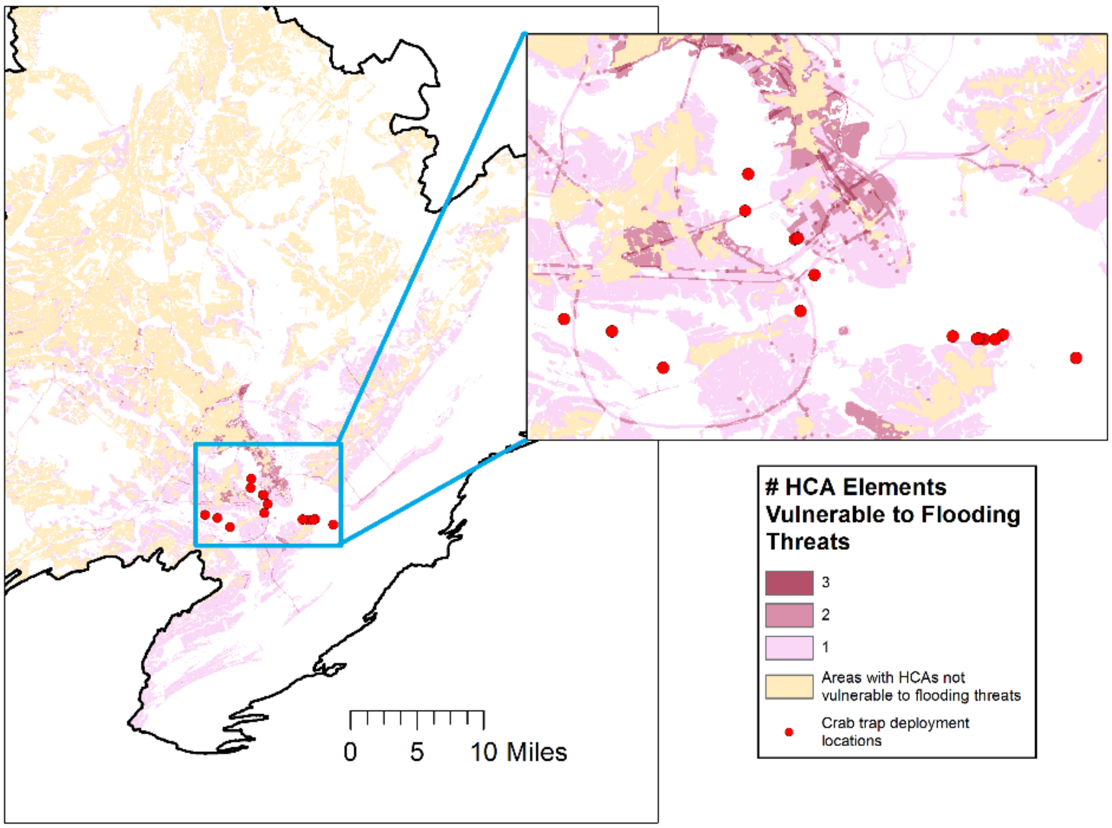


Figure CS2-3. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements). Dots represent areas identified as potential locations for crab trap-based artificial oyster reefs. The pop-out map zooms into the City of Charleston, where there is a high concentration of HCAs and Fish and Wildlife Elements. Tan color indicates areas with HCAs that are not categorized as vulnerable for the purposes of this assessment.*

Table CS2-2. HCAs identified within the project boundary.

Categories of Human Assets Identified within Project Boundary
Densely populated areas Critical infrastructure (Evacuation Route/Highways and Railroad, hazardous transport route) Critical facilities
Mapped Community/Human Assets within Project Boundary
Since the potential project sites are numerous and scattered across the region, the mapped assets are too numerous to list here.

Fish and Wildlife

The potential Crab Traps to Oyster Reef project sites are positioned in locations that harbor both current and potential future habitat for priority fish and wildlife species such as shrimp, summer flounder, blue crab, black rail, sea sparrow, and oystercatcher (**Table CS2-3**).

Table CS2-3. Fish and wildlife habitats and example species for each habitat that potentially occur in the project area. *

Fish/Wildlife Habitat *	**Species of Interest to Stakeholders that may be Represented by these Habitat Types ****
Shrimp Essential Fish Habitat	Penaeid shrimp, summer flounder, blue crab
Important Riverine Systems	Red drum
Open Pine	Eastern diamondback rattlesnake, gopher frog
Interior Live oak Maritime Forest	Prothonotary warbler
Marsh and Tidal Creek (including open water)	Black rail, sea sparrow, oystercatcher
Forested Wetlands (non-tidal)	Wood duck, Swainson's warbler
Cypress Swamp Soils	American alligator
Tidal Swamp	Wood stork, black rail, American bittern
Snapper Grouper Essential Habitat	Snapper, grouper, shark nursery habitat

**Based on modeled data (some of these habitats may not actually exist in the project boundary area or may be potential future or historic occurrences).*

*** Not meant to be an exhaustive list of all species that benefit from this habitat, but instead contains some example species that are likely represented by this layer of information and identified by stakeholders as priority species in the watershed.*

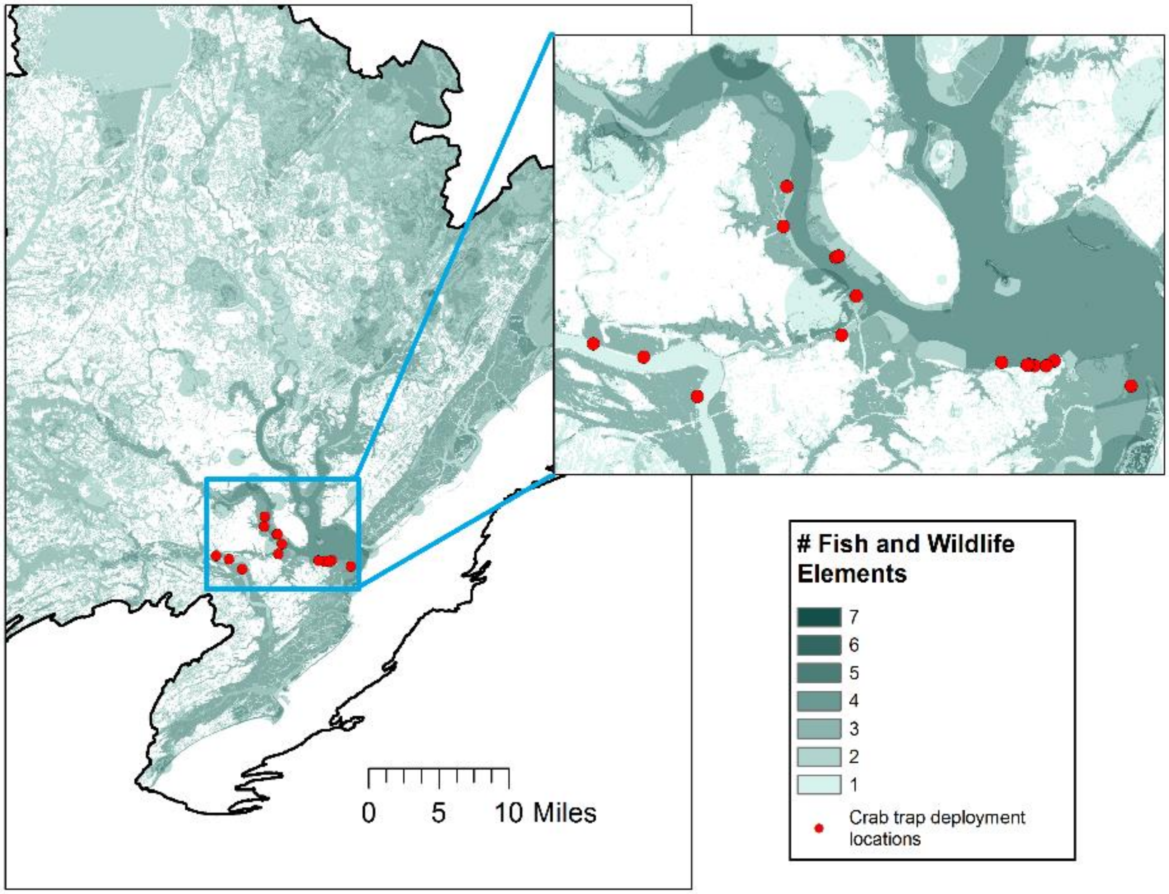


Figure CS2-4. Density of fish and wildlife elements in project area. *Map of fish and wildlife element richness (darker green signifies more elements). The pop-out map zooms into the City of Charleston, where there is a high concentration of HCAs and Fish and Wildlife Elements.*

Expected Project Impact

This project is particularly important because it not only builds resilience along shorelines, but also involves community members in the project. This allows community members to better understand the challenges and risks posed by climate threats while also demonstrating actions communities can take to build resilience ahead of time in response to modeled threats.

The key benefits of this project include:

- Creating oyster reefs, which provide habitat for oysters, a very important species to local stakeholders, as well as the many species that benefit from oyster reefs as nursery habitat.
- Preventing erosion from storms or boat wakes by creating a barrier to wave attenuation.
- Improving water quality (due to the oyster's ability to filter water).
- Removing marine debris and recycling it on-site to become a useful wildlife habitat and buffering feature.
- Keeping waste out of landfills by recycling the old traps.

Figure CS2-5. Gary Sundin of South Carolina Department of Natural Resources coating a crab trap with cement.

Case Study 3: Sea Island Wetland Restoration

Project Overview

Location: James Island, SC

Date Visited: Nov. 20, 2017

Contact: Jessica Hardesty Norris, Charleston Audubon

This project is led by Charleston Audubon but is really a collaboration among multiple community organizations. The project will restore a storm water drainage ditch (4-7 feet deep) to a more natural stream channel before it empties into a tidal slough downstream (**Figure CS3- 1** shows some sections of the study area and **Figure CS3-2** shows the project footprint). As part of the project, proponents plan to change the current channel ditch to increase the flow capacity through an 11-acre recreational park that empties out into an area including 12 acres of salt marsh. The project will also work to eradicate invasive species, plant native species, improve recreational trails, remove litter, and host community stewardship events.

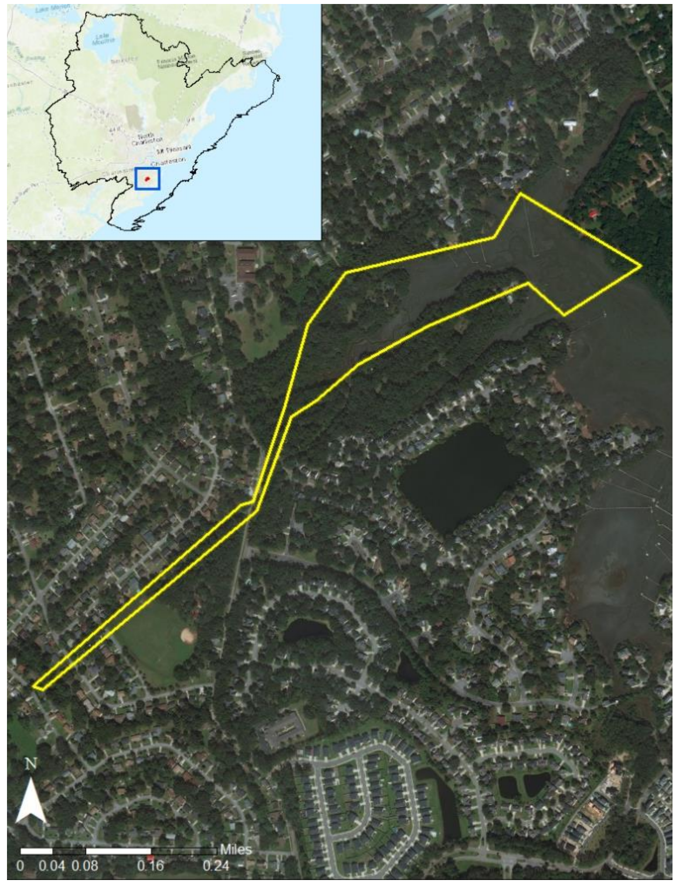


Figure CS3-1. Aerial view of the project site and adjacent neighborhoods. *Yellow line indicates the approximate boundary of the project site.*

Collaborators see the project as a celebration of the unique cultural heritage of this historic sea island, which is part of the Gullah Geechee Heritage Corridor. The project has the potential to not only improve downstream oyster habitat, but may also improve fish nursery habitat provided by the marsh.

More specifically, the project will:

- Facilitate the restoration of marshes, aquatic connectivity, natural stream channel, riparian vegetation, and the floodplain.
- Implement green infrastructure and improve the design and function of wetland drainage into the wetland.
- Improve resilience to flooding by widening and moderating the slopes on each side of the ditch, thus enlarging the capacity of the receiving ditch and outfall.
- Restore a portion of the marsh at the outfall that has suffered severe accretion due to sedimentation and decades of poorly regulated construction.

Estimated Cost of the Project

The cost estimates for this project range from $25,000 (stream channel improvement only) up to $300,000 for stream channel improvement plus additional restoration and site work throughout the project footprint.

Stressors and Threats

This site contains a high concentration of existing stressors and future threats to HCAs and fish and wildlife habitats. Existing threats to fish and wildlife habitats include roads that bisect important habitat and developed areas such as high/medium density housing (**Table CS3-1**). Developed open space is also a threat since lawns and recreational fields increase fragmentation of habitat and contribute nutrient runoff. HCAs and fish and wildlife habitat are also vulnerable to future threats including sea level rise, storm surge, and more frequent flooding which are exacerbated in areas that are highly susceptible to erosion and subsidence.

Table CS3-1. Stressors and threats identified in and near the project site.

Existing Stressors
Local Neighborhood and Connecting Roads
Low Density Housing (Rural)
Ruderal (maintained pasture, old field)
Developed Open Spaces
Silviculture - Intensive
Flooding Threats
100 Year Floodplain
1 Foot - Sea Level Rise
Storm Surge (categories 1-5)
Flat & Poorly or Very Poorly Drained
Flat & Somewhat Poorly Drained
High Erodibility
High Subsidence

Human Community Assets

This site and surrounding area contain a high concentration of HCAs, including high population density areas. **Figure CS3-2** shows (in pink) areas where there are high concentrations of HCAs that are also highly threatened by the threats listed above.

Seacroft Road, directly behind the ditch running through the project area, is one of the most frequently flooded roads on James Island, with frequent road closures and repetitive damage. At the same time, the current drainage ditch creates a channeling effect that is increasing sedimentation in the tidal marsh downstream, affecting all the fish and wildlife that rely on that tidal marsh ecosystem.

For this area, flooding risk is highest for some of the most densely populated low-lying areas with key roads that bisect the project area, especially during high rainfall events. These areas exist in a historically underserved area of the Charleston region.

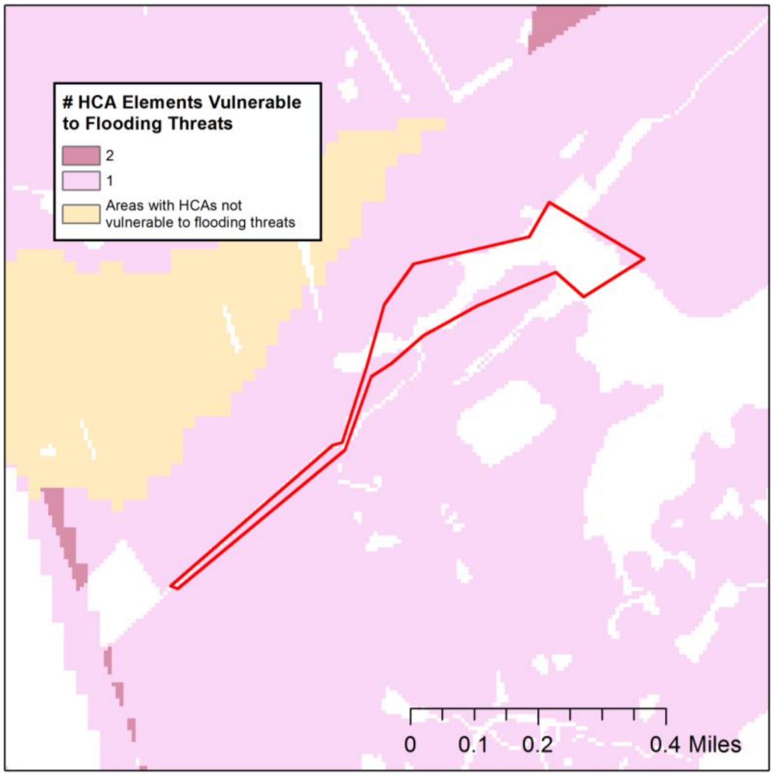


Figure CS3-2. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable Human Community Assets (HCAs) (darker pink/red signifies concentrations of vulnerable HCAs). Tan color indicates areas with HCAs that are not categorized as vulnerable for the purposes of this assessment.*

Table CS3-2. HCAs within the project boundary.

Categories of Human Assets Identified within Project Boundary
Densely populated areas
Mapped Community/Human Assets within Project Boundary
Nothing specific within project boundary, but a community center/recreational area is adjacent to the project area.

Fish and Wildlife

This site contains important current and/or potential habitat for priority fish and wildlife species, including many species highly valued by regional stakeholders. The identified habitats may support a wide variety of fish and wildlife species including nursery habitat for shrimp, summer flounder, and blue crabs, species dependent on maritime/live oak, cypress swamp, and wetland forests, etc. In addition, restoration activities on site have the potential to positively impact species beyond the project boundary since many restoration benefits may be realized downstream and upstream of the project, such as those species that only spend a portion if their lifecycle within the site boundary (e.g., shrimp and snapper/grouper species).

Local shellfish harvest has been closed in the recent past due to water quality concerns. This project would help mitigate that risk by improving water quality at the outfall by creating flows that are slower and more filtered. The ecosystem would also benefit from native plantings, removal of invasive species, and restoration of natural hydrology pattern

Table CS3-3. Fish and wildlife habitats and example species for each habitat that potentially occur in the project area*.

Fish/Wildlife Habitat *	**Species of Interest to Stakeholders that may be Represented by these Habitat Types ****
Shrimp Essential Fish Habitat	Penaeid shrimp, summer flounder, blue crab
Interior Live Oak Maritime Forest	Prothonotary warbler
Marsh and Tidal Creek (including open water)	Black rail, sea sparrow, oystercatcher
Forested Wetlands (non-tidal)	Wood duck, Swainson's warbler
Tidal Swamp	Wood stork, black rail, American bittern

**Based on modeled data (some of these habitats may not actually exist in the project boundary area or may be potential future or historic occurrences)*

*** Not meant to be an exhaustive list of all species that benefit from this habitat, but instead contains some example species that are likely represented by this layer of information and identified by stakeholders as priority species in the watershed.*

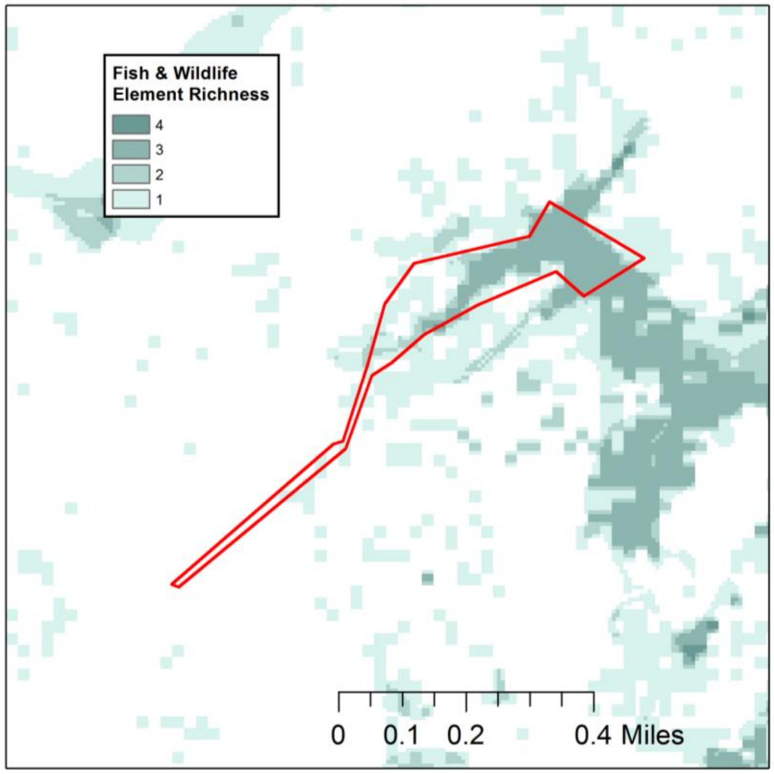


Figure CS3-3. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements combined (darker green signifies more elements).*

Expected Project Impact

Tidal marsh restoration would increase nursery habitat for key species and potentially reduce downstream pollution and sedimentation, which in turn may aid in the recovery of oyster beds that are currently subject to frequent closures. Marsh restoration would increase tidal marsh area and potentially provide water quality, erosion control, and habitat benefits to species dependent on this habitat. Interior live oak maritime forest and scrub forest will also be improved as part of the terrestrial restoration work on this site. Public engagement would provide important community engagement so that the project goals can be met with community support, while also providing opportunities to educate the public about climate threats and actions that can be taken to build resilience. Human community asset benefits include a potential reduction in the extent and period of flooding of nearby homes, the recreation area, and an increase in park safety from shrubby vegetation/invasive species removal to improve sight lines.

Conclusions

This report and accompanying products are the result of an approximately 12-month stakeholder engagement and rapid assessment process. Using a combination of expert-identified and stakeholder-nominated data, the assessment aims to: 1) understand the value and vulnerability of human community assets and fish and wildlife elements (habitats and species), 2) map areas with potential for improving resilience (Resilience Hubs) for these assets and elements, and 3) gather and characterize stakeholder-proposed resilience projects.

The mapping of the Resilience Hubs is intended to inform potential new locations for resilience projects that can provide mutual benefits to community resilience and fish and wildlife. The large spatial extent of open space areas in the Charleston region generated many Resilience Hubs and potential opportunities for improving resilience in the watershed. The final scoring of the Resilience Hubs and their assessment units indicate several focal areas of particularly high potential for offering natural and nature-based resilience.

The Charleston Harbor Watershed Coastal Resilience Assessment and associated datasets are intended to support the development of additional resilience project ideas and can provide the basis for analyses to support project siting, planning, and implementation. The accompanying Coastal Resilience Evaluation and Siting Tool (CREST) was developed to allow users to view, download, and interact with the inputs and results of this assessment (available at resilientcoasts.org). Furthermore, the use of the Vista decision support system (DSS) will enable a variety of additional planning activities to integrate these data into plans for land use, conservation, emergency management, and infrastructure as well as supporting local customization.

Key Findings

The spatial analyses in this assessment confirm what is generally known and routinely experienced in the Charleston Harbor Watershed—that community vulnerability in many locations in the watershed is very high owing to exposure to flooding threats and low elevation. The Charleston Peninsula in particular is highly exposed to storm surge and sea level rise as are areas of the coast positioned between Bull's Bay and Francis Marion National Forest. The Ashley, Cooper, and other rivers in the watershed are all sources of current and future flooding from upstream extreme storm events and from storm surge and sea level rise.

While the urbanized Charleston Peninsula's dense development and hardened shoreline offers few nature-based resilience opportunities, such opportunities are common in the natural shorelines, marshes, wetland areas along key waterways, and adjacent low uplands flanking the harbor mouth and extending along the coast in both directions. These nature-based resilience opportunities are best illustrated via the three case studies featured in this report, which highlight several important opportunities for improving resilience while benefiting fish and wildlife, such as:

- upland and wetland habitat restoration that improves habitat onsite while reducing flooding in adjacent areas and downstream;

- marsh restoration that can restore tidal flow, allowing for improved marshland habitat and reduction in flooding of adjacent communities during high tide storm events and storm surge; and
- oyster reef restoration projects that can restore oyster populations while helping to attenuate wave action, potentially reducing erosion along fragile shorelines.

The case studies are meant to highlight a few options for nature-based actions to build resilience and, combined with the full database of all resilience projects submitted, can serve as a starting point for agencies and funders interested in supporting projects. In addition, the case studies and other submitted projects can serve as examples of potential project ideas that can be implemented within the areas that the analysis identified as Resilience Hubs. In fact, all of the projects featured as case studies fall within very high priority Resilience Hubs, further reinforcing their potential positive impact should they be implemented.

Summary of Limitations

This project conducted a rapid assessment using available data. As such, there are several limitations to be aware of when applying these results to decision-making or other applications. Despite these limitations, the project represents an important set of data and results that can inform many applications and be further refined, updated, and applied to local purposes.

1. This assessment is not a plan and is not intended to assess or supplant any plans for the area (such as those summarized in Appendix 7. Summary of Additional Studies and Plans).
2. The modeling of vulnerability of HCAs and fish and wildlife elements used a simple model and expert knowledge to set parameters of how stressors and threats impact select features. This is neither an engineering-level assessment of individual HCAs to more precisely gauge risk to individual areas or structures, nor a detailed ecological or species population viability analysis for fish and wildlife elements to estimate current or future viability.
3. The spatial data used in this assessment are those that could be readily obtained and that were suitable for the analyses. In general, secondary processing or modeling of the data was not conducted. In a GIS analysis, data availability, precision, resolution, age, interpretation, and integration into a model undoubtedly result in some areas being mistakenly identified for providing natural and nature-based resilience. As with all GIS analyses, the results should be ground-truthed prior to finalizing decisions at the site level.
4. Precise and complete water quality data were not available for this area. The project relied on three sources and methods for approximating water quality: EPA Impaired Waters data was used along with commercial vessel traffic data. This was supplemented with an offsite or distance effect setting in the Vista DSS landscape condition model that extrapolates impacts of nearby stressors (i.e., land uses) to aquatic elements (see Appendix 2 and Appendix 3 for details on this method). This approach has some limitations such as extrapolating impacts in all directions instead of only downslope, only affecting water bodies within the distance effect (e.g., no mixing), and not accounting for downstream accumulation or mixing.

5. The selection of fish and wildlife elements was geared to the specific objectives of this assessment and, therefore, does not represent biodiversity generally or necessarily all fish and wildlife of conservation interest. Not all nominated elements could be represented at the preferred level of precision. A list of elements for which data was not available or was deemed insufficient for appropriately representing the element is provided in Appendix 5. That said, no elements can be assumed to have complete and accurate distributions. The Vista DSS project can be amended with additional elements of interest.

Putting this Assessment to Work

The products represented by this report, the online viewer and portal, and the Vista decision support system (DSS) provide opportunities for application by a variety of users. Potential uses range from those interested in becoming more informed about vulnerability and resilience opportunities in the watershed to those that wish to conduct additional assessment and planning. The use of the online map viewer or the decision support system can allow further exploration of the results and inputs across the watershed or for particular areas of interest.

Addressing the flooding threats assessed in this project is one of the most daunting activities for communities. Fortunately, concepts, examples, and guidance have been in development for several years and continue to improve as more communities confront these challenges. Some potential directions and implementation resources that may be useful include:

- Utilizing a community engagement approach to discuss specific ways to act on the findings of this assessment. One source for information on how to do this can be found here, including guidance on running a community workshop: https://www.communityresiliencebuilding.com/.
- Reviewing the U.S. Climate Resilience Toolkit (https://toolkit.climate.gov/) to explore other case studies, guidance, and tools to incorporate.
- Implementing living shorelines instead of relying on expensive shoreline armoring. Guidance for Considering the Use of Living Shorelines found at https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf.
- Weighing nature-based options for addressing shoreline erosion. For individual property owners a good starting point is: Weighing Your Options: How to Protect Your Property from Shoreline Erosion found at https://www.nccoast.org/wp-content/uploads/2014/12/Weighing-Your-Options.pdf.
- Exploring ideas from other regions to see if they can be applied to Charleston Harbor Watershed. Many guides and reports developed for other areas may also provide great examples and ideas to adapt for local application. For example this one from New Jersey found at https://www.nwf.org/CoastalSolutionsGuideNJ.

Above all, readers are encouraged to embrace this assessment as a useful tool to build community resilience using natural and nature-based solutions. Ample recent experience and forecasts tell us that more frequent and more serious flooding threats will occur, and that seas are rising. The best time to plan for resilience is before the next event turns into catastrophe. Data, tools, guidance, and support exist to inform and plan actions that can build resilience in ways that can also benefit the watershed's fish and wildlife resources.

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Additional Stakeholders

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Audubon
Center for Heirs Property Preservation
Citadel
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Clemson University - Dept. of Forestry and Environmental Conservation
Coastal Carolina University
Coastal Conservation League
College of Charleston
Dewees Island
Enduring Conservation
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SCDNR - ACE Basin National Estuarine Research Reserve
SCDNR - Donnelly Wildlife Management Area

SCDNR - Environmental Programs
SCDNR - Marine Resources Division
SCDNR - Marine Resources Research Institute
SCDNR - Office of Fisheries Management Shellfish Section
SCDNR - Tom Yawkey Wildlife Center
South Atlantic Landscape Conservation Cooperative
South Carolina Aquarium
South Carolina Sea Grant
The Nature Conservancy
Town of Bluffton
U. S. Fish and Wildlife Service (USFWS)
U. S. Forest Service
University of South Carolina (USC)
United States Army Corps of Engineers (USACE)
USC - Computer Science & Engineering Department
USFWS - Cape Romain NWR, Refuge Manager
USFWS - Coastal Program
USFWS - Savannah National Wildlife Refuge
USFWS - Threatened & Endangered Species

Appendices

Appendix 1. Watershed Committee and Stakeholder Engagement Mechanisms and Process

Local guidance and meaningful stakeholder participation were a key part of the Targeted Watershed Assessment process. Their input provided critical information and insights reflecting local knowledge and priorities.

Watershed Committee

The purpose of the Watershed Committee was to provide guidance to the assessment in terms of:

- Identifying dates and venues for initial stakeholder webinars and in-person workshops;
- Developing an inclusive list of individuals invited to participate as stakeholders;
- Approving the final list of fish and wildlife elements and priorities to be included in the assessment; and
- Providing initial leads for appropriate datasets for representing fish and wildlife elements and other data used in the assessment (Appendix 5).

By including a broad range of participants from different organizations (see Acknowledgements for full list), the committee was able to represent the interests and perspectives of the national organizations involved in the assessment as well as those of local watershed organizations.

Stakeholders

Stakeholders provided relevant plans and studies to establish baseline context, ideas, and feedback on the selection of relevant fish and wildlife elements, identification of key stressors and threats, and identified the most appropriate data sets for use in the assessment. In addition, stakeholders were the key source of coastal resilience project plans and ideas. The stakeholder engagement process was designed to be as inclusive as possible and to maximize involvement of participants who could contribute a range of opinions and inputs. Stakeholders were defined as those individuals or groups who have one or more of the following:

- an interest in using and/or providing data to improve the assessment,
- expertise in and/or are working to conserve fish and wildlife species and habitat,
- are involved in designing, constructing, or funding resilience projects, especially nature-based resilience projects, or
- are leading efforts to improve resilience within their communities.

Representatives from federal and state agency personnel, non-profit organizations, local government agencies, academic institutions, and interested private citizens were all invited to participate in the assessment process. Of 117 invited participants, 35 participated in the in-person stakeholder workshops, but many others followed up with additional information and input after the workshops, providing critical data leads and resilience project ideas. (See Acknowledgments section for a list of the agencies represented in the stakeholder process.)

Project Outreach and Coordination Resources

Several resources were developed to inform and support input by stakeholders.

- National and watershed-specific fact sheets to convey project goals.
- A Data Basin portal (https://databasin.org/) for the watershed to keep all stakeholders informed and to provide an online space for information submission, etc. (sign up was required via the South Atlantic LCC Conservation Planning Atlas).
- Dynamic project submission forms with step by step instructions for contributing data and resilience projects.
- A draft list of fish and wildlife data elements that were targets for inclusion in the project.

Watershed Webinars and Stakeholder Workshops

Webinars and in-person workshops were scheduled to maximize involvement from stakeholders throughout the watershed and to keep participants informed about project progress throughout the project timeline. Stakeholders were invited to attend one of two workshops which were preceded by an introductory webinar to provide background in advance of the workshops (see **Table A1-1** for more information on specific engagement opportunities and the Acknowledgements section for more information on the groups represented in the stakeholder process).

After an initial introduction to the proposed analysis and the project timeline, participants were offered a variety of mechanisms in which to provide input, ideas, and comments. In particular, participants were encouraged to:

- Submit ideas for fish and wildlife elements of particular importance in this watershed.
- Highlight important datasets to use in the analysis (both on fish and wildlife, stressors, and coastal threats).
- Submit resilience project ideas.

Table A1-1. List of webinars and in-person meetings with watershed committee and/or stakeholders.

Name of Engagement Activity	Participation	Date
First Watershed Committee meeting (by webinar)	Watershed Committee	April 10, 2017
Pre-stakeholder webinar	Stakeholders, Watershed Committee	May 11, 2017
In-person stakeholder workshops	Stakeholders, Watershed Committee	May 24-25, 2017
Post workshop follow-up to summarize workshop results	Watershed Committee	June 26, 2017
Review of fish and wildlife and vulnerability assets	Watershed Committee	June 26, 2017
Draft results webinar to discuss GIS analysis and obtain final input from all stakeholders that wish to participate	Stakeholders, Watershed Committee	January 9, 2018

Post-workshop Activities

Workshop input and discussion was used to finalize fish and wildlife species and project submissions for the assessment. In addition, the workshops helped to:

- Identify iconic or culturally/economically important species and any other species nominated by stakeholders to the list of fish and wildlife elements for consideration in the assessment.
- Aggregate the fish and wildlife species list into habitat groupings and/or guilds to ensure key habitats were covered in the analyses.
- Capture resilience project ideas submitted during the stakeholder workshops so that core team members could follow-up with project proponents later to collect all information to properly represent each resilience project in the database.

Once these steps were completed, the Watershed Committee and stakeholders were given updates on the process via webinars to review draft products (**Table A1-1**).

Gathering Candidate Projects

Candidate resilience projects were gathered from stakeholders both at the in-person workshops and afterwards via the online portal, email, and phone. These project submissions became the pool from which several were selected for site visits and ultimately the final three case studies featured in this report.

Appendix 2. Condition and Vulnerability Technical Approach and Modeling Methods

This appendix provides additional detail to the Methods Overview and is supported by Appendix 3, which describes the vulnerability assessment model parameters and assumptions. These appendices also provide the details for the condition modeling, which generated some of the indices as an intermediate product of the vulnerability assessment. Not all technical details are described, for more extensive explanation of these, see the Vista Decision Support System (DSS) user manual (see GIS Tools section below). The vulnerability assessment methods for Human Community Assets (HCAs) and fish and wildlife elements were the same and used the same technical approach in the Vista DSS. *Elements* is the common term used in the Vista DSS for all features of assessment and planning interest, so from here-on, *elements* will be used to refer to both HCAs and fish and wildlife elements.

GIS Tools

The extensive and complex spatial assessments required for this project were conducted using the following Geographic Information Systems (GIS) tools:

ArcMap 10.6 is a geographic information system (GIS) developed by Esri (http://www.esri.com) as part of their ArcGIS Desktop product. The Spatial Analyst extension was required for this project.

NatureServe Vista (http://www.natureserve.org/conservation-tools/natureserve-vista) is an extension to ArcGIS that supports complex assessment and planning. Vista was used because it has the functions to support the types of analyses required to meet project objectives. It also serves as a platform to deliver the spatial data, results, and support additional work by stakeholders such as updating, re-prioritizing, and/or expanding the analyses to meet specific planning objectives.

Modeling Approach

A key concept in the Targeted Watershed Assessments is that the Vista DSS uses a *scenario-based* approach. This means that stressors and threats are aggregated into specific scenarios against which vulnerability of elements is assessed. These scenarios were illustrated in the stressor and threat groupings (**Figure 6**) in the Methods Overview. To assess vulnerability, condition of the elements must first be modeled by applying the model parameters in Appendix 3 to the scenario of interest. These condition results were used in several indices. From there, a condition threshold is applied to the condition map and values below the threshold are marked as vulnerable (non-viable in Vista DSS terminology).

The process steps used are listed and described below.

1. Define the scenarios in which stressors and threats are compiled
2. Build response models for how elements respond to the stressors and threats within the scenarios
3. Model condition of elements under each scenario
4. Apply the element condition thresholds and generate vulnerability maps of each element
5. Create vulnerability indices for element groups by summing the number of vulnerable elements at each location (pixel)

Definition of Scenarios

A scenario is a collection of maps of all the stressors and threats identified by stakeholders (for which adequate data existed) that can affect the condition of the elements. These stressors and threats are described as either fish and wildlife *stressors* (such as water quality) that only affect fish and wildlife elements and flooding *threats* that may affect all elements differentially (e.g., soils subject to flooding may affect HCAs but not the natural habitat already adapted to flooding that may occur there). Stressors and threats' effects on elements are evaluated using the assessment models described in the next section. Three scenarios were created and assessed, details on stressors and threats within each are described below.

1. **Baseline** depicts the current stressors within the watershed and supports assessment of the current condition of the fish and wildlife elements to understand how element condition may change in the future based on future threats or restoration actions.
2. **Threats** only includes the flooding threats and supports assessment of how these threats alone may impact element condition. In other words, without considering the current baseline condition, to what extent is a given element impacted by flooding threats.
3. **Combined** combines the baseline and threats scenarios into a cumulative scenario to understand how current and flooding threats may combine to impact fish and wildlife element condition.

Scenarios were built within the Vista DSS using the Scenario Generation function where data attributes were cross-walked to a classification of scenario stressors and threats. Data layers were added and grouped as to whether a feature overrode or dominated stressors and threats below it or combined with other stressors and threats. The objective of that process is to provide the most accurate scenario in terms of whether scenario stressors and threats co-occur in the same location or the presence of a feature precludes the presence of another feature (e.g., where there is a road there is not also agriculture). A large volume of stressor and threat data were gathered, evaluated, and integrated in the Vista DSS to map each of the scenarios. Details on scenario data are described below and the use of individual stressors and threats in each scenario is shown in **Table 2** and **Figure 6** in the Methods Overview.

Table A2-1. List of Stressors and threats indicating in which scenarios each was used.

Fish/Wildlife Stressors	Scenario		
	Baseline	Threats	Combined
Land use, including different levels of housing development, commercial/industrial areas, agriculture, and forestry	X		X
Infrastructure, including different size roadways, railroads, dams, pipelines, and electrical transmission corridors	X		X
Energy, including oil and gas extraction and renewable energy	X		X
Terrestrial and aquatic invasive species	X		X
Water quality or stressors that can affect water quality	X		X
Dredge Material Placement Areas	X		X
Flooding Threats	**Baseline**	**Threats**	**Combined**
Sea level Rise		X	X
Storm surge potential		X	X
Subsidence		X	X
Erosion potential		X	X
Flat and poorly drained soils		X	X
Flood prone areas		X	X

Stressor and Threat Data

The full list of stressors and threats used in the vulnerability assessments is in **Table A2-2** at the end of this appendix, along with the data source used. If no data source was found for a stakeholder-identified fish and wildlife stressor that is noted. This assessment used the flooding threats data developed in the Regional Assessment (Dobson et al. 2019). The following is a brief description of each flooding threat included.

Soil Erodibility

To assess the erodibility of soils throughout the coastal watersheds, the USDA-NRCS Soil Survey Geographic Database (SSURGO) classification kffact was used. The kffact score represents the susceptibility of soil particles to detachment by water. Soil erosion resulting from flooding can drastically alter the landscape and impact wildlife habitat. Erosion can be devastating in extreme flood events. In this assessment, soil erodibility varies tremendously across regions and is dependent on soil type. Also highlighted in this input are beaches and dunes that are migratory by nature. Although these landforms can help buffer a community from flooding, the risk of erosivity is fairly high.[8]

Impermeable Soils

This input was included because it influences the period of time that coastal lands are inundated after a storm event. Poorly drained soils are typically wetland soils or clays and high density development is

[8]Gornitz, V.M., Daniels, R.C., White, T.W., and Birdwell, K.R., 1994, The development of a Coastal Vulnerability Assessment Database: Vulnerability to sea-level rise in the U.S. Southeast: Journal of Coastal Research Special Issue No. 12, p. 330.

also considered very poorly drained because of pavement and rooftops. In many cases the USDA-NRCS SSURGO database is lacking data in urban areas. To account for the obvious impermeable nature of these areas, the National Land Cover Database developed land cover classes are included. To be considered a “very high” rank, the landscape must be a poorly or very poorly drained soil type and mapped as a developed land use.

Sea Level Rise

Sea level rise is occurring at different rates across the U.S. Coasts, for example relative sea level rise along the western portion of the Gulf Coast and a large portion of the North Atlantic Coast will be greater than the Pacific Northwest Coast as a result of groundwater and fossil fuel withdrawals.[9] The sea level rise scenarios modeled by NOAA can inform coastal decision-makers and wildlife managers. Gornitz et al. (1994) cited many studies as early as 1989 that demonstrated the potential vulnerability of the barrier islands and wetlands within the South Atlantic region to changing environmental conditions and other episodic flood events.[10] Scenarios for a 1-5 foot rise in sea level were used in the Regional Assessment but a lower level was used in this Targeted Watershed Assessment (see Methods Overview).

Storm Surge

Surge from hurricanes is the greatest threat to life and property from a storm. Like sea level rise, storm surge varies by region. The width and slope of the continental shelf play an important role in the variation between regions. A shallow slope will potentially produce a greater storm surge than a steep shelf. For example, a Category 4 storm hitting the Louisiana coastline, which has a very wide and shallow continental shelf, may produce a 20-foot storm surge, while the same hurricane in a place like Miami Beach, Florida, where the continental shelf drops off very quickly, might see an eight- or nine-foot surge.

Areas of Low Slope

As the slope of the terrain decreases, more land areas become prone to pooling of water, which can allow for prolonged coastal flooding. This input was created using the Brunn Rule, which indicates that every foot rise in water will result in a 100-foot loss of sandy beach. In this case, a one percent slope or less is likely to be inundated with a one-foot rise in water. This rule provides insight for low-lying coastal areas that are more susceptible to inundation and changing coastal conditions.

Additional stressors on fish and wildlife were identified by stakeholders in the workshops (Appendix 1). Distribution data were submitted by stakeholders and evaluated against data criteria and other regional/national datasets known to the GIS team. The best available data were then used to build each scenario based on currency, completeness, and resolution. Stakeholders, Watershed Committee members, and attendees of any of the review sessions were invited to review data sources and gaps. They were provided with a link to an online form allowing them to enter information on additional

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[9]NOAA, *Global and Regional Sea Level Rise Scenarios for the United States* (2017), 30.

[10]Gornitz, V.M., Daniels, R.C., White, T.W., and Birdwell, K.R., 1994, The development of a Coastal Vulnerability Assessment Database: Vulnerability to sea-level rise in the U.S. Southeast: Journal of Coastal Research Special Issue No. 12, p. 330.

data sources that might be of use as well as a link to a Dropbox folder for uploading data. Requirements for data submissions included:

- Data must be georeferenced and use a defined projection.
- Data should be complete for the full extent of project area and not just a subset of it.
- Data must either be represented as an area (e.g., polygon shapefile, raster) or, if in point or line format, have an explicit buffering rule (either a single distance from all features or variably calculated based on an attribute of each feature).
- Data should be submitted to contain FGDC compliant metadata (strongly preferred). Exceptions were made, but most data lacking metadata did not make it through the initial screening process.

All data sources were further evaluated according to project data requirements. Evaluation included completeness of data across the watershed, precision of data, and accuracy of data compared to other sources or imagery. Where necessary, data were projected to the project standard, clipped/masked to the project boundary, and rasterized if necessary. For readers interested in using these datasets, they can be found in the NatureServe Vista project resource available through NFWF's Coastal Resilience Evaluation and Siting Tool (CREST), available at resilientcoasts.org.

Table A2-2. Fish and wildlife stressors and threats identified by stakeholders. *Table identifies the primary category, secondary category (which was mapped if suitable data was found), data sources identified (if any), and the scenarios in which each was used.*

<table>
<tr><th colspan="2">Stressor/Threat Primary & Secondary Categories</th><th>Data Sources</th><th>Scenarios</th></tr>
<tr><td rowspan="4">Residential & Commercial Development</td><td>High/Medium Density Housing (high imperviousness > 50%)</td><td rowspan="3">USGS Roadless Landcover (Soulard & Acevedo 2016)</td><td rowspan="4">Baseline, Combined</td></tr>
<tr><td>Low Density Housing (moderate imperviousness 20%-40%)</td></tr>
<tr><td>Developed Open Spaces (parks, cemeteries, etc.) (low imperviousness < 20%)</td></tr>
<tr><td>Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)</td><td>National Transportation Atlas Database (2015 or later); Petroleum terminals and refineries (2015 or later): Terminals: EIA-815, "Monthly Bulk Terminal and Blender” Report; Refineries: EIA-820 Refinery Capacity Report; Natural Gas Terminals and Processing Plants (2015 or later): Terminals: EIA, Federal Energy Regulatory Commission, and U.S. Dept. of Transportation; Processing Plants: EIA-757, Natural Gas Processing Plant Survey</td></tr>
<tr><td rowspan="5">Agriculture and Aquaculture</td><td>Silviculture – Sustainable</td><td>No data</td><td>n/a</td></tr>
<tr><td>Silviculture – Intensive</td><td rowspan="3">NatureServe Systems Map (Comer 2009)</td><td rowspan="3">Baseline, Combined</td></tr>
<tr><td>Intensive Agriculture</td></tr>
<tr><td>Ruderal (maintained pasture, old field)</td></tr>
<tr><td>Aquaculture</td><td>No data</td><td>n/a</td></tr>
<tr><td rowspan="4">Energy Production and Mining</td><td>Solar Arrays</td><td rowspan="4">No data</td><td rowspan="4">n/a</td></tr>
<tr><td>Wind</td></tr>
<tr><td>Oil and Gas Fields</td></tr>
<tr><td>Mining</td></tr>
<tr><td rowspan="3">Transportation and Service Corridors</td><td>Primary Roads</td><td rowspan="3">Tiger roads (U.S. Census 2016)</td><td rowspan="3">Baseline, Combined</td></tr>
<tr><td>Secondary Roads</td></tr>
<tr><td>Local, neighborhood and connecting roads, bridges/culverts</td></tr>
</table>

Stressor/Threat Primary & Secondary Categories		Data Sources	Scenarios
	Dirt/Private roads/culverts		
	Railroads, bridges, culverts	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later); Federal Highway Administration, NBI v.7, NTAD (2015 or later)	
	Utility & Service Lines (overhead transmission, cell towers, etc.)	No data	n/a
Dredge Material Placement Areas		USACE (Michael Sarhan pers. comm.)	Baseline, Combined
Dams & Reservoirs		USDOT/Bureau of Statistics's NTAD (2015 or later)	Baseline, Combined
Sea Level Rise – 1 ft		NOAA Sea-level Rise Scenarios	Flooding Threats, Combined
Storm Surge	Category 1	FEMA National Flood Hazard Layer	Flooding Threats, Combined
	Category 2		
	Category 3		
	Category 4		
	Category 5		
Water Quality	Moderate	EPA Impaired Waters	Baseline, Combined
	Low	AIS Commercial Vessel Traffic Density (MarineCadaster.gov, 2012, obtained from Rua Mordecai pers. comm.)	
Invasive Species	Terrestrial	No data	n/a
	Aquatic		
Landslide Susceptibility	High Susceptibility, Moderate Incidence	USGS Landslide Susceptibility Data	Flooding Threats, Combined
	High Incidence		
Subsidence	Moderate	UNAVCO Subsidence Data	Flooding Threats, Combined
	High		
	Very High		
Poorly drained areas	Flat & Somewhat Poorly Drained	NRCS SSURGO	Flooding Threats, Combined
	Flat & Poorly or Very Poorly Drained		
Erosion	High Erodability	NRCS SSURGO Soil Erodibility Data	Flooding Threats, Combined
	Very High Erodability		
Flood Prone Areas	Occasional Flooded Soils	FEMA National Flood Hazard Layer	Flooding Threats, Combined
	Frequent Flooded Soils		
	500 Year Floodplain		
	100 Year Floodplain		
	Floodway*		

**A "Regulatory Floodway" means the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height (https://www.fema.gov/floodway).*

Building Element Response Models

Response models reflect how each element responds in the presence, or within a certain distance, of a scenario feature. Four response models were developed to model element condition and assess their vulnerability. One model was developed for HCAs; fish and wildlife elements were put into three groups, assuming that the elements within a group respond similarly to the stressors and threats: a Terrestrial Elements model (models condition of all terrestrial wildlife elements), a Freshwater Elements model (models condition of all freshwater wetlands, stream and lake habitats, and aquatic freshwater animal species), and an Estuarine Elements model (models condition of all elements adapted to brackish and saltwater conditions—wetland, submerged aquatic habitats, estuarine habitats, and aquatic marine animal species). For each of these four groups of elements, parameters for the models included an element condition threshold (where condition drops below a state viable for the element), site intensity impacts (within the immediate footprint of stressors/threats relevant to a given scenario), and distance effects (to what extent impacts from a given stressor or threat extend out from mappable features). The threshold score is a subjective value (between 0.0 and 1.0) that is assigned based on the perceived relative sensitivity of the element category such that a high threshold (e.g., 0.8) would indicate an element that is very intolerant of disturbance, whereas a low threshold, (e.g., 0.5) would indicate an element that can remain viable with a considerable amount of disturbance. In the case of this project, "viable" should be interpreted as the ability to persist if conditions remain constant regarding a given scenario or the ability to recover from impacts without intervention in a relatively short time. Settings for each parameter were informed by Hak and Comer (2017), Powell et al. (2017), and prior experience of the NatureServe assessment team with input from the Charleston Harbor Watershed Committee and other stakeholders. Model inputs and assumptions are described in Appendices 2 and 3.

Model Element Condition

Modeling element condition is the first step to assess vulnerability, but the intermediate product of element condition was also used in the Fish and Wildlife Condition-Weighted Index and as a factor in the ranking of *Resilience Hubs*. The spatial analyses were conducted using the "landscape condition model" (LCM) within the Vista DSS, which is based on a model developed by Hak and Comer (2017). The condition of each element was assessed under the relevant scenarios described above by applying the appropriate response model to generate a set of condition maps that cover the entire watershed. HCAs were only assessed against the *threats scenario* with the assumption that current HCAs are compatible with other human development and wildlife stressors and are only impacted by the flooding threats. Fish and wildlife elements were assessed against all three scenarios to inform their current condition under the baseline scenario, the potential impacts from just the flooding threats, and the cumulative impacts of the stressors in the baseline scenario and the flooding threats in the Combined Scenario.

The LCM calculates the condition score of every pixel in the watershed as depicted in the four maps below (**Figure A2-1**) using the relevant response models per above without regard to locations of elements to which the scores will be applied. The LCM first calculates the response scores on each individual scenario feature (site intensity within the scenario feature footprint and the distance effect offsite) and then overlapping feature responses are multiplied to calculate a cumulative effect. For example, where a condition score of 0.7 in a pixel resulting when one stressor overlaps with a condition score of 0.6 from another overlapping stressor, the scores are multiplied to obtain a combined score of 0.42 reflecting the cumulative impact of the two stressors. Vista then intersects the watershed-wide condition map with each relevant element distribution map to attribute the element's condition on a pixel basis (every pixel within an element's distribution receives a condition score). The condition maps and intermediate layers for each element are available in the Vista DSS project.

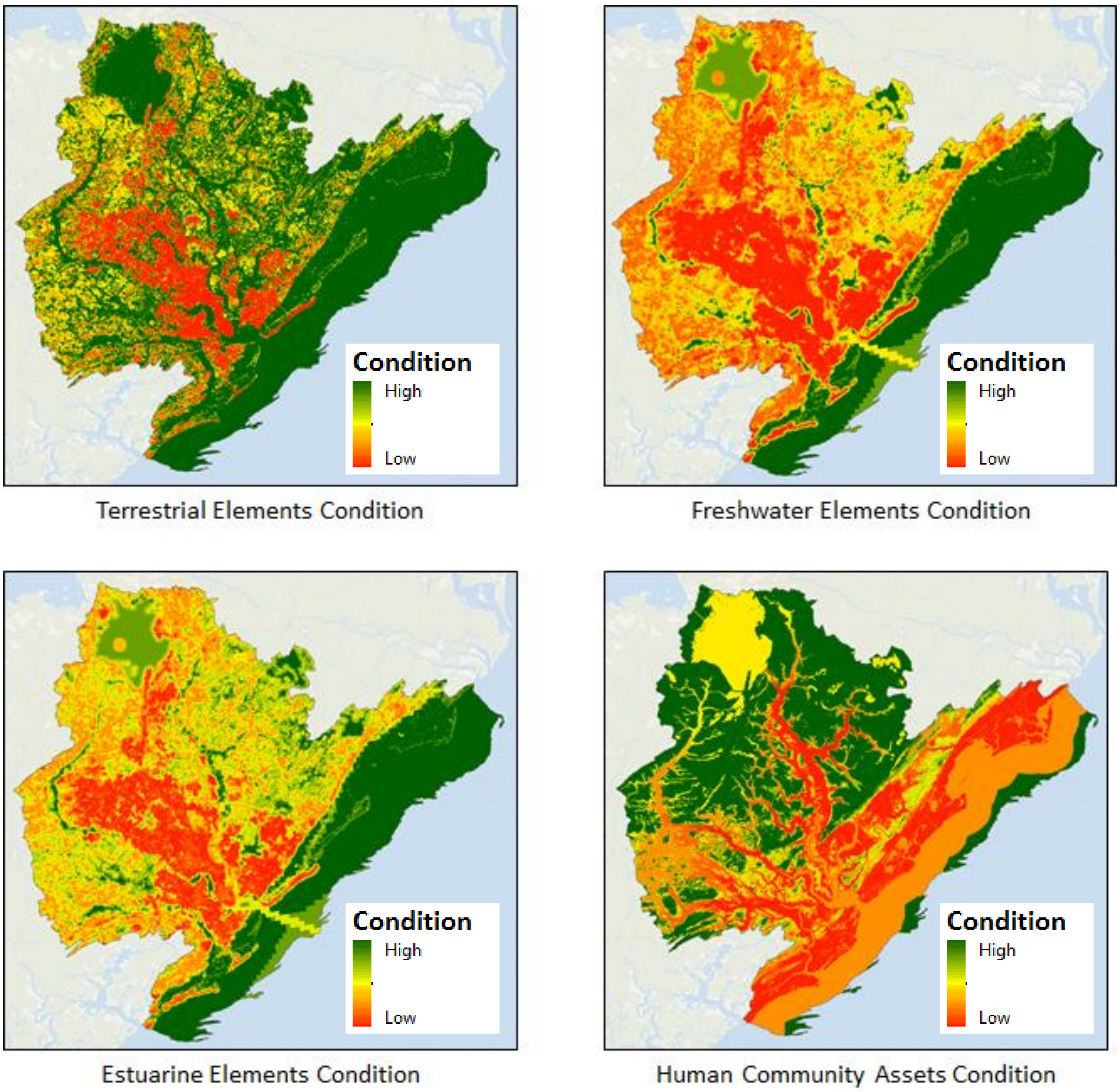

Figure A2-1. Landscape condition model outputs for the Charleston Harbor Watershed. *These maps depict the watershed-wide results of each of the four landscape condition models used in the assessments.*

Model Element Vulnerability

To assess vulnerability, the individual element results from the condition modeling above were subjected to the condition threshold for the same element groups described above in Building Element Response Models (see Appendix 3 for thresholds). All pixels below the threshold were attributed as non-viable (vulnerable); those above as viable (not vulnerable). For example, all HCAs were assigned a condition threshold of 0.5 indicating that when enough cumulative stressors reduce the condition of a pixel below 0.5, any HCAs falling within that pixel would be marked as non-viable. The elements were overlaid together and the non-viable pixels were summed across elements to generate a raster index where the value of a pixel is the count of the number of vulnerable elements in each pixel. This resulted in the Human Community Vulnerability Index and the Fish and Wildlife Vulnerability Index (described further in Appendix 4). The Vista DSS also accommodates the use of a minimum viable patch/occurrence size for elements to further define viability, but this was not used in the project. For example, one can specify a minimum size for a marsh type at 100 acres. A patch would then need to have at least 100 acres of viable pixels to be viable or the entire patch is marked vulnerable. That function is available for users to add that parameter to the model and update the results.

Appendix 3. Structure, Parameters, and Assumptions for Condition and Vulnerability Models

This appendix provides the model settings and details established in the condition modeling and vulnerability assessments (Appendix 4) so users may better understand the results and may consider refining the settings based on additional local knowledge or different objectives. Hereon, the term *elements* is used to describe both fish and wildlife and HCAs as that is the functional term used in the Vista DSS for all features of assessment/planning interest. While some literature was used to inform the model parameters, these are primarily subjective, expert knowledge-informed settings for which empirical data do not generally exist. Instead, assumptions are provided so they may be challenged and refined when better information or knowledge becomes available.

The four models' parameters described in the tables below are provided as four separate tables in the following order:

1. **Table A3-1**: Terrestrial Vulnerability Model
2. **Table A3-2**: Freshwater Vulnerability Model
3. **Table A3-3:** Estuarine Vulnerability Model
4. **Table A3-4**: Human Asset Vulnerability Model

While Vista allows response models tailored to individual elements, for this rapid assessment, grouping the elements was an efficient way to generate reasonable models and end products. Each table is organized according to the following column headings and categories.

- ***Key Assumptions of this Model***: Describes which elements the model applies to and the general assumption for how effects of scenario stressors and threats were scored.
- ***Importance Weighting:*** Only applicable to HCAs (**Table A3-4**) and only for the weighted richness index, but weights can be assigned to any of the elements if desired.
- ***Element Condition Threshold***: Score, between 0.0 and 1.0, representing the relative sensitivity of an element to stressors and threats. Relatively high numbers (e.g., 0.8) indicate high sensitivity/low adaptive capacity to disturbance while low numbers (e.g., 0.4) would indicate low sensitivity/high adaptive capacity.

The next section of each table provides the classification of the stressors and threats including both Primary Category and Secondary Category, the response parameters of the elements in the group to those stressors and threats, and the assumptions made in those responses. The following column headings indicate:

- ***Response Type***: Column represents one of three possible parameter types used in the Vista Scenario Evaluation model:
    - ***Categorical Response*** is set as negative (negative impact from the stressor/threat) neutral (no effect), and positive (a beneficial effect—this only applies to the list of actions established for resilience projects). This response was not directly used in the assessment but serves two purposes—first to inform the setting of the other responses by narrowing whether they should be above or below the condition

threshold; second to support use of the Vista project for planning purposes where it allows rapid testing of proposed actions at the site scale (in the Vista DSS see the Site Explorer function).

  - ***LCM Site Intensity*** indicates how much of an element's condition would be left if the stressor/threat fell directly on the element. This setting assumes a starting condition of 1.0 (high or perfect condition in the absence of other stressors). This is an important assumption to understand in Vista, that without a mapped stressor, condition will be perfect. While ultimately whether the score is above or below the threshold determines viability of the element at a location, the gradient is useful to understand how much above or below the threshold the element condition is to inform decisions about conservation and restoration. The model does not allow a setting of 0.0, so .05 is generally used to indicate complete removal/reduction of condition.
  - ***LCM Distance*** indicates the distance in meters from the edge of a stressor that the impacts may extend. The LCM does not use a buffer but instead models an S-shaped curve where the impacts start off high from the edge, drop off steeply, then level out to no effect at the specified distance.

- ***Responses:*** Column indicates the settings established by the project team.
- ***Response Assumptions:*** Provides a short description of the team's assumptions of the setting.

Storm surge effects modeling

Because only a single threats scenario was assessed in this rapid assessment, all 5 categories of storm surge had to be combined and treated simultaneously. The scores for the site intensity (impact) for each category of storm surge were, therefore, set with this combination in mind versus scoring each independently. The scores are described in the tables below, but the general logic of the combination is that where category 1 surge overlaps with all other categories and, therefore, deeper flooding and higher energy water movement, the impact is highest; where there is category 5 surge (not overlapping any other categories) and thus the shallowest, lowest energy fringe area of flooding (furthest inland), the impact is lowest. Categories 2-4 will have intermediate levels of impact from high to low respectively. While the individual impact scores are not severe, the multiplication of them, where they overlap, equates to high impact. To illustrate, the impact on human assets from a category 5 surge that overlaps with the category 1-4 surges (that area closest to the coast) would be scored as category 1 (.65) x category 2 (.7) x category 3 (.75) x category 4 (.8) x category 5 (.85) = a cumulative impact score of .23 which is far below the vulnerability threshold of 0.5. If the Vista DSS user wished to create separate scenarios for each category of storm surge, the settings should be adjusted to reflect the anticipated level of each category independently.

Table A3-1. Terrestrial Exposure Model Structure and Assumptions.

Key Assumptions of this Model			
Applies to Terrestrial Habitats and Species		Is focused more on keeping the habitat intact for resilience to flooding impacts and understanding current condition relative to flood mitigation than for biotic component retention	
Importance Weighting (Optional, used only for the CVS)	Values range from: 0.0 (Low) to 1.0 (High). There may be as many weighting systems as desired based on rarity, cultural or economic value, etc. Value based on G-rank can be automatically populated if G-rank attribute is provided	n/a	Importance weighting not set for fish and wildlife elements. Assumption is that all are equally important.
Element Condition Threshold	Values range from: 0.0 (Low) to 1.0 (High). This value will determine the LCM result threshold under which a species is no longer viable in a pixel. Nearing 0.0 indicates increasing resilience to stressors and nearing 1.0 indicates increasing sensitivity.	0.6	Sensitivity Assumptions: Terrestrial habitats may sustain significant impacts from stressors and threats and still provide the desired functions for controlling runoff volume and pollutants and generally maintaining same habitat type but not necessarily all ecosystem biotic components.
Land Use Intents (term used in Vista 3.x for all land uses, infrastructure, other stressors and threats, and conservation management and practices anticipated under any scenario). The IUCN/CMP classification list (v3.1, 2011) of direct threats and conservation practices was modified to meet the needs of this project.			

Primary Category	**Secondary Category**	**Response Types**	**Responses**	**Response Assumptions**
Residential & Commercial Development	High/Medium Density Housing (high imperviousness >50%)	Categorical Response	Negative	Assume total loss.
		LCM Site Intensity	0.05	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Low Density Housing (moderate imperviousness 20-49%)	Categorical Response	Neutral	In NLCD, individual houses or groups of houses are mapped as this type, so habitat type may have significant modification and fragmentation, considerable runoff and pollution can impact nearby aquatic systems. Impact less than high/moderate density because pixels do incorporate adjacent undeveloped areas. If local data suggests different densities of development and imperviousness, these assumptions and scores can be modified.
		LCM Site Intensity	0.2	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Developed open spaces (parks, cemeteries, etc.) (low imperviousness <20%)	Categorical Response	Negative	Assume nearly complete conversion to maintained landscape but with some potential for restoration, particularly to land cover with more habitat value if not original habitat type. Some increased runoff generated in volume and pollutants from landscape maintenance.
		LCM Site Intensity	0.3	
		LCM Distance	50	Relatively small distance effect because of vegetative cover reducing pollutant runoff.
	Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)	Categorical Response	Negative	Assume total loss.
		LCM Site Intensity	0.05	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
Agriculture and Aquaculture	Silviculture - Sustainable	Categorical Response	Neutral	Not significant impact on ecosystem process/hydrologic function, some impact on habitat quality/diversity, but would remain viable in absence of other stressors. High restorability
		LCM Site Intensity	0.7	
		LCM Distance	0	Negligible distance effect because of expected continuous vegetation coverage.
	Intensive Agriculture	Categorical Response	Negative	Complete habitat conversion, but some maintenance of hydrologic function. Potential long-term restorability.
		LCM Site Intensity	0.2	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Ruderal (maintained pasture, old field)	Categorical Response	Negative	Near complete conversion to managed landscape, but with some significant natural vegetation maintained in portions. May have herbicide applied for weed control, but otherwise hydrologic function would be closer to natural than more intensive agriculture types.
		LCM Site Intensity	0.4	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Aquaculture	Categorical Response	Neutral	Only assesses impact of adjacent aquaculture on terrestrial habitat vs. conversion to aquaculture. Assume clearing and hydrologic process impacts, difficult to restore to original habitat type.
		LCM Site Intensity	0.3	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change
Energy Production and Mining: assume on land	Solar arrays	Categorical Response	Negative	Cleared but not paved footprint, potential for restoration.
		LCM Site Intensity	0.3	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Wind	Categorical Response	Negative	Assumption is for a wind field, not individual wind towers. Less footprint clearing and maintaining than solar and greater restorability with more remaining natural cover.
		LCM Site Intensity	0.4	
		LCM Distance	300	Height of towers leading to larger visual and noise avoidance impacts will be highly variable.
	Oil and Gas Fields	Categorical Response	Negative	Assumptions for well field, not individual pads. Assume dispersed clearing, maintained dirt pads, roads, noise but with mostly natural habitat in between and fairly high restorability.
		LCM Site Intensity	0.4	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Mining	Categorical Response	Negative	Assumption for pit type mining. Effects can include complete removal of habitat, deep excavation, noise, dust, runoff of sediment, vehicle traffic. Difficult to restore to original ecosystem type.
		LCM Site Intensity	0.1	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Transportation and Service Corridors	Primary roads, e.g., Interstates, high traffic/volume, wide roads, bridges	Categorical Response	Negative	Complete clearing, pavement, vehicular visual and noise disturbance, wildlife mortality, fragmentation, loss of connectivity.
		LCM Site Intensity	0.05	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Secondary roads, e.g., moderate traffic/volume state highways, bridges	Categorical Response	Negative	Somewhat reduced footprint and traffic impacts than a primary road but still highly significant.
		LCM Site Intensity	0.2	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Local, neighborhood and connecting roads, bridges/culverts	Categorical Response	Negative	Similar effects as secondary road.
		LCM Site Intensity	0.2	
		LCM Distance	50	Smaller distance effect due to narrower footprint and reduced traffic volume.
	Dirt/Private roads/culverts	Categorical Response	Negative	Very narrow footprint, very low traffic volume, and can have continuous forest canopy over road, higher potential for restorability than wider/public roads.
		LCM Site Intensity	0.4	
		LCM Distance	30	Narrow footprint, low traffic volume, and potential for continuous forest canopy means smaller distance effect.
	Railroads, bridges, culverts	Categorical Response	Negative	Similar effects as secondary road.
		LCM Site Intensity	0.2	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a change to the existing habitat type.
	Utility & Service Lines (overhead transmission, cell towers, etc.)	Categorical Response	Negative	Localized clearing and maintained artificial clearing but not paved, variable effects on animal behavior, potential for invasive introductions, fairly high restorability.
		LCM Site Intensity	0.4	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a change to the existing habitat type.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Dredge Material Placement Areas	Locations where dredge material is permanently deposited	Categorical Response	Negative	Assumption that any habitat is likely to experience recurring dredge deposition with associated salt and other pollutants. Moderate effort required to restore vegetative cover.
		LCM Site Intensity	0.3	
		LCM Distance	0	Assume no offsite effects on terrestrial elements.
Dams and Reservoirs	Any mapped dams and reservoirs	Categorical Response	Negative	Conversion from natural habitat but some potential for restoration through restored connectivity/dam removal.
		LCM Site Intensity	0.3	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a change to habitat type.
Sea Level Rise	See flooding threats table for level used.	Categorical Response	Negative	Complete and irreversible habitat conversion.
		LCM Site Intensity	0.05	
		LCM Distance	50	Some typical edge effect of habitat conversion, plus allowance for groundwater backup and/or saltwater intrusion causing effects beyond the inundation point.
Other threats	Water Quality - Moderate	Categorical Response	Neutral	Assume no effect on terrestrial elements.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Water Quality - Low	Categorical Response	Neutral	Assume no effect on terrestrial elements.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Invasive Species - Aquatic	Categorical Response	Neutral	Assume no effect on terrestrial elements.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Invasive Species - Terrestrial	Categorical Response	Negative	
		LCM Site Intensity	0.6	Effects can change biotic composition and sometimes habitat structure, which may lead to increased erosion, occasionally change an entire habitat type (to invasives dominated). Score is at threshold, so viability will be retained, but will benefit from control of invasives.
		LCM Distance	100	Indicates potential for spread over relatively short time without control depending on species.
	High Subsidence (Rank 4)	Categorical Response		
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response		
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response		Assume slightly less impact than for Very High Erodibility below.
		LCM Site Intensity	0.95	
		LCM Distance		
	Very High Erodibility	Categorical Response		Assume exposure to Category 3 storm surge in combination with very erodible soils would result in reduction of condition to just below threshold necessitating restoration for near term recovery. See assumptions for storm surge categories.
		LCM Site Intensity	0.9	
		LCM Distance		Assume no offsite effect.
Flood Prone Areas	500 Year Floodplain	Categorical Response	Negative	Assume enough damage to habitat through soil erosion or deposition to require some restoration to bring back habitat and species viability or several years for natural recovery.
		LCM Site Intensity	0.5	
		LCM Distance	n/a	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	100 Year Floodplain	Categorical Response	n/a	Assume elements are adapted to this flood level.
		LCM Site Intensity	n/a	
		LCM Distance	n/a	Assume no offsite effect.
	Floodway	Categorical Response	n/a	Assume elements are adapted to this flood level.
		LCM Site Intensity	n/a	
		LCM Distance	n/a	Assume no offsite effect.
Conservation Areas	Areas limited to conservation use	Categorical Response	Positive	No stressors inherent in this use other than those overlapping from other categories. Supports condition and allows for natural restoration.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Resilience Project Protection/ Restoration Actions	Living shoreline implementation	Categorical Response	Positive	Project enacts a shoreline management strategy for controlling erosion and enhancing water quality by providing long-term protection, restoration, or enhancement of vegetated or non-vegetated shoreline habitats. Restoration practices uniformly indicating positive response for human assets, understanding that in some cases some individual structures might potentially be removed for purposes such as allowing for marsh expansion, but at this time it is quite unlikely.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Projects with on-the-ground actions focused on improving beach or dune conditions. May reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Marsh restorations.	Categorical Response	Positive	Projects with on-the-ground actions that improve marsh conditions and/or expand marsh area by means of hydrology and thin layer dredge activities that are designed to enhance ecological assets may reduce flooding by slowing and lowering height of storm surge, reducing coastal erosion, and reducing effects of sea level rise.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Restoration of aquatic connectivity	Categorical Response	Positive	Projects with on-the-ground actions in riverine settings that remove or replace man-made barriers to water flow and fish movement (e.g., dams and culverts) may reduce flooding threats and culvert/road failures.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Upland restoration	Categorical Response	Positive	Projects with on-the-ground actions that improve upland conditions and/or expand natural upland area by means that are designed to enhance ecological assets may reduce flooding effects from precipitation-caused flooding upstream.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Riparian and floodplain restoration	Categorical Response	Positive	Projects with on-the-ground actions to improve conditions and/or expand floodplain or riparian area by means that are designed to enhance ecological assets will reduce/prevent erosion and may reduce flooding effects.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Storm Surge	Category 1	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.5	
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.7	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.

Table A3-2. Freshwater Exposure Model structure and assumptions.

Key Assumptions of this Model			
Applies to any consistently wet habitats or species adapted to freshwater environments.	Responses to stressors focused on water quality impacts, increased salinization, physical impacts on submerged aquatic vegetation, and the potential for other biotic impacts.		
Importance Weighting (Optional, used only for the CVS)	Values range from: 0.0 (Low) to 1.0 (High). There may be as many weighting systems as desired based on rarity, cultural or economic value, etc. Value based on G-rank can be automatically populated if G-rank attribute is provided.	n/a	Importance weighting is not set for fish and wildlife elements. Assumption is that all fish and wildlife elements are equally important.
Element Condition Threshold	Values range from: 0.0 (Low) to 1.0 (High). This value will determine the LCM result threshold under which a species is no longer viable in a pixel. Nearing 0.0 indicates increasing resilience and nearing 1.0 indicates increasing sensitivity.	0.7	Assumption is that freshwater elements have less adaptive capacity to the stressors and threats in this assessment (flooding scour, erosion, salinization) than terrestrial elements. Therefore, they require better condition to maintain function.
Land Use Intents (term used in Vista 3.x for all land uses, infrastructure, other stressors and threats, and conservation management and practices anticipated under any scenario). The IUCN/CMP classification list (v3.1, 2011) of direct threats and conservation practices was modified to meet the needs of this project.			

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Residential & Commercial Development	High/Medium Density Housing (high imperviousness >50%)	Categorical Response	Negative	Developed/armored shorelines, heavy runoff volume and pollutants, lack of shading with temperature increases. Low restorability.
		LCM Site Intensity	0.2	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Low Density Housing (moderate imperviousness 20-49%)	Categorical Response	Neutral	Septic tank pollutants, effects of clearing such as loss of tree cover and temperature increases, and increased runoff volume and landscape chemicals. Low restorability in general although there is potential to restore hydrologic connectivity and vegetation along streams.
		LCM Site Intensity	0.3	
		LCM Distance	300	Long distance effect to compensate for lack of water quality data.
	Developed open spaces (parks, cemeteries, etc.) (low imperviousness <20%)	Categorical Response	Negative	Clearing and temperature increases, human access, and landscaping (runoff volume, pollutants) will degrade habitat below threshold but high restorability potential.
		LCM Site Intensity	0.5	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)	Categorical Response	Negative	Developed/armored shorelines, heavy runoff of freshwater and pollutants may include effects such as waterfowl hazing and noise impacts that would greatly reduce condition Very low potential for restoration.
		LCM Site Intensity	0.2	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
Agriculture and Aquaculture	Silviculture - Intensive	Categorical Response	Neutral	Periodic clearing with high impacts on habitat, some impacts on hydrology through sedimentation and potential chemical application. In-wetland harvesting occurs in the Charleston area and would stress habitats well below the viability threshold and require significant wetland restoration.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Silviculture - Sustainable	Categorical Response	Neutral	Small runoff effects from these practices.
		LCM Site Intensity	0.9	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
	Intensive Agriculture	Categorical Response	Negative	Agricultural chemical runoff, sediment runoff, and shoreline erosion may stress elements below the viability threshold. Where agriculture occurs directly on wetlands, significant restoration would be required to bring it back.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Ruderal (maintained pasture, old field)	Categorical Response	Negative	NOAA indicated some agriculture chemicals used on pastures. Runoff is anticipated to be low but sediment may runoff depending on uses, and shoreline erosion may stress these elements up to their viability threshold.
		LCM Site Intensity	0.7	
		LCM Distance	300	Long distance effect to compensate for lack of water quality data.
	Aquaculture	Categorical Response	Negative	Habitat alteration, infrastructure, ongoing impacts of waste, nitrogen, and pathogens but high restorability.
		LCM Site Intensity	0.5	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Energy Production and Mining: assume on land	Solar arrays	Categorical Response	Negative	Assessed for impacts from adjacent solar arrays, not within the aquatic elements. More intensive clearing and maintaining of barren ground affects temperature, sedimentation, and some herbicide runoff but with fairly high restorability to natural vegetative cover.
		LCM Site Intensity	0.4	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
Energy Production and Mining: assume on land	Wind	Categorical Response	Negative	Assumption is for a wind field not individual wind towers. Less footprint clearing and maintaining than solar and greater restorability with more remaining natural cover, but height and visual/noise effects may lead to overall similar effect as solar.
		LCM Site Intensity	0.4	
		LCM Distance	300	Height of towers leading to larger visual and noise avoidance impacts will be highly variable.
	Oil and Gas Fields	Categorical Response	Negative	Assumptions for well field, not individual pads. Assume dispersed clearing, maintained dirt pads, roads, noise but with mostly natural habitat in between. Some pollutant runoff expected but fairly high restorability.
		LCM Site Intensity	0.4	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
	Mining	Categorical Response	Negative	Assumption for pit type mining. Effects can include complete removal of habitat, deep excavation, noise, dust, runoff of sediment, vehicle traffic. Difficult restorability and typically to different ecosystem type.
		LCM Site Intensity	0.1	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
Transportation and Service Corridors	Primary roads, e.g., Interstates, high traffic/volume, wide roads, bridges	Categorical Response	Negative	Complete clearing, pavement, vehicular visual and noise disturbance, wildlife mortality, fragmentation, loss of connectivity, and pollutant runoff.
		LCM Site Intensity	0.05	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Transportation and Service Corridors	Secondary roads, e.g., moderate traffic/volume state highways, bridges	Categorical Response	Negative	Assume over water assume bridge with in water and shoreline structures, and clearing leading to altered hydrology, shading, and noise impacts. Assume these impacts will drop immediate area to just below viability threshold.
		LCM Site Intensity	0.6	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Local, neighborhood and connecting roads, bridges/culverts	Categorical Response	Negative	Assume culvert instead of bridge with in water and shoreline structures, and clearing, altered hydrology, shading, and noise impacts, in addition to the loss of ecological connectivity. Likely denser than other road types. Assume these impacts will drop immediate area to just below viability threshold.
		LCM Site Intensity	0.6	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Dirt/Private roads/culverts	Categorical Response	Negative	Assume culverts with intensive onsite impact, shoreline structures, and clearing, altered hydrology, shading, noise, dirt runoff, and impacted connectivity. Assume some restorability.
		LCM Site Intensity	0.5	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Railroads, bridges, culverts	Categorical Response	Negative	Over water assume bridge with in-water and shoreline structures, and clearing, altered hydrology, shading, and noise impacts. Assume these impacts will drop immediate area to just below viability threshold and low restorability.
		LCM Site Intensity	0.6	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Utility & Service Lines (overhead transmission, cell towers, etc.)	Categorical Response	Neutral	Assume over water feature with in-water support structures, infrequent maintenance, and noise impacts. High restorability.
		LCM Site Intensity	0.9	
		LCM Distance	20	Very small distance effect.
Dredge Material Placement Areas		Categorical Response	Negative	Assumption is not for dredge materials to be placed within aquatic systems but that offsite effects would include chemical and sediment runoff. Moderate restorability to vegetative cover that would reduce impacts to adjacent aquatic systems.
		LCM Site Intensity	0.3	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Dams & Reservoirs	All dams and reservoirs	Categorical Response	Negative	Significant change of ecosystem type, hydrology, connectivity, long term sedimentation and significant costs to restore.
		LCM Site Intensity	0.2	
		LCM Distance	300	Fairly long-distance effect in terms of changed water chemistry and temperature, disrupted connectivity, and reduced natural sedimentation.
Sea Level Rise	See flooding threats table for level used.	Categorical Response	Negative	Conversion to saline adapted habitat, no ability to restore.
		LCM Site Intensity	0.05	
		LCM Distance	30	Distance effects include groundwater backup and saline intrusion, and edge effects of habitat conversion. Impacts will be highly variable based on topography and groundwater formations.
Storm Surge	Category 1	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.75	
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.85	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Other threats	Water Quality - Moderate	Categorical Response	Neutral	Assume moderate water quality will just maintain viability.
		LCM Site Intensity	0.7	
		LCM Distance	100	For partial water quality data, distance effect can extrapolate further, optional distance effect depending on the nature of data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Water Quality - Low	Categorical Response	Negative	These levels set to indicate restoration even with improved water quality may be difficult to remediate, since contaminated sediments have ongoing long-term effects.
		LCM Site Intensity	0.4	
		LCM Distance	100	For partial water quality data, distance effect can extrapolate further, optional distance effect depending on the nature of data.
	Invasive Species - Aquatic	Categorical Response	Negative	Aquatic species cause biotic and sometimes habitat level effects and are difficult to control.
		LCM Site Intensity	0.5	
		LCM Distance	300	Indicates potential for spread of invasives over a large distance depending on species and conditions.
Subsidence	Moderate Subsidence (Rank 3)	Categorical Response	Neutral	Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have a small multiplicative effect.
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.
	High Subsidence (Rank 4)	Categorical Response	Neutral	Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have a small multiplicative effect.
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	Neutral	Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response	Neutral	Freshwater wetland systems would be less exposed to erosion events, so in combination with Storm Surge Category 4 would drop below viability threshold.
		LCM Site Intensity	0.85	
		LCM Distance		Assume no offsite effect.
	Very High Erodibility	Categorical Response	Neutral	Freshwater wetland systems would be less exposed to erosion events, so in combination with Storm Surge Category 4 would drop below viability threshold.
		LCM Site Intensity	0.85	
		LCM Distance		Assume no offsite effect.
Flood Prone Areas	500 Year Floodplain	Categorical Response	Negative	Impact at just below viability threshold to indicate that some restoration action and/or years may be needed to restore viability from erosion, sedimentation, deposition of pollutants and anthropogenic debris, dispersal of invasives, and other severe impacts on species life histories/populations.
		LCM Site Intensity	0.6	
		LCM Distance	n/a	No offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Conservation Areas		Categorical Response	Positive	No stressors inherent in this use other than those overlapping from other categories. Supports condition and allows for natural restoration.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Resilience Project Protection/ Restoration Actions *(categories needed for Scenario breakouts)*	Living shoreline implementation	Categorical Response	Neutral	Project enacts a shoreline management strategy for controlling erosion and enhancing water quality by providing long-term protection, and restoration or enhancement of vegetated or non-vegetated shoreline habitats. Restoration practices uniformly indicate positive response for human assets, understanding that in some cases individual structures might be removed for purposes such as allowing for marsh expansion in the future.
		LCM Site Intensity	.9	
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Projects with on-the-ground actions focused on improving beach or dune conditions may reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Marsh restorations	Categorical Response	Positive	Projects with on-the-ground actions that improve marsh conditions and/or expand marsh area by means of hydrologic restoration and thin layer sediment deposition can enhance ecological assets and reduce flooding by slowing and lowering height of storm surge, reducing coastal erosion, and reducing the effects of sea level rise.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Restoration of aquatic connectivity	Categorical Response	Positive	Projects with on-the-ground actions in riverine settings that remove or replace man-made barriers to water flow and fish movement (e.g., dams and culverts) may reduce flooding threats and culvert/road failures.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Upland restoration	Categorical Response	Positive	Projects with on-the-ground actions that improve upland conditions and/or expand natural upland area by means designed to enhance ecological assets may reduce flooding effects from precipitation-caused flooding upstream.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Riparian and floodplain restoration	Categorical Response	Positive	Projects with on-the-ground actions to improve conditions and/or expand floodplain or riparian area by means designed to enhance ecological assets may reduce/prevent erosion and may reduce flooding effects.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

Table A3-3. Estuarine exposure model structure and assumptions.

Key Assumptions of this Model			
Applies to any consistently wet habitats or species adapted to brackish conditions but not necessarily ocean-level salinity so may be sensitive to storm surges and sea level rise.	Responses to stressors focused on water quality impacts, increased salinization, physical impacts on submerged aquatic vegetation, and the potential for other biotic impacts.		
Importance Weighting (Optional, used only for the CVS)	Values range from: 0.0 (Low) to 1.0 (High). There may be as many weighting systems as desired based on rarity, cultural or economic value, etc. Value based on G-rank can be automatically populated if G-rank attribute is provided.		Importance weighting not set for fish and wildlife elements. The assumption is all are equally important.
Element Condition Threshold	Values range from: 0.0 (Low) to 1.0 (High). This value will determine the LCM result threshold under which a species is no longer viable in a pixel. Nearing 0.0 indicates increasing resilience and nearing 1.0 indicates increasing sensitivity.	0.6	Assume that saltwater/brackish habitats for this project's consideration are better adapted to the types of flooding impacts and will have greater connectivity and ability to recover from impacts.
Land Use Intents (term used in Vista 3.x for all land uses, infrastructure, other stressors and threats, and conservation management and practices anticipated under any scenario). The IUCN/CMP classification list (v3.1, 2011) of direct threats and conservation practices was modified to meet the needs of this project.			

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Residential & Commercial Development	High/Medium Density Housing (high imperviousness>50%)	Categorical Response	Negative	Developed/armored shorelines, clearing, heavy runoff volume and pollutants (more dilution capability than FW systems assumed), very low restorability.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Low Density Housing (moderate imperviousness 20-49%)	Categorical Response	Neutral	Assume primary impacts are septic tank pollutants, effects of clearing such as loss of tree cover and temperature increases, and increased runoff volume and landscape chemicals. In brackish systems, impacts may also include shoreline armoring and dock structures within habitats. Some restoration possible depending on density of development to restore hydrologic connectivity and shoreline vegetation.
		LCM Site Intensity	0.5	
		LCM Distance	300	Long distance effect to compensate for lack of water quality data.
	Developed open spaces (parks, cemeteries, etc.) (low imperviousness <20%)	Categorical Response	Neutral	Assume clearing and temperature increases, human access, and landscaping (runoff volume, pollutants) will degrade below viability threshold but high restorability.
		LCM Site Intensity	0.5	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)	Categorical Response	Negative	Assume developed/armored shorelines and heavy runoff of freshwater and pollutants may cause effects, such as waterfowl hazing and noise that would greatly reduce condition below viability. Substantial restoration required to bring back viability, and in some cases successful restoration might not be possible.
		LCM Site Intensity	0.2	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
Agriculture and Aquaculture	Silviculture - Intensive	Categorical Response	Neutral	Assume periodic clearing with high impacts on habitat, some on hydrology, sedimentation, and from chemical application. Some in-wetland harvesting occurs in the Charleston area. It would induce stress well below the viability threshold and require significant restoration.
		LCM Site Intensity	0.6	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Silviculture - Sustainable	Categorical Response	Neutral	Small runoff effects from these practices.
		LCM Site Intensity	0.9	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
	Intensive Agriculture	Categorical Response	Negative	Assume no agriculture directly in brackish elements, so expect sediment and pesticide runoff from adjacent land use. Estuarine elements assumed to have somewhat less sensitivity to runoff than freshwater elements. Restoration potential is high.
		LCM Site Intensity	0.5	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Ruderal (maintained pasture, old field)	Categorical Response	Negative	NOAA indicated some agriculture chemicals used on pastures. Runoff is anticipated to be low, but some sediment may runoff depending on uses, and shoreline erosion may stress these elements to their viability threshold making them not viable.
		LCM Site Intensity	0.7	
		LCM Distance	300	Long distance effect to compensate for lack of water quality data.
	Aquaculture	Categorical Response	Negative	Assume habitat alteration, infrastructure, ongoing impacts of waste, nitrogen, and pathogens. Somewhat less impact relative to the viability threshold than on freshwater habitats due to dilution effect. High restorability.
		LCM Site Intensity	0.5	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Energy Production and Mining: assume on land	Solar arrays	Categorical Response	Negative	Assessed for impacts from adjacent solar arrays, not within the aquatic elements. Assume more intensive clearing and maintaining of barren ground affects temperature, sedimentation, and potential for some herbicide runoff but with fairly high restorability to natural vegetative cover.
		LCM Site Intensity	0.4	
		LCM Distance	50	Moderate distance effect to compensate for lack of water quality data.
	Wind	Categorical Response	Neutral	Assume a wind generation field, not individual turbines that can have intensive site impacts that take condition to the viability threshold but with high restorability.
		LCM Site Intensity	0.6	
		LCM Distance	300	Height of towers leading to larger visual and noise avoidance by some species.
	Oil and Gas Fields	Categorical Response	Negative	Assume well field, not individual pads, requires clearing, maintained dirt pads, roads affecting hydrology (changed grades, culverts), and creates noise. These activities are likely to increase runoff, sedimentation, and toxins, potentially armored shorelines. Moderate restorability.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Mining	Categorical Response	Negative	Assume land-based mining. Effects can include noise, dust, runoff of sediment, vehicle traffic, and the installation of culverts. Hydrological restoration is difficult; restoration efforts often result in different hydrological conditions or even a different ecosystem type.
		LCM Site Intensity	0.3	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
Transportation and Service Corridors	Primary roads, e.g., Interstates, high traffic/volume, wide roads, bridges	Categorical Response	Neutral	Assume over water bridge will have in-water and shoreline structures, shoreline clearing, altered hydrology, shading, and noise impacts. The impacts will drop immediate area to just below viability threshold. Restorability unlikely for public roads.
		LCM Site Intensity	0.4	
		LCM Distance	50	Somewhat longer distance effect when lack of water quality data.
	Secondary roads e.g., moderate traffic/volume state highways, bridges	Categorical Response	Negative	Assume over water bridge will have in-water and shoreline structures, shoreline clearing, altered hydrology, shading, and noise impacts. The impacts will drop immediate area to just below viability threshold. Restorability unlikely for public roads.
		LCM Site Intensity	0.5	
		LCM Distance	30	Relatively small distance effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Local, neighborhood and connecting roads, bridges/culverts	Categorical Response	Negative	Assume mostly culverts instead of bridges with in-water and shoreline structures, clearing, altered hydrology, shading, and noise impacts, and loss of ecological connectivity. Likely more dense than other road types causing the immediate area to drop just below the viability threshold.
		LCM Site Intensity	0.5	
		LCM Distance	50	Relatively small distance effect.
	Dirt/Private roads/culverts	Categorical Response	Negative	Assume culverts with intensive onsite impact, shoreline structures, clearing, altered hydrology, shading, noise impacts, dirt runoff, and impacted connectivity. Assume some restorability possible.
		LCM Site Intensity	0.5	
		LCM Distance	50	Relatively small distance effect.
	Railroads, bridges, culverts	Categorical Response	Negative	Assume bridge with in-water and shoreline structures, clearing, altered hydrology, shading, and noise impacts. Assume these impacts will drop immediately affected area to just below viability threshold.
		LCM Site Intensity	0.5	
		LCM Distance	50	Relatively small distance effect.
	Utility & Service Lines (overhead transmission, cell towers, etc.)	Categorical Response	Neutral	Assume over-water feature with some in-water support structures, but infrequent maintenance or noise. High restorability.
		LCM Site Intensity	0.9	
		LCM Distance	20	Relatively small distance effect.
Dredge Material Placement Areas		Categorical Response	Negative	Assume dredge materials will not be placed within aquatic systems. Offsite effects could include chemical and sediment runoff. Moderate restorability for vegetative cover that would reduce impacts to adjacent aquatic systems.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Dams & Reservoirs	Any mapped dams and reservoirs	Categorical Response	Negative	Assume dam is on a stream that feeds into an estuarine habitat (although GIS only assessing distance effect from dam itself). Impacts include changes in hydrology/freshwater flow, reduction of sediment, temperature changes, potential increased salinity, and reduced connectivity for anadromous fish. Some potential for restoration through restored connectivity/dam removal.
		LCM Site Intensity	0.4	
		LCM Distance	300	Distance effect in terms of changed water chemistry and temperature, disrupted connectivity, and reduced natural sedimentation.
Sea Level Rise	See flooding threats table for level used.	Categorical Response	Negative	Assume water column will deepen affecting light, increased salinity and wave action. For the SLR level used in assessment, assume some adaptive capacity for marshes to accrete and maintain elevation, but habitat type conversion is likely. Total loss is not expected. The effect will be highly variable depending on the location and type of element. Restorability possible for techniques such as thin layer deposition to assist adaptation.
		LCM Site Intensity	0.4	
		LCM Distance	30	Distance effects include groundwater backup and saline intrusion, and edge effects of habitat conversion. The effects will be highly variable based on topography and groundwater formations.
Storm Surge	Category 1	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.75	
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.85	
		LCM Distance	0	Assume no offsite effect.
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Other threats	Water Quality - Moderate	Categorical Response	Neutral	Assume moderate water quality is just above element viability threshold, so viability is maintained. Restoration is possible if sources impairing water quality are addressed.
		LCM Site Intensity	0.7	
		LCM Distance	100	Extrapolates incomplete water quality data to surrounding waters.
	Water Quality - Low	Categorical Response	Negative	Assume impact relative to threshold is somewhat less than freshwater. It assumes greater dilution/flushing action. Restorability is possible if sources impairing water quality are addressed.
		LCM Site Intensity	0.5	
		LCM Distance	100	Extrapolates incomplete water quality data to surrounding waters.
	Invasive Species - Aquatic	Categorical Response	Negative	Assume aquatic species are much more difficult to control in an open marine/estuarine system compared to streams/lakes. Restorability is low because it is difficult to manage and effectively remove aquatic species from a given habitat.
		LCM Site Intensity	0.3	
		LCM Distance	300	Indicates a potentially large distance of spread of invasives depending on species and conditions.
	Invasive Species - Terrestrial	Categorical Response	Neutral	No anticipated effect.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Subsidence	Moderate Subsidence (Rank 3)	Categorical Response	Neutral	Assume minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect. Restoration generally not feasible.
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	High Subsidence (Rank 4)	Categorical Response	Neutral	Assumption: Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect. Restoration generally not feasible.
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	Neutral	Assume minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect. Restorability not feasible.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response	Neutral	Assume estuarine wetland systems are better adapted to currents from tidal action so the element would be above the viability threshold, however if erosion is combined with Storm Surge Category 3, it would drop below the viability threshold. Restorability is high.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Very High Erodibility	Categorical Response	Neutral	Assume estuarine wetland systems are better adapted to currents from tidal action so the element would be above the viability threshold, however if erosion is combined with e Storm Surge Category 3, it would drop below the viability threshold. Restorability is high.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect
Flood Prone Areas	500 Year Floodplain	Categorical Response	Negative	Assume impact right at viability threshold. Experience from Hurricane Harvey indicated nearshore (and deeper) habitat impacts from high levels of freshwater input that occurred for an extensive period of time and traveled long distances in plumes. Assume will recover on own over time. Other impacts can include sedimentation, deposition of pollutants and anthropogenic debris, some impacts on species life histories/populations, and vegetation from freshwater exposure. Note: Because floodplain effects not mapped into marine areas, not capable of mapping the distance effect currently. Restorability would require extensive work and investment.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Conservation Areas		Categorical Response	Positive	Assume no stressors inherent in this use other than those overlapping from other categories. Supports condition and allows for natural restoration. Restorability is high.
		LCM Site Intensity	1	Assume no offsite effect.
		LCM Distance	0	
Resilience Project Protection/ Restoration Actions *(categories needed for Scenario breakouts)*	Living shoreline implementation	Categorical Response	Positive	Assume project enacts a management strategy for controlling erosion and enhancing water quality by providing long-term protection, and restoration or enhancement of vegetated or non-vegetated shoreline habitats Restoration practices uniformly indicate positive response for human assets, understanding that in some cases individual structures might be removed in the future for purposes, such as allowing for marsh expansion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Assume projects with on-the-ground actions focused on improving beach or dune conditions may reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Marsh restorations.	Categorical Response	Positive	Assume projects with on-the-ground actions that improve marsh conditions and/or expand marsh area by means of hydrology and thin layer dredge activities are designed to enhance ecological assets. They may reduce flooding by slowing and lowering height of storm surge, reducing coastal erosion, and reducing effects of sea level rise.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Restoration of aquatic connectivity	Categorical Response	Positive	Assume projects with on-the-ground actions in riverine settings that remove or replace man-made barriers to water flow and fish movement (e.g., dams and culverts) may reduce flooding threats and culvert/road failures.
		LCM Site Intensity	1	Assume no offsite effect.
		LCM Distance	0	

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Upland restoration	Categorical Response	Positive	Assume projects with on-the-ground actions that improve upland conditions and/or expand natural upland area by means designed to enhance ecological assets may reduce flooding effects from precipitation-caused flooding upstream.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Riparian and floodplain restoration	Categorical Response	Positive	Assume projects with on-the-ground actions to improve conditions and/or expand floodplain or riparian area by means designed to enhance ecological assets should reduce/prevent erosion and may reduce flooding effects.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

Table A3-4. Human Asset Exposure Model Structure and Assumption.

Key Assumptions of this Model			
Applies to all human community assets		Responses to stressors focused on physical damage/loss from flooding	
Note: elevated roads/bridges were not separated from surface roads is the source data, so they are treated equally.			
Importance Weighting (Optional, used only for the CVS)	Values range from: 0.0 (Low) to 1.0 (High). These ratings were approximated from those used in the regional coastal resilience assessment.	.2	Critical Infrastructure (Rank 1)
		.2	Environmental Justice Rank 1
		.2	Population Density (Rank 1)
		.4	Critical Infrastructure (Rank 2)
		.4	Population Density (Rank 2)
		.6	Critical Infrastructure (Rank 3)
		.6	Population Density (Rank 3)
		.8	Population Density (Rank 4)
		1.0	Critical Facilities
		1.0	Population Density (Rank 5)
Element Condition Threshold	Values range from: 0.0 (Low) to 1.0 (High). This value will determine the LCM result threshold under which a species is no longer viable in a pixel. Nearing 0.0 indicates increasing resilience and nearing 1.0 indicates increasing sensitivity.	0.5	Assume human assets have moderate sensitivity owing to their ability to repair/rebuild vs. ecological features that can rarely be restored to original type/health or take a very long time to recover naturally.
Land Use Intents (term used in Vista 3.x for all land uses, infrastructure, other stressors and threats, and conservation management and practices anticipated under any scenario). The IUCN/CMP classification list (v3.1, 2011) of direct threats and conservation practices was modified to meet the needs of this project.			

Primary Category	**Secondary Category**	**Response Types**	**Responses**	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
Sea Level Rise	Use 1-foot SLR in targeted watersheds to represent 2050 timeframe for planning purposes.	Categorical Response	Negative	Assume severe impact but not complete loss if there is built protection for key assets. This may include raising structures, converting key roads to causeways, etc.
		LCM Site Intensity	0.2	
		LCM Distance	50	Distance indicating impacts from backup of groundwater can flood/destabilize foundations of structures and increase susceptibility to wave action.
Storm Surge	Category 1	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.65	
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.7	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions *(Restorability is not included because assets are not natural features to be restored.)*
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.75	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.85	
		LCM Distance	0	Assume no offsite effect.
Subsidence	Moderate Subsidence (Rank 3)	Categorical Response		
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.
	High Subsidence (Rank 4)	Categorical Response		
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response		
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Flat (Slope <=0.75%) & Poor Drainage	Flat & Somewhat poorly drained	Categorical Response		Assume areas of flattest slope and somewhat poorly draining soils under extreme precipitation events will lead to flooding. It could approach the 100-year floodplain in level of impact.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect.
	Flat & Poor or Very poorly drained	Categorical Response		Assume areas of flattest slope and poorest draining soils under extreme precipitation events may lead to flooding approaching that of a 100-year floodplain.
		LCM Site Intensity	0.5	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response		Assume only a minor impact on human community assets that may require some remediation.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Very High Erodibility	Categorical Response		Assume that in combination with Storm Surge Category 3, expect condition to drop below the viability threshold.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.

Primary Category	**Secondary Category**	**Response Types**	**Responses**	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
Flood Prone Areas	Occasional Flooded Soils	Categorical Response	Neutral	Assume structures may be vulnerable but will remain viable unless there are additional stressors or threats in these areas.
		LCM Site Intensity	0.5	
		LCM Distance	0	Assume no offsite effect.
	Frequent Flooded Soils	Categorical Response	Negative	Assume conditions should indicate older structures as just barely non-viable because newer structures built in floodplain areas are probably designed for them.
		LCM Site Intensity	0.4	
		LCM Distance	0	Assume no offsite effect.
	500 Year Floodplain	Categorical Response	Negative	Assume similar impacts to full cumulative storm surge.
		LCM Site Intensity	0.2	
		LCM Distance	0	Assume no offsite effect.
	100 Year Floodplain	Categorical Response	Negative	Assume structures in these areas will sustain some damage bringing them to just below the viability threshold. Therefore, if flooded, the structures would require repair to remain viable.
		LCM Site Intensity	0.4	
		LCM Distance	0	Assume no offsite effect.
	Floodway	Categorical Response	Negative	Assume it is highly unlikely to have human community assets directly within the floodway. A score of .9 was applied to assets in the floodway. They are vulnerable, however, likely to remain viable because they were designed with the anticipation of flooding in the area.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
Conservation Areas	Areas designated for conservation use	Categorical Response	Positive	Assume no stressors inherent in this use other than those overlapping from other categories. Conservation areas will support condition and allow for natural restoration.
		LCM Site Intensity	1.0	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
Resilience Project Protection/ Restoration Actions *(categories needed for Scenario breakouts)*	Living shoreline implementation	Categorical Response		Assume project enacts a shoreline management strategy for controlling erosion and enhancing water quality by providing long-term protection, restoration, or enhancement of vegetated or non-vegetated shoreline habitats.
		LCM Site Intensity	1	Restoration practices uniformly indicating positive response for human assets, understanding that in some cases individual structures might be removed in the future to promote and maintain resilience of the human or natural communities. For example, marsh expansion that would help mitigate flooding.
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Projects with on-the-ground actions focused on improving beach or dune conditions. May reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect
	Marsh restorations	Categorical Response	Positive	Assume projects with on-the-ground actions that improve marsh conditions and/or expand marsh area by means of hydrology and thin layer dredge activities are designed to enhance ecological assets. They may reduce flooding by slowing and lowering the height of storm surge, as well as reducing coastal erosion, and the effects of sea level rise.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Restoration of aquatic connectivity	Categorical Response	Positive	Assume projects with on-the-ground actions in riverine settings that remove or replace man-made barriers to water flow and fish movement (e.g., dams and culverts) may reduce flooding threats and culvert/road failures.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
	Upland restoration	Categorical Response	Positive	Assume projects with on-the-ground actions that improve upland conditions and/or expand natural upland area by means designed to enhance ecological assets may reduce flooding effects from precipitation-caused flooding upstream
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.2
	Riparian and floodplain restoration	Categorical Response	Positive	Assume projects with on-the-ground actions to improve conditions and/or expand floodplain or riparian area by means designed to enhance ecological assets may reduce/prevent erosion and may reduce flooding effects.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

Appendix 4. Fish and Wildlife Vulnerability Index

The purpose of the fish and wildlife vulnerability index analyses is to understand how condition (and therefore vulnerability) of the fish and wildlife elements may be impacted from the stressors and threats. The modeling of the elements' current condition informed scoring of the Resilience Hubs but vulnerability to stressors and threats was also modeled. These assessments can be informative for several uses. Most directly, they can inform resilience project design to understand what stressors and threats fish and wildlife located at the project site may be subject to and, therefore, what actions will be needed to mitigate those threats. The flooding threats assessment can also inform the potential lifespan of resilience projects relative to fish and wildlife; in particular, whether the area is subject to sea level rise over the 20-30-year timespan of this assessment. Separate from the intended co-benefits of building nature-based community resilience projects, this index can also be very useful for those organizations primarily concerned with fish and wildlife conservation by informing areas of high value but also vulnerability and the nature of stressors and threats in those areas.

Methods

Vulnerability is calculated based on the effect of stressors and threats on condition, subject to application of a threshold where condition scores below a specified level equate to vulnerability. The three scenarios under which vulnerability were assessed are:

1. Current vulnerability (where elements are subject to current stressors such as land uses and impaired water quality),
2. Vulnerability to flooding threats (where elements are subject to flooding threats only), and
3. Combined vulnerability (where elements are subject to the cumulative effects of all stressors and threats).

This analysis goes beyond an exposure assessment by combining element exposure, sensitivity, and adaptive capacity in the model. Specifically, the objectives were to:

1. Understand the current condition for selected fish and wildlife elements by assessing their vulnerability to the fish and wildlife stressors. The current condition of elements can help inform actions for areas based on: 1) whether protection alone is adequate to maintain the viability of elements (good condition), 2) areas where restoration is practical and would return elements to a viable state (intermediate condition), and 3) areas that may have a poor return on conservation or restoration investment (poor condition) because mitigation of stressors is either not practical or cost prohibitive.
2. Understand where and how element condition may change from flooding threats. This analysis can inform how these threats alone may impact element viability, if action is practical in threatened areas, and, if so, what type of action and over what time frame may be effective.
3. Understand where and how current stressors and flooding threats may act cumulatively to further reduce condition of elements to non-viable states. For example, where an element is currently viable, but experiencing moderate impacts from water quality such that it may become non-viable when the threat of storm surge is added. This information can inform

decisions about actions in terms of the ability to keep elements in a viable state when stressors and threats combine and for what duration a viable state may be sustained (i.e., relative to the assessed sea level rise).

The method for assessing vulnerability under each group of stressors and threats is the same as described and depicted in the steps and **Figure A4-1** below.

The steps of the process, detailed in Appendix 2 and Appendix 3, are outlined below:

1. Assemble fish and wildlife element distribution data and viability requirements.
2. Compile the relevant fish and wildlife stressors (stressors) and flooding threats (threats) data in scenarios to be assessed (current stressors, threats, combined stressors, and threats).

Steps to model element vulnerability under each scenario:

1. Select fish and wildlife elements to be assessed.
2. Select the stressors and threats scenarios to assess the elements' vulnerability.
3. Populate vulnerability (condition) models (not shown) of how each element group (terrestrial, freshwater, estuarine) responds to each stressor and threat that can occur in a scenario (see Appendix 3 for model parameters).
4. Apply the vulnerability models to the scenario to generate watershed-wide vulnerability maps.
5. Intersect fish and wildlife distributions with the resulting watershed condition maps to generate vulnerability maps for each element and apply the condition threshold (see Appendix 3) to each element condition map to identify areas falling below the threshold. This indicates what areas of the element's distribution is vulnerable.
6. Sum the vulnerable elements in each area to generate the index.

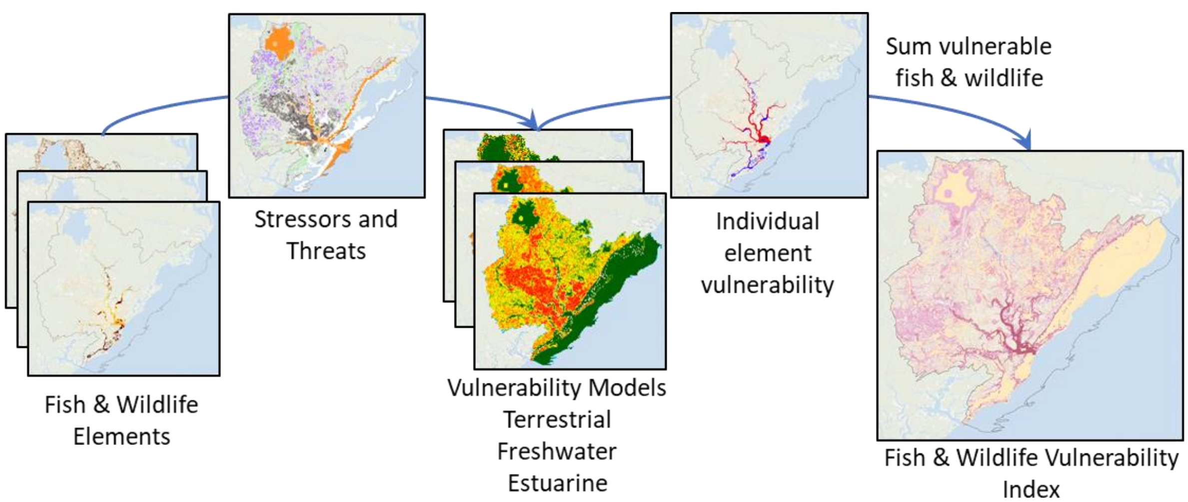

Figure A4-1. Method for calculating fish and wildlife vulnerability indices. *Elements are intersected with stressors and/ or threats, the vulnerability model is applied, and individual element vulnerability results are summed to create each index.*

Results

This set of analyses represents vulnerability of fish and wildlife elements based on current stressors in the watershed, flooding threats, and the combination of those stressors and threats to model the potential synergies among them. Each of these analyses, illustrated and described below, provides unique information to inform actions to conserve or restore fish and wildlife habitat.

1. **Baseline Vulnerability Analysis.** This analysis evaluated the effects of current stressors on fish and wildlife elements and illustrates currently impacted areas that may be targeted for mitigation of stressors and restoration actions.

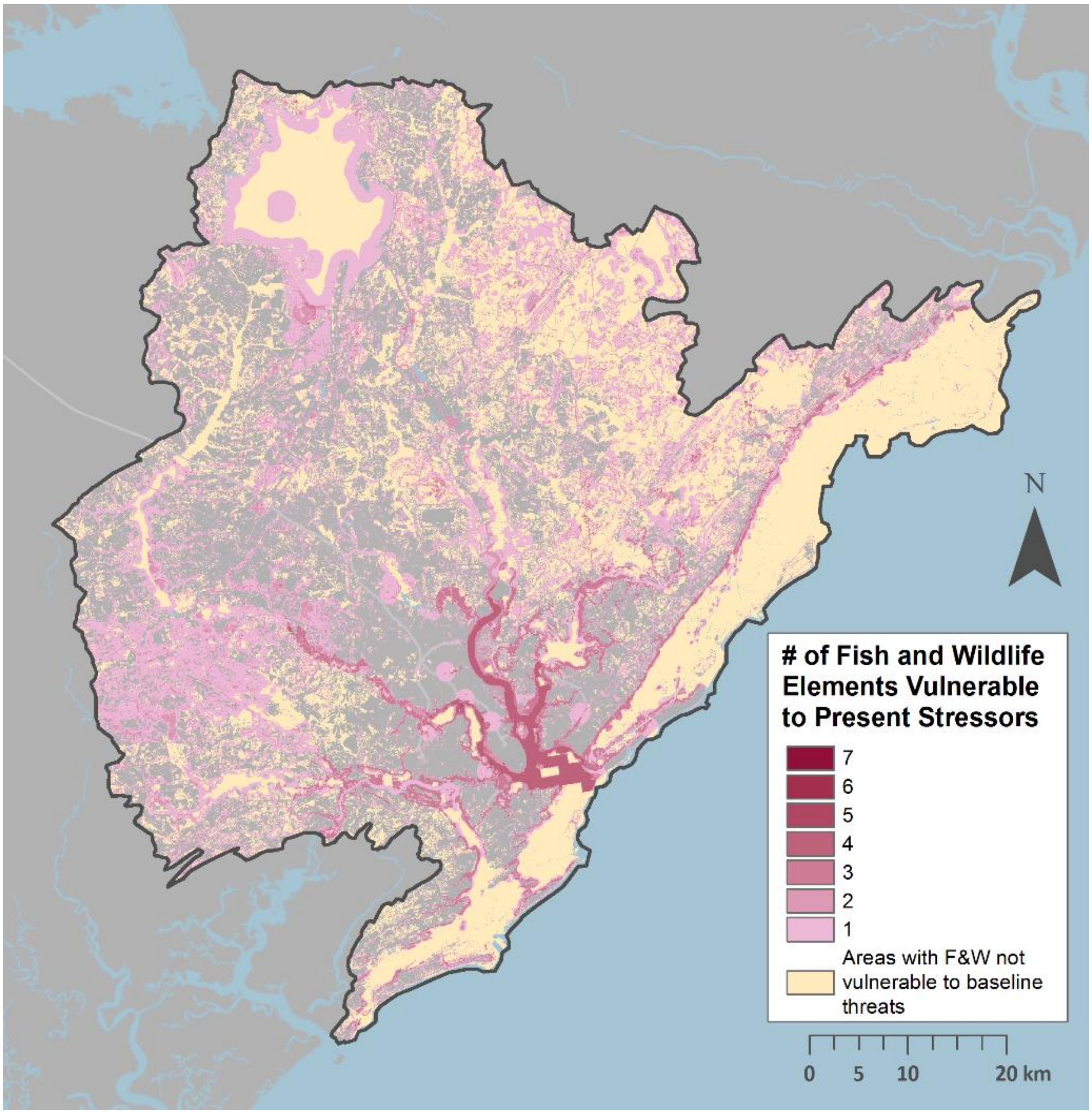

Figure A4-2. Fish and Wildlife Baseline Vulnerability for the Charleston Harbor Watershed. *This map is an overlay or index of all fish and wildlife elements that are vulnerable to the existing mapped stressors. Gray areas within the project boundary represent areas with no mapped fish and wildlife elements.*

2. **Fish and wildlife vulnerability to flooding threats**. This index models the vulnerability of fish and wildlife elements to flooding threats. It illustrates areas where, regardless of current condition, fish and wildlife populations and habitat may be significantly impacted by flooding threats (for example, bird nesting habitat and fish spawning substrate may be altered or destroyed). It also identifies areas where the benefits of conservation or restoration actions may ultimately be reduced by flooding.

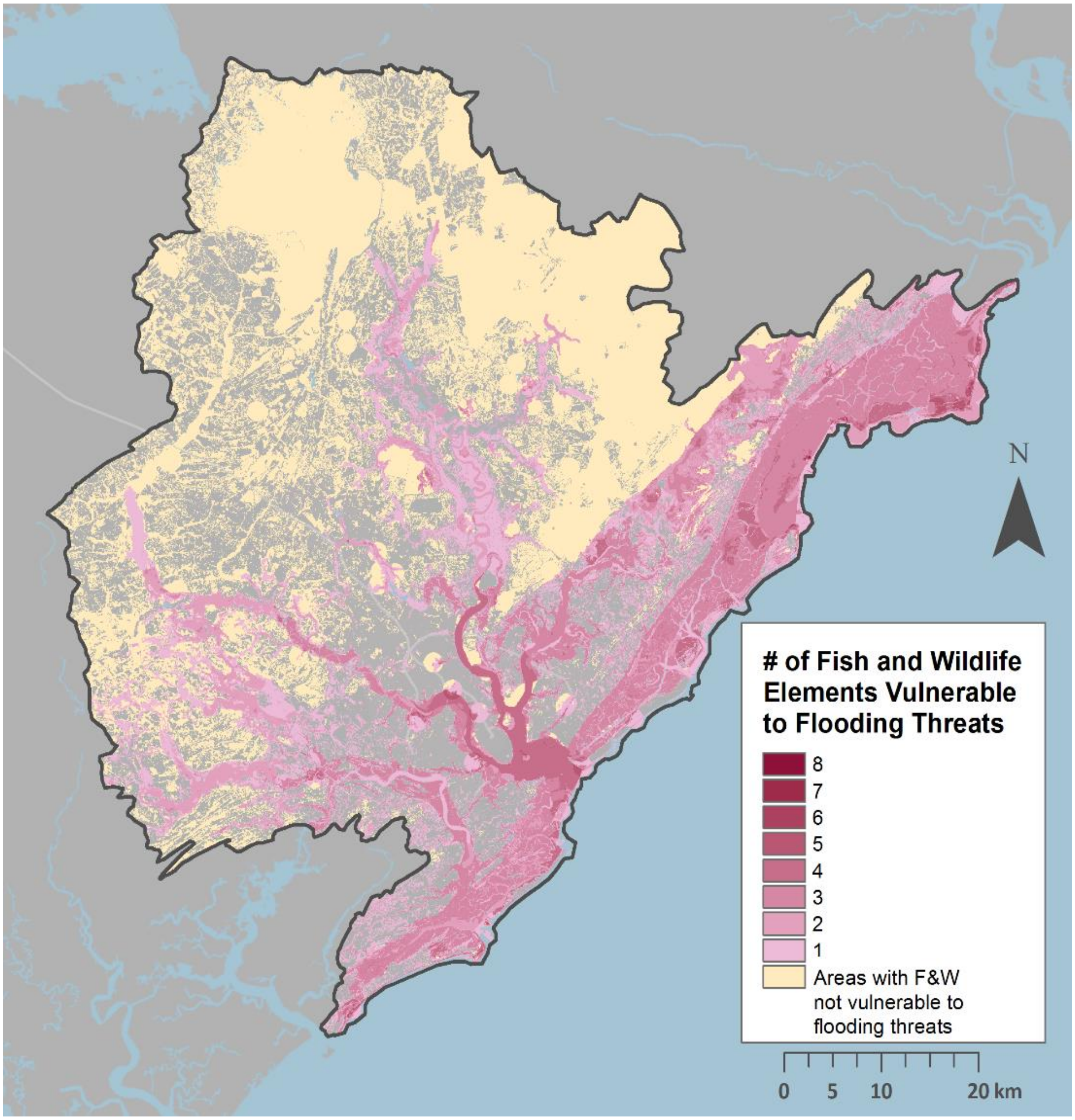

Figure A4-3. Fish and wildlife vulnerability to flooding threats in the Charleston Harbor Watershed. *Pink to red shades indicate the number of elements vulnerable to flooding threats. Tan areas indicate areas of low to no impact. Gray areas within the project boundary represent areas with no mapped fish and wildlife elements.*

3. **Combined Fish and Wildlife Vulnerability Index**. This index combines the results of the above two analyses to model the cumulative effects of current stressors and flooding threats. This index illustrates areas where cumulative effects may increase the vulnerability of fish and wildlife.

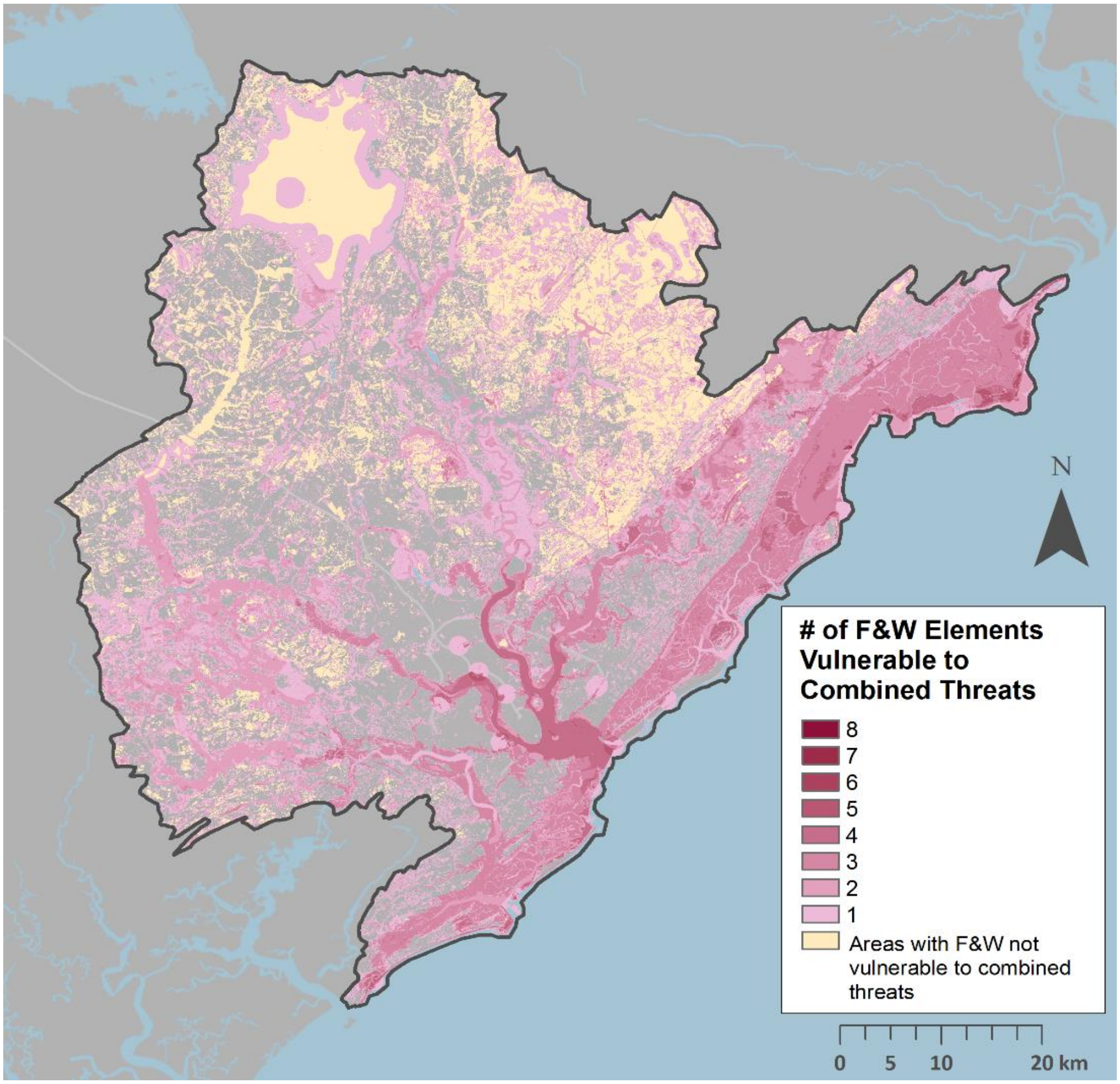

Figure A4-4. Fish and wildlife elements vulnerability to combined stressors and flooding threats for the Charleston Harbor Watershed. *Pink to red shades indicate the number of elements vulnerable to threats. Tan areas indicate areas of low to no impact from the baseline threats. Gray areas within the project boundary represent areas with no mapped fish and wildlife elements.*

As observed in these results, there are areas of vulnerability to stressors associated with human uses and impaired water quality throughout much of the watershed. The combination of stressors and flooding threats intensifies vulnerability in the areas closest to the coast and extending up the rivers.

These results may be accessed through the Vista project.

Limitations

These analyses are subject to limitations of the available data and decisions about the selection of fish and wildlife stressors and the flooding threats. The vulnerability indices used a relatively simple model. Limitations expressed in the Fish and Wildlife Assessments methods are incorporated in these limitations. In addition to those limitations, the setting of condition thresholds for the three fish and wildlife groups (terrestrial, freshwater, and estuarine) is subjective; whether an element is calculated as vulnerable in a location is highly sensitive to the threshold set.

Appendix 5. Fish and Wildlife Element Selection and Inventory of Elements

This appendix includes additional detailed information about the fish and wildlife elements used in the Fish and Wildlife Richness Index.

Table A5-1. Data sources and preparation notes for spatial data used to represent fish and wildlife elements considered in this assessment. *For the 'Data Source(s) Used' column, the following notation is used:* Name of Data Source (Source Agency or Organization) [Attributed Used].

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
NOAA Trust Resources		
Diadromous fish habitat	Atlantic sturgeon critical habitat (NOAA) [manual edits from Keith Hanson at NOAA and Bill Post at South Carolina Department of Natural Resources (SCDNR) based on their expert knowledge].	
Important riverine systems	Distribution created from National Hydrography Dataset (USGS) areas that overlapped with sub-adult red drum distribution points (SCDNR).	
Important shark habitat	Bryan Frazier (SCDNR) created a polygon representing the key areas for this element.	
Marshes and tidal creeks (includes open water)	National Wetland distribution.	
Oysters beds/reefs	Data from SCDNR on live and washed shell natural reefs (SCDNR intertidal oyster reefs) was used to represent this distribution. A discussion was carried out about distinguishing between natural vs. man-made and protected vs. harvestable. Harvest prohibitions do exist and are driven by public health concerns. These prohibited areas are subject to change and for 2017 largely fall in areas with high surrounding development. These areas were determined not to be a good predictor of reef health and therefore not incorporated into the analysis. Data for man-made reef restoration projects exists but is point-based and not adequate to represent a distribution.	

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
NOAA Trust Resources		
Snapper/grouper essential fish habitat	NOAA Essential Fish Habitat and Habitat Areas of Particular Concern Snapper and grouper were identified as the best surrogates to use for representing essential fish habitat for a suite of key marine/coastal species.	
Shrimp essential fish habitat	NOAA Essential Fish Habitat and Habitat Areas of Particular Concern	
At-Risk Species and Multi-species Aggregations		
Federally listed Threatened or Endangered Terrestrial Species	This element is an aggregate of element occurrence data contributed directly from the South Carolina Natural Heritage Program for the species listed in **Table A3-3**.	
Terrestrial Species listed as imperiled, rare, uncommon, or endangered at the global or state level	This element is an aggregate of element occurrence data contributed directly from the South Carolina Natural Heritage Program for the species listed in **Table A3-4**.	
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species		
Forested Wetlands (non-tidal) and Non-tidal Creek stretches	National Wetlands Inventory (USFWS) [‘freshwater forests’ category] is the most comprehensive layer available for forested wetland sites.	• **Terrestrial Systems (NatureServe)** [CE_POTENTIAL = "Forested wetlands"]. Coarser than NWI, which is more detailed, so used NWI instead. • **NLCD 2011 landcover data (USGS)** [Land_Cover = "Woody Wetlands"]. Overrepresents the wetlands, while the NWI is more specific and follows the contours of the land, so used NWI as main layer.
Tidal hardwood swamp forest (with and without cypress)	NatureServe's ecological systems map was the only adequate source identified to determine distribution.	
Freshwater emergent wetlands	National Wetlands Inventory (USFWS) [‘freshwater emergent wetland’ category] is the most comprehensive layer available for forested wetland sites.	

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species		
Cypress swamps and domes - potential habitat	Osier and Rutledge soil distributions were determined by SCDNR as the most suitable soils for cypress swamps after a thorough review of detailed soil surveys. This is likely to over-represent this element.	
Wading bird and ally colonies	SCDNR data for wading bird rookeries (WadingBird_SCDNR_Rookeries_500ftBuffer.shp) was used. These represent documented locations of wading bird rookeries only, with other elements capturing some habitat types that may also be used by wading bird colonies.	• **Breeding Bird Survey data**. The available data was too coarse to be useful in our analyses.
Beach and dune habitat	The South Atlantic Landscape Conservation Cooperative (SALCC) shorebird layer includes beach and dune as well as adjacent habitat also important to species represented by this target. For this reason, this layer (instead of the ecological systems map layer or SALCC beach and dune layer) was chosen to determine distribution.	• **SALCC seabird layer (Southern Atlantic Land Conservation Cooperative)**. Only covers a small section of Savannah study area. • **SALCC beach and dune layer (Southern Atlantic Land Conservation Cooperative)**. SALCC shorebird layer found to be higher resolution and more accurate. • **NatureServe Terrestrial Systems** [CE_POTENTIAL = "Beach and Dunes"]. Includes apparently incorrect inland areas; SALCC layer deemed more accurate.
Barrier island live oak hammock forest and scrub	NatureServe's ecological systems map was used to determine maritime forest in the project area, including barrier island and interior maritime forests. Based on expert review within NatureServe and Billy McCord (SCDNR) the barrier island portion was manually broken out for the final distribution.	
Interior live oak maritime forest	NatureServe's ecological systems map was used to determine maritime forest in the project area, including barrier island and interior maritime forests. Based on expert review within NatureServe and in collaboration with Billy McCord (SCDNR) the interior forest portion was manually broken out for the final distribution.	• **CCAP land cover (NOAA)**. This element not represented in these data.

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species		
Open pine habitat	Ecological Terrestrial Systems v3.4 (NatureServe) ['open pine']	• **Swallow-tailed kite survey data (Andy Day).** Given close association of swallow-tailed kite with open pine habitat, these data were suggested as a candidate for supplementing other open pine habitat distribution data. However, the dataset did not cover the entire watershed and the portions it did cover were already correctly mapped as open pine habitat. • **Swallow-tailed kite distribution data (Center for Birds of Prey).** Similar logic as above. However, the spatial distribution represented by these data overlapped primary open pine habitat distribution so was not seen as enhancing this distribution. • **Swallow-tailed kite distribution data (Avian Research and Conservation Initiative).** Surveys were not comprehensive across geographic area • **Eastern diamondback rattlesnake distribution based on a species distribution model (Orianne Society).** Given close association of eastern diamondback rattlesnake with open pine habitat, these data were suggested as candidate to supplement other open pine habitat distribution data. However, the dataset only covers the state of Georgia
Sea turtle nesting hotspots	Nesting density data (SCDNR) and national ecological systems map (beach and dunes) (NatureServe) were combined to create this layer. Pixels from the ecological systems layer that were labeled beach/dune but did not align with beaches in the latest imagery, were removed. In addition, since there is some level of sea turtle nesting at all main beaches throughout the project area, we chose to include stretches with at least 2 nests/km to create a layer of the nesting hotspots.	

Fish/Wildlife Element	**Data Source(s) Used**	**Data Sources Not Used and Why**
Cross-cutting Elements		
Continental and Global Important Bird Areas	Global and Continental IBAs (Audubon Society)	

Table A5-1. Fish and wildlife elements proposed but ultimately <u>not included</u> in this assessment. *For each element, a brief description is provided explaining why it was not included.*

Fish/Wildlife Element Proposed for Inclusion	**Reason Element Not Included in Assessment**
Manatee	Current occurrence data are not useful determinants of habitat quality.
Bald eagle (nests)	Species now too common to allow for useful analysis because it is everywhere.
Robust redhorse	Insufficient data (only a handful of points despite the fact that appropriate habitat for this fish covers large stretches of some rivers).
Tri-colored bat	Insufficient data (only some point data exists despite the fact that this species could roost and/or nest in many forested areas throughout the study area).
Swampfish (*Chologaster cornuta*)	Insufficient data (only a few location points available that don't represent the extent of appropriate habitat within the region).
Carolina bays	Carolina Bay data layer is incomplete for this geographic area. Bay habitat exists in the Francis Marion National Forest (which is mostly within the study area) but the layer of information doesn't show Carolina Bays where we know they exist in the region.
Sweetgrass habitat	Insufficient data. To our knowledge a layer that specifically targets sweetgrass habitat does not exist.
Rice fields/managed tidal wetlands	Insufficient data. No data source could be found for rice fields, and any effort to develop such a layer was out of the scope for this project.
Important river mussel habitat	Insufficient data. Although there is some limited point data on river mussels, it was not extensive enough to allow for a full map layer that represented important habitat.
Cypress swamps/domes	Included in the more general forested wetlands category included in the analysis so was not needed as a separate layer.
Threatened or Endangered aquatic species	Available data was for sturgeon and nesting turtles only, so these layers were pulled out as separate layers rather than a comprehensive aquatic layer.
G1-G3 and S1-S3 aquatic species	Apart from T&E species, data is not comprehensive enough across the geographic footprint to allow for a fine scale analysis, so we did not feel it was appropriate to use.
Shell middens/hammock islands	Data insufficient and final data layer overlaps with live oak hammock forests.

Table A5-3. Threatened and Endangered Animal Species. *Element occurrence data was compiled for all terrestrial animal species listed under the Endangered Species Act as being either threatened or endangered. These were combined into a single terrestrial layer. Aquatic species were treated as individual layers.*

Common Name of Species used in Assessment	Scientific Name	G-rank	S-rank	Federal Status
American alligator	*Alligator mississippiensis*	G5	S5	FT
Bachman's warbler	*Vermivora bachmanii*	GH	SX	LE
Black rail	*Laterallus jamaicensis*	G3/G4	SNR	proposed FT
Flatwoods salamander (Frosted)	*Ambystoma cingulatum*	G2	S1	FT
Gopher tortoise	*Gopherus polyphemus*	G3	S1	C
Piping plover	*Charadrius melodus*	G3	SNR	FE
Red knot	*Calidris canutus rufa*	G4	SNR	FT
Red-cockaded woodpecker	*Picoides borealis*	G3	S2	FE
Wood stork	*Mycteria americana*	G4	S1/S2	FT

Table A5-4. G1-G3/S1-S3 Terrestrial Animal Species Element Occurrences. *Data was compiled for all terrestrial G1-G3/S1-S3 species found in the project footprint (aquatic species were treated as separate layers).*

Common Name of Species Used in Assessment	Scientific Name	G-rank	S-rank
Southern hognose snake	*Heterodon simus*	G2	SNR
Southeastern bat (*Myotis*)	*Myotis austroriparius*	G3/G4	S1
Island glass lizard	*Ophisaurus compressus*	G3/G4	S1/S2
Gopher frog	*Rana capito*	G3	S1
Bachman's sparrow	*Aimophila aestivalis*	G3	S3
Mimic glass lizard	*Ophisaurus mimicus*	G3	SNR
Eastern tiger salamander	*Ambystoma tigrinum*	G5	S2/S3
Wilson's plover	*Charadrius wilsonia*	G5	S3
Star-nosed mole	*Condylura cristata*	G5	S3
Eastern diamondback rattlesnake	*Crotalus adamanteus*	G4	S3
American swallow-tailed kite	*Elanoides forficatus*	G5	S2
Bald eagle	*Haliaeetus leucocephalus*	G5	S2
Loggerhead shrike	*Lanius ludovicianus*	G4	S3
Eastern coral snake	*Micrurus fulvius*	G5	S2
Eastern woodrat	*Neotoma floridana haematoreia*	G5	S3/S4
Florida green watersnake	*Nerodia floridana*	G5	S2
Brown pelican	*Pelecanus occidentalis*	G4	S1/S2

Common Name of Species Used in Assessment	Scientific Name	G-rank	S-rank
Pine snake (gopher snake)	*Pituophis melanoleucus*	G4	S3/S4
Florida pine snake	*Pituophis melanoleucus mugitus*	G4/T3	S2
Dwarf siren	*Pseudobranchus striatus*	G5	S2
Black skimmer	*Rynchops niger*	G5	S2
Yellow-throated warbler	*Setophaga dominica*	G5	S3
Least tern	*Sterna antillarum*	G4	S3
Common tern	*Sterna hirundo*	G5	S3
Black bear	*Ursus americanus*	G5	S3
Yellow-throated vireo	*Vireo flavifrons*	G5	S3
Wod thrush	*Hylocichla mustelina*	G5	S3
Prothonotary warbler	*Protonotaria citrea*	G5	S3

Table A5-2. Examples of species that rely on fish and wildlife elements explicitly included in this Assessment. *ESA Status refers to species status under the U.S. Endangered Species Act.*

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	SC S-rank
	Common Name	Scientific Name			
Beach and Dune	Black skimmer	*Rynchops niger*		G5	S2
	Common tern	*Sterna hirundo*		G5	S3
	Green sea turtle	*Chelonia mydas*	FE (SE)	G3	SNR
	Hawksbill sea turtle	*Eretmochelys imbricata*	FE	G3	SNR
	Island glass lizard	*Ophisaurus compressus*		G3G4	S1S2
	Kemp's ridley sea turtle	*Lepidochelys kempii*	FE (SE)	G1	S
	Least tern	*Sternula antillarum*	ST	G4	S3
	Leatherback sea turtle	*Dermochelys coriacea*	FE (SE)	G2	S
	Loggerhead sea turtle	*Caretta*	FT (ST)	G3	S3
	Red knot	*Calidris canutus*	FT	G4	SNR
	Wilson's plover	*Charadrius wilsonia*	ST	G5	S3
Diadromous fish habitat	Atlantic sturgeon	*Acipenser oxyrinchus*	FE (SE)	G3	S3
	Shortnose sturgeon	*Acipenser brevirostrum*	FE (SE)	G3	S3
	Blueback herring	*Alosa aestivalis*		G3	S3
	Hickory shad	*Alosa mediocris*		G5	S4
	American shad	*Alosa sapidissima*		G5	S5
	American eel	*Anguilla rostrata*		G5	SNR
	menhaden	*Brevoortia tyrannus*		G5	
	Striped bass	*Morone saxatilis*		G5	S5

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	SC S-rank
	Common Name	Scientific Name			
Forested wetlands (non-tidal) AND cypress swamps/domes AND Tidal hardwood/swamp forest	Acadian flycatcher	*Empidonax virescens*		G5	S4B
	Kentucky warbler	*Oporornis formosus*		G5	S4
	Louisiana waterthrush	*Seiurus motacilla*		G5	S4
	Prothonotary warbler	*Protonotaria citrea*		G5	S3
	Red-shouldered hawk	*Buteo lineatus*		G5	SNR
	Rusty blackbird	*Euphagus carolinus*		G4	SNR
	Swainson's warbler	*Limnothlypis swainsonii*		G4	S4
	Wood duck	*Aix sponsa*		G5	SNR
Important Riverine Systems	Red drum	*Sciaenops ocellatus*		G5	S5
	Shark species (lemon and bull seasonally in lower sections)				
Maritime live oak hammock forest and scrub	Maritime Live Oak Hammock	*Quercus virginiana - (Pinus elliottii var. elliottii, Sabal palmetto) / Persea borbonia - Callicarpa americana Forest*			
	Painted bunting	*Passerina ciris*		G5	SNR
Marsh and tidal creek (including open water)	American oystercatcher habitat				
	Black skimmer habitat				
	Sea sparrow hotspots				
	American bittern	*Botaurus lentiginosus*		G5	SNR
	American coot	*Fulica americana*		G5	SHB, SNR
	Black rail	*Laterallus jamaicensis*	Under Review	G3G4	SNR
	Clapper rail	*Rallus longirostris*		G5	SNR
	Common gallinule	*Gallinula galeata*		G5	SNR
	King rail	*Rallus elegans*		G4	SNR
	Least bittern	*Ixobrychus exilis*		G5	SNR
	Pied-billed grebe	*Podilymbus podiceps*		G5	SNR
	Purple gallinule	*Porphyrula martinica*		G5	S4
	Sedge wren	*Cistothorus platensis*		G5	SNR
	Sora	*Porzana Carolina*		G5	SNR
	yellow rail	*Coturnicops noveboracensis*		G4	S3?
	Virginia rail	*Rallus limicola*		G5	SNR

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	SC S-rank
	Common Name	Scientific Name			
	Wilson's snipe	*Gallinago delicata*		G5	S5
	Summer flounder nursery habitat				
	Penaeid shrimp nursery habitat				
	Blue crab nursery habitat				
	Snapper-grouper complex				
	Spanish and king mackerel				
	Cobia	*Rachycentron canadum*		GNR	
	Bluefish	*Pomatomus saltatrix*			
	Black sea bass	*Centropristis striata*			
	Red drum	*Sciaenops ocellatus*		G5	S5
	Spotted seatrout, weakfish, spot, Southern flounder				
	Shark species (lemon, bull, blacknose, finetooth, dusky, bonnethead, and Atlantic sharpnose)				
	Diamondback terrapin	*Malaclemys terrapin*		G4	
Longleaf/Open Pine	American kestrel – Southeastern race	*Peucaea aestivalis*		G5	S4
	Bachman's sparrow	*Aimophila aestivalis; Peucaea aestivalis*		G3	S3
	Brown-headed nuthatch	*Sitta pusilla*		G5	S4B
	Carolina gopher frog	*Lithobates capito*	Under Review	G3	S3
	Coral snake (harlequin)	*Micrurus fulvius*		G5	S3
	Eastern indigo snake	*Drymarchon couperi*	FT	G3Q	S2
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	Under Review	G4	S3
	Florida pine snake	*Pituophis melanoleucus mugitus*	Under Review	G4T3	S2
	Florida pine snake	*Pituophis melanoleucus*		G4T4	S2
	Frosted flatwoods salamander	*Ambystoma cingulatum*	FT	G2	S2
	Gopher tortoise	*Gopherus polyphemus*	C (SE)	G3	S1

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	SC S-rank
	Common Name	Scientific Name			
	Henslow's sparrow	*Ammodramus henslowii – winter population*		G4	SNR
	Mimic glass lizard	*Ophisaurus mimicus*		G3	SNR
	Northern pine snake	*Pituophis melanoleucus mugitus*	Under Review	G4T3	S2
	Pine savannah crayfish	*Cambarus reflexus*		G4	S3
	Pine warbler	*Dendroica pinus*		G5	SNR
	Pine woods litter snake	*Rhadinea flavilata*		G4	SNR
	Red-cockaded woodpecker	*Picoides borealis*	FE (SE)	G3	S2
	Slender glass lizard	*Ophisaurus attenuatus*		G5	S4
	Southern hognose snake	*Heterodon simus*	Under Review	G2	SNR
	Swallow-tailed kite	*Elanoides forficatus*		G5	S2
Tidal Hardwood Swamp Forest	Tidal Hardwood Swamp Forest	*Nyssa biflora - (Nyssa aquatica, Taxodium distichum) Tidal Forest*			
Wading bird and ally colonies	Black-crowned night heron	*Nycticorax*		G5	SNR
	Glossy ibis	*Plegadis falcinellus*		G5	SHB, SNRN
	Great blue heron	*Ardea herodias*		G5	SNR
	Great egret	*Casmerodius albus*		G5	SNR
	Green heron	*Butorides virescens*		G5	SNR
	Little blue heron	*Egretta caerulea*		G5	SNR
	Reddish egret	*Egretta rufescens*		G4	SNR
	Roseate spoonbill	*Platalea ajaja*		G5	SNR
	Snowy egret	*Egretta thula*		G5	SNR
	Tricolored heron	*Egretta tricolor*		G5	SNR
	White ibis	*Eudocimus albus*		G5	SNR
	Wood stork	*Mycteria americana*	FT (SE)	G4	S1S2
	Yellow-crowned night heron	*Nyctanassa violacea*		G5	SNR
	Anhinga	*Anhinga*		G5	SNR

Fish/Wildlife Element	**Species Represented**		**ESA Status**	**G-rank**	**SC S-rank**
	Common Name	Scientific Name			
Freshwater emergent Wetlands	Wetlands (inclusive of all wetland types)				
Oyster beds/reefs	Eastern oyster	*Crassostrea virginica*		G3G4	
	Blue crab	*Callinectes sapidus*			
	Shrimp species				

Appendix 6. Resilience Project Information

Appendix provides additional information about the resilience projects submitted by stakeholders.

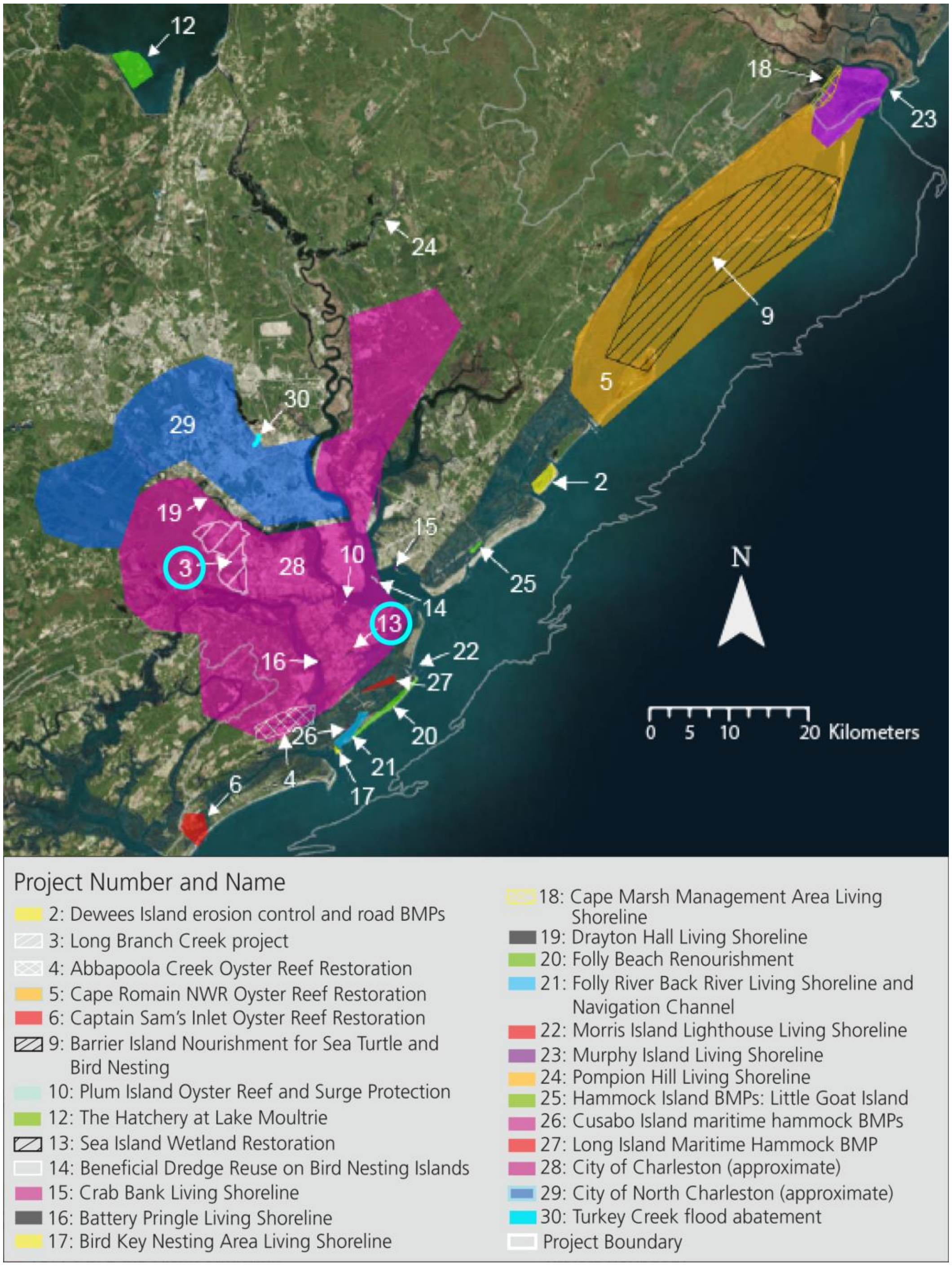

Figure A6-1. Map showing the boundaries of resilience projects compiled for the Charleston Harbor Watershed. *Projects #3 and #13, for which detailed case studies were developed, are indicated with a blue circle around the project number. A case study was also developed for project #8 but due to its distributed spatial nature, it is not shown here. Projects #1, #7, and #11 are not pictured due to their large size. See* ***Table A6-1*** *for a full list of projects submitted.*

Resilience Projects Information as Submitted by Stakeholders

A summary of all resilience project submitted for the Charleston Harbor Watershed can be found in **Table A6-1**. More detailed information about each project are also included below.

Table A6-1. All resilience projects submitted for Charleston Harbor Watershed and the number of assets/elements mapped within each project boundary. *Sorted in order of Community Exposure Index, from greatest to least. A zero in any column indicates that those features were not found within the project boundary as provided but may exist or may exist nearby.*

Project Name	Community Exposure Index	Number of Human Assets Mapped	Fish/Wildlife Elements within project boundary	Map ID Number
Sea Island Wetland Restoration	6.87	6	6	13
Long Branch Creek	5.83	9	10	3
Folly Island Beach Renourishment	4.17	7	13	20
Hammock Island Best Management Practices: Little Goat Island	4.02	3	8	25
Turkey Creek Flooding Mitigation and Wetland Enhancement	3.78	7	3	30
Drayton Hall Living Shoreline	3.66	4	8	19
Hammock Island Best Management Practices for Cusabo Island	3.65	1	6	26
Battery Pringle Living Shoreline	3.55	2	7	16
Crab Bank Living Shoreline	3.5	1	9	15
City of Charleston Vulnerability Assessment	3.42	12	18	28
Captain Sam's Inlet Oyster Reef Restoration	3.27	5	14	6
Plum Island Oyster Reef and Surge Protection	3.19	2	6	10
Hammock Island Best Management Practices for Long Island	3.14	1	7	27
Beneficial Dredge Reuse on Bird Nesting Islands	3.07	1	10	14
City of North Charleston Vulnerability Assessment	3.03	11	16	29
Folly Beach Back River Living Shoreline and Navigation Channel	3.01	8	10	21
Cape Marsh Management Area Living Shoreline	2.98	N/A falls mostly outside project area	0	18

Project Name	Community Exposure Index	Number of Human Assets Mapped	Fish/Wildlife Elements within project boundary	Map ID Number
Abbapoola Creek Oyster Reef Restoration	2.97	4	11	4
Dewees Island Erosion Control and Road BMPs	2.94	3	9	2
Murphy Island Living Shoreline	2.89	N/A falls mostly outside project area		23
Morris Island Lighthouse Living Shoreline	2.71	1	4	22
Cape Romain NWR Oyster Reef Restoration	2.68	6	17	5
Bird Key Nesting Area Living Shoreline	2.68	1	8	17
Barrier Island Nourishment for Sea Turtle and Bird Nesting	2.65	7	17	9
Pompion Hill Living Shoreline	2.58	2	5	24
Hatchery Area Restoration in Lake Moultrie	1.14	2	8	12
SCORE Oyster Reef (Region wide)	N/A project is region wide so can't calculate score	N/A project is region wide	N/A project is region wide	7
Riparian Buffer Restoration (Regionwide)	N/A project is region wide	N/A project is region wide	N/A project is region wide	11
Crab Traps to Oyster Reefs (Regionwide)	N/A project is region wide	N/A project is region wide	N/A project is region wide	8
Marine Debris Removal (Regionwide)	N/A project is region wide	N/A project is region wide	N/A project is region wide	1

Project ID# 1
Name: Marine Debris Removal
Submitted by: Sarah Latshaw, Southeast Regional Coordinator of the Marine Debris Program
Organization: NOAA
Project Type: Marsh restoration, Other (describe): Removal of derelict vessels that are in the marsh in Charleston Harbor
Description: Removal of derelict vessels that have washed up into the marsh from storms will open up estuarine marsh habitat that is currently occupied by abandoned vessels. They are an eyesore and a potential threat in terms of diesel, gas, and oil release, as well as moving into new areas during additional storms to ruin more habitat. The project area includes 80 derelict vessels in the marsh or on the edge and have been abandoned.

Project ID# 2

Name: Dewees Island Erosion Control and Road BMPs
Submitted by: Lori Sheridan Wilson
Organization: Dewees Island Property Owners Association
Project Type: Conservation Best Management Practices
Description: Dewees Island is a private single-family home community within a nature preserve on a barrier island accessible only by private ferry. Currently 64 homes are on Dewees Island with 150 home sites. There are ~5 miles of shell and sand roads which provide access on the island. Golf carts are the main method of transportation; vehicles such as backhoes, lulls and fire trucks also utilize the roads to provide needed services. During rain events many roads do to not drain properly, thereby creating standing water within the roadbed. If roads do drain, many drain directly into wetland areas with little to no vegetative buffer increasing turbidity and decreasing water quality. During king tide events, the tide covers about 1 mile of roadway up to ~16" deep thereby taking road material when the tide recedes. The community would like to implement proper road drainage to reduce flooding and prevent road material from entering nearby wetlands.

Project ID# 3

Name: Long Branch Creek: Restoring Ecosystem Services to Improve Flood Resilience
Submitted by: Susan Lovelace
Organization: SC Sea Grant Consortium
Project Type: Community resilience planning, Green infrastructure implementations, Living shoreline, implementation, Marsh restoration, Restoration of aquatic connectivity, Riparian and floodplain restoration
Description: Long Branch Creek is a large creek in Charleston that floods roads, neighborhoods, and commercial areas and has roads and multi-use paths where the culverts are undersized. This project includes engineering, construction, education, and planning efforts such as: determining tidal hydrology throughout the system to improve flow without exacerbating flooding, improving hydraulic function and removing physical alterations to improve flow in the system. Engaging residents and creek users through Creek Cafés, to learn about the creek and to work with scientists and engineers in developing a system wide Watershed Restoration Plan, to take part in community oyster reef construction and salt marsh planting, and by supporting the "Seeds to Schools" program that grows smooth cordgrass (*Spartina alterniflora*) from seed with the help and engagement of West Ashley students.

Project ID# 4

Name: Abbapoola Creek Oyster Reef Restoration
Submitted by: Jason Ayers
Organization: US Fish and Wildlife Service (USFWS)
Project Type: Living shoreline implementation, Marsh restoration, Wetlands created, Other (describe): oyster reef creation
Description: The USFWS has been successful in creating new oyster reefs and would like to add new reef structures in areas to enhance the benefits of previous efforts. Sites that were experiencing moderate erosion were planted with oyster bags and the new reefs were able to reduce erosion by building up sediment while also creating good habitat. Planting smooth cordgrass (*Spartina alterniflora*) plugs behind the oyster reefs helps establish salt marsh, enhances habitat, and stabilizes the shoreline.

Project ID# 5

Name: Cape Romain NWR Oyster Reef Restoration
Submitted by: Jason Ayers
Organization: US Fish and Wildlife Service
Project Type: Living shoreline implementation, Marsh restoration, Wetlands created, Other (describe): oyster reef creation
Main Project Type: Oyster Reef
Description: The USFWS has been successful in creating new oyster reefs and would like to add new reef structures in areas to enhance the benefits of previous efforts. Sites that were experiencing moderate erosion were planted with oyster bags and the new reefs were able to reduce erosion by building up sediment while also creating good habitat. Planting smooth cordgrass (*Spartina alterniflora*) plugs behind the oyster reefs helps establish salt marsh, enhances habitat, and stabilizes the shoreline.

Project ID# 6

Name: Captain Sam's Inlet Oyster Reef Restoration
Submitted by: Jason Ayers
Organization: US Fish and Wildlife Service
Project Type: Living shoreline implementation, Marsh restoration, Wetlands created, Other (describe): oyster reef creation
Description: The USFWS has been successful in creating new oyster reefs and would like to add new reef structures in areas to enhance the benefits of previous efforts. Sites that were experiencing moderate erosion were planted with oyster bags and the new reefs were able to reduce erosion by building up sediment while also creating good habitat. Planting smooth cordgrass (*Spartina alterniflora*) plugs behind the oyster reefs helps establish salt marsh, enhances habitat, and stabilizes the shoreline.

Project ID# 7

Name: South Carolina Oyster Restoration and Enhancement (SCORE) Oyster Reef
Submitted by: Michael Hodges
Organization: South Carolina Department of Natural Resources
Project Type: Living shoreline implementation
Description: The South Carolina Oyster Restoration and Enhancement (SCORE) program works with community members to get them involved in oyster restoration activities. There are two major components to the SCORE program: oyster shell recycling and community-based restoration. By working together, community members and biologists can restore oyster populations while 1) enhancing habitat for fish, shrimp, and crabs, 2) improving water quality of estuarine areas, and 3) informing and educating children, industry, and the general public. Volunteers can participate by recycling oyster shell from restaurants, creating bags of recycled shells, placing this bagged shell at intertidal sites, and monitoring the growth and health of the created reef. Oyster reefs are limited by substrate in Charleston Harbor and this program engages businesses and the public in efforts to return oyster shell to the environment to provide habitat for oyster larvae to attach. The project could be supported through increasing the number of participating restaurants in the recycling program, expanding shell collection sites, and supporting the outreach, supply, and budgetary needs of the program. The SCORE program also places large volumes of loose, not bagged, oyster shell, along intertidal and shallow subtidal areas from a barge. This work does not involve volunteers but enables DNR to place shell in areas that are valuable, even though they are less accessible than areas where volunteers can be involved.

Project ID# 8

Name: Crab Traps to Oyster Reefs
Submitted by: Ben Stone, Andrew Tweel, Steve Arnott, Gary Sundin, Nancy Hadley, Biologists
Organization: South Carolina Department of Natural Resources
Project Type: Living shoreline implementation
Description: This program uses abandoned crab traps to create new and thriving oyster reef habitat. The project collects old traps from the public, commercial fishermen, and those found in the marsh, closes their openings so that turtles and other large organisms don't become trapped inside, and coats the traps in concrete to stimulate oyster spat recruitment. The large surface area and structure of the traps allows them to be placed in softer sediments where denser bags of shell may sink.

Project ID# 9

Name: Barrier Island Nourishment for Sea Turtle and Bird Nesting
Submitted by: Sarah Dawsey, Reserve Manager
Organization: USFWS Cape Romain National Wildlife Refuge
Project Type: Beach or dune restoration
Description: In Cape Romain National Wildlife Refuge (CRNWF), eroded areas on small islands would be nourished and a bird nesting island would be created. The project seeks to repair breaches in barrier islands in CRNWF to protect and enhance nesting areas and improve storm buffer functions to protect the estuary and coastal communities.

Project ID# 10

Name: Plum Island Oyster Reef and Surge Protection
Submitted by: Joy Brown, Marine Program Manager
Organization: The Nature Conservancy
Project Type: Green infrastructure implementations
Description: The project would install specialized pilings that hold discs with concrete to allow for oyster spat settlement in the area to the east of Plum Island. These artificial reef structures hold the oyster settlement forms at the correct elevation so that they create habitat and structure that dissipates wave energy. The artificial reef-enhanced pilings would protect the wastewater treatment facility at Plum Island. Oyster settlement disks are attached to pilings and kept at intertidal and shallow subtidal levels to enhance habitat.

Project ID# 11

Name: Audubon: Riparian Buffer Restoration
Submitted by: Sharon Richardson, Executive Director
Organization: Audubon South Carolina
Project Type: Marsh restoration, Riparian and floodplain restoration, Wetlands restored/enhanced
Description: Through the proposed project, Audubon would work with communities to plant native riparian vegetation and restore native plant communities along swales, ditches, and in low lying areas. These efforts would help to restore the habitats along those areas which are not currently protected by the buffer regulations, which apply to jurisdictional freshwater systems and tidal wetlands.

Project ID# 12

Name: Hatchery Area Restoration in Lake Moultrie
Submitted by: Scott Lamprecht, Freshwater Fisheries Coordinator
Organization: South Carolina Department of Natural Resources
Project Type: Living shoreline implementation, Marsh restoration, Wetlands restored/enhanced
Description: The Hatchery Management Area is a 2,100-acre shallow area of subtidal vegetation that provides nursery habitat for freshwater fish. This area is an important habitat because it is shallow, relatively protected, and contains islands that provide cover and a diversity of habitat. The project would re-establish freshwater marsh habitat in the old 'Hatchery' section of Lake Moultrie. This is an old diked sub-section of the lake that was important for waterfowl, wading bird, anadromous blueback herring, and resident freshwater fish habitat. The dike is 75 years old and has failed and exposed the interior of the area to open lake energy with fetches up to 12 miles. The project would entail installing wave attenuation structures along the original dike foot print to allow native aquatic vegetation to re-establish.

Project ID# 13

Name: Sea Island Wetland Restoration
Submitted by: Jessica Hardesty Norris, President
Organization: Charleston Audubon
Project Type: Green infrastructure implementations, Marsh restoration, Restoration of aquatic connectivity, Riparian and floodplain restoration, Wetlands restored/enhanced
Description: The project would restore a 4-7' deep stormwater drainage ditch to a more natural stream channel leading to a tidal slough. The ditch runs through Westchester Neighborhood, along Thomas Johnson Park, and to Clark Sound which is part of Charleston Harbor. The proponents plan to enhance the 11-acre park and 12 acres of salt marsh, eradicate invasive species, and plant native species, improve the recreational trails, upgrade lighting, remove litter, and host community stewardship events. The final implementation would also install artwork celebrating the unique cultural heritage of this historic sea island, which is part of the Gullah Geechee Heritage Corridor.

Project ID# 14

Name: Beneficial Dredge Reuse on Bird Nesting Islands
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration
Description: Bird nesting islands in Charleston Harbor would receive dredged material to combat erosion that has taken place over time. The USACE would place dredged material on Castle Pinckney or Crab Bank to prevent these islands from eroding away.

Project ID# 15

Name: Crab Bank Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. The assets that are threatened include bird nesting areas, such as Crab Bank. The USACE would prevent loss of bird nesting islands by using dredged material and living shorelines to augment Crab Bank's footprint and prevent it from eroding away.

Project ID# 16

Name: Battery Pringle Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. The assets that are threatened include historic sites, such as Battery Pringle. The USACE has successfully created oyster reefs on the Atlantic Intracoastal Waterway (ICW) where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 17

Name: Bird Key Nesting Area Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. The assets that are threatened include bird nesting areas, such as Bird Key in the Cape Romain National Wildlife Refuge. The USACE has successfully created oyster reefs on the ICW where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 18

Name: Cape Marsh Management Area Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. The assets that are threatened include waterways that are critical for commercial and recreational vessel traffic such as the Cape Marsh Management Area. The USACE has successfully created oyster reefs on the ICW where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 19

Name: Drayton Hall Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. In many cases, erosion has caused the loss of marsh that once protected impoundment dikes. Dikes are breached by storm surges and eroded by boat wakes, in addition to other threats contributing to shoreline erosion. The assets that are threatened include historic sites, such as Drayton Hall. The USACE has successfully created oyster reefs on the ICW where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 20

Name: Folly Island Beach Renourishment
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines and beach renourishment to protect resources in the project area, including along the beachfront on Folly Island.

Project ID# 21

Name: Folly Beach Back River Living Shoreline and Navigation Channel
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. In many cases, erosion has caused the loss of marsh that once protected the island from storms. Boat wake impacts continue to erode the shorelines. The assets that are threatened include waterways that are critical for commercial and recreational vessel traffic, including the Stono River entrance and Folly River. The USACE has successfully created oyster reefs on the ICW where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 22

Name: Morris Island Lighthouse Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. The assets that are threatened include iconic sites such as the Morris Island Lighthouse. The USACE has successfully created oyster reefs on the ICW where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 23

Name: Murphy Island Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. The assets that are threatened include waterways that are critical for commercial and recreational vessel traffic, including the ICW and Santee River, where Murphy Island is located. The USACE has successfully created oyster reefs on the ICW where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 24

Name: Pompion Hill Living Shoreline
Submitted by: Alan Shirey, Environmental Engineer
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration, Living shoreline implementation
Description: The USACE has identified numerous opportunities to reinforce shorelines using living shorelines to protect resources in the project area. The assets that are threatened include historic sites, such as Pompion Hill Chapel. The USACE has successfully created oyster reefs on the ICW where there are eroding embankments. They would like to repeat such projects in other areas to gain protection from erosion while creating habitat.

Project ID# 25, 26, and 27

Name: Hammock Island Best Management Practices: Little Goat Island (25), Cusabo Island (26), Long Island (27)
Submitted by: Anna Smith, USFWS/SCDNR Liaison & State Wildlife Action Plan Coordinator
Organization: South Carolina Department of Natural Resources
Project Type: Conservation Best Management Practices
Description: Hammocks or hummocks are islands in the marsh that provide a unique habitat type in the coastal zone. The hammocks provide nesting habitat for endangered species such as wood storks and rare species such as painted buntings and may contain Native American shell middens. Marsh hammocks are not only threatened by sea level rise, but development. Although the costs associated with building a bridge to access islands delays their development, the seclusion that makes them ideal for native species to nest is often lost with the introduction of human habitation and associated construction, pets, pests, etc. Conservation of hammock islands with covenants or land trust purchase would benefit habitat and resilience. For those that are developed, implementation of Best Management Practices for maritime forests as described in South Carolina Department of Natural Resources (SCDNR) development guidance and studies would support the islands' continued habitat value. By engaging with developers and owners of hammock islands, the project could promote the best management practices to help inform low impact development.

Project ID# 28

Name: City of Charleston Vulnerability Assessment
Submitted by: Mark Wilbert, Chief Resilience Officer
Organization: City of Charleston
Project Type: Community resilience planning
Description: The City of Charleston is embarking on a vulnerability assessment with earmarked funds for analyzing where to invest and adapt, and for reaching out to the community. The vulnerability analysis would look at threats and hazards from flooding, hurricanes, earthquakes, and sea level rise. They would consider and evaluate the exposure of City wide assets, city owned facilities, bridges, roads, infrastructure, National Register buildings, and historic treasures. They look at vulnerability as potential impacts to assets from threats, minus adaptive capacity. They are looking at ways to adapt including land use planning, infrastructure adaptation strategies, and other means to create the City of Charleston's Resilience Plan. They are also looking at regulatory mechanisms, individual watershed analysis, updating environmental standards, green infrastructure, buyouts and elevating projects, adopt-a-drain programs, increasing awareness of flood risk, and recently hired dedicated floodplain manager.

Project ID# 29

Name: City of North Charleston Vulnerability Assessment
Submitted by: Butch Barfield, Emergency Preparedness Coordinator
Organization: City of North Charleston
Project Type: Community resilience planning
Description: The City of North Charleston needs a vulnerability assessment to help decide what can be done to mitigate the effects of flooding, sea level rise, and climate change. Using a data-driven approach, they would look at threats and hazards ranging from nuisance flooding to hurricanes, extreme precipitation, and sea level rise. They would consider and evaluate the exposure of City wide assets, city owned facilities, bridges, roads, infrastructure, and economically vulnerable populations with public safety a top priority.

Project ID# 30

Name: Turkey Creek Flooding Mitigation and Wetland Enhancement
Submitted by: John Cribb, City Manager
Organization: City of Hanahan
Project Type: Flooding Mitigation
Description: Turkey Creek is brackish to saltwater, depending on the influence of the tide. During high tides and rain events, residents living along the creek experience nuisance flooding on a regular basis. During extreme events, neighboring homes have been damaged by first floor flooding. The project would evaluate ways to mitigate flooding through engineering or other solutions. Potential alternatives include removing large debris from the channelized portion of the creek that impound water, installing tide gates on pipes that allow tidal water to flow into neighborhoods, deepening the channelized portion of the creek that has filled with sediment and lacks capacity to hold flow and runoff, building berms along the channelized portion of the creek to prevent tidal flow from flooding neighborhoods, and creating stormwater detention ponds in vacant and/or undeveloped properties.

Appendix 7. Summary of Additional Studies and Plans

A component of the Targeted Watershed Assessment was to compile and summarize existing studies and plans to serve as an inventory and quick reference for stakeholders. The table below is the result of a rapid assessment to identify and summarize relevant documents through a keyword search and those identified by the local Watershed Committee and stakeholders. The use of "N/A" indicates "not applicable" meaning that the information represented by that column was not found in a search of relevant terms in that document. It may be the case that the subject matter is included but did not use the terms searched.

Table A7-1. A review of plans to identify key resilience concerns in terms of areas, key infrastructure features, species, and habitats.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
South Carolina's State Wildlife Action Plan (SWAP) 2015 South Carolina Department of Natural Resources. October 14, 2014. South Carolina's State Wildlife Action Plan (SWAP) 2015. http://dnr.sc.gov/swap/main/2015StateWildlifeActionPlan-chaptersonly.pdf	State of South Carolina	Taxonomic groups: mammals, birds, reptiles, amphibians, freshwater fishes, diadromous fishes, marine fishes, marine invertebrates, crayfish, freshwater mussels, freshwater snails, leeches (aquatic and terrestrial), insects (freshwater and terrestrial). 493 animal species on the State's List of Species with the Greatest Conservation Need (total 825 species).	Cultivated (agricultural) land and pasture land; managed woodland; urban green spaces (parks, squares, gardens, and greenways); natural landscape, farm, and forest lands within an urban setting; residential neighborhoods; hunting areas and fishing facilities; man-made structures covering the developed coastline; sand dunes and beaches.	Changes in precipitation patterns and tropical storm intensities; increased drought and heat; more non-native invasive plant species, timber and crop pests, and emerging diseases in forests; sea-level rise; salt water intrusion; coastal forest losses.
Climate Change Impacts to Natural Resources in South Carolina http://www.dnr.sc.gov/pubs/CCINatResReport.pdf	State of South Carolina	Birds (wood stork), reptiles, amphibians and mammals (coyotes, armadillo); invasive species (tilapia, peacock bass, and other invasive fish; marine invertebrates; invasive species)	Increased need for beach nourishment due to shoreline retreat; coastal zone development; dam and hydroelectric reservoir development; marsh front or water front property; sea walls or revetments; aquaculture replenishment stocking or seafood pond; managed tidal wetlands (rice fields, diked marshes and coastal	Water-related challenges including water quality, water quantity and changes in sea level; sea-level rise, drought and flooding; the increase in intense storm events; temperature rise; ocean acidification (decreasing Ph); precipitation changes; (potential) climate shifts can increase proliferation of exotic or invasive plant and animal species, including parasites and pathogens.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
			impoundments) – unique and primarily in SC; embankment.	
Preliminary Analysis of the South Carolina Coastal Zone Boundary South Carolina Department of Health and Environmental Control. December 2016. Preliminary Analysis of the South Carolina Coastal Zone Boundary. Charleston, SC. https://www.scdhec.gov/HomeAndEnvironment/Docs/DHEC_CZBoundary_Study.pdf	An area of 7,544 square miles of the South Carolina Coastal Zone	Migratory, indigenous and state and federally-listed threatened and endangered species (such as the loggerhead sea turtle, Carolina heelsplitter, frosted flatwoods salamander, piping plover, and the Atlantic sturgeon). Example species list in Dorchester County, SC.	An area of 7,544 square miles of the South Carolina Coastal Zone that includes 14 counties, representing the occurrence of estuarine and marine waters and wetlands, tidal influence, or Category 4 storm surge inundation. Coastal tourism areas; commercial and recreational fisheries; coastal metropolitan areas.	Acute meteorological events, including hurricanes and extreme precipitation events, floods and storm surge inundation; sea-level rise.
Sea Level Rise Strategy City of Charleston. December 21, 2015. Sea Level Rise Strategy. Charleston, SC. http://www.charleston-sc.gov/DocumentCenter/View/10089	The City of Charleston	N/A	Charleston International Airport; parking lots; emergency facilities; drainage systems and tunnels; transportation systems; communities and critical infrastructure in the Charleston metropolitan area; Charleston Harbor; low lying areas to absorb or deflect SLR; green infrastructure (living shorelines, floating breakwaters, wetland mitigation banking structures); public housing units; vulnerable natural, cultural, and historic resources; low impact development; hard and landscape features; utilities, schools, critical care, hazardous material sites.	Sea level rise; increased tidal flooding; greater storm surges.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Understanding the October 2015 Charleston Floods: A Symposium Report Charleston Resilience Network. February 23, 2016. Understanding the October 2015 Charleston Floods: A Symposium Report. http://www.charlestonresilience.net/wp-content/uploads/2017/03/CRN_Flood_Symposium_Report-_FINAL.pdf	The Charleston, South Carolina (SC) region (Berkeley, Charleston, and Dorchester Counties)	N/A	(Critical infrastructure/lifelines assets and facilities) Charleston Water System (CWS): water and wastewater treatment plants, sewer systems (collection mains, pump stations, and deep tunnels that carry wastewater), storm water system; South Carolina Department of Transportation (SCDOT): the state highway system and a statewide mass transit system; energy (electricity and natural gas facilities).	Major meteorological rainfall and flooding events; relative sea level rise, inundating precipitation and storm surge associated with tropical storms; increasing nuisance flooding that threatens infrastructure such as the storm water and transportation systems.
Best Management Practices for Wildlife in Maritime Forest Developments Whitaker, J.D., J.W. McCord, B. Pulley, and E.H. Mullins. November 2009. Best Management Practices for Wildlife in Maritime Forest Developments. SCDNR publication. http://www.dnr.sc.gov/marine/pub/BMPsforCoastWeb.pdf	SC maritime forests (broad definition)	Animals in maritime forests (birds: resident landbirds, nearctic-neotropical landbirds, summer residents, transient landbirds, winter resident landbirds, birds of prey, colonial nesting wading birds, waterfowl or waterbirds; amphibians; reptiles; mammals); invasive species.	Residential lots, communities, developed neighborhoods, and single homes built near South Carolina's coastal woodlands.	N/A
Evaluating and Conserving Green Infrastructure Across the Landscape: A Practitioner's Guide Firehock K. and R. A. Walker. February 2015. Evaluating and Conserving Green Infrastructure Across the Landscape: A Practitioner's Guide. Edited by T. Lewis. The Green Infrastructure Center Inc. Charlottesville, VA.	Berkeley County, South Carolina	Salamanders: (eastern tiger, slimy, frosted flatwoods salamanders); reptiles: eastern cottonmouth, southern copperhead, eastern diamondback rattlesnake, larger timber rattlesnake, Carolina pygmy rattlesnake, eastern coral snake, eastern hognose snake, southern hognose snake, common eastern garter snake, American alligator; large	Historic and archaeological sites; churches; plantation homes; designated scenic roads; other historic resources and natural assets; agricultural preservation districts; green infrastructure network; trails and corridors.	Various climate change impacts such as increasing air temperature; inundation; changing water levels.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
http://www.state.sc.us/forest/gic-sc15.pdf		mammals: American black bear, otters, beavers, bobcats, deer, raccoons, coyotes; resident and migratory birds: red cockaded woodpecker, Bachman's sparrow.		
Adapting to Shoreline Change Shoreline Change Advisory Committee. April 2010. Adapting to Shoreline Change. South Carolina Department of Health and Environmental Control.	State of South Carolina	Sea birds, sea turtles, and other wildlife species.	Shoreline development; beachfront communities; hard stabilization structures (seawalls, revetments); groins, breakwaters, temporary structures; beachfront lands and easements.	Accelerated sea level rise; increased coastal storms.
A Comprehensive Spatial Mapping Effort of South Carolina's Coastal Resources and Activities Van Dolah, R.F., J.B. Boynton, K.S. Schulte, and J.C. Felber. October 14, 2011. A Comprehensive Spatial Mapping Effort of South Carolina's Coastal Resources and Activities. Marine Resources Research Institute, SCDNR, Charleston, SC. http://www.dnr.sc.gov/GIS/gisenergy.html	South Carolina's coastal zone from 30 miles inland to the 200 m depth contour offshore	Shallow water finfish and crustacean species; deep water groundfish, reef fish, ichthyoplankton, and coastal pelagic fishes; marine mammals: North Atlantic right whale, dolphin; loggerhead sea turtle, Kemp's ridley and Green turtles; coastal birds: piping plover.	N/A [Summary: this report summarizes the data layers included in the three geodatabases (Biological Resources, Habitat Resources, ***Human Uses***) that were developed as a precursor for a comprehensive marine spatial planning effort for South Carolina waters and beyond.]	N/A
The Citizen's Guide to the Charleston Harbor Project Cofer-Shabica, S., J. Hackett, F. Phillips, G. Phipps, W. Reynolds, and H. Robinson. The Citizen's Guide to the Charleston Harbor Project. SC Department of Health and Environmental Control publication.	Charleston Harbor Watershed, SC	Wetland animals; fish, shrimp, and crab species; colonial wading birds (e.g., egrets, herons, and wood storks); eagles; ospreys; migratory songbirds.	Charleston metropolitan area; beaches, seashores, and coastal development; growing industrial, commercial, and residential developments with marsh vistas, vast wooded tracts, and swamps; the harbor and estuary, nursery waters for shrimp and gamefish; water-based recreation facilities, sites, and put-in points; Tidal	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
			Creeks vital ecosystems; historic plantations; civil war sites; protected lands, parks, refuges, and easements to preserve habitats; Superfund sites; 19th century rice fields as specialized habitats; Santee-Cooper Hydroelectric Project.	
Charleston Harbor Dredging Project Environmental Assessment: Biological and Sediment Composition Sampling Sanger, D., S. Crowe, G. Riekerk, and M. Levisen. July 2013. Charleston Harbor Dredging Project Environmental Assessment: Biological and Sediment Composition Sampling. Marine Resources Research Institute, South Carolina Department of Natural Resources. Charleston, SC. http://www.sac.usace.army.mil/Portals/43/docs/civilworks/post45/CHD_Final_Report_Jul2013_SCDNR.pdf	Cooper, Ashley, and Wando Rivers in South Carolina	Macrobenthic community major taxonomic groups: Amphipoda, Crustacea (minus Amphipoda), Mollusca, Polychaeta, Oligochaeta, and others (Nemertea, Echinodermata, Phoronida, and Insecta).	N/A	N/A
Seasonal and inter-annual changes in offshore reef fish assemblages associated with hydrographic, meteorological and climatic conditions Arendt, M.D., C.A. Barans, J.C. Johnson, S.M. Pate, et al. October 2, 2009. Seasonal and inter-annual changes in offshore reef fish assemblages associated with hydrographic, meteorological and climatic conditions. Marine Resources Division, SCDNR, Charleston, SC.	A small, unfished research reef located off GA	Black sea bass; gray triggerfish; Atlantic spadefish; sheepshead; snappers; groupers; tomtate; vermilion snapper; traditional bait species such as scad, herring, anchovies, and sardines; blue runner; amberjacks; great barracuda; little tunny; cobia; requiem sharks: blacktip sharks, spinners, sandbar sharks.	N/A	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
http://fishwatch.dnr.sc.gov/SRFAC-Report-FishWatch.pdf				
Managing Oysters in South Carolina: A Five Year Program to Enhance/Restore Shellfish Stocks and Reef Habitats Through Shell Planting and Technology Improvements Coen, L.D., N. Hadley, V. Shervette, and B. Anderson. 2011. A Five Year Program to Enhance/Restore Shellfish Stocks and Reef Habitats Through Shell Planting and Technology Improvements. Marine Resources Center, SCDNR, Charleston, SC. http://www.dnr.sc.gov/marine/pub/Coen2011ShellfishReport.pdf	South Carolina	Shellfish communities; Eastern oyster (*Crassostrea virginica*).	N/A	N/A
Habitat Plan for the South Atlantic region: Essential Fish Habitat Requirements for Fishery South Atlantic Fishery Management Council. October 1998. Habitat Plan for the South Atlantic region: Essential Fish Habitat Requirements for Fishery. Charleston, SC. http://safmc.net/habitat-and-ecosystems/safmc-habitat-plan/	North Carolina, South Carolina, Georgia, and Florida estuarine inshore habitats & adjacent offshore marine habitats	South Atlantic snapper-grouper (triggerfishes, jacks, spadefishes, grunts, wrasses, snappers, tilefishes, temperate basses, sea basses and groupers, porgies) ; coastal migratory pelagics (cero, cobia, dolphin, king mackerel, little tunny, Spanish mackerel) ; shrimp (brown, pink, rock, royal red, seabob, and white shrimps) ; spiny lobster ; golden crab ; corals ; red drum ; Calico scallops.	Artificial/manmade reefs; docks and piers; boat ramps; marinas; bulkheads and seawalls; cables, pipelines, transmission lines; transportation corridors and facilities; navigation channels and boat access canals; disposal sites; impoundments; drainage canals and ditches; oil and gas extraction site; mining sites; sewage treatment and discharge facilities; steam-electric plants; mariculture and aquaculture facilities.	Rising relative sea level; severe storms; hurricanes; floods; severe acute and chronic perturbations; habitat erosion, alteration, and inundation; increasing water temperature causing coral bleaching; significant loss of coral reefs, salt marshes, and mangrove swamps; loss of species; elevated nutrient and sediment loading; saltwater intrusion; invasion of warmer water species.
Through a Fish's Eye: The Status of Fish Habitats in the United States 2015 Crawford, S., Whelan, G., Infante, D.M., Blackhart, K., Daniel, W.M.,	Southeastern Atlantic states: North Carolina, South	Pinewoods darter (*Etheostoma mariae*); shoal bass (*Micropterus cataractae*); native black bass; robust redhorse; shortnose sturgeon.	Charleston Harbor; Cape Romain National Wildlife Refuge; Augusta Canal Diversion Dam and Lock; City of Savannah.	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Fuller, P.L., Birdsong, T., Wieferich, D.J., McClees-Funinan, R., Stedman, S.M., Herreman, K., and Ruhl, P. 2016. Through a Fish's Eye: The Status of Fish Habitats in the United States 2015. National Fish Habitat Partnership. accessed on November 8, 2017, at http://assessment.fishhabitat.org/	Carolina, Georgia			
Ch. 17: Southeast and the Caribbean. Climate Change Impacts in the United States: The Third National Climate Assessment Carter, L. M., J. W. Jones, L. Berry, V. Burkett, J. F. Murley, J. Obeysekera, P. J. Schramm, and D. Wear, October 2014: Ch. 17: Southeast and the Caribbean. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 396-417. doi:10.7930/J0NP22CB. http://nca2014.globalchange.gov/report/regions/southeast and http://s3.amazonaws.com/nca2014/low/NCA3_Full_Report_17_Southeast_LowRes.pdf?download=1	The Southeast and Caribbean	Coral reefs, wetlands, forests, marshes, natural resources	Cities, metropolitan areas; roads, railways, ports, airports; oil and gas facilities, water supplies, stormwater drainage systems; homes and infrastructure in low-lying areas; fishery habitat; coastal water control structures and water management systems, flood control facilities; porous aquifers and drinking water wells.	Sea level rise, increasing temperatures and the associated increase in frequency, intensity, and duration of extreme heat events, increased droughts and wildfires, projected increase in ground-level ozone, public health threats from climate-sensitive diseases, expected increase in harmful algal blooms and disease-causing agents, expected change in spread of non-native invasive species, increased tree stress, shifting phenology, and altered insect and pathogen lifecycles, hurricanes, decreased water availability, change in projected precipitation, saltwater intrusion.
Comprehensive Spatial Data on Biological Resources and Uses in Southeastern Coastal Waters of the U.S.	Coastal waters off North Carolina, South Carolina,	Shallow water finfish and crustacean species; deep water groundfish, reef fish, ichthyoplankton, and coastal pelagic fishes; marine mammals: North Atlantic right whale, fin	N/A	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Boynton, J.B., R.F. Van Dolah, M.D. Arendt, M.J. Reichert. 2013. Comprehensive Spatial Data on Biological Resources and Uses in Southeastern Coastal Waters of the U.S. Marine Resources Research Institute, SCDNR, Charleston, SC. http://www.dnr.sc.gov/GIS/gsaa.html	Georgia, and Florida from the beach out to the 200m bathymetric contour	whale, minke whale, sperm whale, bottlenose dolphin; loggerhead sea turtle, green and leatherback turtles, hawksbill and Kemp's ridley turtles; seabird species: brown pelican, laughing gull, royal tern, sandwich tern, least tern, gull-billed tern, and black skimmer); piping plover.		
South Atlantic Conservation Blueprint 2.2: Development Process and Implementation Strategy. South Atlantic Landscape Conservation Cooperative. November 2017. http://www.southatlanticlcc.org/blueprint/	Piedmont, coastal plain, and ocean from Southeast VA to North FL	Indicators designed to cover all terrestrial and aquatic species of the region. Multiple approaches to terrestrial and freshwater resilience for these species.	Historic districts and infrastructure, urban open space, shoreline alteration.	Sea-level rise, urban growth, climate change.
Charleston Harbor Post 45 Final Integrated Feasibility Report/ Environmental Impact Statement U.S. Army Corps of Engineers, Charleston District. June 2015. Charleston Harbor Post 45 Final Integrated Feasibility Report/Environmental Impact Statement. U.S. Army Corps of Engineers, Charleston District. Charleston, SC. http://www.sac.usace.army.mil/Missions/Civil-Works/Charleston-Harbor-Post-45/	Charleston Harbor		N/A	N/A
Charleston Harbor Post 45 Appendix F1: Biological Assessment of Threatened and Endangered Species U.S. Army Corps of Engineers, Charleston District. May 2015.	Charleston Harbor	Marine mammals (humpback whale, North Atlantic right whale, West Indian Manatee); marine turtles (Kemp's ridley sea turtle, leatherback sea turtle,	N/A	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Charleston Harbor Post 45 Appendix F1: Biological Assessment of Threatened and Endangered Species. U.S. Army Corps of Engineers, Charleston District. Charleston, SC. http://www.sac.usace.army.mil/Missions/Civil-Works/Charleston-Harbor-Post-45/		loggerhead sea turtle, green sea turtle); fish (shortnose sturgeon, Atlantic sturgeon); birds (wood stork, piping plover, red knot).		
Charleston Harbor Post 45 Appendix H: Essential Fish Habitat Assessment U.S. Army Corps of Engineers, Charleston District. May 2015. Charleston Harbor Post 45 Appendix H: Essential Fish Habitat Assessment. U.S. Army Corps of Engineers, Charleston District. Charleston, SC. http://www.sac.usace.army.mil/Missions/Civil-Works/Charleston-Harbor-Post-45/	Charleston Harbor	Marine and estuarine species: penaeid shrimp; blue crabs; Atlantic croaker, bay anchovy, Atlantic menhaden, spotted hake, weakfish, spot, blackcheek tonguefish, white catfish, and silver perch; southern flounder, red drum, spotted seatrout, bluefish, black drum; snapper grouper species; coastal migratory pelagic species; summer flounder; black sea bass; sharks; zooplankton.		

Glossary and Key to Acronyms and Abbreviations Used in this Report

At-risk species: All species formally included in one of the following categories at the time of this assessment:

- A species listed as 'endangered', 'threatened', or 'candidate' under the provisions of Endangered Species Act (ESA)[11]
- A species with a NatureServe global imperilment rank of G1, G2, or G3[12]
- A species with a NatureServe state imperilment rank of S1, S2, or S3
- A State Species of Greatest Conservation Need (SGCN) as recorded in current State Wildlife Action Plans [13]

Community Vulnerability Index: An index of the number of Human Community Assets (HCAs) with vulnerability to flooding threats.

Condition: The results obtained from applying the landscape condition model to either the fish and wildlife elements or the HCAs to calculate a condition score for fish and wildlife elements or HCAs ranging from 0.0 (low condition) to 1.0 (high condition).

Conservation Value Summary: Mapped values that are the output of a Vista DSS overlay function that allows for a wide range of calculations based on element layers and user-specified attributes. Examples include richness (the number of overlapping elements at a location) and weighted richness where, for example, a simple richness index is modified by the modeled condition of elements. Several indices calculated for this assessment are conservation value summaries.

CVS: See Conservation Value Summary.

Distance effect: The off-site impacts from a stressor or threat used in the Landscape Condition Model (LCM) to estimate the condition of elements and assets.

Distinctive ecological systems: Mid- to local- scale ecological units useful for standardized mapping and conservation assessments of habitat diversity and landscape conditions. Ecological systems reflect similar physical environments, similar species composition, and similar ecological processes.

Element: A fish or wildlife habitat type, species, or species aggregation.

Element Occurrence (EO): An area of land and/or water in which a species or natural community is, or was, present. An EO should have practical conservation value for the element as evidenced by potential continued (or historical) presence and/or regular recurrence at a given location.

EO: See Element Occurrence.

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[11] These categories are established by the **US Endangered Species Act of 1973, as amended through the 100th Congress**. (United States Government 1988) (See this factsheet for further explanation: https://www.fws.gov/endangered/esa-library/pdf/ESA_basics.pdf)

[12] These categories, used throughout the Americas are documented in the publication **NatureServe Conservation Status Assessments: Methodology for Assigning Ranks (Faber-Langendoen et al. 2012)** (Available here: http://www.natureserve.org/sites/default/files/publications/files/natureserveconservationstatusmethodology_jun12_0.pdf)

[13] The basis for this designation varies by state.

EPA: Environmental Protection Agency

ESA: Endangered Species Act

Essential Fish Habitat (EFH): Those waters and substrate necessary for the spawning, breeding, feeding, or growth to maturity of a species of fish.

GIS: Geographic information system

G-Rank or Global Rank: NatureServe rank based on assessment of how imperiled a species or community is throughout its entire range (G1-G5 with G1 being most imperiled and G5 being most secure).

Habitat Area of Particular Concern (HAPC): NOAA-designated areas that provide important ecological functions and/or are especially vulnerable to degradation. HAPCs are a discrete subset of the Essential Fish Habitat for a species of fish.

HCA: See Human Community Asset.

HUC: See Hydrologic unit code.

HUC8 Units (also called Level 4 hydrologic units or subbasins): A hierarchical 'level' of hydrologic unit often used for establishing the boundaries in natural resource and agricultural assessment, planning, management, and monitoring. HUC8 units served as the framework for defining targeted watersheds in this assessment. They have an average size of approximately 700 square miles.

Hydrologic Unit Code (HUC): A systematic code used as a unique identifier for hydrological units of different scales. There are six levels of units that nest within each other in a spatial hierarchy. (For more information, see this useful resource: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042207.pdf)

Human Community Asset (HCA): Human populations and/or critical infrastructure or facilities.

Important bird areas: Areas identified using an internationally agreed set of criteria as being globally important for the conservation of bird populations.

LCC: See Landscape conservation cooperative.

Landscape condition model: A model of ecological condition reflecting information about the interaction of one or more conservation targets with phenomena known or estimated to impact their condition in an explicit way (change agents). A landscape condition model uses available spatial data to transparently express interactions between targets and change agents. Change agent selection and effects can be based on published literature and/or expert knowledge.

Landscape Conservation Cooperative: A cooperative effort that brings stakeholders together around landscape-scale conservation objectives that require broad coordination (often at the scale of multiple states).

LCM: See Landscape condition model.

Living shoreline: A broad term that encompasses a range of shoreline stabilization techniques along estuarine coasts, bays, sheltered coastlines, and tributaries. A living shoreline has a footprint that is made up mostly of native material. It incorporates vegetation or other living, natural “soft” elements alone or in combination with some type of harder shoreline structure (e.g. oyster reefs or rock sills) for added stability. Living shorelines maintain continuity of the natural land–water interface and reduce erosion while providing habitat value and enhancing coastal resilience.

National Hydrography Dataset: “A comprehensive set of digital spatial data that encodes information about naturally occurring and constructed bodies of surface water (lakes, ponds, and reservoirs), paths through which water flows (canals, ditches, streams, and rivers), and related entities such as point features (springs, wells, stream gages, and dams)” (USGS 2017).

Natural and Nature-Based Solutions: “Actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” as defined by IUCN.

NatureServe Vista™: A software extension to ArcGIS used in this assessment to store, manage, and conduct a variety of analyses with relevant spatial data.

NEMAC: National Environmental Modeling and Analysis Center

NFWF: National Fish and Wildlife Foundation

NHD: see National Hydrography Dataset.

NOAA: National Oceanic and Atmospheric Administration

NOAA Trust Resource: Living marine resources that include: commercial and recreational fishery resources (marine fish and shellfish and their habitats); anadromous species (fish, such as salmon and striped bass, that spawn in freshwater and then migrate to the sea); endangered and threatened marine species and their habitats; marine mammals, turtles, and their habitats; marshes, mangroves, seagrass beds, coral reefs, and other coastal habitats; and resources associated with National Marine Sanctuaries and National Estuarine Research Reserves.

NWI: National Wetlands Inventory (USFWS product)

Resilience: The ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events, as defined by the National Academies of Science. For fish and wildlife, this can mean the ability to recover to a viable and functioning state, either naturally or through restoration actions.

Resilience Hub: Large patches of contiguous, natural areas that provide communities with protection and buffering from the growing impacts of sea-level rise, changing flood patterns, increased frequency and intensity of storms, and other environmental stressors while supporting populations of fish and wildlife habitat and species.

Resilience Project: A planned or proposed nature-based project that has not yet been undertaken and that would have mutual benefits for human community assets and fish and wildlife elements when implemented.

SGCN: See Species of Greatest Conservation Need.

Site Intensity: The on-site condition remaining in the presence of a stressor/threat used in the Landscape Condition Model (LCM). Values range from 0 (low condition) to 1 (high condition) and are applied to the footprint of the stressor/threat as defined by the scenario.

SLR: Sea level rise

Species congregation area: A place where individuals of one or more species congregate in high numbers for nesting, roosting, or foraging.

Species of Greatest Conservation Need: Those species identified by state wildlife agencies as priorities for conservation in their State Wildlife Action Plans.

S-Rank or State rank: NatureServe rank based on assessment of how imperiled a species or community is within South Carolina (S1-S5 with S1 being most imperiled and S5 being most secure).

SCDNR: South Carolina Department of Natural Resources

TNC: The Nature Conservancy

USACE: U.S. Army Corps of Engineers

USFWS: U.S. Fish and Wildlife Service

Vista DSS: See NatureServe Vista, DSS stands for Decision Support System

Vulnerability: The risk or possibility of an HCA or element to experience stressors and/or threats causing its condition to drop below a defined threshold of viability.

Watershed: A region or area bounded by a divide and draining ultimately into a watercourse or body of water, often mapped with HUCs.