Coastal Resilience Assessment of the Savannah River Watershed

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IMPORTANT INFORMATION/DISCLAIMER: This report represents a Regional Coastal Resilience Assessment that can be used to identify places on the landscape for resilience-building efforts and conservation actions through understanding coastal flood threats, the exposure of populations and infrastructure have to those threats, and the presence of suitable fish and wildlife habitat. As with all remotely sensed or publicly available data, all features should be verified with a site visit, as the locations of suitable landscapes or areas containing flood hazards and community assets are approximate. The data, maps, and analysis provided should be used only as a screening-level resource to support management decisions. This report should be used strictly as a planning reference tool and not for permitting or other legal purposes.

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U.S. ARMY CORPS OF ENGINEERS DISCLAIMER: NFWF's assessment methodology focuses on identifying and ranking Resilience Hubs, or <u>undeveloped</u> areas of open space. Actions recommended in these areas seek to improve fish and wildlife habitats through implementation of restoration and conservation projects or installation of natural or nature-based solutions, while at the same time, potentially supporting human community resilience. The assessment may be helpful during planning studies when considering the resilience of ocean and coastal ecosystems. This report is not designed to inform the siting of gray or hardened infrastructure projects. The views, opinions and findings contained in this report are those of the authors(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other official documentation.

Cover Image: Talmadge Memorial Bridge, Savannah, Georgia

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Abstract

The Savannah River Watershed Coastal Resilience Assessment focuses on identifying areas of open space where the implementation of fish and wildlife habitat restoration or conservation actions could build human community resilience in the face of increasing storms and flooding impacts. Although many of the oldest parts of the city of Savannah are built on high ground, other sections of the city and surrounding communities, especially those on barrier islands, experience flooding from storms and increasingly during king tides (exceptionally high tides).

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 areas of contiguous open space 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 a 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 resilience project ideas that have potential to build human community resilience and fish and wildlife habitat within the Savannah River Watershed.

As part of the assessment process, 22 resilience-related project ideas were submitted through the stakeholder engagement process, of which two 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 flooding and 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 (GIS) 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

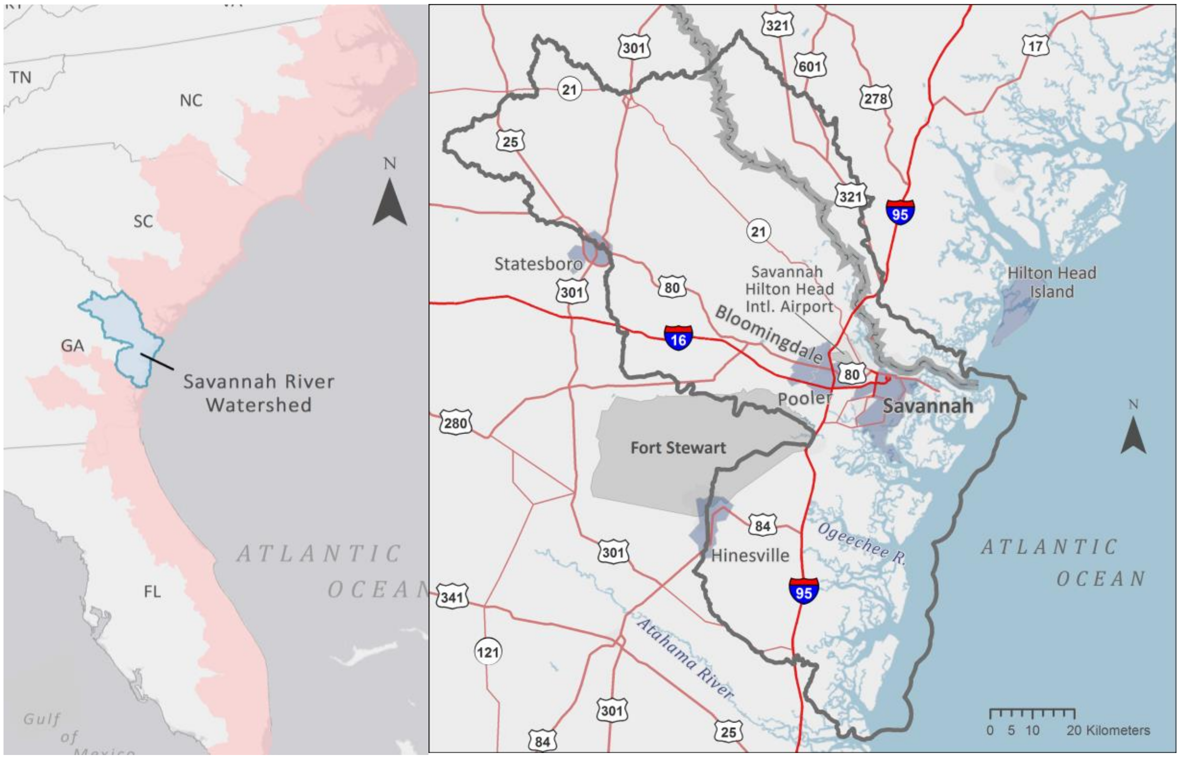
In response to increasing frequency and intensity of coastal storm events, the National Fish and Wildlife Foundation (NFWF) is committed to supporting programs and projects that improve community resilience by reducing communities' vulnerability to these coastal storms, sea-level rise, and flooding through 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 local level assessments nest within these broader regional assessments and provide the opportunity to incorporate local data and knowledge into the larger coastal assessment model.

This assessment focuses on the Savannah River 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.

Savannah River Watershed

The Savannah River Watershed study area is situated in coastal Georgia and an adjacent portion of South Carolina (see map below). The Savannah River and its watershed form the northern boundary of the project area, extending inland to encompass the Ogeechee River drainage and south to the watershed boundary of the Altamaha River. The Savannah River flows from the Blue Ridge Mountains through the Piedmont and Coastal Plain and has the third highest discharge rate among all river systems on the Atlantic coast of the U.S. The river also features some of the highest levels of aquatic biodiversity in the U.S. The largest city in the watershed is Savannah (2017 population approximately 400,000), which is primarily situated on a bluff inland from the mouth of the Savannah River. Key economic sectors in the region include tourism, health, and manufacturing. Significant areas of Savannah and surrounding areas are susceptible to flooding during storms and king tides.



Location and boundary of the Savannah River Watershed study area*. The map on the left shows the watershed study area in the context of the South Atlantic Coast Regional Assessment area (pink). In the map on the right, the study area is indicated by the dark gray outline. Note that it consists of the Savannah River Watershed *and* several contiguous coastal watersheds to the south of Savannah.*

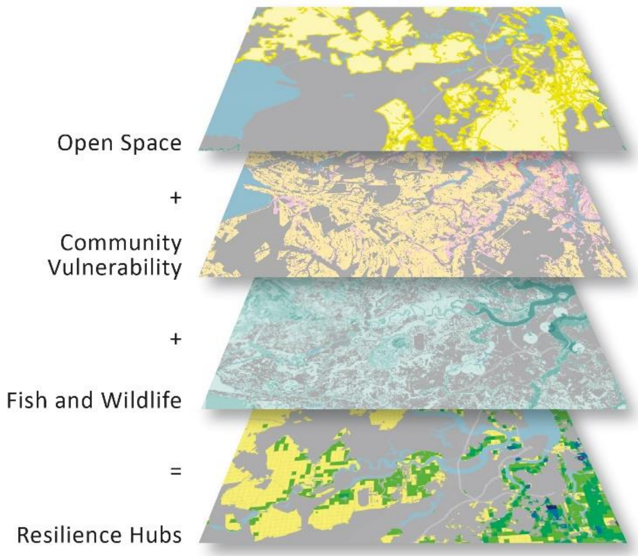
Assessment Objectives

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 HCAsand 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.



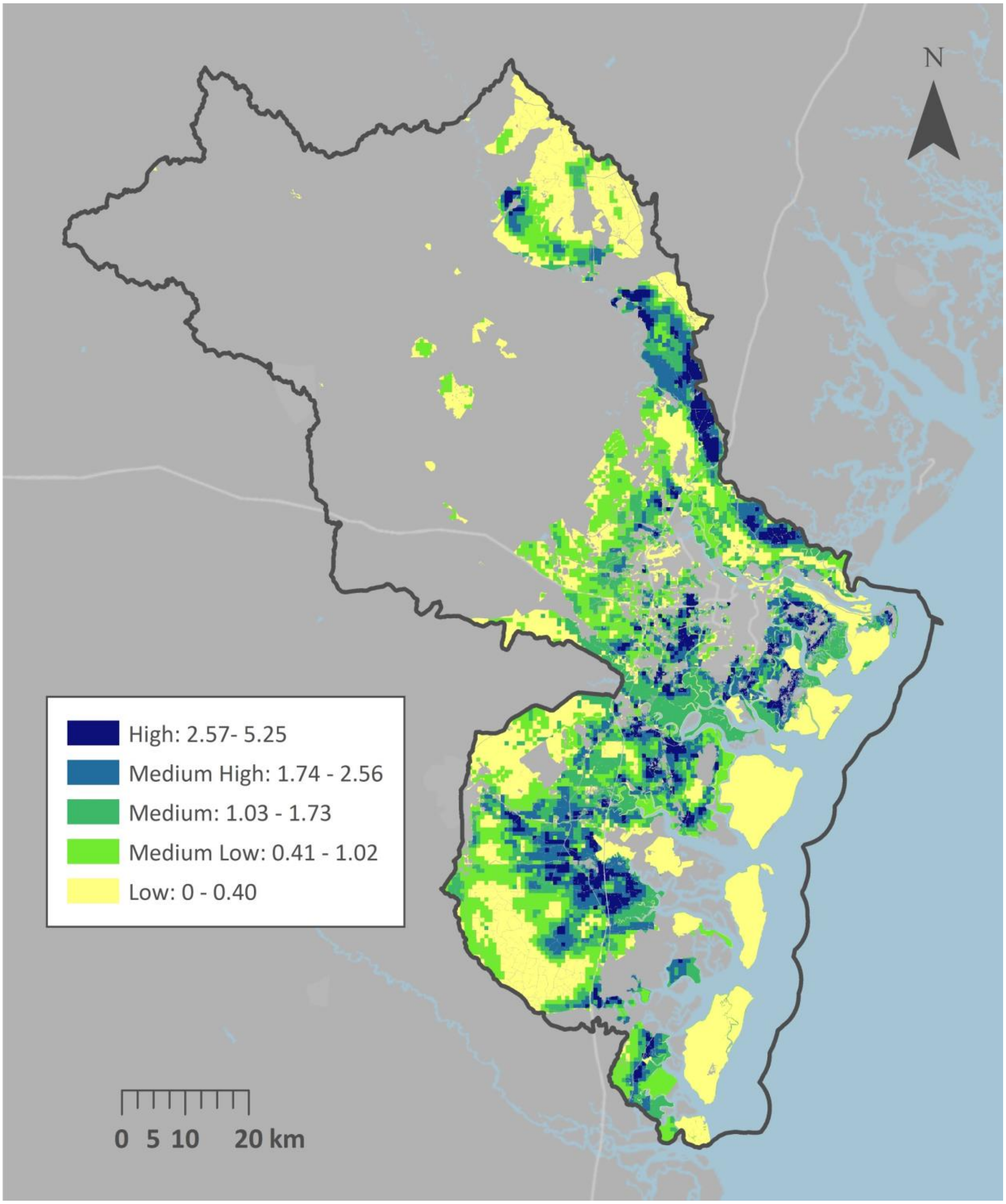
Left: Diagram of the overall approach of this assessment. *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas in proximity to HCAs with high vulnerability* ***and*** *high fish and wildlife richness 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.



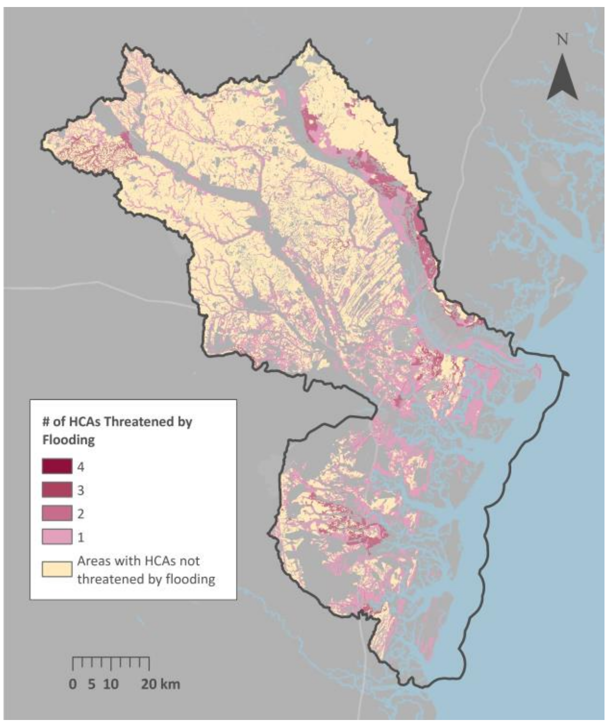
Resilience Hubs assessment relative unit scores for the Savannah River Watershed. *Assessment units are 100-acres grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieveboth community resilience and fish and wildlife benefits. Gray areas are outside of Hubs.*

Community Vulnerability

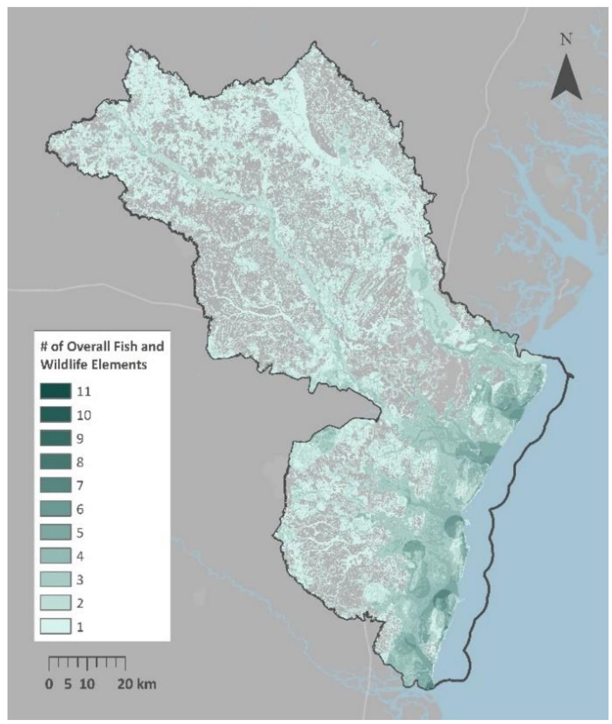
The Community Vulnerability Index (see map below) accounts for approximately half of the scoring of the Resilience Hubs. This index communicates threats to human community assets wherever they occur as well as concentrated areas of threat. Vulnerability is highest in the immediate coastal areas where 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 19 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 Savannah River 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 Savannah River 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 two case studies presented later in this report:

- Case Study 1: Improving Fish Passage and Habitat Connectivity in the Lower Savannah River Basin
- Case Study 2: Culvert Assessment for State Roads in High Flood Risk Areas

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 Savannah River Watershed, other local 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 (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 grantmaking 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 decisions and respond rapidly for maximum impact.

Regional Assessment

Developed through a separate but similar effort, the Regional Assessments (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 (US 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.

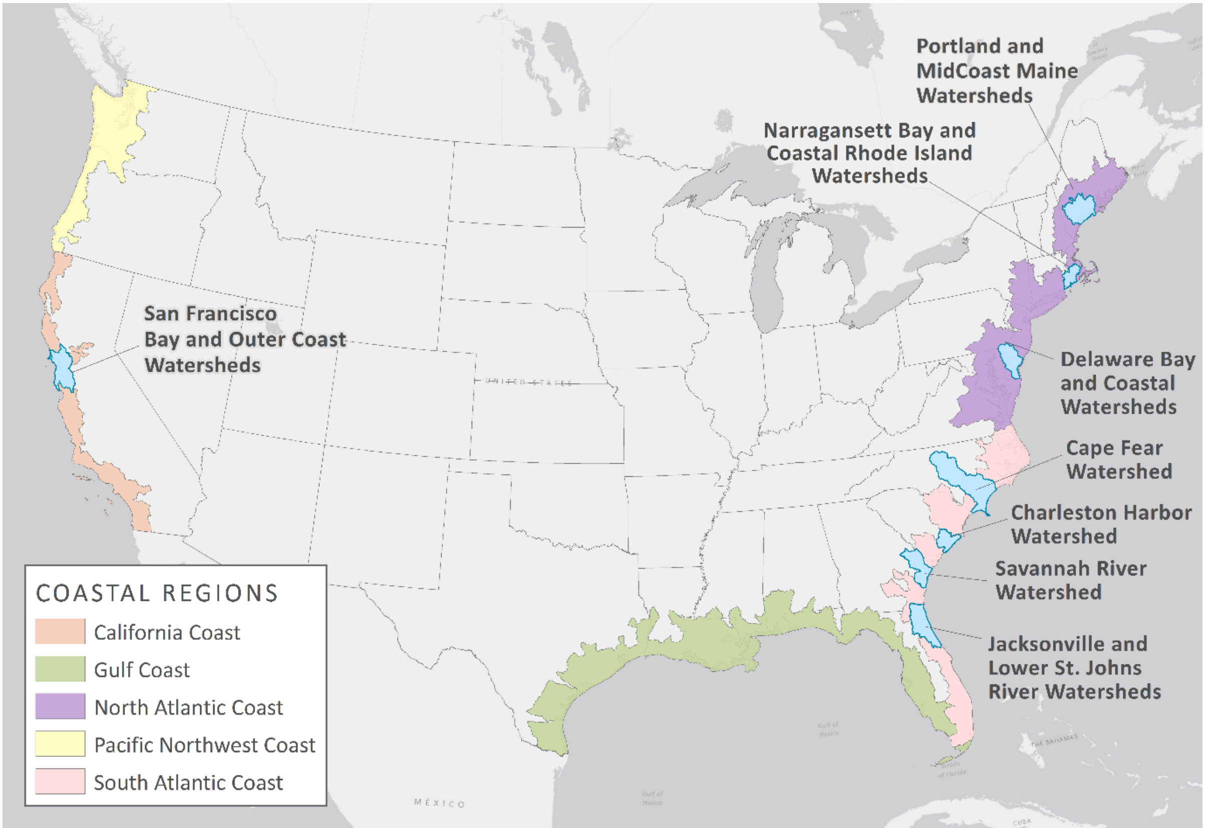


Figure 1. Map showing study areas for the Regional and Targeted Watershed Assessments. *The broad Regional Assessment included five coastal regions. High resolution assessments were carried out in eight coastal Targeted Watershed Assessment study areas (in blue); the Cape Fear Watershed was conducted 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 subbasin that drains to the sea, and in some places, a subbasin 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. Two 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/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.**

Savannah River Watershed

The Savannah River Watershed study area is situated in coastal Georgia and an adjacent portion of South Carolina (**Figure 2**). The Savannah River and its watershed form the northern boundary of the project area, extending inland to encompass the Ogeechee River drainage and south to the watershed boundary of the Altamaha River.

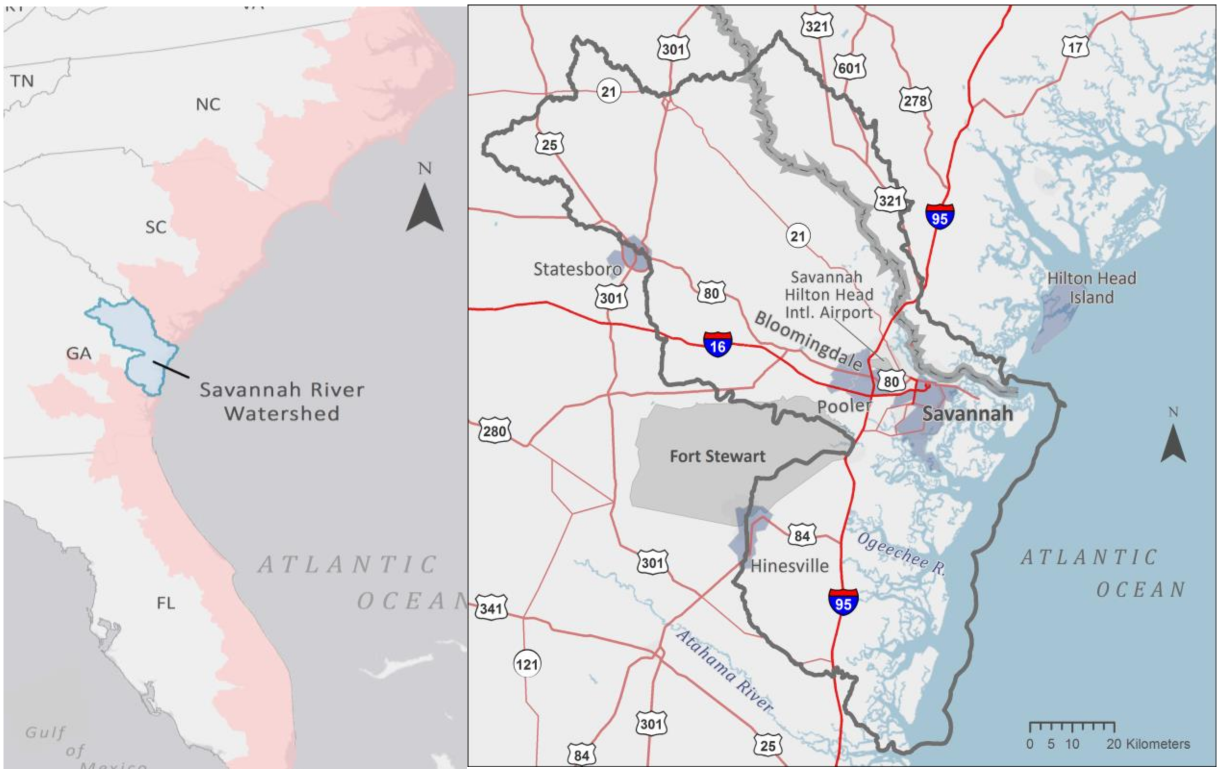


Figure 2. Location and boundary of the Savannah River Watershed study area*. The map on the left shows the watershed in the context of the South Atlantic Coast Regional Assessment area (pink). In the map on the right, the study area is indicated by the dark gray outline. Note that it consists of the Savannah River Watershed *and* several contiguous coastal watersheds to the south of Savannah.*

The dominant watershed features include the Savannah River and the extensive coastal marsh and barrier island system between the mainland and the Atlantic Ocean. The Savannah River is a large river flowing from the Blue Ridge Mountains through the Piedmont and Coastal Plain and forms much of the state boundary between Georgia and South Carolina. It has the third highest discharge rate and is one of the most aquatically biodiverse river systems on the Atlantic coast of the U.S.

The coastal reaches of the watershed consist of a chain of barrier islands behind which are extensive tidal brackish and salt marshes. The marsh ecosystem has the highest annual production (over ten tons of organic material per acre per year) among all terrestrial, freshwater, and marine ecosystems in the world (Giblin 1992). Georgia has 33% of the remaining intact marsh acreage on the Atlantic Coast of the U.S., and the marshes are some of the most pristine, least polluted in the country (USACE 2017).

The marshes, and the variation in water and salinity levels provide essential feeding habitat for many species.

The largest city in the watershed is Savannah, which is located on a large bluff inland from the mouth of the Savannah River. In 2017, the metropolitan area's population was nearly 400,000, and includes the area from Tybee and Wilmington Islands, to downtown Savannah, and communities inland along the Savannah and Ogeechee Rivers. The port is the second largest on the U.S. east coast and the fourth busiest and fastest growing container terminal in the entire U.S.[1] Key economic sectors in the region include tourism, health, and manufacturing. Compared to the city center of nearby Charleston, South Carolina, which is a more populous city that is only 12 feet in elevation, the city of Savannah has significantly higher elavaation at 49 feet; however, despite a higher elevation in the city center, significant areas of the greater Savannah region are lower in elevation and flood during storms and king tides (exceptionally high tides).

Five of the eight largest barrier islands along the coast of Georgia are within the Savannah Watershed, including, from north to south, Tybee Island, Wassaw Island, Ossabaw Island, St. Catherines Island, and Sapelo Island. Barrier islands provide numerous ecosystems for plants and animals, including beach and dune communities, upland depression forests and wetlands, maritime live oak and hickory forests, and maritime longleaf pine woodlands. Sea turtles (loggerhead and green), shorebirds (American oystercatcher, Wilson's plover, least tern, and wood storks) are among the rarest species found on the island ecosystems.

The inland areas of the watershed consist of forested wetlands and pine uplands (originally longleaf pine). The forested tidal freshwater swamps were historically cleared for agriculture including indigo, rice, and cotton.

Historic Impacts from Flooding

Flooding affects many areas along the coastal reaches of the watershed. Some of the most extensive flooding has occurred in recent years, both from episodic and chronic events, extensively damaging human assets.

- Hurricane Matthew, in 2016, produced a storm surge of nearly eight feet at Fort Pulaski, located just inland from the mouth of the Savannah River. The surge set a new record tide level of 12.57 feet above normal low tide.
- Hurricane Irma, in 2017, produced tidal surges only slightly lower than that of Hurricane Matthew at Fort Pulaski, but produced higher water levels along tidal creeks due tothe prevailing wind direction.
- The impacts from king tide have been more prominent in recent years, most severely impacting roads and other assets near marshes, but king tides have increasingly exacerbated upland flooding due to reduced storm water drainage. The only road to Tybee Island, U.S. 80, now experiences road closing floods six to 12 times a year. Under current projections, by 2060 the road is expected to flood 50 times a year (Evans et al. 2016).

[1] http://gaports.com/port-of-savannah

These same weather events that affect human communities also affect fish and wildlife habitat, resulting in inundated beaches, submerged marshes, and extensive flooding of upland forests and savannas. The Nature Conservancy of Georgia has an active coastal resilience program for coastal Georgia (http://coastalresilience.org/project/georgia/). In 2016, the city of Tybee Island became the first municipality in Georgia to create a municipal seal level rise plan to help them understand effects and address sea level rise over the next 50 years in this low-lying community (Evans et al. 2016).

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). Process diagrams (e.g., **Figure 4**) use the Charleston, SC region as an example and do not represent inputs or results for this watershed; they are only intended to illustrate methods.

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 lands 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.

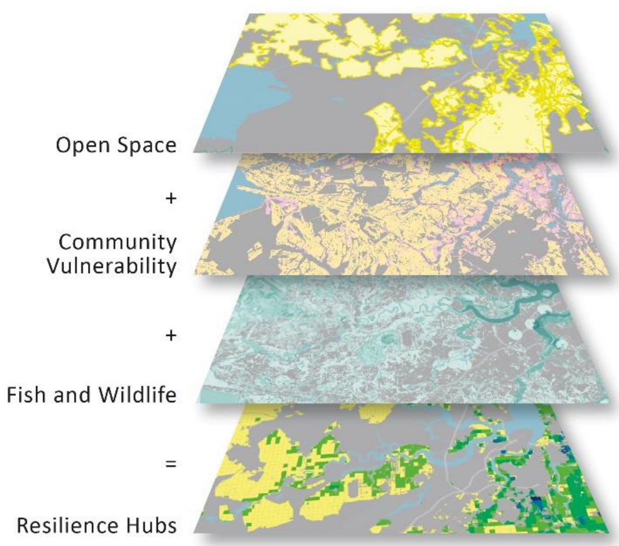


Figure 3. Diagram of the overall approach of this assessment*. Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas with high HCA vulnerability and high fish and wildlife richness are mapped as Resilience 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

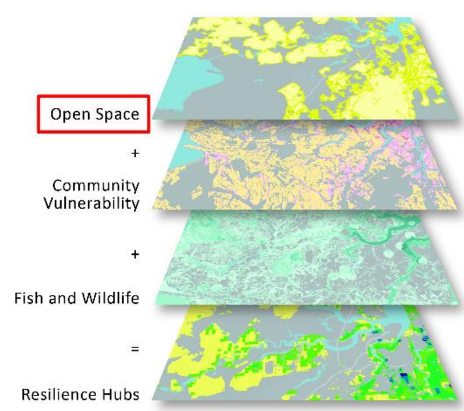
A fundamental part of this Targeted Watershed Assessment was to engage and work with individual and organizational stakeholders and partners within the Savannah River Watershed. Stakeholder involvement can improve the quality of decisions and policy—especially in the context of complex environmental and social challenges (Elliott 2016, Reed 2008). The stakeholder engagement process for Savannah River 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 Savannah River Watershed Committee was formed consisting of local experts from the National Oceanic and Atmospheric Administration (NOAA), the South Atlantic Landscape Conservation Cooperative (LCC), City of Savannah, University of Georgia (UGA) Marine Extension and Georgia Sea Grant programs, 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:

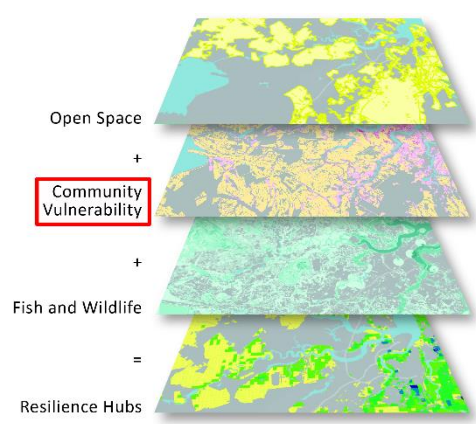
1. Protected areas, which are defined as lands that are part of the USGS Protected Areas Database of the United States (PAD-US).
2. Unprotected privately owned lands with contiguous habitat, as identified from the United States Geological Survey (USGS) National Land Cover Database (NLCD). The open space 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. 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 or restoration.
3. Impervious surfaces were deleted from the Hubsusing 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.

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** (below) 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 infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.).	0.2
Critical Infrastructure (Rank 2)	**Medium** spatial concentration infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.).	0.4
Critical Infrastructure (Rank 3)	**High** spatial concentration infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.).	0.6
Social Vulnerability	The 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[2] by first assigning a weighting factor that approximated the ranked weights used in the Regional Assessment (see **Table 1)**. For the purposes of the Targeted Watershed 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

[2] 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.

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)
- 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

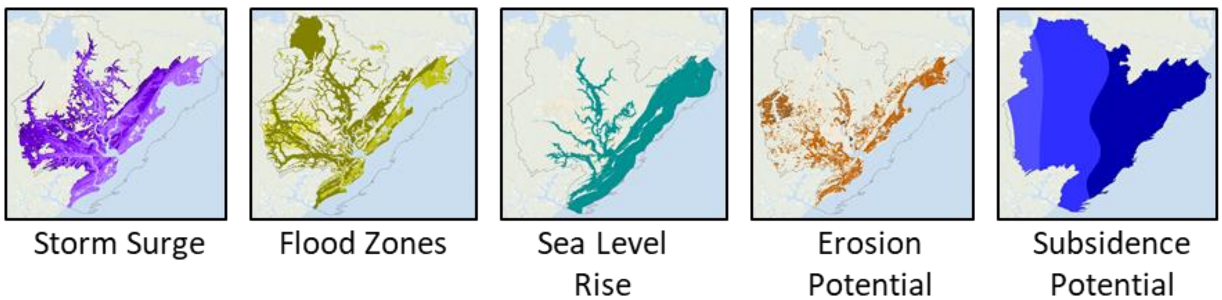


Figure 4. Flooding threats used to assess community vulnerability. *Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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.

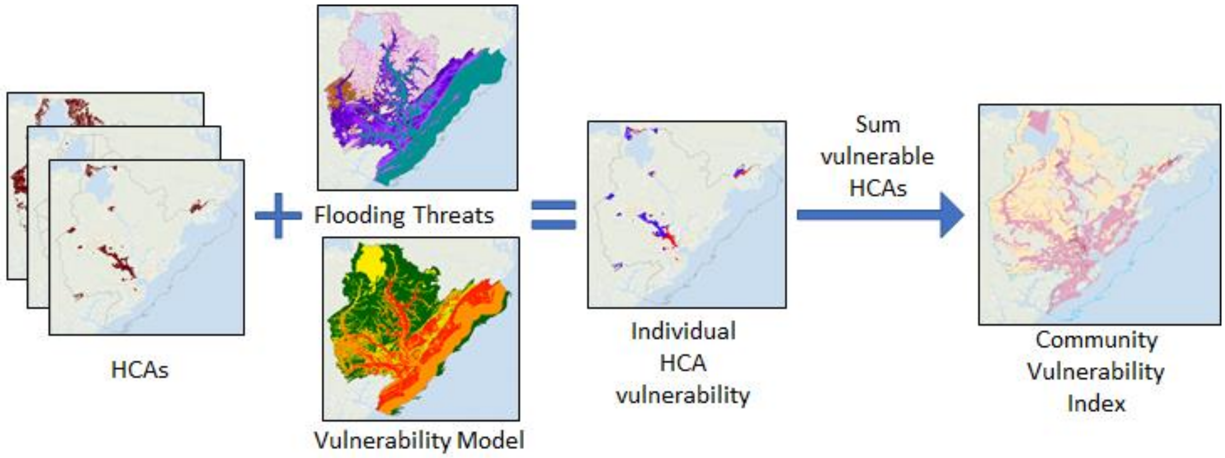
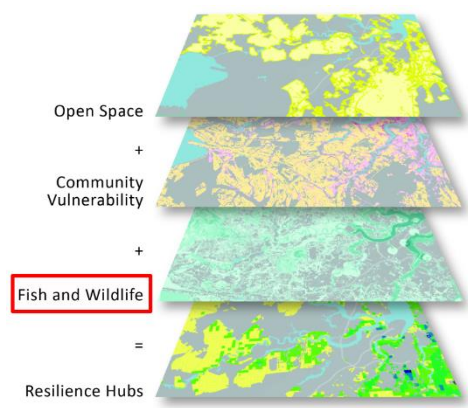


Figure 5. Community vulnerability assessment process. *Human Community Assets (HCAs) are intersected with the flooding threats, a vulnerability model is applied, and individual HCA results are summed to create the Community Vulnerability Index. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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 HHubs characterization and scoring used in the Targeted Watershed Assessment (see section below): 1) the Fish and Wildlife Richness Index, and 2) the 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 1, 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[3]
- 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)[4]
    - A species with a NatureServe global imperilment rank of G1, G2, or G3[5]
    - 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

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[3] 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).

[4] 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)

[5] 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)

- A distinctive ecological system or species congregation area that represents a 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:
    - 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

CCurrent 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, 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.

Figure 6. Fish and wildlife stressors used to model current habitat condition. *Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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.

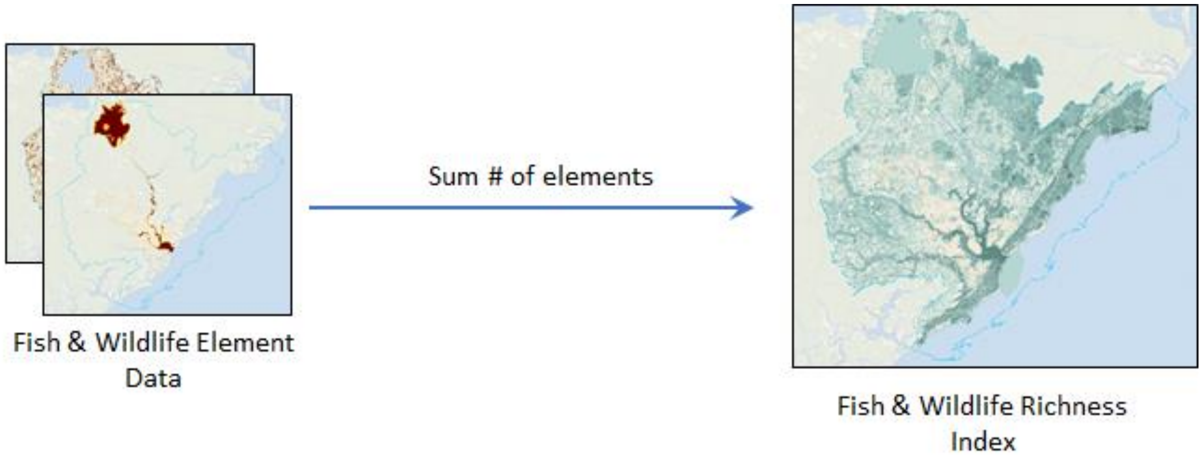


Figure 7. Method for generating the Fish and Wildlife Richness Index. *All elements are overlaid and the sum of elements occurring in a location is calculated. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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.

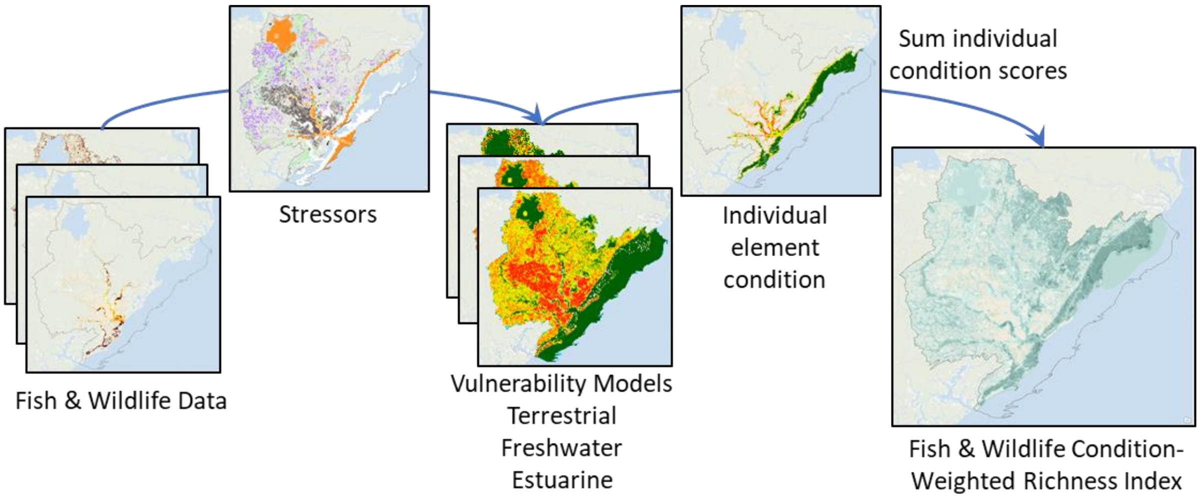
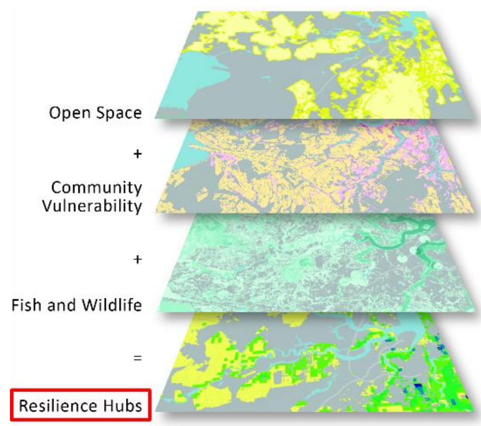


***Figure 8*. Method for generating the Fish and Wildlife Condition-Weighted Richness Index.** *Fish and wildlife elements are intersected with stressors, the vulnerability model is applied, and individual element condition results are summed. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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**.

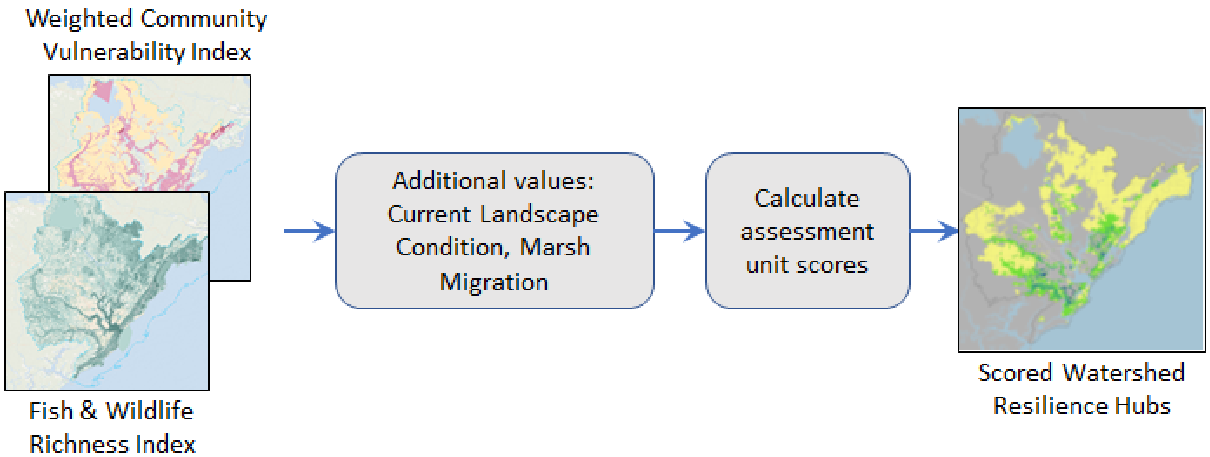


Figure 9**. **Method for scoring watershed Resilience Hubs. *Resilience Hub assessment units were scored based on their community resilience and fish and wildlife. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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 1 km (0.62 mi) 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 Hub 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 km (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 two 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 two projects to be used as the focus for detailed case studies (see Case Studies section below).

Results

This section presents 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 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 Savannah River 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 Savannah River Watershed. The Threat 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).

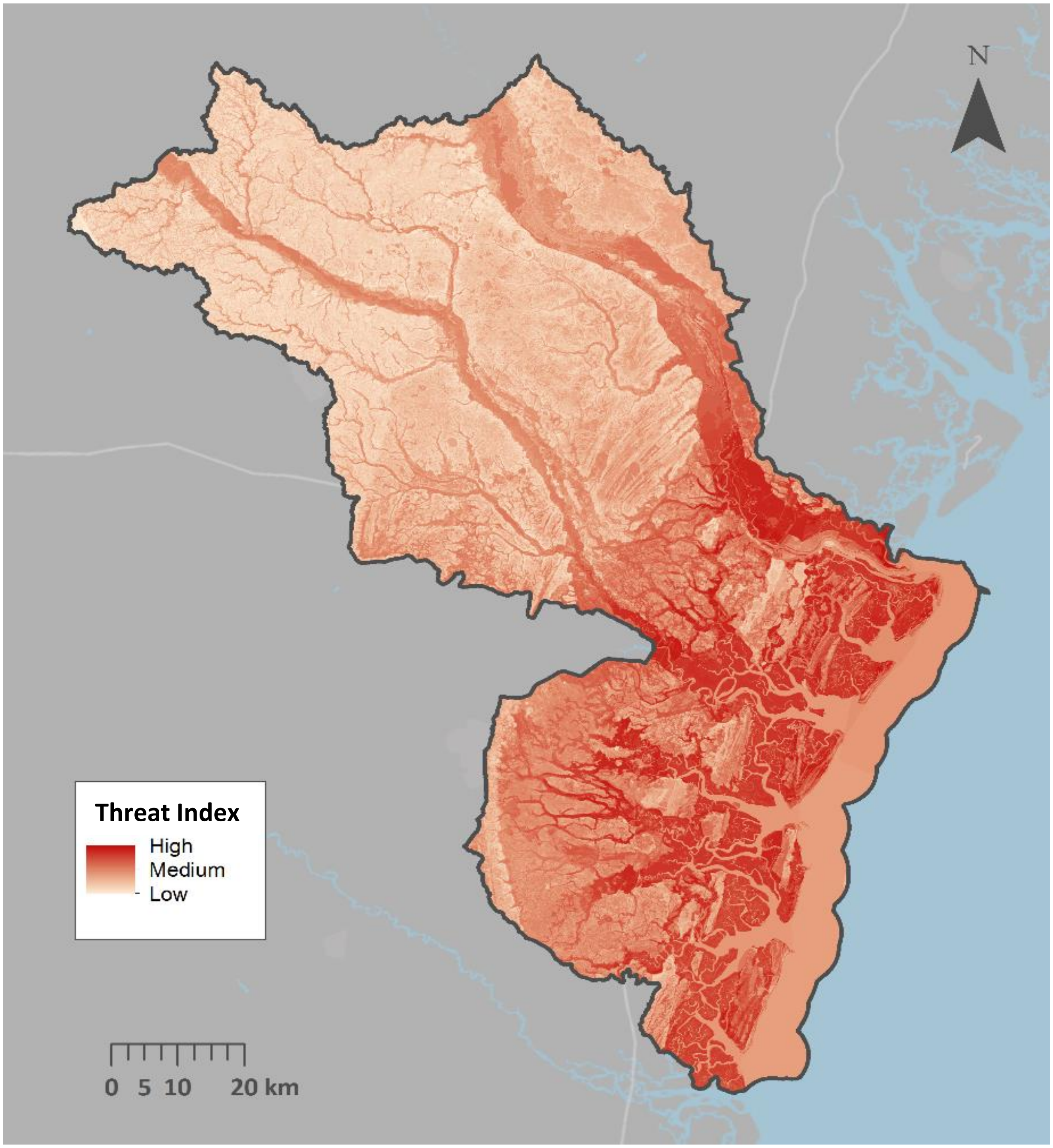


Figure 10. Weighted Threat Index for the Savannah River Watershed. *Map shows the number of overlapping threats modified by a weighting based on their probability of occurrence.*

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 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.

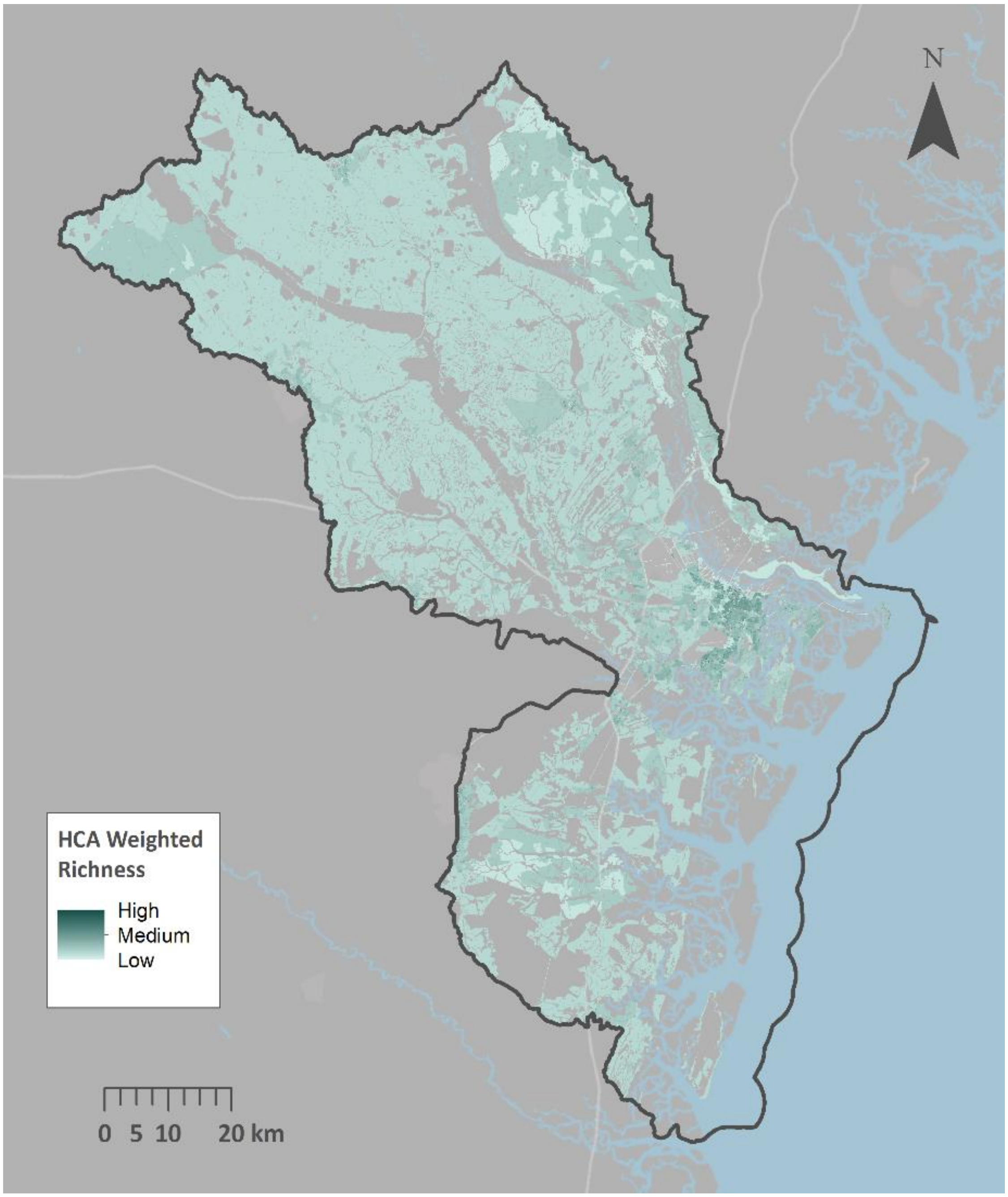


Figure 11. Human Community Asset (HCA) Weighted Richness Index for the Savannah River Watershed*. Darker shades indicate higher value based on the number and importance weightings of HCAs in each location. Gray areas within the project boundary represent areas with no mapped HCAs.*

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**).

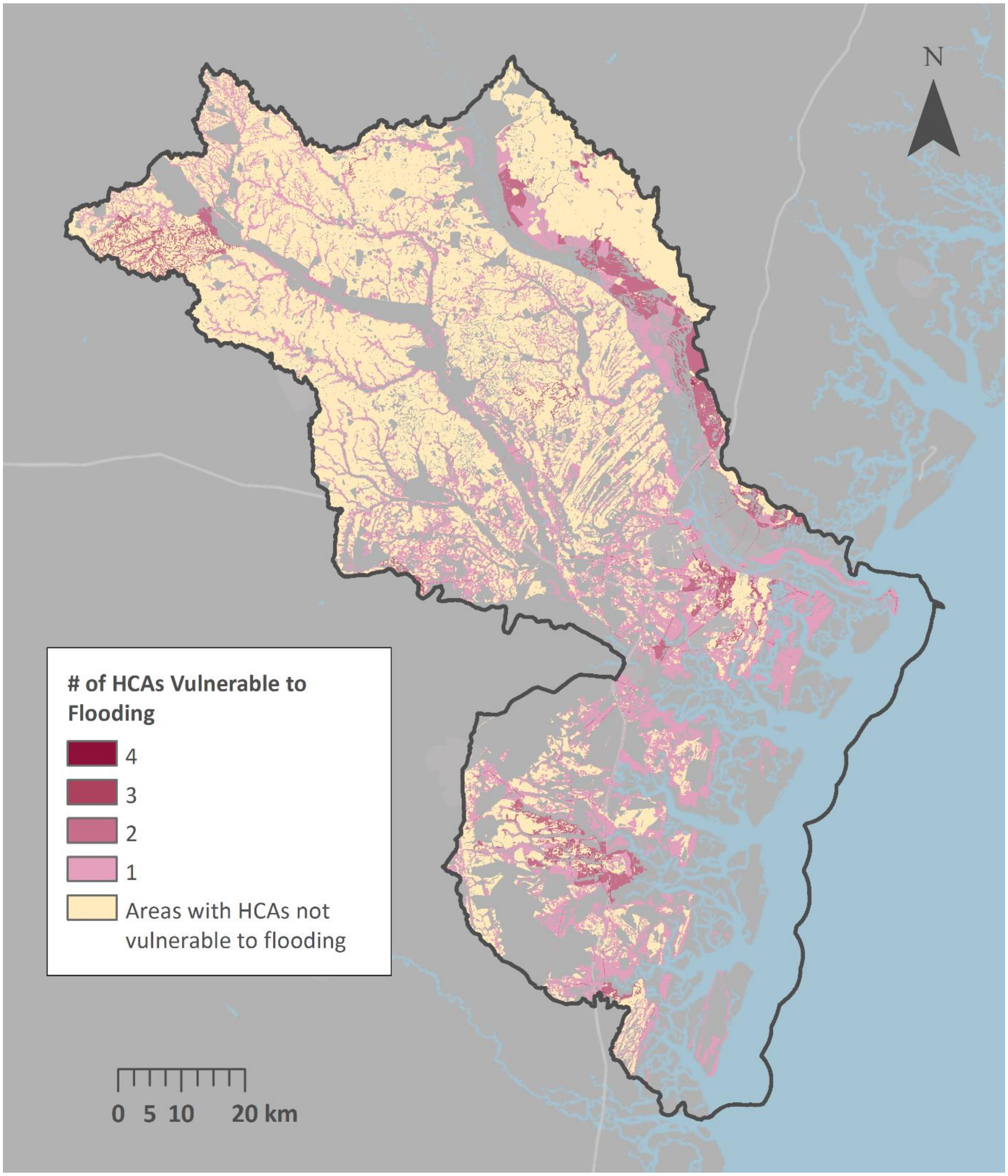


Figure 12. Community Vulnerability Index for the Savannah River Watershed*. Pink to red shades indicate the number of Human Community Assets (HCAs) exposed to threats. Tan areas indicate areas of low to no impact from the flooding threats. Gray within the project boundary represents areas with no mapped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

Vulnerability is highest in the communities along the coastal plain and along the low elevation northeastern side of the Savannah River 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 higher elevation areas of Savannah are not particularly vulnerable to flooding (as indicated by tan shading), but there are numberous areas within the watershed that are vulnerable (indicated by red shades). For instance, the southwest area of Ludowici, Walthourville, Hinesville , and other areas shown in dark red, all have a high concentration of HCAs that are vulnerable to flooding The coast along this watershed contains extensive beaches and wetlands that currently provide some buffering from storms. Protecting the 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).

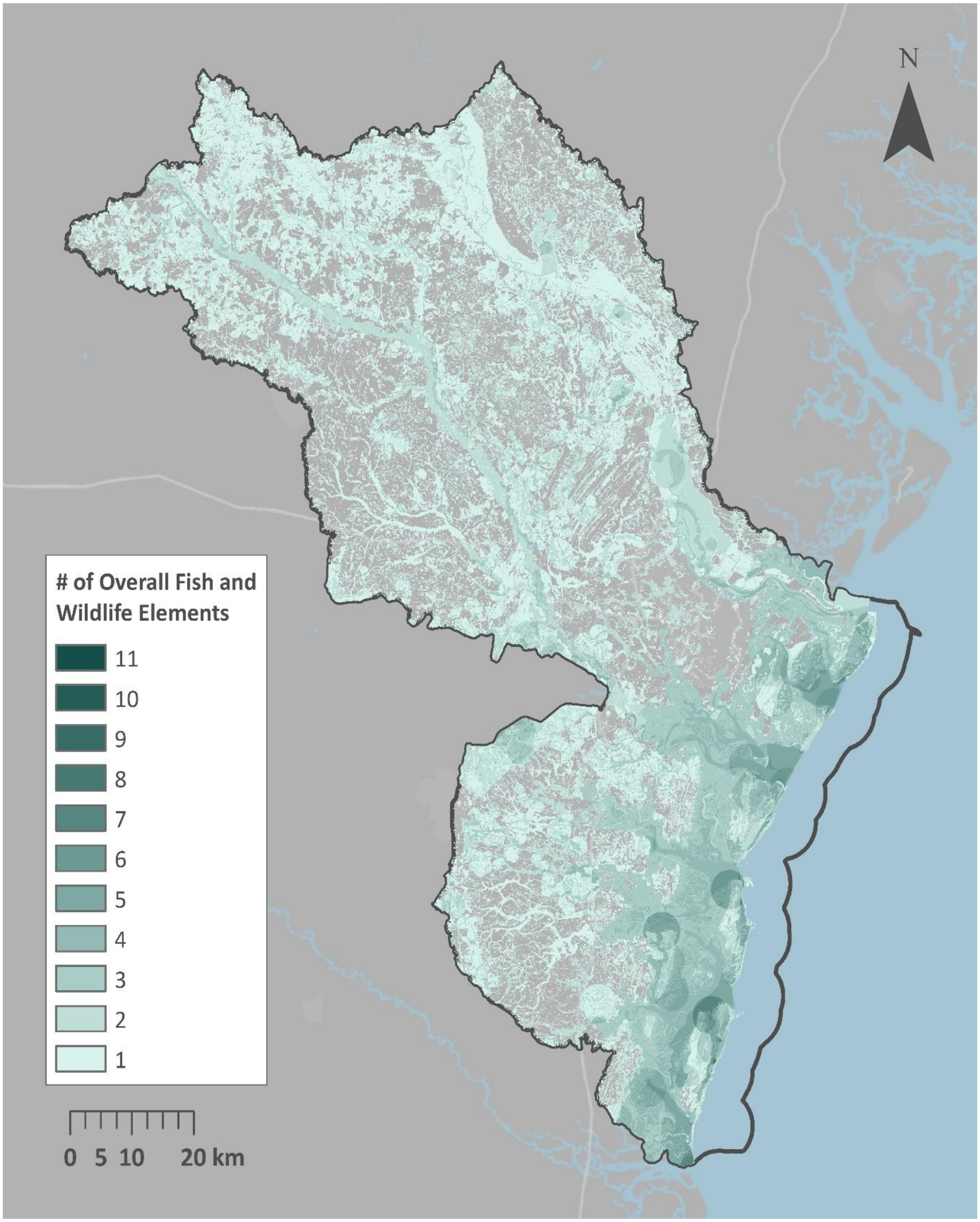


***Figure 13. Richness of fish and wildlife elements in the Savannah River Watershed**. Green shades indicate the number of elements found in a location. Gray within the project boundary are areas with no fish and wildlife elements considered in this assessment.*

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.

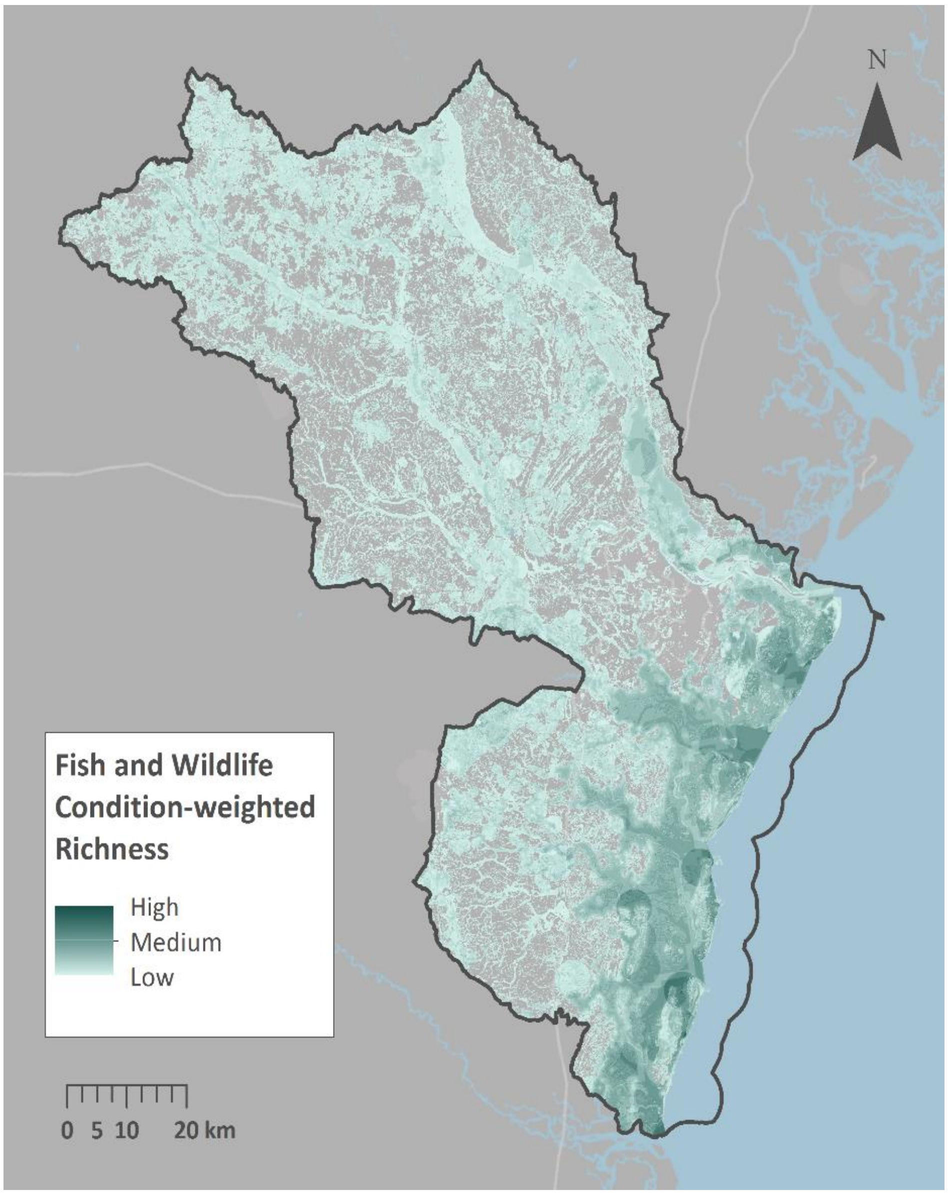


***Figure 14. Fish and Wildlife Condition-weighted Richness Index results for the Savannah River Watershed**. Green shades indicate the added condition scores of the elements found in a location, with a maximum value of one per element. Grey areas within the project boundary signify areas with no mapped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

Richness and condition are currently highest in the immediate coastal areas and the rivers extending inland. When viewed at the full extent of the watershed, the differences between the two indices appear, subtle but some differences can be seen in the condition-weighted richness (**Figure 14**). For example, the rivers and wetlands in the less-developed area between Savannah and Darien (at the south end of the study area) show darker green indicating their relatively higher condition compared to the surrounding areas.

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 (**Figure 16**) 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.

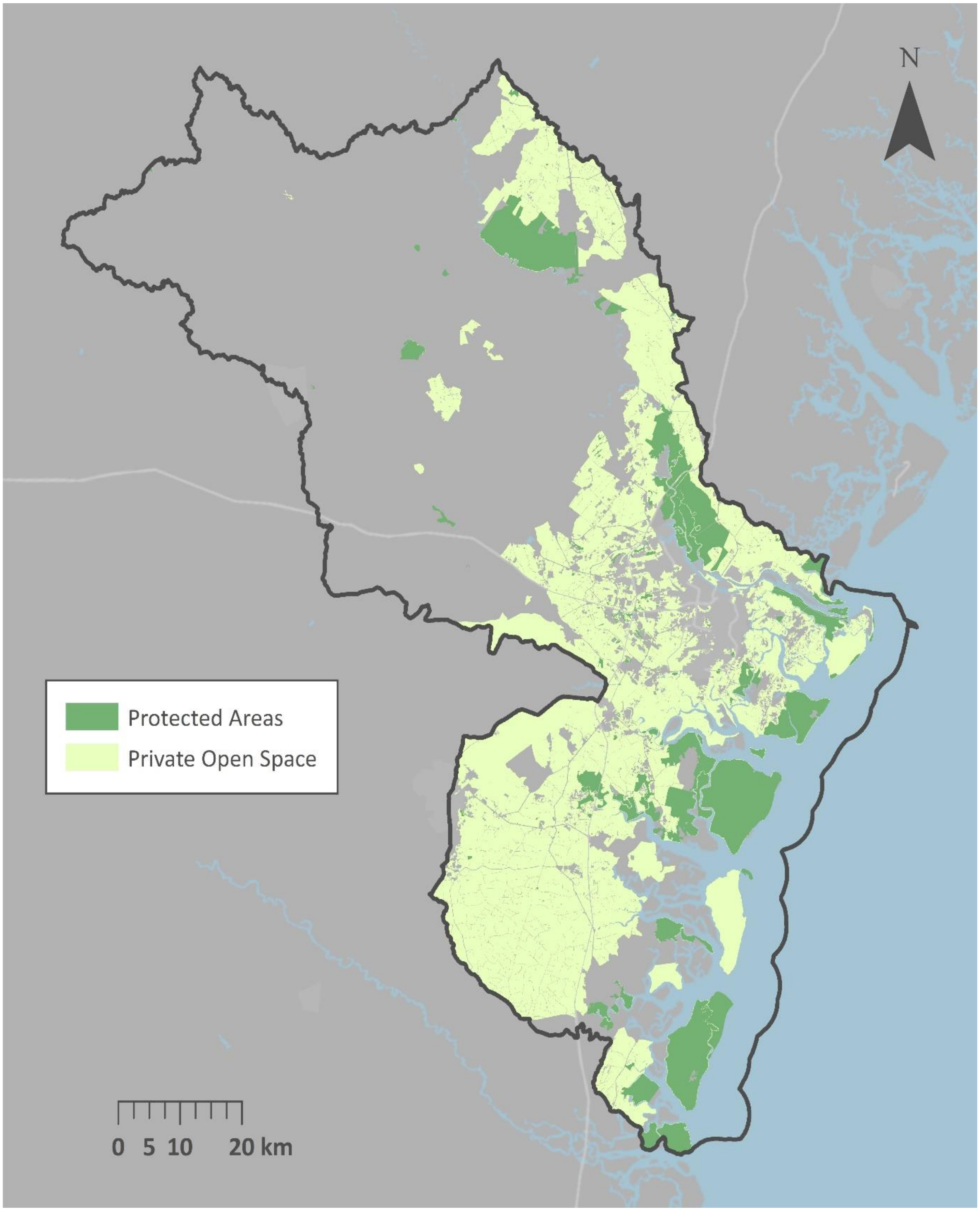


Figure 15. Undeveloped protected areas and unprotected privately owned areas of open space in the Savannah River Watershed. *Map displays the distribution of these areas within Resilience Hubs identified in the study area and therefore does not include all such areas within the study area.*

By design, the Resilience Hubs occur where concentrations of vulnerable HCAs are proximate to protected 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 the Hubs are already in protected status determines which resilience project 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, 19,352 assessment units were analyzed and scored within the Savannah River 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**).

The highest scoring portions of the Resilience Hubs are distributed across the coastal plain with notable concentrations along the Savannah River from the City of Savannah upstream to the area around Rincon and Hardeeville as well as the communities along and just inland from I-95. Three high scoring areas of resilience hubs are featured below and are associated with the case study resilience projects.

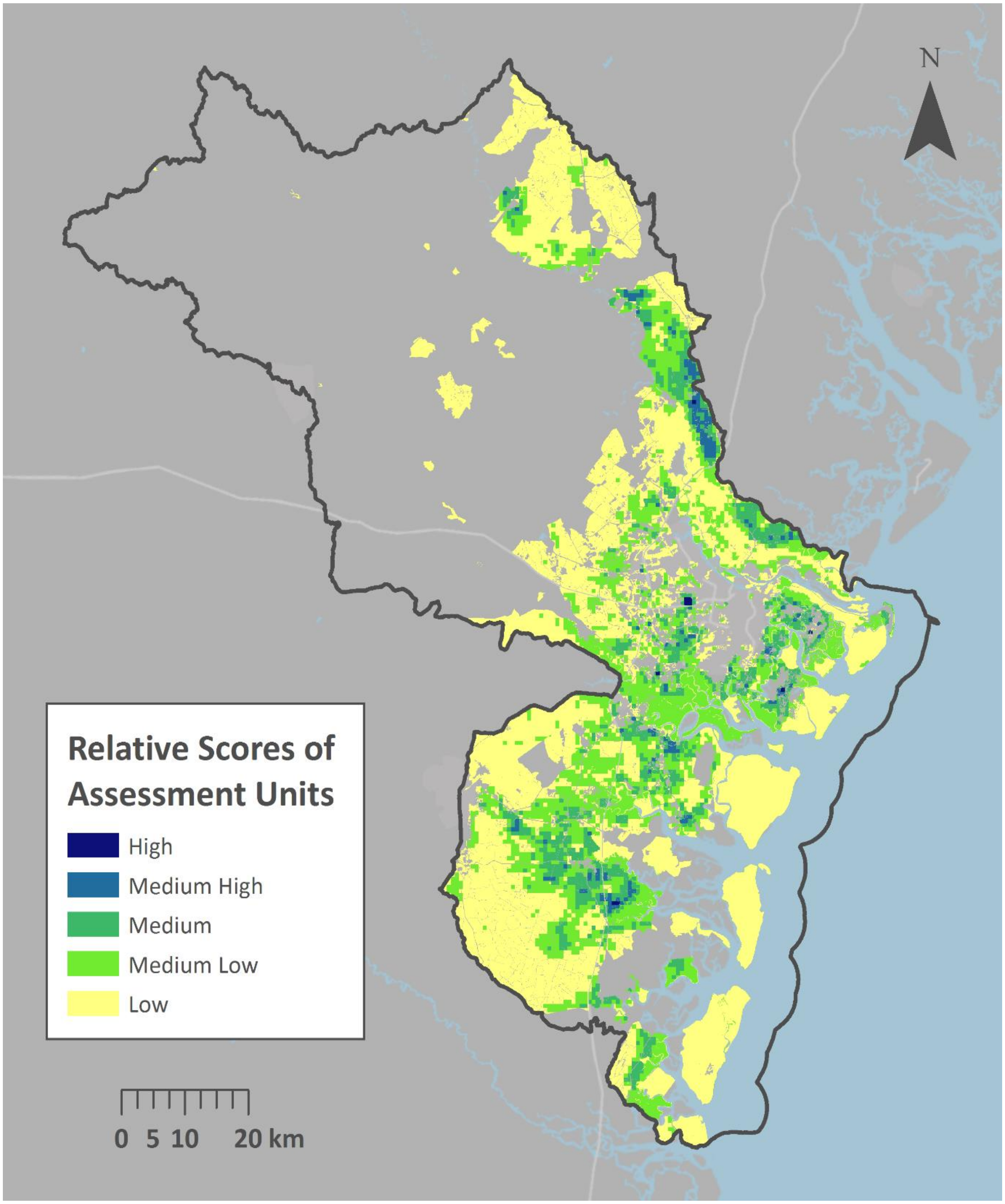


Figure 16. Resilience Hubs assessment unit relative scores for the Savannah River Watershed. *Assessment units are 100-acre grids or smaller parcels. Darker shades indicate higher scores signifying greater potential for community resilience and fish and wildlife benefits.*

Suggested Uses

The Resilience Hubs map for the Savannah River 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. Nor do these examples attempt to suggest specific actions that should be taken to increase resilience.

Isle of Hope Resilience Hub Area Example

The area is on the seaward side of Isle of Hope (**Figure 17**) is highly developed but is also surrounded by tidal streams and marshes, which makes it very vulnerable to storm flooding. This area ranked in the top 11 of over 19,000 hub assessment units analysed asbecause it has very high HCA vulnerability (including dense developed areas and multiple critical facilities), fish and wildlife diversity, restorability, and modeled future marsh suitability. Conservation and restoration of these marsh areas would serve to buffer the community from flooding and increase fish and wildlife habitat condition for many rare terrestrial habitats and species in addition to numerous important estuarine species such as snapper, grouper, and oysters. While no currently proposed resilience projects are found specifically in this area, it may be a good location to consider projects that would have the highest impact in the future.

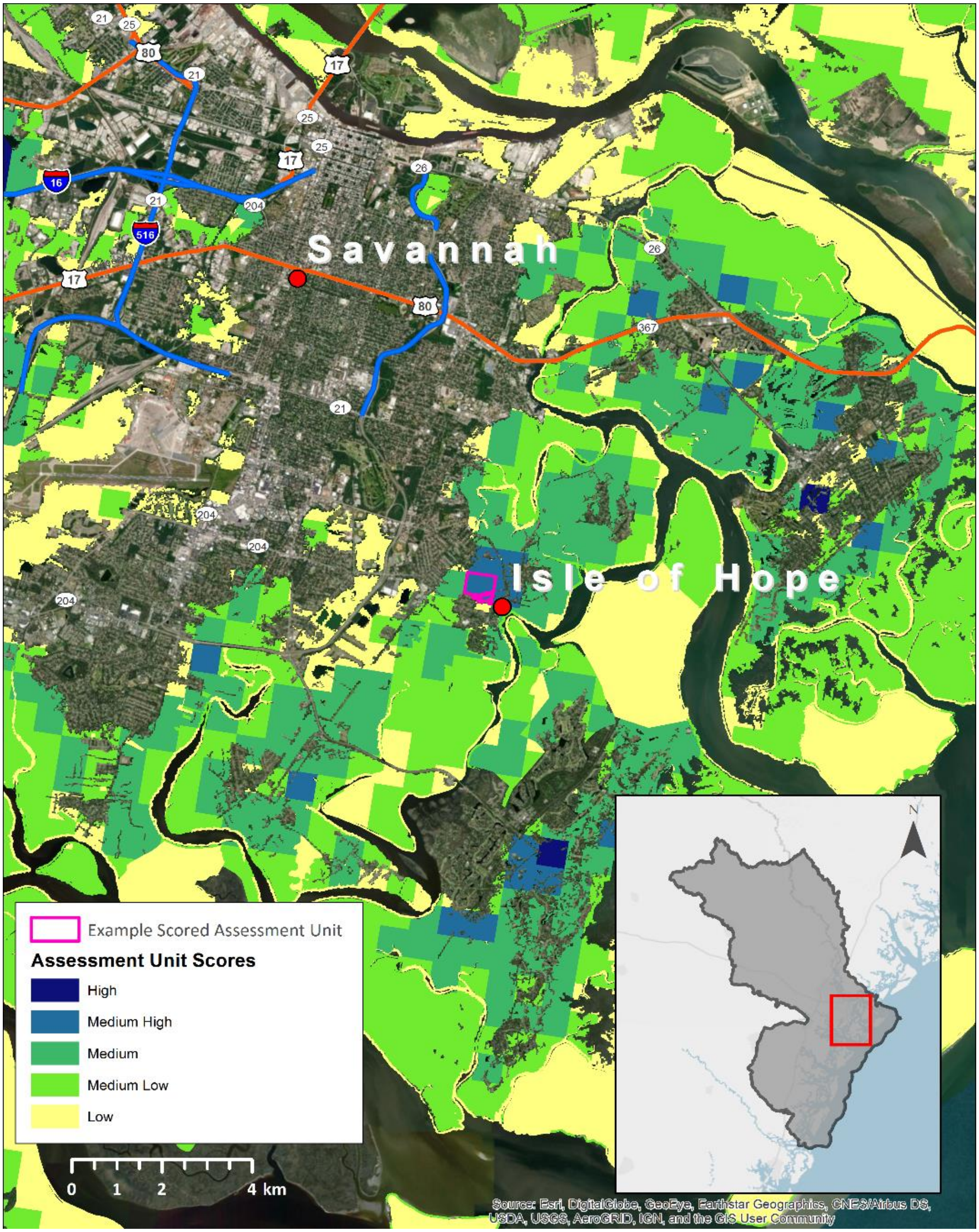


Figure 17. Isle of Hope Resilience Hub area example. *The yellow-blue shaded areas are the scored resilience hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- G1G3, S1S3 Terrestrial species
- Maritime Liveoak Hammock Forest and Scrub
- Open Pine Habitat
- Snapper Grouper
- T&E Aquatic
- Cypress Swamps and Domes
- Diadromous Fish Habitat and Important Riverine Systems
- Marsh and Tidal Creek
- Oyster Beds and Reefs
- Shrimp

HCA elements in or near assessment unit:

- Critical Infrastructure Rank 1 (Bluff Drive)
- Critical Facilities
- Population Density Ranks 2, 3, and 4.

Table 3. Attributes used to calculate the final score for the Isle of Hope 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 and wildlife elements out of 16 possible)	10
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1, mean value of 0.07, standard deviation 0.12)	0.64 (very high)
Restorability index	1 (good candidate for protection)
Average Condition (1= current very high condition)	0.52 (moderate)
Final score	**4.20 (rank #11 out of 19,352 units)**

Hardeeville Resilience Hub Area Example

This area is located to the north of the town of Hardeeville, South Carolina and adjacent to the Savannah National Wildlife Refuge (**Figure 18**). It scored highly because of high flood risk to the rural communities with high environmental justice rankings adjacent to the low-lying Savannah River floodplain. In addition, this area is at the intersection of key transportation corridors (I-95 and Highway 17) and contains a number of other high priority human assets that serve the adjacent Hardeeville community. This area has also been identified as a potentially important area for habitats and species that currently exist within the national wildlife refuge but that may need to migrate inland and upstream as sea level rise affects the location of the transition area from saltwater to brackish to freshwater As indicated in **Table 4** below, the hub assessment unit used to characterize this area scored highly in multiple areas of the prioritization model—high human asset vulnerability, ability to support future marsh habitat under sea level rise, and high restorability— despite being very low in current fish and wildlife richness. The juxtaposition of this area adjacent to a large protected area, on agricultural land amenable to habitat restoration, and between the river (source of flooding threats) and vulnerable human assets makes it a high scoring resilience hub area. This area would benefit from both restoration and protection to ensure long-term resilience benefits. Because the area is largely agricultural, restoration could be relatively passive, accommodating marsh development with rising waters but near term active restoration may improve flood protection for the adjacent HCAs.

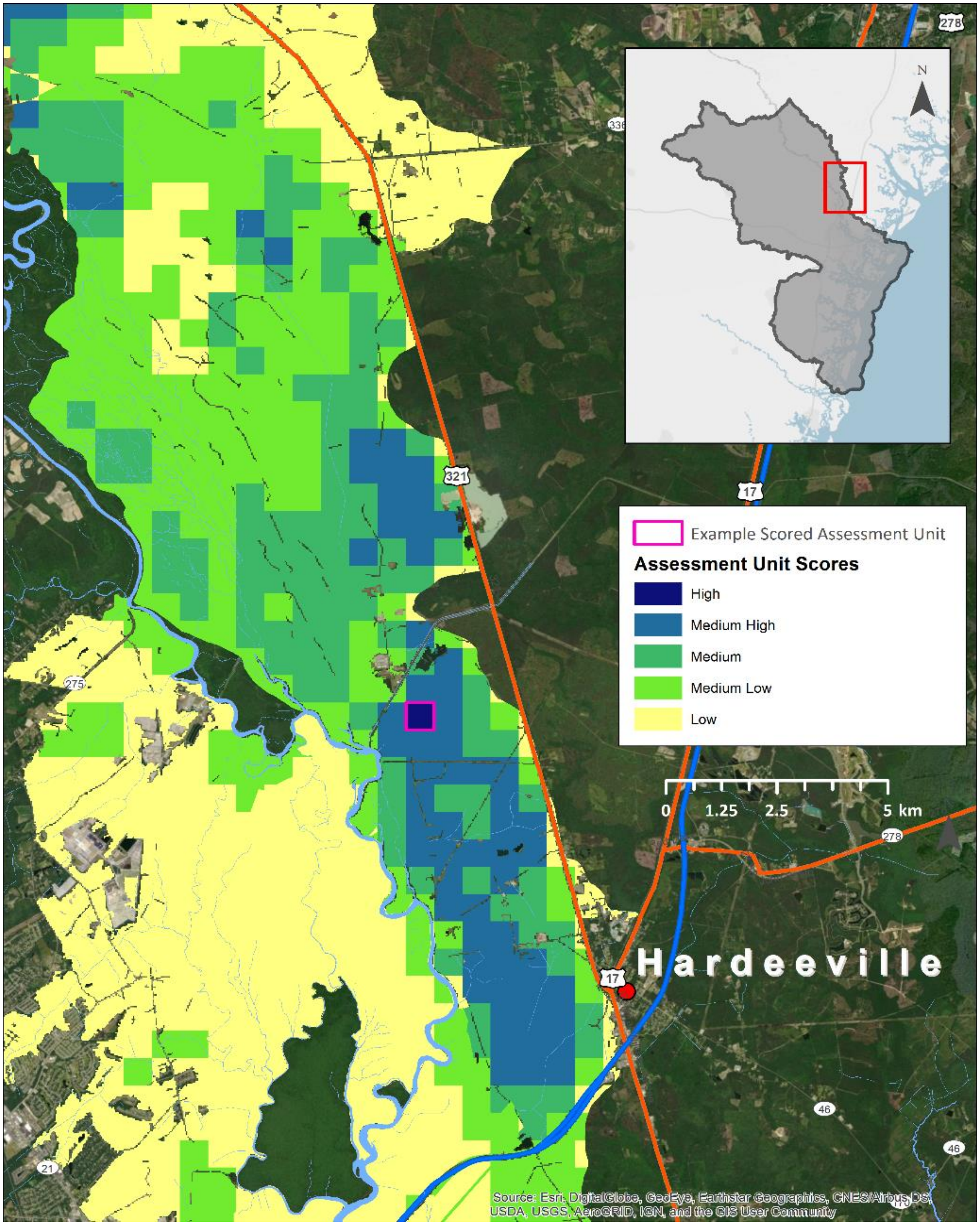


***Figure 18. Hardeeville Resilience Hub example area**. The yellow to blue shaded areas are the scored resilience hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Open Pine Habitat
- Forested Wetlands (non-tidal)

HCA elements in or near assessment unit:

- Environmental Justice
- Population Density Rank 1

Table 4. Attributes used to calculate the final score for the Hardeeville 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)	2
Presence of marsh under 3ft SLR	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1, mean value of 0.07, standard deviation 0.12)	0.81 (very high)
Restorability index	1 (highly restorable)
Average Condition	0.56 (moderate)
Final score	**4.35 (high, Rank # 10 out of 19,352 units)**

Fish and Wildlife Elements

The final list of elements explicitly represented in the Savannah River Watershed analysis is shown in **Table 5** 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 5. Final list of elements used in the Savannah River Watershed assessment.

Fish/Wildlife Element	***Description/Significance***
NOAA Trust Resources	
Beach and dune habitat	This habitat includes open sandy coastal expanses that support a large set of high priority wildlife species such as sea turtles (for nesting sites--a NOAA trust resource when offshore and USFWS jurisdiction when off the coast) and numerous migratory bird species.
Diadromous fish habitat and important riverine systems	This element includes critical habitat for Atlantic sturgeon and habitat used by most diadromous fish species in the watershed (i.e. Atlantic and shortnose sturgeon, shortnose sturgeon, shad, blueback herring, hickory shad, American shad, American eel, menhaden, and striped bass) as well as red drum, several shark species (nursery habitat), and other large ocean fish species that utilize large brackish and freshwater river stretches. River mussels also rely on this habitat.
Marsh and tidal creek (including open water)	These habitats represent extremely important nursery areas for a number of fish species (including most NOAA trust species). Species that depend on this habitat include summer flounder, snapper-grouper complex, Spanish and king mackerel, cobia, bluefish, black sea bass, red drum, spotted seatrout, weakfish, spot, southern flounder, numerous sharks (lemon, bull, blacknose, finetooth, dusky, bonnethead, and Atlantic sharpnose), penaeid shrimp, and blue crab.
Oyster beds/reefs	These formations are an iconic feature of the watershed and provide habitat (especially nursery habitat) to many commercially and other species.
Important shark habitat	Habitat of sandbar and sand tiger sharks—both of which, due to the sensitivity of these species to small changes in their habitat, are indicative of the overall health of populations of these declining species.
Shrimp Essential Fish Habitat	Waters and substrate necessary for shrimp spawning, breeding, feeding, or growth to maturity. In this analysis, it represents habitat important for all penaeid shrimp species.
Snapper-Grouper Essential Fish Habitat	Waters and substrate necessary for snapper-grouper species for spawning, breeding, feeding or growth to maturity. Several other key commercial species also rely on this habitat.

Fish/Wildlife Element	*Description/Significance*
At-Risk Species and Multi-species Aggregations	
Threatened and endangered terrestrial species element occurrences	Documented areas of occurrence for all available ESA Threatened and Endangered species. Given that the only data available for aquatic species was for sea turtles and sturgeon—the distributions of which are closely mirrored by other explicit elements in this study, these species were not treated as independent elements.
G1-G3/S1-S3 terrestrial species element occurrences	Documented areas of occurrence of all G1-G3/S1-S3 species made available for this analysis. Species already included in the Threatened and Endangered Species group (see above) were left out of this group.
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Cypress dome/pondshore	This habitat supports aquatic and terrestrial species of interest including flatwood salamanders, and important roosting sites for wood storks and white ibis.
Forested wetlands (non-tidal)	This habitat supports numerous important migratory bird species such as prothonotary warblers and other Neotropical migrants (especially for breeding).
Tidal hardwood swamp forest (with and without cypress)	This habitat supports high levels of biodiversity that in turn contribute to its relatively high contribution to maintaining water quality. These areas are also highly susceptible to sea level rise since they are tidally influenced.
Freshwater emergent wetlands	This habitat supports many important coastal communities.
Seaside sparrow habitat	Due to the close ecological dependency of Seaside Sparrow on particularly high-quality marsh and tidal creek habitat, mapped distributions of these sparrows are an approximation of the highest quality examples of these habitats that in turn support distinctive communities.
Wading bird and ally colonies	These areas are important because the nesting requirements of some species are fairly rigorous and changes may threaten current colonies, forcing them into substandard habitat in the future. • This element includes occurrence information of: Black-crowned Night Heron, Wood Stork, and Yellow-crowned Night Heron
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Maritime live oak hammock forest and scrub	This iconic habitat occurs on and adjacent to the barrier islands of the Carolinas, Georgia, and Florida. It is highly threatened by development, sea level rise, and storm surge. In addition to supporting a range of distinctive species, these habitats buffer communities from the effects of wind and water from storms. This habitat includes newer scrub habitat and older, fully developed maritime live oak forest. Maritime Live Oak Hammock forest is considered a G2 (very imperiled) community. The associated younger scrub is optimal habitat for the declining painted bunting.

Fish/Wildlife Element	*Description/Significance*
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Open pine habitat	This habitat 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 including American kestrel, Bachman's sparrow, brown-headed nuthatch, swallow-tailed kite, Henslow's sparrow (Winter), pine warbler, coral snake, Eastern diamondback rattlesnake, Florida pine snake, Northern pine snake, pine woods litter snake, southern hognose snake, mimic glass lizard, slender glass lizard, gopher tortoise, Carolina gopher frog, frosted flatwoods salamander, and pine savannah crayfish. Because of their close ecological dependency on this habitat, distribution information from the following species were used in combination with the general habitat type to map this element: • Eastern Indigo Snake is an open pine obligate of critical concern, and an indicator of particularly high quality open pine over sandy substrate. • Red-cockaded Woodpecker is an Endangered open pine obligate species of particular importance in terms of regulation and management. • Gopher Tortoise is also an open pine obligate species, Threatened in parts of its range, that is of particular importance in terms of regulation and management.
Important river mussel habitat	River mussels require high water quality and specific substrate conditions. Their distributions therefore indicate that both the waters they occur in and adjacent bottomland and uplands have a relatively low level of pollutants. This element combines element occurrences of the following species of mussel: Altamaha arcmussel, brother spike, Carolina elephantear (slabshell), Carolina slabshell, Halcyon marstonia, Roanoke slabshell, Savannah lilliput, Say's spiketail, tidewater mucket, and yellow lampmussel.
Cross-cutting Elements	
Continental and global Important Bird Areas	These areas highlight geographies of key importance for birds. They are defined in the US by the National Audubon Society by applying a widely used international standard.

Resilience Projects Portfolio

A portfolio of resilience projects within the Savannah River Watershedwas compiled from plans and other project documents submitted by stakeholders (**Table 6**). A total of 22 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. Given the significant risk posed by climate threats in this watershed and the scope for increasing resilience revealed in this assessment, increasing efforts and resources to develop and execute resilience-related projects would almost certainly result in future returns in the face of increasing risks.
2. Some of the most important and high impact resilience projects involve working with transportation planners and engineers to help ensure current and future roadwork takes coastal threats into consideration and potentially improves habitat connectivity while reducing flooding threats to key roads.

Table 6. Summary of resilience-related projects identified for the Savannah River Watershed study area. *Table shows the implementation stage of each project at the time of compilation.*

Project Type	Project Phase				
	Unknown	Conceptual	Planning Complete	Ready to Implement	Total
Studies & Modeling	1	1	1	2	5
Living Shorelines	2	1			3
Aquatic Connectivity		3			3
Dredging & Navigation	2				2
Beach or Dune Restoration			1		1
Monitoring & Mitigation	1	1			2
Riparian Restoration	1	2			3
Wetland Restoration		2			2
Land Conservation				1	1
Totals	**7**	**10**	2	3	**22**

As can be seen in **Figure 19**, the submitted resilience projects are primarily clustered along the immediate coastal section of the study area and around the city of Savannah. In addition, there are a few projects that span the entire region, and two of those projects are featured as case studies in this report. 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 six project ideas, demonstrating that the stakeholder engagement process was effective in attracting project ideas from local stakeholders. There were nine submissions from federal agencies, and seven from state agencies/university partners. Project sizes ranged from small scale living shoreline installations to regional-scale projects that cover most or all of the study area footprint.

Three submitted projects focus on the installation of living shorelines or oyster reef restoration/creation, with the dual goals of improving fish/wildlife habitat while reducing future shoreline erosion. Five other submitted projects were planning/modeling studies, for which there seems to be a great need in this region. Other submitted projects ranged from beach/dune restoration to aquatic connectivity to wetland/riparian restoration. A full list of submitted projects and summary information about each is in Appendix 6.

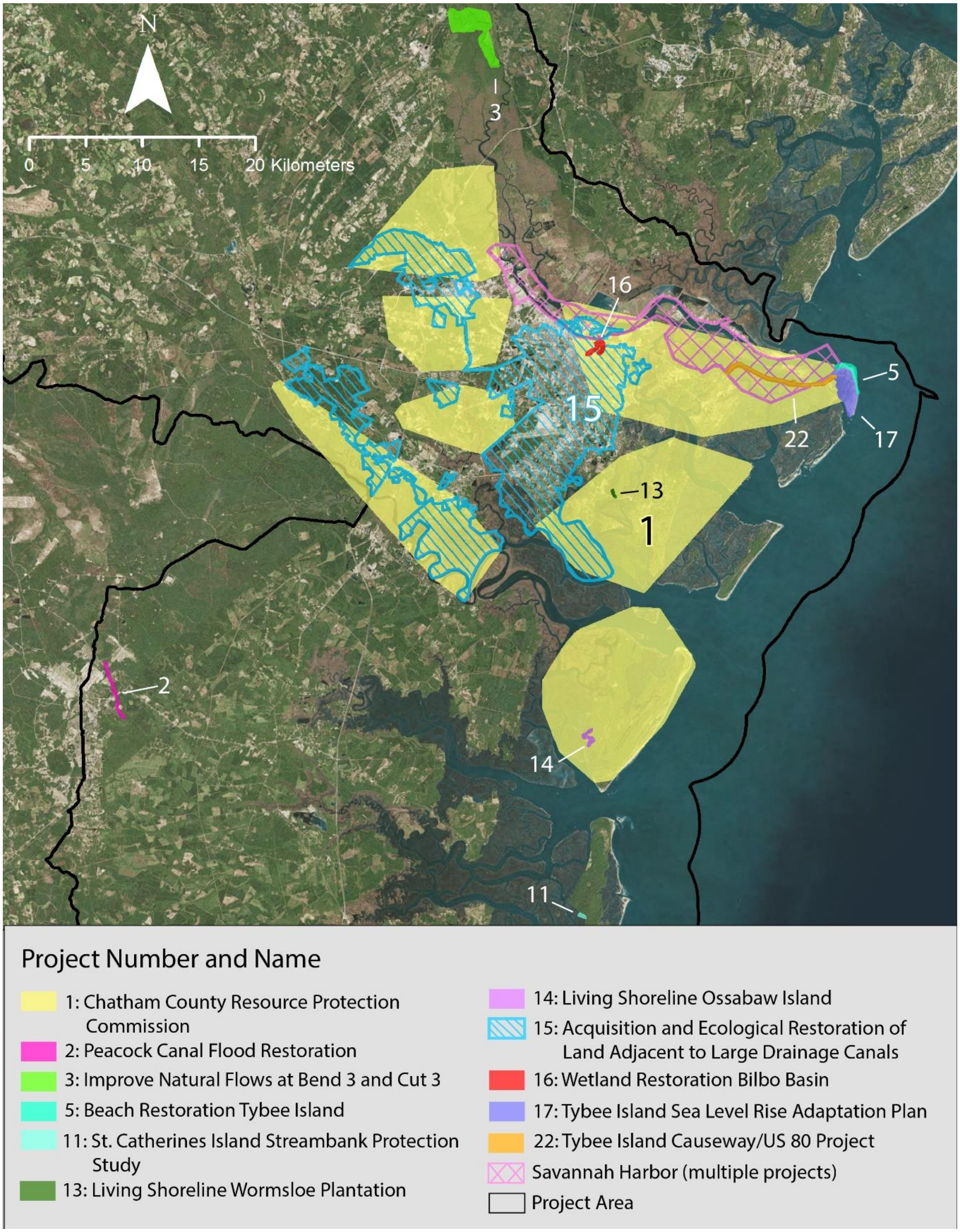


Figure 19. Map showing the boundaries of resilience projects compiled for the Savannah River Watershed. *Projects #4, #6-10, #12, and #18-21 are not pictured due to their large size. See Appendix 6,* ***Table A6-1*** *for the full list of projects.*

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 two case studies that follow illustrate how proposed resilience projects may benefit fish and wildlife habitat and human communities faced with coastal resilience challenges, especially related to heavy rainfall events and storm surge that might affect road infrastructure such as culverts and bridge spans. In this watershed, it was clear that there is an urgent need for basic plans and studies that lay the groundwork for prioritized action. In addition to addressing this gap in planning, both featured case studies would:

- Provide a clear and prioritized plan for focusing effort on improving aquatic connectivity and upstream flooding issues where road/stream crossings currently overly restrict flow.
- Both 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.
- Both projects would benefit aquatic species through enhanced connectivity and possibly some terrestrial species that benefit from high quality bottomland habitat.

The two 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: Improving Fish Passage and Habitat Connectivity in the Lower Savannah River

Figure CS1-1. Example of a box culvert that would be assessed as part of a regional analysis looking at fish passage barriers across the state.

Project Overview

Location: Regionwide

Date Visited: Nov. 6, 2017

Contact: Dr. Jessica Graham, Coordinator and Kat Hoenke, Spatial Ecologist for Southeast Aquatic Resource Partnership

The Southeast Aquatic Resources Partnership (SARP) has identified barriers to fish passage through the development of the Southeast Comprehensive Aquatic Barrier Inventory. This inventory includes two datasets: a road-related barrier dataset and a dataset of dams; however, many of the barriers identified in these datasets need to be assessed in person in order to fully understand their condition so they may be prioritized for potential replacements or modifications. With regard to culverts, SARP has developed standardized field protocols to more deeply evaluate unassessed road-related barriers by collecting key data that can be fed into a local or regional analysis. Once these culverts are assessed in the field and updated within the database, SARP can work with partners to identify which culverts are priorities for removal or replacement.

With regard to dams, a dataset exists that combines all known inventories of dams from state, federal, and local organizations (**Figure CS1-2**). Using this dataset, SARP has worked with partners to prioritize the dams for removal or bypass using ecological metrics developed by the Southeast Aquatic

Connectivity Assessment Project (SEACAP). SARP has developed a methodology that allows data collectors to visit dam locations in the watershed that are high priority and explore their social feasibility for removal. The prioritization and assessment of culverts and dams through this project will allow for identification of those structures that are socially and ecologically feasible to remove as well as a prioritized list of aquatic organism passage projects to pursue for project implementation.

In summary, this project will:

- Direct action that will potentially restore aquatic connectivity to hundreds of miles of streams, allowing for fish passage for diadromous fish and other important wildlife to strengthen population numbers.
- Prioritize projects for direct action based on the potential project impact as well as social and practical feasibility for dam removal or culvert replacement.
- Engage stakeholders, staff, and volunteers in collecting the data that feeds into the prioritization, involving them in solutions-oriented work.

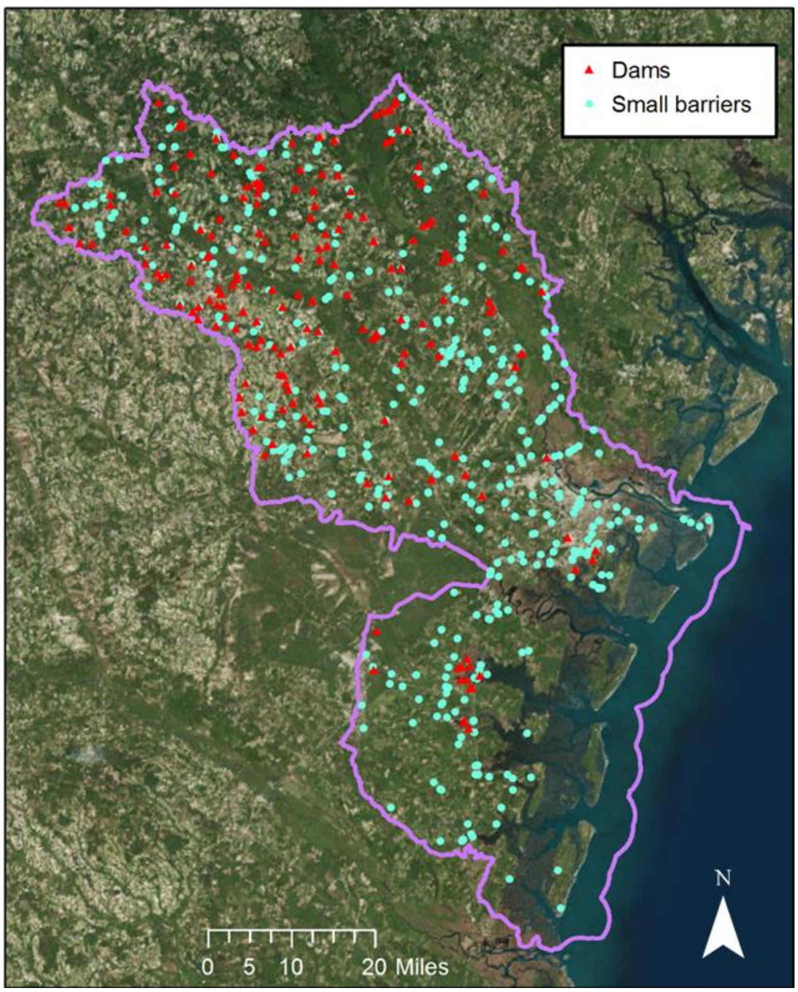


***Figure CS1-2**. Location of aquatic barriers within the Savannah River Watershed. Points representing where dams (triangles) or small barriers such as culverts (circles) exist.*

Estimated Cost of the Project

For the Savannah River area, costs would include refining the methodology, training assessors to use the identification and evaluation processes, and communicating results of the analysis to key decision makers and landowners. The completed SEACAP project identified dams. Efforts to date for training include having held one training in Georgia that was open to people from the Savannah area. While costs for assessment may vary, as a reference, SARP spent $80,000 for assessing eight HUC8s on another project using student labor. The cost for training includes three days of space rental, travel, and logistical support, for an approximate cost of $3,000. Therefore, the cost is estimated to be between $83,000-$123,000 to implement this assessment for this area of Georgia, depending upon labor costs.

Stressors and Threats

The project would address a number of threats to human community resilience including property loss due to flooding created by undersized or non-functional bridges, dams, or culverts. Flooding threats will depend upon the specific bridge or culvert. For bridges/culverts in tidal areas, sea level rise and storm surge may be significant factors. Further inland, 100- and 500-year floodplains, poorly drained soils, and frequent flooded spaces are the most typical flooding threats.

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

Existing Stressors
Developed Open Spaces
High/Medium Density Housing
Low Density Housing (Rural Residential)
Railroads
Ruderal (Maintained Pasture, Old Field)
Siviculture – Intensive
Intensive Agriculture
Water Quality – Low
Primary Roads
Secondary Roads
Local Neighborhood and Connecting Roads
Dirt/Private Roads
Commercial & Industrial Areas (incl. Airports)
Dams/Reservoirs
Flooding Threats
Storm Surge – Categories 1-5
Sea Level Rise
Frequent Flooded Soils
Occasional Flooded Soils
100 Year Floodplain
500 Year Floodplain

Human Community Assets

Since this project addresses the region in general, and since each potential bridge/culvert site is unique, the range of human community assets varies by site. However, all sites have in common the potential to alleviate flooding issues for critical infrastructure, particularly roads that can flood more frequently when under-sized culverts or bridges remain in an area.

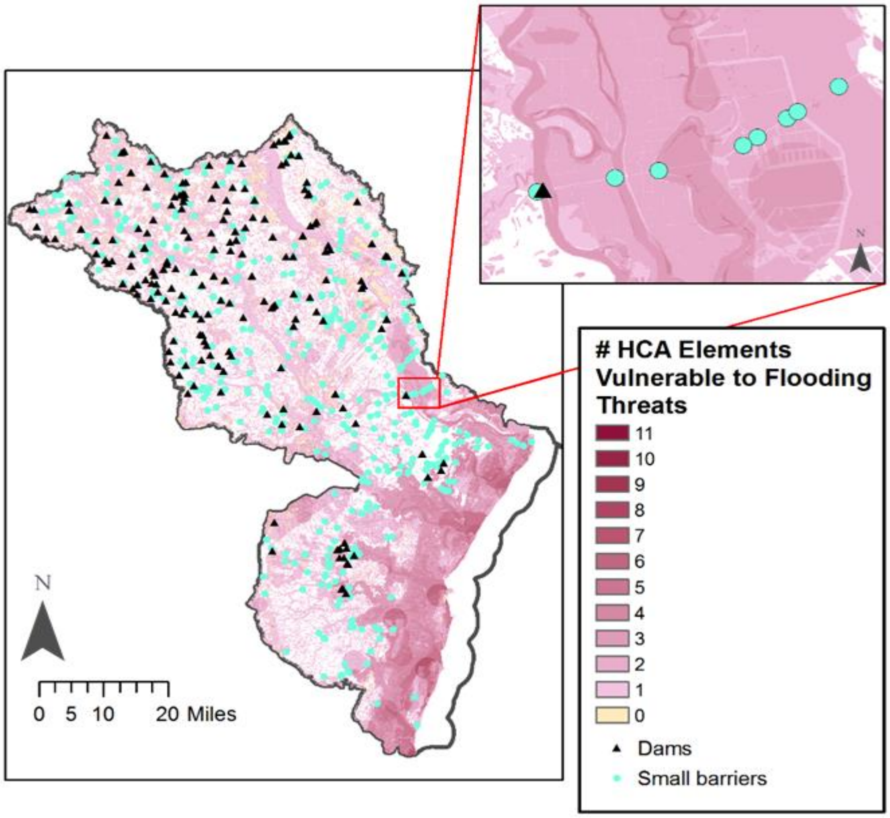


***Figure CS1-3**. **Human Community Asset (HCA) elements vulnerable to flooding threats.** Map of region with a zoomed in look at one area with a large concentration of bridges and culverts and a high concentration of human community assets nearby.*

Table CS1-2. HCAs identified within the project boundary.

Categories of Human Assets Identified within Project Boundary
Densely populated areas Critical Infrastructure Critical Facilities Environmental Justice
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

Fish and wildlife that would benefit from the analysis and subsequent action to address dams and culverts are mainly ones which would benefit from increased aquatic connectivity. Depending upon the stream or river involved, this could include Atlantic and shortnose sturgeon, blueback herring, American shad, and other diadromous fish species. In tidal areas where bridges or culverts are changed to accommodate better water flow, the project could also benefit marsh and tidal creek species such as rails, sea sparrows, and oystercatchers and wetland nursery habitat for red drum, shrimp, summer flounder, blue crab, snapper, grouper, shark, etc. Finally, several critically imperiled aquatic species will benefit from better aquatic connectivity.

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 **
Beach and dune	Ghost (sand) crabs, terns, piping plovers
Important riverine systems	Red drum
Cypress swamp soils	American alligator
Diadromous fish habitats	Atlantic and shortnose sturgeon, blueback herring, American shad
Forested wetlands (non-tidal)	Wood duck, Swainson's warbler
Maritime live oak hammock forest and scrub	Prothonotary warbler
Marsh and tidal creek (incl. open water)	Black rail, sea sparrow, oystercatcher
Open pine habitat	Eastern diamondback rattlesnake, gopher frog
Seaside sparrow essential habitat	Seaside sparrow
Shrimp essential fish habitat	Penaeid shrimp, summer flounder, blue crab
Snapper Grouper Essential Habitat	Snapper, grouper, shark nursery habitat
G1-3/S1-3 aquatic	Pine snake, least tern
Tidal hardwood swamp forest	Wood stork, black rail, American bittern
Wading bird and ally colonies	Great blue heron, snowy egret, wood stork

**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.*

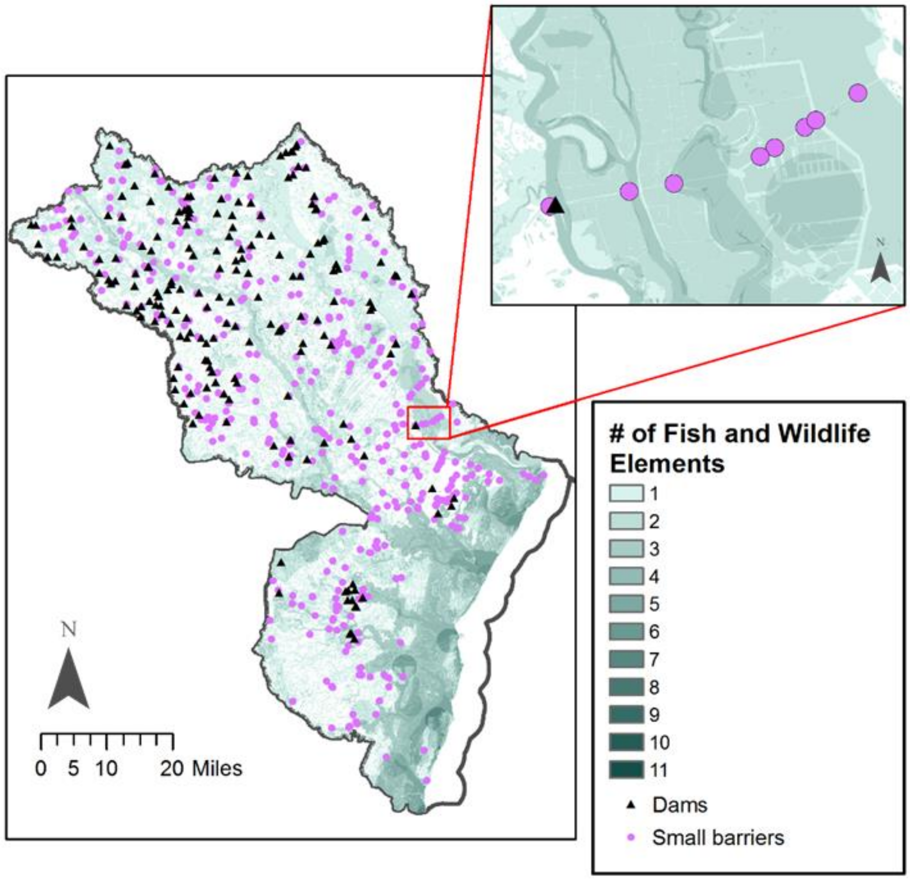


Figure CS1-4. Density of fish and wildlife elements in Savannah River Watershed. *Map of all fish and wildlife elements combined (darker green signifies more elements/value).*

Expected Project Impact

This project will provide a prioritization of potential projects with the highest impact to aquatic connectivity. Once completed and combined with the current resilience analysis, users will be able to prioritize sites located within resilience hubs to maximize dual impacts to human communities and fish/wildlife.

Overall, the socioeconomic outcomes that are expected include a reduced risk of nuisance flooding, which could in turn prevent future scenarios where emergency personnel have difficulty accessing locations due to flooding from blocked culverts. Species that would be positively impacted include shortnose and Atlantic sturgeon and other diadromous fish. Opening restrictions to fish passage would increase habitat available for diadromous and resident fish and restore corridors for wildlife travel. Through training in culvert assessment, this project will also engage a corps of local stakeholders who can become more familiar with potential culvert pinch points and projects and potentially help seek resources to fix problems.

Case Study 2: Culvert Assessment for State Roads in High Flood Risk Areas

Figure CS2-1. Example of a box culvert that would be assessed as part of a regional analysis looking at fish passage barriers across the study area. *Credit: US Fish and Wildlife Service.*

Project Overview

Location: Regionwide

Date Visited: Nov. 6, 2017

Contact: Dr. Carrie Straight, Fish and Wildlife Biologist for US Fish and Wildlife Service, Athens, GA

The project goal is to identify and prioritize culverts and bridges that, if modified, offer the best opportunities to improve infrastructure resiliency to flooding and reduce the longevity of flooding events. This project would lead to improve safety for roadways by identifying structures and surrounding roadbed substructure likely to lose structural integrity by future flooding and to improve timeliness of emergency response. This analysis is uniquely valuable in that it will identify opportunities where roads or bridges are already scheduled for replacement and would benefit from new culvert designs that can better accommoate increased flooding risk and aquatic connectivity when replacement occurs.

Since the state does not have an exhaustive catalog of culverts, the first step in this process is to create a catalog and assessment of coastal culverts or culverts in high risk flood areas using key metrics. This catalog would serve multiple purposes: 1) to identify culverts, 2) assess culverts for risk of failure during flooding events, 3) assess fish passage, and 4) identify and prioritize culverts for replacement to minimize future damage to road substructure. Regular assessment is important for these structures because erosion, changes in the stream channel, debris accumulation, and degradation of the structure over time can create public safety concerns and fish passage obstacles as time passes and the culverts age. Varying flow conditions further complicate efforts to assess structures because what is passable in one season may be impassible in another.

In summary, this project will:

- Focus on problem roads/bridges as identified by the state of Georgia that are already scheduled for replacement to potentially restore aquatic connectivity to hundreds of miles of streams, allowing for fish passage for diadromous fish and other important wildlife to strengthen population numbers.
- Prioritize projects for direct action based on the potential project impact as well as social and practical feasibility for dam removal or culvert replacement.

Figure CS2-2*. *Perched double barrel box culvert showing a plunge pool and stream widening immediately downstream of the structure. *Dawson County, GA (USFWS photo).*

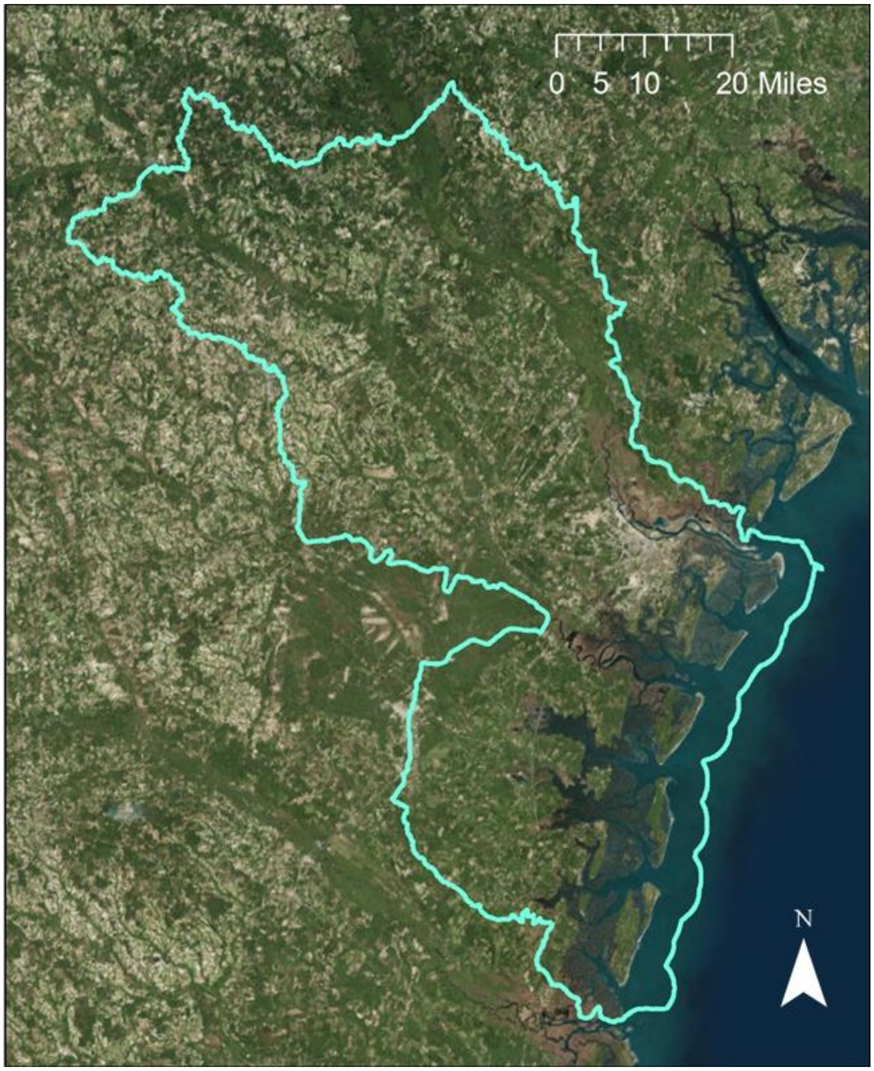


Figure CS2-3. Aerial view of the study area*. This project is region-wide, so the project boundary is the same as the Savannah watershed boundary.*

Estimated Cost of the Project

In order to conduct an assessment of the study area, preliminary estimates approximate project costs between $50,000-$150,000. Implementation costs associated with upgrading or replacing culverts are not considered here, but will depend upon local site conditions, size, and the overall goal of each project. However, for most culvert projects, a portion of construction costs are likely to be included in the routinely scheduled replacement or maintenance of bridges.

Stressors and Threats

The project would address human community resilience threats primarily related to property loss due to flooding created by undersized culverts. Flooding threats will depend upon the specific culvert. For culverts in tidal areas, sea level rise and storm surge may be significant factors. Further inland, 100-

and 500-year floodplains, poorly drained soils, and frequent flooded spaces are the most typical flooding threats.

Table CS2-1. Threats identified in and near the project site.

Existing Stressors
Developed Open Spaces
High/Medium Density Housing
Low Density Housing (Rural Residential)
Railroads
Ruderal (Maintained Pasture, Old Field)
Silviculture - Intensive
Intensive Agriculture
Water Quality - Low
Primary Roads
Secondary Roads
Local Neighborhood and Connecting Roads
Dirt/Private Roads
Commercial & Industrial Areas (incl. Airports)
Dams/Reservoirs
Flooding Threats
Storm Surge – Categories 1-5
Sea Level Rise
Frequent Flooded Soils
Occasional Flooded Soils
100 Year Floodplain
500 Year Floodplain

Human Community Assets

Since this project encompasses the entire study area, and since each potential culvert site is unique, the range of human community assets varies by site. However, all sites have the potential to alleviate flooding issues for critical infrastructure, particularly roads that can flood more frequently when under-sized culverts remain in an area.

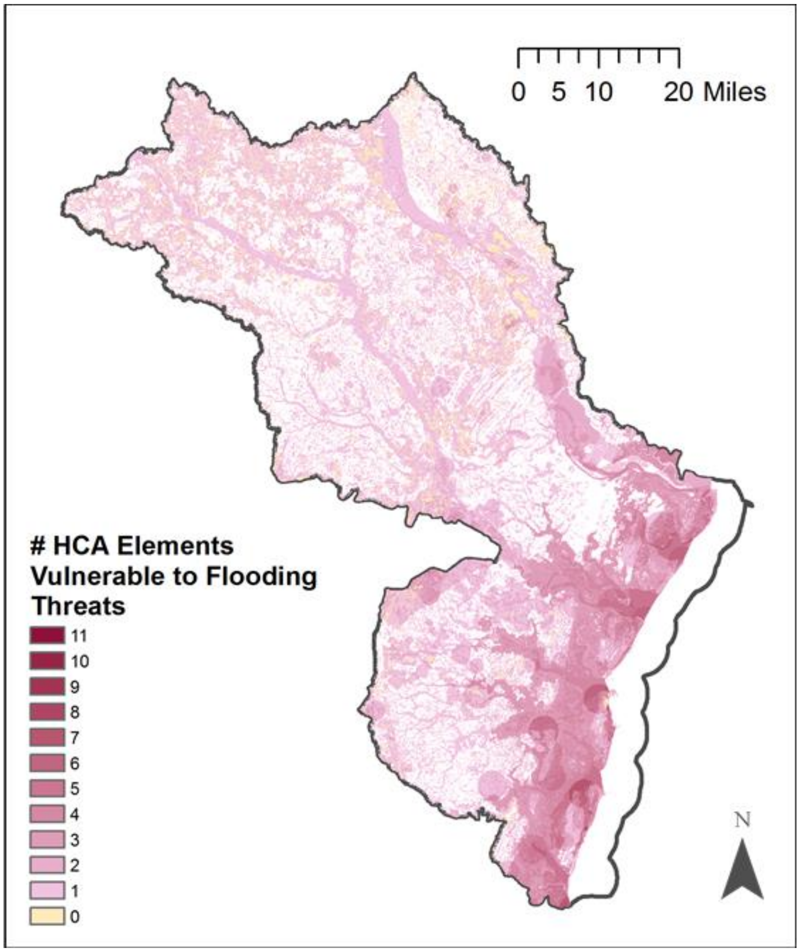


Figure CS2-4. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are human community values and high levels of threat (darker pink/red signifies higher threat to human community assets).*

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

Categories of Human Assets Identified within Project Boundary
Densely populated areas Critical infrastructure Critical facilities Environmental Justice
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

Fish and wildlife that would benefit from the analysis and subsequent action to address dams and culverts are mainly ones which would benefit from increased aquatic connectivity. Depending upon the stream or river involved, this could include Atlantic and shortnose sturgeon, blueback herring, American shad, and other diadromous fish species. In tidal areas where bridges or culverts are changed to accommodate better water flow, this could also benefit marsh and tidal creek species such as rails, sea sparrows and oystercatchers and wetland nursery habitat for shrimp, summer flounder, blue crab, snapper, grouper, shark, etc. Finally, a number of critically imperiled aquatic species will benefit from better aquatic connectivity.

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 ****
Beach and dune	Ghost (sand) crabs, terns, piping plovers
Important riverine systems	Red drum
Cypress swamp soils	American alligator
Diadromous fish habitats	Atlantic sturgeon, blueback herring, American shad
Forested wetlands (non-tidal)	Wood duck, Swainson's warbler
Important Bird Areas	
Maritime live oak hammock forest and scrub	Prothonotary Warbler
Marsh and tidal creek (incl. open water)	Black rail, sea sparrow, oystercatcher
Open pine habitat	Eastern diamondback rattlesnake, gopher frog
Seaside sparrow essential habitat	Seaside sparrow
Shrimp Essential Fish Habitat	Penaeid shrimp, summer flounder, blue crab
Snapper Grouper Essential Habitat	Snapper, grouper, shark nursery habitat
T & E aquatic	
T & E terrestrial	
G1-3/S1-3 aquatic	Pine snake, least tern
Tidal hardwood swamp forest	Wood stork, black rail, American bittern
Wading bird and ally colonies	Great blue heron, snowy egret, wood stork

**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.*

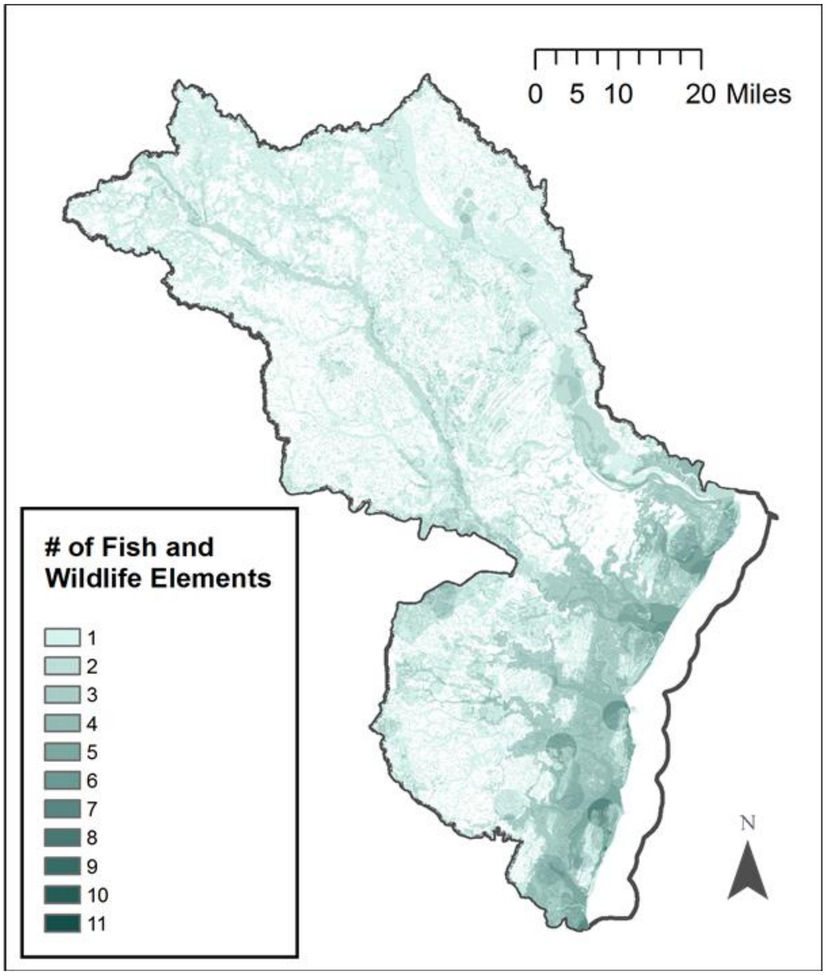


Figure CS2-5. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements combined (darker green signifies more elements/value). Red outlines are project boundary.*

Expected Project Impact

This project will provide a prioritization of culverts along state roads, thereby giving state planners proactive information on failing or aging culverts prior to planning action on larger road improvement projects. The individual culvert projects assessed as part of this work would be implemented using existing road improvement funds to replace culverts and bridges as opportunities to restore fish passage on streams and rivers in Georgia. By having this additional information, state Department of Transportation officials will have the ability to replace failing culverts while completing funded road projects. Combined with the current resilience analysis, users of the final analysis would also be able to prioritize sites located within resilience hubs to maximize dual impacts to human communities and fish and wildlife.

Overall, the socioeconomic outcomes that are expected include a reduced risk of nuisance flooding, which could in turn prevent future scenarios where emergency personnel have difficulty accessing locations due to flooding from blocked and undersized culverts. Species that would be positively impacted include shortnose and Atlantic sturgeon and other diadromous fishes. Opening restrictions to fish passage would increase habitat available for diadromous and resident fishes and restore corridors for wildlife travel.

Although both case studies are related to culverts/bridges, there are many other great examples of resilience projects that were submitted as part of this project. The two case studies that have been featured have a clear benefit to both fish and wildlife and human assets, whereas many of the other submitted projects were located in areas where the benefit was more heavily weighted to fish and wildlife with a limited benefit to human assets resilience.

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 aim to: 1) understand the value and vulnerability of human community assets (HCAs) 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 Savannah 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 Savannah River 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 Savannah River Watershed—that community vulnerability in many locations in the watershed is very high owing to exposure to flooding threats and low elevation. While the core of the city of Savannah is built on a high bluff and not vulnerable to flooding, the communities in the lowest-lying areas and along the Savannah River—and for a considerable distance upstream—are highly exposed to storm surge and sea level rise.

There are many good opportunities for nature-based resilience projects in the natural shorelines, marshes, and adjacent low uplands between the coastal communities and the ocean shore. The floodplain and adjacent areas along the Savannah River also offer opportunities to accommodate marsh migration from sea level rise and improve resilience of communities like Hardeeville, South Carolina. These nature-based resilience opportunities are best illustrated via the two case studies featured in this report, which highlight the following opportunities for improving resilience while benefiting fish and wildlife:

- Aquatic connectivity improvement through replacement of poorly functioning culverts and bridges can help reduce nuisance flooding while improving habitat for key aquatic species.
- Potential for stream restoration and enhancement upstream and downstream from roads with culvert/dam improvement projects with willing partners as part of future projects that can improve habitat for species dependent on streamside and bottomland forest habitat.

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.

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 Savannah River 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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Workshop Venue Sponsors

Local partner engagement in the form of the in-person workshops was a key aspect in ensuring that the final analysis would include the types of data and information that would provide the best and most useful product possible. This high level of stakeholder engagement would not have been possible without venue space for workshops provided by Armstrong State University and the Coastal Electric Cooperative.

Project Team and Partners

National Fish and Wildlife Foundation	Mandy Chesnutt Suzanne Sessine Kristen Byler
NatureServe	Patrick Crist Allison Kenlan Rickie White Pete Cutter Cameron Scott Ellie Linden Jianyu Wu Suzanne Young Travis Hicks Emily Seddon
Enduring Conservation Outcomes	Rob Sutter

Steering Committee

National Fish and Wildlife Foundation	Tony Chatwin Amanda Bassow Jay Jensen
National Oceanic and Atmospheric Administration	Chris Doley Kara Meckley Tisa Shostik
U.S. Army Corps of Engineers	Gib Owen

Technical Committee

National Fish and Wildlife Foundation	Mandy Chesnutt Christina Kakoyannis Suzanne Sessine
National Oceanic and Atmospheric Administration	Julia Royster Janine Harris Adam Stein
U.S. Army Corps of Engineers	Christian Manalo, Booz Allen Hamilton Sheri Moore

Watershed Committee

City of Savannah	Nick Deffley
National Oceanic and Atmospheric Administration	Howard Schnabolk Bridget Lussier
South Atlantic LCC	Rua Mordecai
UGA Marine Extension and GA Sea Grant	Jill Gambill
U.S. Army Corps of Engineers	Debby Scerno

Additional Stakeholders

Representatives from the following organizations, agencies, and other institutions contributed their time, expertise, data, and invaluable perspective to this process and we are grateful for their valuable inputs.

Armstong State University
Camden County Planner
Center for a Sustainable Coast
Center for Research & Education at Wormsloe
Chatham County Board of Assessors
Chatham County Extension Service
City of Port Wentworth
City of Savannah
City of Savannah - Metropolitan Planning Commission
Coastal Georgia Greenway
Coastal WildScapes
College of Coastal Georgia
Ecological Planning Group
Emergent Savannah
Enduring Conservation
Federal Emergency Management Agency
GA DNR - Coastal Management
GA DNR - Coastal Resources
GA DNR - Coastal Resources Division - Living Shorelines
GA DNR - Georgia Environmental Protection Division
GA DNR - Historic Preservation Division
GA DNR - Parks & Historic Sites
GA DNR - South Watershed Planning and Monitoring Program
GA DNR - Watershed Protection Branch
Georgia Coastal Ecosystems Long Term Ecological Research Program
Georgia Conservancy
Georgia Department of Community Affairs

Georgia Department of Natural Resources (GA DNR)
Georgia Emergency Management Agency
Georgia Forestry Commission
Georgia Ports Authority
Georgia Sea Grant Consortium
Georgia Southern University
Georgia State University
Georgia-Alabama Land Trust
Gray's Reef National Marine Sanctuary
Invasive Species
jB+a
Jekyll Island Authority Georgia Sea Turtle Center
Liberty Consolidated Planning Commission
Liberty County - Emergency Management
Local Government
National Fish and Wildlife Foundation (NFWF)
National Oceanic and Atmospheric Administration (NOAA)
National Sea Grant Office
NatureServe
NOAA - Gray's Reef National Marine Sanctuary
Oatland Wildlife Center
Oconee River Chapter Trout Unlimited
Ogeechee Audubon
One Hundred Miles
Ossabaw Island Foundation
Sapelo Island National Estuarine Research Reserve
Savannah College of Art & Design - Sustainability/Emergent Structures
Savannah College of Art & Design - Urban Design
Savannah National Wildlife Refuge
Savannah River Clean Water Fund
Savannah River Keeper
Savannah State University (SSU)
Sierra Club
Sierra Club - Coastal Group Georgia
South Atlantic Landscape Conservation Cooperative
South Carolina Department of Health and Environmental Control
South Carolina Department of Natural Resources
South Carolina Sea Grant Consortium
Southern Georgia Regional Commission
Sponsor
SSU - Emeritus Fisheries
SSU - Urban Planning
St. Catherines Island
State Efforts
Symbioscity
The Georgia Conservancy
The Nature Conservancy
The Pew Charitable Trusts
The Savannah Tree Foundation
U. S. Army Corps of Enginners
U. S. Fish and Wildlife Service (USFWS)
U. S. Green Building Council
U.S. Environmental Protection Agency
U.S. Geological Survey
UGA - Marine Extension Service
UGA - Marine Institute
UGA - Skidaway Institute of Oceanography
University of Georgia (UGA)
University of Georgia Marine Institute
University of North Carolina at Asheville - National Environmental Modeling and Analysis Center
USFWS - South Carolina

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 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 the 150 invited participants, 21 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 of engagement and 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	March 23, 2017
Pre-stakeholder webinar	Stakeholders, Watershed Committee	April 20, 2017
In-person stakeholder workshops	Stakeholders, Watershed Committee	April 27-28, 2017
Post workshop follow-up to summarize workshop results	Watershed Committee	August 8, 2017
Review of fish and wildlife and vulnerability assets	Watershed Committee	August 8, 2017
Draft results webinar to discuss GIS analysis and obtain final input from all stakeholders that wish to participate	Stakeholders, Watershed Committee	February 23, 2018

Post-workshop Activities

Workshop input and discussion was used to finalize fish and wildlife species and project submissions for the assessment and do. 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 werecompleted, 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 two 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 assessment 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** and **Figure 8**) 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 1** 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
Water quality or stressors that can affect water quality	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.

<u>Soil Erodibility</u>
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.[6]

<u>Impermeable Soils</u>
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 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

[6]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.

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.[7] 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.[8] 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 workshop (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 data sources that might be of use as well as a link to a Dropbox folder for uploading data. Data requirements for submissions included:

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

[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.

- 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 have a defined buffer to use on features with no area (e.g., points or lines). A single buffer can be provided for all features or an attribute can specify the buffer for each feature.
- dataDshould be submitted to contain FGDC compliant metadata. (strongly preferred) Exceptions were made, but most data lacking metadata did not make it through the evaluation 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 packaged 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.*

Stressor/Threat Primary & Secondary Categories		**Data Sources**	**Scenarios**
Residential & Commercial Development	High/Medium Density Housing (high imperviousness > 50%)	USGS Roadless Landcover (Soulard & Acevedo 2016)	Baseline, Combined
	Low Density Housing (moderate imperviousness 20%-40%)		
	Developed Open Spaces (parks, cemetaries, etc.) (low imperviousness < 20%)		
	Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)	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	
Agriculture and Aquaculture	Silviculture – Sustainable	No data	N/A
	Silviculture – Intensive		

<table>
<tr><th colspan="2">Stressor/Threat Primary & Secondary Categories</th><th>Data Sources</th><th>Scenarios</th></tr>
<tr><td rowspan="3"></td><td>Intensive Agriculture</td><td rowspan="2">NatureServe Systems Map (Comer 2009)</td><td rowspan="2">Baseline, Combined</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="6">Transportation and Service Corridors</td><td>Primary Roads</td><td rowspan="4">Tiger roads (U.S. Census 2016)</td><td rowspan="5">Baseline, Combined</td></tr>
<tr><td>Secondary Roads</td></tr>
<tr><td>Local, neighborhood and connecting roads, bridges/culverts</td></tr>
<tr><td>Dirt/Private roads/culverts</td></tr>
<tr><td>Railroads, bridges, culverts</td><td>USDOT/Bureau of Transportation Statistics's National Transportation Atlas Database (2015 or later); Federal Highway Administration, NBI v.7, NTAD (2015 or later)</td></tr>
<tr><td>Utility & Service Lines (overhead transmission, cell towers, etc.)</td><td>No data</td><td>N/A</td></tr>
<tr><td colspan="2">Dredge Material Placement Areas</td><td>No data</td><td>N/A</td></tr>
<tr><td colspan="2">Dams & Reservoirs</td><td>USDOT/Bureau of Statistics's NTAD (2015 or later)</td><td>Baseline, Combined</td></tr>
<tr><td colspan="2">Sea Level Rise – 1 ft</td><td>NOAA Sea-level Rise Scenarios</td><td>Flooding Threats, Combined</td></tr>
<tr><td rowspan="5">Storm Surge</td><td>Category 1</td><td rowspan="5">FEMA National Flood Hazard Layer</td><td rowspan="5">Flooding Threats, Combined</td></tr>
<tr><td>Category 2</td></tr>
<tr><td>Category 3</td></tr>
<tr><td>Category 4</td></tr>
<tr><td>Category 5</td></tr>
<tr><td rowspan="2">Water Quality</td><td>Moderate</td><td rowspan="2">EPA Impaired Waters
AIS Commercial Vessel Traffic Density (Office of Coastal Management, obtained from Rua Mordecai pers. comm.)</td><td rowspan="2">Baseline, Combined</td></tr>
<tr><td>Low</td></tr>
<tr><td rowspan="2">Invasive Species</td><td>Terrestrial</td><td rowspan="2">No data</td><td rowspan="2">N/A</td></tr>
<tr><td>Aquatic</td></tr>
</table>

Stressor/Threat Primary & Secondary Categories		Data Sources	Scenarios
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).*

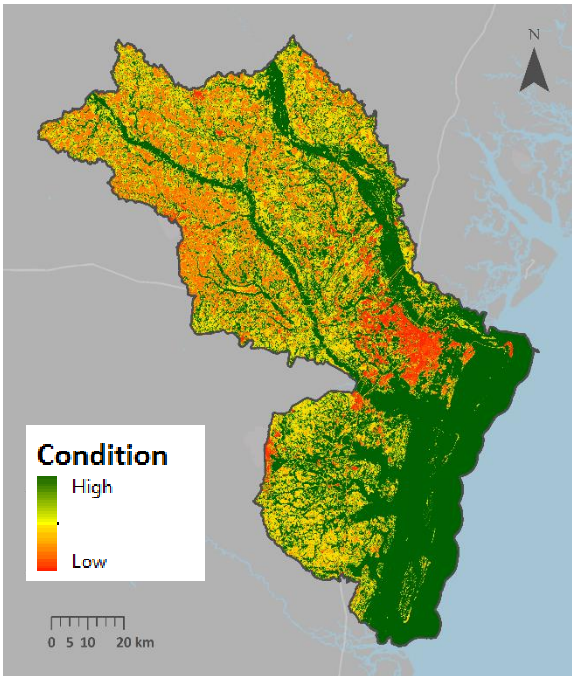
Building Element Response Models

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.

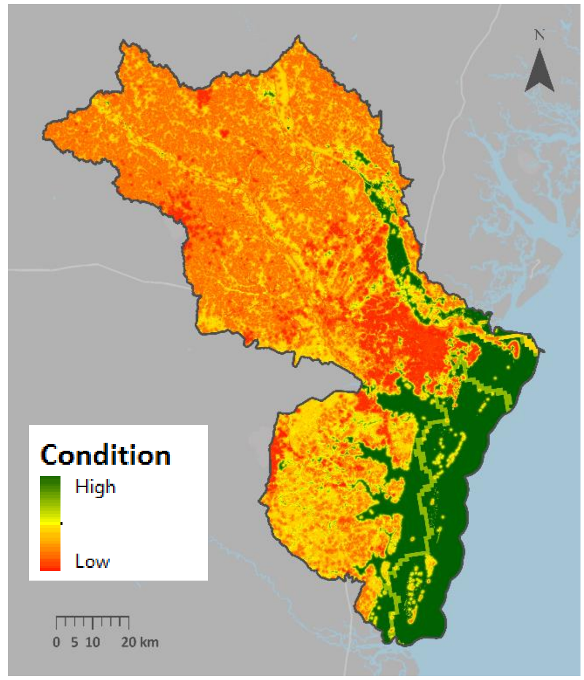
Model Element Condition

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.

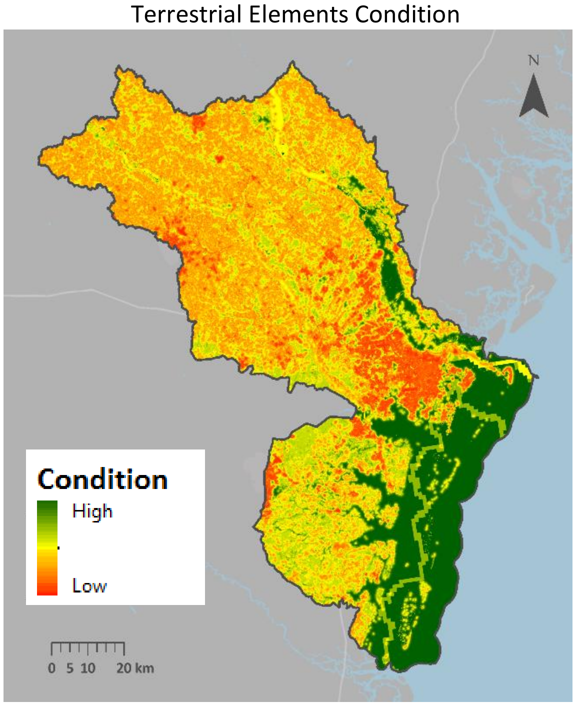
The LCM calculates the condition score of every pixel in the watershed as depicted in the four maps below (**Figure A2-1**) using the relevant response models per above. The LCM first calculates the response scores on each individual scenario feature (site intensity within the scenario feature footprint 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.



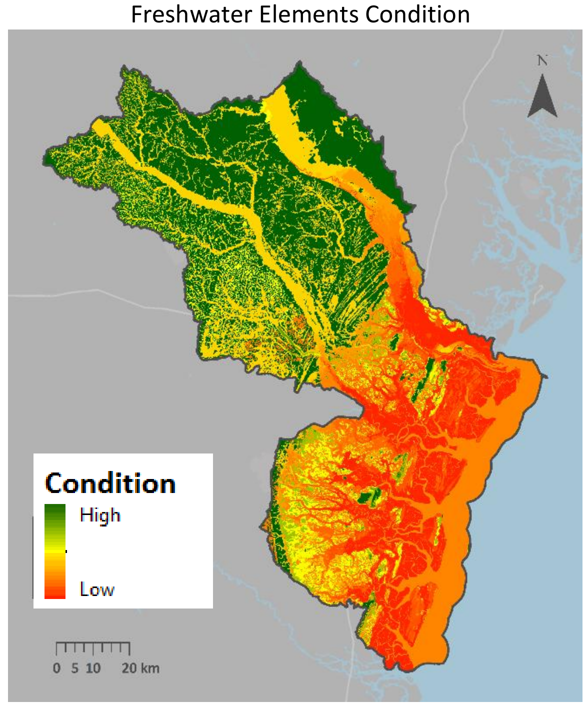
Terrestrial Elements Condition



Freshwater Elements Condition



Estuarine Elements Condition



Human Community Assess Condition

Figure A2-1. Landscape condition model outputs for the Savannah River 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.

<table>
<tr><th colspan="4">Key Assumptions of this Model</th></tr>
<tr><td colspan="2">Applies to any consistently wet habitats or species adapted to freshwater environments.</td><td colspan="2">Responses to stressors focused on water quality impacts, increased salinization, physical impacts on submerged aquatic vegetation, and the potential for other biotic impacts.</td></tr>
<tr><td>Importance Weighting (Optional, used only for the CVS)</td><td>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.</td><td>n/a</td><td>Importance weighting is not set for fish and wildlife elements. Assumption is that that all fish and wildlife elements are equally important.</td></tr>
<tr><td>Element Condition Threshold</td><td>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.</td><td>0.7</td><td>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.</td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

<table>
<tr><th>Primary Category</th><th>Secondary Category</th><th>Response Types</th><th>Responses</th><th>Response Assumptions</th></tr>
<tr><td rowspan="9">Residential & Commercial Development</td><td rowspan="3">High/Medium Density Housing (high imperviousness >50%)</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">Developed/armored shorelines, heavy runoff volume and pollutants, lack of shading with temperature increases. Low restorability.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.2</td></tr>
<tr><td>LCM Distance</td><td>1000</td><td>Long distance effect to compensate for lack of water quality data.</td></tr>
<tr><td rowspan="3">Low Density Housing (moderate imperviousness 20-49%)</td><td>Categorical Response</td><td>Neutral</td><td rowspan="2">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.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.3</td></tr>
<tr><td>LCM Distance</td><td>300</td><td>Long distance effect to compensate for lack of water quality data.</td></tr>
<tr><td rowspan="3">Developed open spaces (parks, cemeteries, etc.) (low imperviousness <20%)</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">Clearing and temperature increases, human access, and landscaping (runoff volume, pollutants) will degrade habitat below threshold but high restorability potential.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.5</td></tr>
<tr><td>LCM Distance</td><td>100</td><td>Moderate distance effect to compensate for lack of water quality data.</td></tr>
</table>

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 Savannah 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 more dense 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.

Primary Category	**Secondary Category**	**Response Types**	**Responses**	**Response Assumptions**
Dredge Material Placement Areas		Categorical Response	Negative	Assumption is not for dredge materials to be placed within aquatic systems but 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.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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 nature of data.
	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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
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.
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, but in some cases individual structures may be removed to allow for marsh expansion in the future, for instance.
		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.

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 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.
	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.

<table>
<tr><th colspan="4">Key Assumptions of this model</th></tr>
<tr><td colspan="2">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.</td><td colspan="2">Responses to stressors focused on water quality impacts, increased salinization, physical impacts on submerged aquatic vegetation, and the potential for other biotic impacts.</td></tr>
<tr><td>Importance Weighting (Optional, used only for the CVS)</td><td>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.</td><td></td><td>Importance weighting not set for fish and wildlife elements. The assumption is all are equally important.</td></tr>
<tr><td>Element Condition Threshold</td><td>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.</td><td>0.6</td><td>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.</td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

<table>
<tr><th>Primary Category</th><th>Secondary Category</th><th>Response Types</th><th>Responses</th><th>Response Assumptions</th></tr>
<tr><td rowspan="9">Residential & Commercial Development</td><td rowspan="3">High/Medium Density Housing (high imperviousness>50%)</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">Developed/armored shorelines, clearing, heavy runoff volume and pollutants (more dilution capability than FW systems assumed), very low restorability.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.4</td></tr>
<tr><td>LCM Distance</td><td>1000</td><td>Long distance effect to compensate for lack of water quality data.</td></tr>
<tr><td rowspan="3">Low Density Housing (moderate imperviousness 20-49%)</td><td>Categorical Response</td><td>Neutral</td><td rowspan="2">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.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.5</td></tr>
<tr><td>LCM Distance</td><td>300</td><td>Long distance effect to compensate for lack of water quality data.</td></tr>
<tr><td rowspan="3">Developed open spaces (parks, cemeteries, etc.) (low imperviousness <20%)</td><td>Categorical Response</td><td>Neutral</td><td rowspan="2">Assume clearing and temperature increases, human access, and landscaping (runoff volume, pollutants) will degrade below viability threshold but high restorability.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.5</td></tr>
<tr><td>LCM Distance</td><td>100</td><td>Moderate distance effect to compensate for lack of water quality data.</td></tr>
</table>

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 Savannah 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 increased 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. Hydrology is Difficult restorability typically to 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.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
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.
	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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
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 Assume 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.
	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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
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 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.
	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.
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	

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
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 t 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 Assumptions.

<table>
<tr><th colspan="4">Key Assumptions of this Model</th></tr>
<tr><td colspan="2">Applies to all human community assets</td><td colspan="2">Responses to stressors focused on physical damage/loss from flooding</td></tr>
<tr><td colspan="4">Note: elevated roads/bridges were not separated from surface roads is the source data, so they are treated equally.</td></tr>
<tr><td rowspan="10">Importance Weighting (Optional, used only for the CVS)</td><td rowspan="10">Values range from: 0.0 (Low) to 1.0 (High). These ratings were approximated from those used in the regional coastal resilience assessment.</td><td>.2</td><td>Critical Infrastructure (Rank 1)</td></tr>
<tr><td>.2</td><td>Environmental Justice Rank 1</td></tr>
<tr><td>.2</td><td>Population Density (Rank 1)</td></tr>
<tr><td>.4</td><td>Critical Infrastructure (Rank 2)</td></tr>
<tr><td>.4</td><td>Population Density (Rank 2)</td></tr>
<tr><td>.6</td><td>Critical Infrastructure (Rank 3)</td></tr>
<tr><td>.6</td><td>Population Density (Rank 3)</td></tr>
<tr><td>.8</td><td>Population Density (Rank 4)</td></tr>
<tr><td>1.0</td><td>Critical Facilities</td></tr>
<tr><td>1.0</td><td>Population Density (Rank 5)</td></tr>
<tr><td>Element Condition Threshold</td><td>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.</td><td>0.5</td><td>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.</td></tr>
<tr><td colspan="4">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.</td></tr>
</table>

<table>
<tr><th>Primary Category</th><th>Secondary Category</th><th>Response Types</th><th>Responses</th><th>Response Assumptions
(Restorability is not included because assets are not natural features to be restored.)</th></tr>
<tr><td rowspan="3">Sea Level Rise</td><td rowspan="3">U se 1-foot SLR in targeted watersheds to represent 2050 timeframe for planning purposes.</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">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.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.2</td></tr>
<tr><td>LCM Distance</td><td>50</td><td>Distance indicating impacts from backup of groundwater can flood/destabilize foundations of structures, and increase susceptibility to wave action.</td></tr>
<tr><td rowspan="6">Storm Surge</td><td rowspan="3">Category 1</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">See assumptions in Appendix introduction.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.65</td></tr>
<tr><td>LCM Distance</td><td>0</td><td>Assume no offsite effect.</td></tr>
<tr><td rowspan="3">Category 2</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">See assumptions in Appendix introduction.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.7</td></tr>
<tr><td>LCM Distance</td><td>0</td><td>Assume no offsite effect.</td></tr>
</table>

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 outlined below.

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 the flooding threats
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.

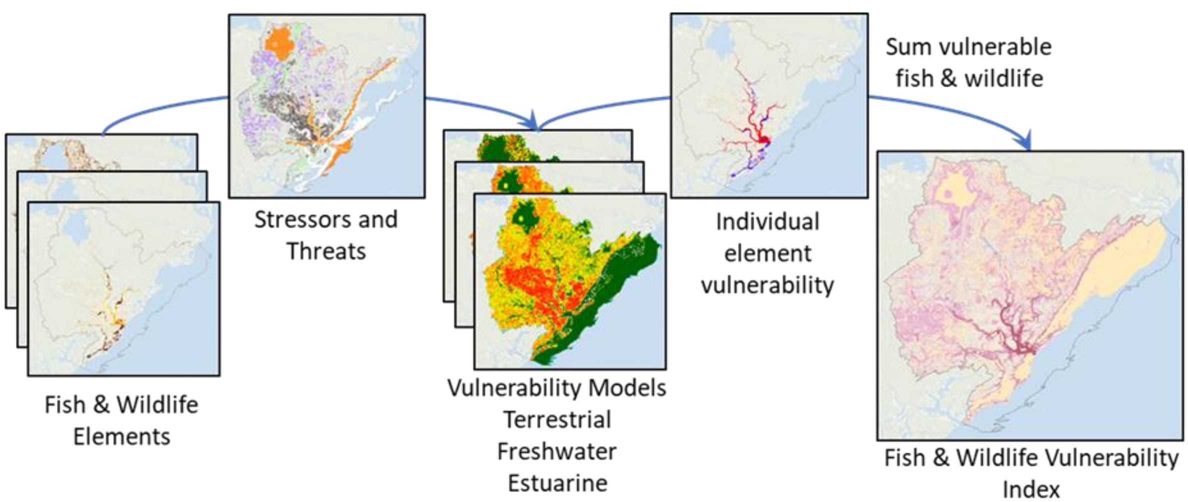


Figure A4-1. Method for calculating fish and wildlife vulnerability indices. *Elements are intersected with stressors and/ or threats, the vulnerability model is applied, and individual element vulnerability results are summed to create each index. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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.

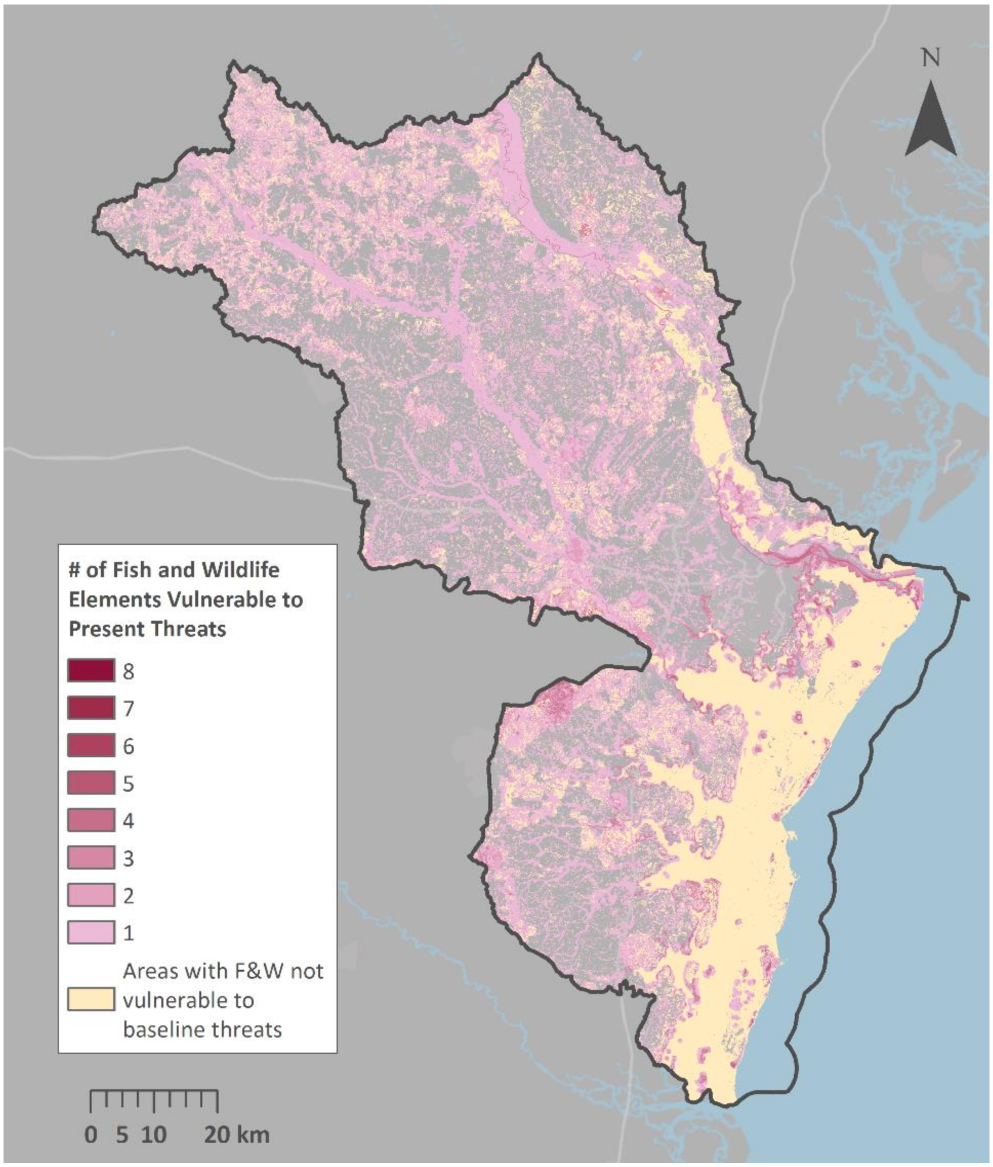


Figure A4-2. Fish and Wildlife Baseline Vulnerability. for the Savannah River Watershed. *This map is an overlay or index of all fish and wildlife elements that are vulnerable to the existing mapped stressors. Gray areas within the project boundary represent areas with no mapped fish and wildlife elements.*

2. **Fish and wildlife vulnerability to flooding threats**. This index models 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.

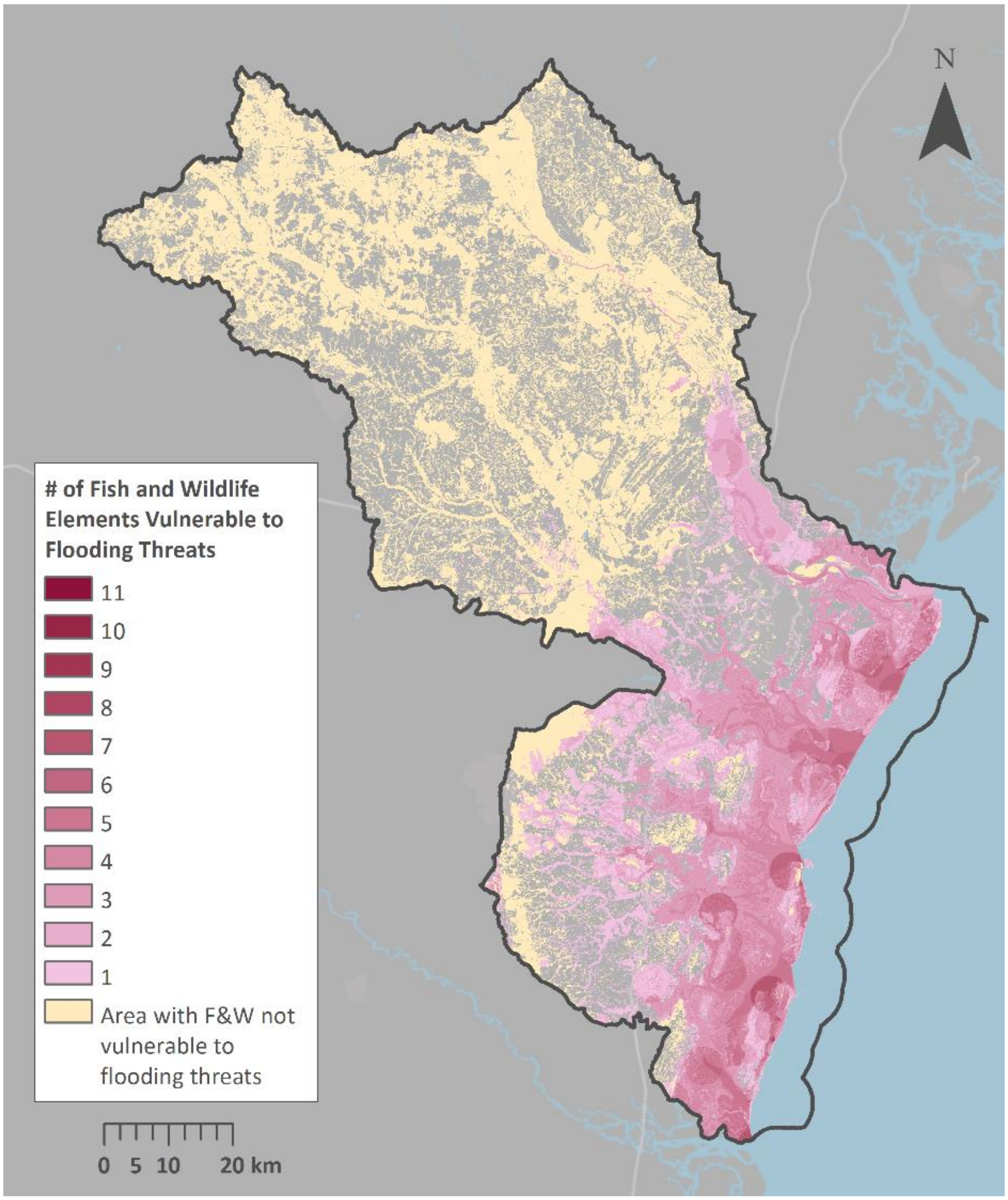


***Figure A4-3. Fish and wildlife vulnerability to flooding threats**. **in the Savannah River Watershed**. Pink to red shades indicate the number of elements vulnerable to flooding threats. Tan areas indicate areas of low to no impact. Gray areas within the project boundary represent areas with no mapped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

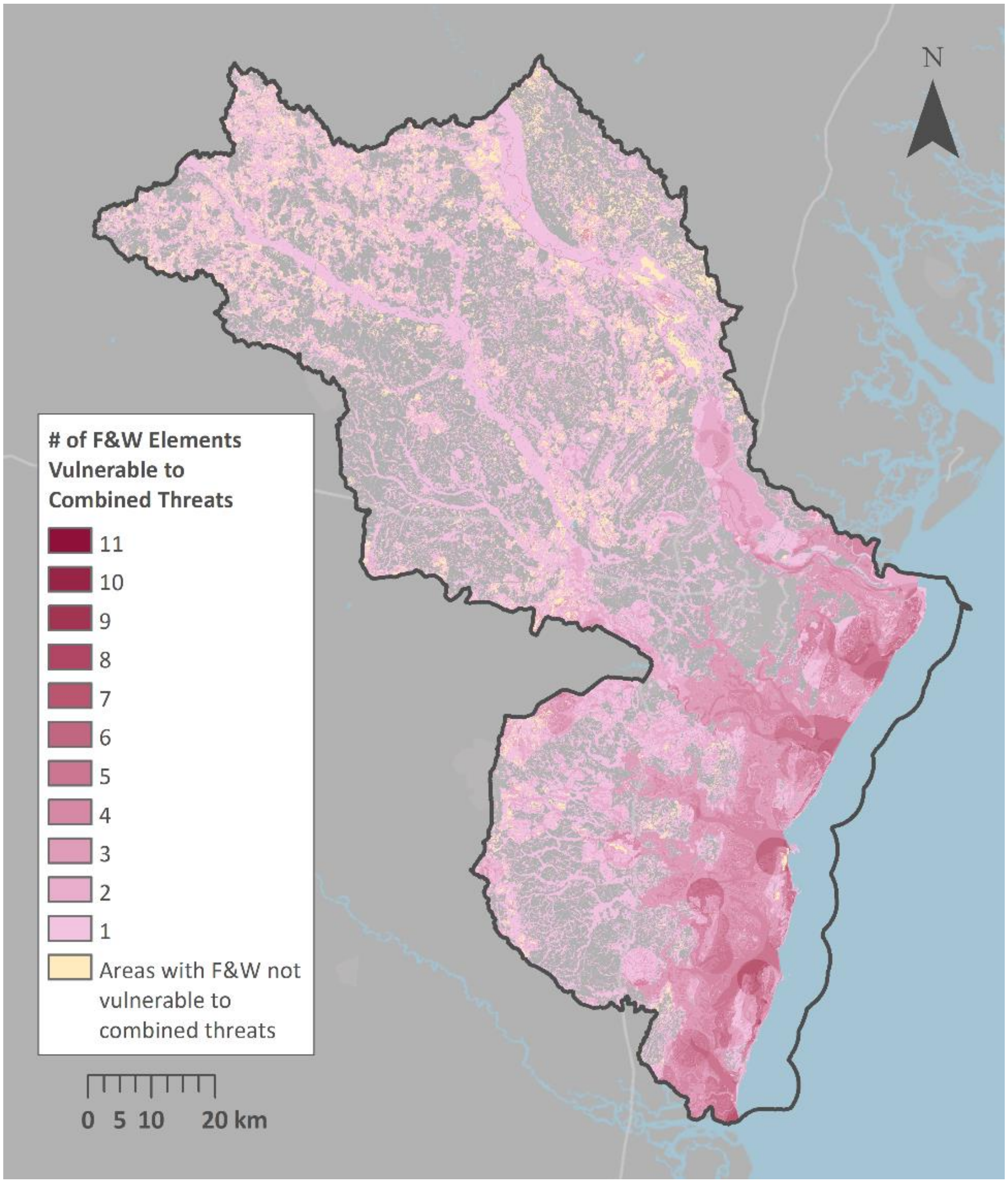


Figure A4-4. Fish and wildlife elements vulnerability to combined stressors and flooding threats. *for the Savannah River Watershed. Pink to red shades indicate the number of elements vulnerable to threats. Tan areas indicate areas of low to no impact from the baseline threats. Gray areas within the 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 used in this assessment. *For the 'Data Source(s) Used' column, the following notation is used:* Name of Data Source (Source Agency or Organization) [Attributes used].

Fish/Wildlife Element	*Data Source(s) Used*	*Data Sources Not Used and Why*
NOAA Trust Resources		
Beach and dune habitat	Regional shorebird layer (South Atlantic Land Conservation Cooperative)	• **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.

Diadromous fish habitat and important riverine systems	The following data were combined to create the distribution of this element:
	• Atlantic sturgeon habitat: Constructed via a spatial join of the following:
	    o National Hydrography Dataset Waterbody areas (USGS)
	    o Proposed Atlantic sturgeon Critical Habitat layer (NOAA)
	    o Georgia Anadromous Fish Upper Stream Limits (NOAA)
	• Riverine systems: Constructed via a spatial join of the following:
	    o National Hydrography Dataset Waterbody areas (USGS) [FType = 'Sea Ocean' or 'Stream River')
	    o Polygons from this layer that overlap with GA DNR point records for Red drum, shrimp, and blue crab.
	• The result of the above was then adjusted based on expert wetland ecologist knowledge.
		• **High priority watersheds (Georgia SWAP)**. Data of insufficient detail enough to capture some important riverine systems; only covers GA section of study area.
		• **Sub adult red drum points (SC DNR)**. No points fall within study area boundary.

Fish/Wildlife Element	***Data Source(s) Used***	***Data Sources Not Used and Why***
NOAA Trust Resources		
Marsh and tidal creek (including open water)	• In GA: GA Habitat Map (GA DNR) [“Comment” field = ‘Southern Atlantic Coastal Plain Salt and Brackish Tidal Marsh’] • In SC: National Wetlands Inventory (USFWS) [‘Estuarine’ and ‘Marine Wetland’ categories)	N/A
Oyster beds/reefs	• In GA: GA Oyster Reefs (2015) (NOAA) • In SC: Intertidal Oyster Reefs (SC DNR)	Oyster bed distribution (GA DNR Coastal Resources Division). Data type (points) inconsistent with SC data (polygons).
Important shark habitat	Atlantic Highly Migratory Species Essential Fish Habitat for sandbar and tiger sharks (NOAA)	N/A
Shrimp Essential Fish Habitat	Shrimp Essential Fish Habitat (NOAA)	N/A
Snapper-Grouper Essential Fish Habitat	Snapper-Grouper Essential Fish Habitat (NOAA)	N/A
At-Risk Species and Multi-species Aggregations		
Threatened and endangered terrestrial species element occurrences	• In GA: Element occurrence data for all available Threatened and Endangered species (Georgia NHP) • In SC: Element occurrence data for all available Threatened and Endangered species (SC Heritage Trust)	N/A
G1-G3/S1-S3 terrestrial species element occurrences	Constructed by a spatial join of: • In GA: Element occurrence data for all available G1-G3/S1-S3 species not included in the above group of ESA T&E species (Georgia NHP) • In SC: Element occurrence data for all available G1-G3/S1-S3 species not included in the above group of ESA T&E species (SC Heritage Trust)	N/A

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 dome/pondshore	The following data were combined to create this distribution: • Ecological Systems Map (NatureServe) ['Southern Coastal Plain Nonriverine Cypress Dome' category in "ESLF_NAME" field] • In GA: GA Habitat Map (GA DNR) ['Southern Atlantic Coastal Plain Depression Pondshore' category in "NS_ECO_NAM" field]	N/A
Forested wetlands (non-tidal)	National Wetlands Inventory (USFWS) ['Freshwater -Forested and Shrub wetland' category]	• **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)	GA Habitat Map (GA DNR) ['Southern Atlantic Coastal Plain Small Blackwater River Floodplain Forest' category in "NS_ECO_NAM" field]	N/A
Freshwater emergent wetlands	National Wetlands Inventory (USFWS) ['Freshwater Emergent wetland' category]	N/A
Seaside sparrow habitat	Distribution follows that of a model constructed by Elizabeth Hunter (University of Georgia) [1.22 suitability cutoff value used] *Hunter, Elizabeth, Nibbelink, N., an Cooper, R. (2016). Divergent forecasts for two salt marsh specialists in response to sea level rise. Animal Conservation, 20, 20-28.*	N/A

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		
Wading bird and ally colonies	• In GA: Element occurrence data (Georgia NHP) [EO data for Black-crowned Night Heron, Wood Stork, and Yellow-crowned Night Heron as well as 'Wading Bird Colony" category of "SCOMNAME" field] • In SC: Element occurrence data (SC Heritage Trust) [EO data for Black-crowned Night Heron, Wood Stork, and Yellow-crowned Night Heron as well as 'Wading Bird Colony" category of "SCOMNAME" field]	N/A
Maritime live oak hammock forest and scrub	• In GA: GA Habitat Map (GA DNR) ['Southern Coastal Plain Oak Dome and Hammock' & 'Southern Atlantic Coastal Plain Maritime Forest' in "NS_ECO_NAM" field) • In SC: Ecological Systems Map (NatureServe) ['Southern Atlantic Coastal Plain Maritime Forest' category in "LABEL" field)	• **CCAP land cover (NOAA)**. This element not represented in these data.
Open pine habitat	The following data were combined to create the distribution of this element: • Ecological Systems Map (NatureServe) ['Atlantic Coastal Plain Upload Longleaf Pine Woodland' and 'Southern Atlantic Coastal Plain Wet Savanna and Flatwoods' categories of the "LABEL" field] • Eastern Indigo Snake distribution: Orianne society distribution model • Red-cockaded woodpecker: o In GA: Element occurrence data (Georgia NHP) o In SC: Element occurrence data (SC Heritage Trust) • Gopher Tortoise: o In GA: University of Georgia distribution model (Matt Elliot – Warnell School of Forestry & Natural Resources, University of Georgia) o In SC: ▪ Element occurrences; and	• **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 full geographic area • **Eastern diamondback rattlesnake distribution based on a species distribution model (Orianne Society)**.

Fish/Wildlife Element	*Data Source(s) Used*	*Data Sources Not Used and Why*
	▪ Buncombe soil distribution (as an additional proxy for the distribution of this species) (SC Heritage Trust)	Given close association of eastern diamondback rattlesnake with open pine habitat, these data were suggested as a candidate for supplementing other open pine habitat distribution data. However, the dataset only covers the state of Georgia.
Important river mussel habitat	• In GA: Element occurrence data for Altamaha Arcmussel, Brother Spike, Carolina Elephantear (Slabshell), Carolina Slabshell, *Halcyon marstonia,* Roanoke Slabshell, Savannah Lilliput, Say's Spiketail, Tidewater Mucket, and Yellow Lampmussel (Georgia NHP) • In SC: Element occurrence data for Altamaha Arcmussel, Brother Spike, Carolina Elephantear (Slabshell), Carolina Slabshell, *Halcyon marstonia,* Roanoke Slabshell, Savannah Lilliput, Say's Spiketail, Tidewater Mucket, and Yellow Lampmussel (SC Heritage Trust)	N/A
Cross-cutting Elements		
Continental and global Important Bird Areas	IBAs (National Audubon Society) [“Priority” field = “Continental or Global”]	N/A

** Another dataset that was suggested as a potential resource for several elements was the Breeding bird survey data / bird atlas (USGS). This dataset was ultimately deemed too coarse for the resolution of this assessment.*

***Table A5-2. Fish and Wildlife Elements proposed but ultimately <u>not included</u> in the 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**
Southern Atlantic coastal plain small blackwater river floodplain forest	This element was originally included because it specifically targeted blackwater river floodplains, which provide important habitat for key reptiles and migratory bird species. It was ultimately removed because it overlapped directly with the Forested Wetlands (non-tidal) element, which was too redundant.
Carolina bays	Habitat is not represented in study area of this assessment
Sweetgrass habitat	Distribution data not available for this element
Rice fields/managed tidal wetlands	Distribution data not available for this element
Robust redhorse	Data insufficient (EO data is not comprehensive for entire watershed)
Manatee	Best data set identified for this element (Heritage Program element occurrence data) is somewhat opportunistic and not representative of actual distribution.
Bald eagle (nests)	Species now too common to allow for useful analyses.
Tri-colored bat	Data insufficient (EO data is not comprehensive for entire watershed)
Swampfish (*Chologaster cornuta*)	Data insufficient (EO data is not comprehensive for entire watershed)
Diamondback terrapin	Data insufficient (EO data is not comprehensive for entire watershed)

Table A5-3. 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. Endanderged Species Act.*

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	GA S-rank	SC S-rank
	Common Name	**Scientific Name**				
Beach and dune	black skimmer	*Rynchops niger*		G5	S1	S2
	common tern	*Sterna hirundo*		G5	SNRN	S3?B
	green sea turtle	*Chelonia mydas*	FE (SE)	G3	S1	SNR
	hawksbill sea turtle	*Eretmochelys imbricata*	FE	G3		SNR
	island glass lizard	*Ophisaurus compressus*		G3G4	S2	S1S2
	Kemp's ridley sea turtle	*Lepidochelys kempii*	FE (SE)	G1	S1	
	least tern	*Sternula antillarum*	ST	G4	S3	S3
	leatherback sea turtle	*Dermochelys coriacea*	FE (SE)	G2	S1	
	loggerhead sea turtle	*Caretta caretta*	FT (ST)	G3	S2	S3
	red knot	*Calidris canutus*	FT	G4	S3N	SNRN
	Wilson's plover	*Charadrius wilsonia*		G5	S2	S3?
Cypress domes	Flatwoods salamanders, white ibis, wood stork					
Diadromous fish habitat and riverine systems	Atlantic sturgeon	*Acipenser oxyrinchus oxyrinchus*	FE (SE)	G3	SNR	S3
	shad					
	shortnose sturgeon	*Acipenser brevirostrum*	FE (SE)	G3	S2	S3
	blueback herring	*Alosa aestivalis*		G3G4	SNR	S5
	hickory shad	*Alosa mediocris*		G4	SNR	S4
	American shad	*Alosa sapidissima*		G5	S5	S4S5
	American eel	*Anguilla rostrata*		G4	S3S4	SNR
	menhaden					
	striped bass	*Morone saxatilis*		G5	S5	SNR
	red drum	*Sciaenops ocellatus*		G5	S5	
	Shark species (lemon and bull seasonally in lower sections)					
Forested wetlands (non-tidal) AND cypress swamps/domes and	Acadian flycatcher	*Empidonax virescens*		G5	S5	S4B
	Kentucky warbler	*Oporornis formosus*		G5	S5	S4B
	Louisiana waterthrush	*Seiurus motacilla*		G5	S5	S4B
	prothonotary warbler	*Protonotaria citrea*		G5	S5	S3B
	red-shouldered hawk	*Buteo lineatus*		G5	S4	SNR
	rusty blackbird	*Euphagus carolinus*		G4	S5	SNRN

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	GA S-rank	SC S-rank
	Common Name	Scientific Name				
tidal hardwood/swamp forest	Swainson's warbler	*Limnothlypis swainsonii*		G4	S3	S4
	wood duck	*Aix sponsa*		G5	S5	SNRB, SNRN, SNRM
Important shark habitat	sandtiger shark	*Carcharias taurus*		G3G4		
	sandbar shark	*Carcharhinus plumbeus*		G4		
Maritime live oak hammock forest and scrub	Maritime Live Oak Hammock	*Quercus virginiana – (Pinus elliottii var. elliottii, Sabal palmetto) / Persea borbonia – Callicarpa 129mericana Forest*				
	painted bunting	*Passerina ciris*		G5	S3	SNRB
Marsh and tidal creek (including open water)	American oystercatcher habitat					
	black skimmer habitat					
	sea sparrow hotspots					
	American bittern	*Botaurus lentiginosus*		G5	S3?	SRN
	American coot	*Fulica americana*		G5	S4	SHB, SNRN
	black rail	*Laterallus jamaicensis*	Under Review	G3G4	S2?	SNRB, SNRN
	clapper rail	*Rallus longirostris; Rallus crepitans*		G5	S5	S4
	common gallinule	*Gallinula galeata*		G5	S5	SNR
	king rail	*Rallus elegans*		G4	S4S5	SNR
	least bittern	*Ixobrychus exilis*		G5	S4	SNRB, SNRN
	pied-billed grebe	*Podilymbus podiceps*		G5	S4S5	SNRB, SNRN
	purple gallinule	*Porphyrula martinica*		G5	S4	SHB
	sedge wren	*Cistothorus platensis*		G5	S3	SUB
	sora	*Porzana Carolina*		G5	S4	SNRN
	yellow rail	*Coturnicops noveboracensis*		G4	S3?	S2N
	Virginia rail	*Rallus limicola*		G5	S3S4	SNRN
	Wilson's snipe	*Gallinago delicata*		G5	S5	SNRN
	summer flounder nursery habitat					

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	GA S-rank	SC S-rank
	Common Name	Scientific Name				
	Penaeid shrimp nursery habitat					
	blue crab nursery habitat					
	snapper-grouper complex					
	Spanish and king mackerel					
	cobia	*Rachycentron canadum*		GNR		
	bluefish					
	black sea bass					
	red drum	*Sciaenops ocellatus*		G5	S5	
	spotted seatrout, weakfish, spot, southern flounder					
	Shark species (lemon, bull, blacknose, finetooth, dusky, bonnethead, and Atlantic sharpnose)					
Important river mussel habitat	Altamaha arcmussel	*Alasmidonta arcula*	Status Undefined	G2	S2	
	Atlantic pigtoe	*Fusconaia masoni*	Under Review	G2	S1	SH
	brother spike	*Elliptio fraterna*	Under Review	G1G2	S1	S1
	Carolina elephantear (slabshell)	*Elliptio congaraea*		G3	S3	S3
	Carolina slabshell	*Elliptio congaraea*		G3	S3	S3
	halcyon marstonia	*Marstonia halcyon*		G4	S4	
	rayed pink fatmucket	*Lampsilis splendida*		G3	S3	S2
	Roanoke slabshell	*Elliptio roanokensis*		G3	S2	S2
	Savannah lilliput	*Toxolasma pullus*	Under Review	G2	S2	S1
	say's spiketail	*Cordulegaster sayi*	Status Undefined	G2	S1S2	
	Tidewater mucket	*Leptodea ochracea*		G3G4	SU	S2
	triangle floater	*Alasmidonta undulata*		G4	S1S2	S1
	yellow lampmussel	*Lampsilis cariosa*	proposed FT	G3G4	S2	S2

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	GA S-rank	SC S-rank
	Common Name	Scientific Name				
Open pine	American kestrel – southeastern race	*Falco sparverius paulus*		G5T4	S2	SNR
	Bachman's sparrow	*Aimophila aestivalis; Peucaea aestivalis*		G3	S2	S3
	brown-headed nuthatch	*Sitta pusilla*		G4	S5	S4
	Carolina gopher frog	*Lithobates capito*	Under Review	G3	S3	S1
	coral snake (Harlequin)	*Micrurus fulvius*		G5	S3	S2
	Eastern indigo snake	*Drymarchon couperi*	FT	G3Q	S2	SNR
	Eastern diamondback rattlesnake	*Crotalus adamanteus*	Under Review	G4	S4	S3
	Florida pine snake	*Pituophis melanoleucus mugitus*	Under Review	G4T3	S3	S2
	Northern pine snake	*Pituophis melanoleucus melanoleucus*		G4T4	S2	SNR
	frosted flatwoods salamander	*Ambystoma cingulatum*	FT	G2	S2	S1
	gopher tortoise	*Gopherus polyphemus*	C (SE)	G3	S2	S1
	Henslow's sparrow	*Ammodramus henslowii – winter population*		G4	S2	SNA
	mimic glass lizard	*Ophisaurus mimicus*		G3	S2	SNR
	Northern pine snake	*Pituophis melanoleucus mugitus*	Under Review	G4T3	S3	S2
	pine savannah crayfish	*Cambarus reflexus*		G4	S2	S3
	pine warbler	*Dendroica pinus*		G5	S5	SNR
	pine woods litter snake	*Rhadinaea flavilata*		G4	S2	SNR
	red-cockaded woodpecker	*Picoides borealis*	FE (SE)	G3	S2	S2
	slender glass lizard	*Ophisaurus attenuatus*		G5	S3	S4
	Southern hognose snake	*Heterodon simus*	Under Review	G2	S2	SNR
	swallow-tailed kite	*Elanoides forficatus*		G5	S2	S2

Fish/Wildlife Element	Species Represented		ESA Status	G-rank	GA S-rank	SC S-rank
	Common Name	Scientific Name				
Oyster beds/reefs	**Eastern oyster**	*Crassostrea virginica*		G3G4		
Shell middens/ hammocks	Shell middens and hammock islands					
Tidal Hardwood Swamp Forest	Tidal hardwood Forest with cypress					
	Tidal Hardwood Swamp Forest	*Nyssa biflora - (Nyssa aquatica, Taxodium distichum) Tidal Forest*				
Wading bird and ally colonies	black-crowned night heron	*Nycticorax nycticorax*		G5	S4	SNRB, SNRN
	glossy ibis	*Plegadis falcinellus*		G5	S2	SHB, SNRN
	great blue heron	*Ardea herodias*		G5	S4	SNRB, SNRN
	great egret	*Casmerodius albus; Ardea alba*		G5	S4	SNRB, SNRN
	green heron	*Butorides virescens*		G5	S5	S5B
	little blue heron	*Egretta caerulea*		G5	S4	SNRB, SNRN
	reddish egret	*Egretta rufescens*		G4	S4	
	roseate spoonbill	*Platalea ajaja*		G5		
	snowy egret	*Egretta thula*		G5	S4	SNRB, SNRN
	tricolored heron	*Egretta tricolor*		G5	S4	SNRB, SNRN
	white ibis	*Eudocimus albus*		G5	S4	SNR
	wood stork	*Mycteria americana*	FT (SE)	G4	S2	S1S2
	yellow-crowned night heron	*Nyctanassa violacea*		G5	S3S4	SNRB, SNRN
	anhinga	*Anhinga anhinga*		G5	S5	SNRB, SNRN
Wetlands	Wetlands (inclusive of all wetland types)					

Appendix 6. Resilience Project Information

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

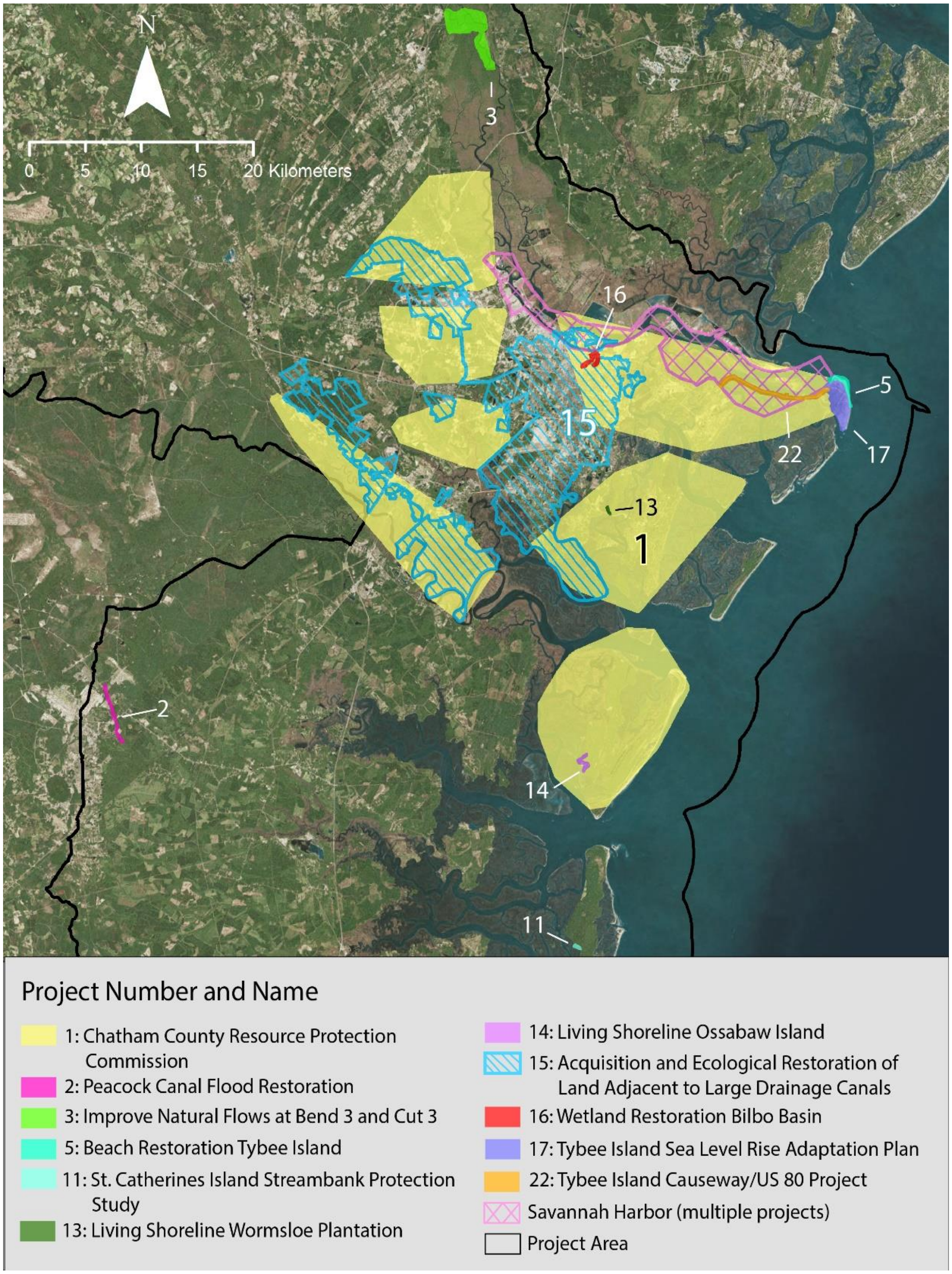


Figure A6-1. Map showing the boundaries of resilience projects compiled for the Savannah River Watershed. *Projects #4, #6-10, #12, and #18-21 are not pictured due to their large size. See* ***Table A6-1*** *for a full list of projects submitted.*

Resilience Projects Information as Submitted by Stakeholders

A summary of all resilience project submitted for the Savannah River Watershed can be found in **Table A6-1**. More detailed information about each project was provided by project submitters and is included below.

Table A6-1. All resilience projects submitted for the Savannah River 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
Tybee Island Sea Level Rise Adaptation Plan	5.57	7	11	17
Wetland Restoration Bilbo Basin	4.35	7	6	16
Peacock Canal Flood Restoration and Resilience Project	4.11	4	5	2
Tybee Island Causeway/US 80 project looking at inundation of road and future road impacts on marsh species such as diamondback terrapin	3.96	3	10	22
Improve Natural Flows at Bend 3 and Cut 3	3.75	3	10	3
Acquisition and ecological restoration of land adjacent to large drainage canals.	3.52	8	14	15
Living Shoreline Wormsloe Plantation	2.88	0	8	13
St. Catherines Island Streambank Protection Study	2.75	0	6	11
Living Shoreline Ossabaw Island	2.74	0	9	14
Beach Restoration Tybee Island - Limited Reevaluation Report on Beach Erosion	2.30	4	7	5
Savannah Harbor Expansion Monitoring and Mitigation for Navigation Impacts	1.95	5	16	4
Savannah Harbor Navigation Project	1.95	5	16	7
Savannah Chatham Drainage Project	1.95	5	16	12
Chatham County Resource Protection Commission	Community Exposure Index calculated for each polygon individually	8	20	1
Overcoming passage barriers in the Savannah River	Multiple points	Multiple points	Multiple points	10
Atlantic Intracoastal Waterway (AIWW) Savannah District Project	Entire study area	Entire study area	Entire study area	8

Project Name	Community Exposure Index	Number of Human Assets Mapped	Fish/Wildlife Elements within project boundary	Map ID Number
Hurricane Matthew Research on experiences, risk perceptions and decision making of coastal residents	Entire study area	Entire study area	Entire study area	18
Hurricane Irma Research #1	Entire study area	Entire study area	Entire study area	19
Hurricane Irma Research #2	Entire study area	Entire study area	Entire study area	20
Culvert Assessment for culverts in high flood risk areas	Entire study area	Entire study area	Entire study area	21
Ecosystem restoration for bends south of Augusta	Outside study area	Outside study area	Outside study area	6
Noyes Cut Section 1135 Ecosystem Restoration for Satilla River	Outside study area	Outside study area	Outside study area	9
Savannah River Clean Water Fund	Entire study area	Entire study area	Entire study area	23

Project ID# 1
Name: Chatham County Resource Protection Commission
Submitted by: Nick Helmholdt, point of contact is new Director, Melanie Wilson
Organization: Chatham County Savannah Metropolitan Planning Commission
Project Type: Upland restoration, Riparian and floodplain restoration
Description: The Chatham County Resource Protection Commission (RPC) seeks to provide for the protection, enhancement and perpetuation of areas having significant natural, historic, cultural or aesthetic interest or value, or which protect current or future sources of potable water. The RPC evaluates properties for their ecological, historic, and cultural value according to a set of established site ranking criteria. Top ranking properties are recommended for protection. Protection methods available include fee simple acquisition, the creation of conservation easements, and the purchase of development/mineral rights. Once a protection measure is chosen, the Chatham County Board of Commissioners may authorize the measure. (Please note, the exact locations of properties under consideration by the RPC cannot be shared externally. The attached map files show generalized areas and the total acreage under consideration.)

Project ID# 2
Name: Peacock Canal Flood Restoration and Resilience Project
Submitted by: Larry Logan
Organization: Liberty County EMA
Project Type: Community resilience planning, Green infrastructure implementations, Wetlands created, Wetlands restored/enhanced
Description: A project to reduce flooding from the Peacock Canal by using nature-based restoration design. The area that is flooded has public facilities (park, recreation center) and private homes and disrupts critical services and damages infrastructure. The area is officially an emergency staging area for disasters (e.g. hurricanes), yet floods. The area has numerous fish and wildlife species, including alligators, fish species, and high bird diversity. The canal was established along the route of a former drainage that goes directly from uplands on Fort Stewart to coastal marshes.

Project ID# 3
Name: Improve Function of Natural Flows at Bend 3 and Filled Cut 3
Submitted by: Bob Sirard
Organization: U. S. Army Corps of Engineers
Project Type: Other (describe): Environmental/ecosystem restoration
Description: This project was constructed in 2002 and needs maintenance. The project plan included a large partial diversion structure at cut #3; a plug in bend #3 below the mouth of Bear Creak and realignment and restoration of the mouths of Bear and Mill Creeks, which provides improved flows into both creeks. The project is inspected on an annual basis to ensure its continued functionality and verify that O&M is adequate. There are future opportunities to improve natural flows into Bear and Mills Creek and associated wetlands.

Project ID# 4
Name: Savannah Harbor Expansion Monitoring and Mitigation for Navigation Impacts
Submitted by: Nathan Dayan
Organization: U. S. Army Corps of Engineers
Project Type: Community resilience planning, Dam removal/fish passage, Marsh restoration, Restoration of aquatic connectivity, Wetlands created, Wetlands restored/enhanced
Description: The monitoring and mitigation portion of SHEP compensates for impacts anticipated during the deepening of the Savannah River. Mitigation and monitoring information can be found at http://www.shep.uga.edu/#&panel1-1.

Project ID# 5
Name: Beach Restoration Tybee Island - Limited Reevaluation Report on Beach Erosion
Submitted by: Taylor Wimberly
Organization: U. S. Army Corps of Engineers
Project Type: Beach or dune restoration
Description: The work consisted of dredging a maximum of 1,748,750 cy from Borrow Area 4 and placement of approximately 1,399,000 cy along the Oceanfront Beach and Back River/Tybee Creek portions of the project.

Project ID# 6
Name: Ecosystem restoration for bends in the Savannah River Below Augusta
Submitted by: Taylor Wimberly
Organization: U. S. Army Corps of Engineers
Project Type: Upland restoration
Description: Restore natural flow by closing cuts and restoring bendways in the river.

Project ID# 7
Name: Savannah Harbor Navigation Project
Submitted by: Kathryn Kuehn
Organization: U.S. Army Corps of Engineers
Project Type: Other (describe): Navigation
Description: Harbor dredging using adjacent dredged material containment areas with extensive mitigation requirements being implemented by the Savannah District Corps of Engineers. Mitigation is for waterfowl use and bare ground nesting habitat. Alternate mitigation sites are being investigated.

Project ID# 8
Name: Atlantic Intracoastal Waterway (AIWW) Savannah District Project
Submitted by: Roger Lafond
Organization: U.S. Army Corps of Engineers
Project Type: Other (describe): Navigation
Description: The shallow draft navigation channel that parallels the Atlantic Ocean along the coast of GA.

Project ID# 9
Name: Noyes Cut Section 1135 Ecosystem Restoration for Satilla River
Submitted by: Taylor Wimberly
Organization: U. S. Army Corps of Engineers
Project Type: Restoration of aquatic connectivity, Wetlands restored/enhanced
Description: The Satilla River estuary contains a complex network of tidal channels. Man-made cuts changed the hydraulic circulation patterns in the estuary by (1) altering local patterns of tidal exchange; (2) disrupting gradual salinity gradients from the headwaters to the mouth of the creeks; and (3) reducing access to headwaters for estuarine species due to channel sedimentation, which has caused a significant degradation to the watershed habitat. Dover and Umbrella Creeks are the primary creeks within the system and serve as both key habitats and primary routes for movement of organisms and water.

Project ID# 10
Name: Overcoming passage barriers in the Savannah River
Submitted by: Jessica Graham, Coordinator and Kat Hoenke, Spatial Ecologist
Organization: Southeast Aquatic Resource Partnership
Project Type: Dam removal/fish passage, Restoration of aquatic connectivity
Description: The Southeast Aquatic Resources Partnership (SARP) has identified culverts and bridges that may be barriers to fish passage and habitat connectivity. These culverts and bridges still need to be assessed in the field for aquatic organism passage. SARP is in the process of assessing fish passage at individual structures in priority basins. SARP has also begun reconnaissance on dams in the watershed that may be removed to benefit fish passage and habitat connectivity. The project will identify those dams that are socially and ecologically feasible to remove as part of their Southeast Aquatic Connectivity Assessment Project (SEACAP).

Project ID# 11
Name: St. Catherines Island Streambank Protection Study
Submitted by: Jeff Morris
Organization: U. S. Army Corps of Engineers
Project Type: Living shoreline implementation, Marsh restoration
Description: The area of concern is located on the southern end of the island, along Wamassee Creek. The historic and cultural resources and the ecosystem are threatened by streambank erosion in this area.

Project ID# 12
Name: Savannah Chatham Drainage Project
Submitted by: Laura Walker
Organization: City of Savannah
Project Type: Community resilience planning, Green infrastructure implementations, Wetlands created
Description: Completion of hydrologic basin models and update and modification of existing basin models to include water quality parameters and flood control.

Project ID# 13
Name: Living Shoreline Wormsloe Plantation
Submitted by: Jan Mackinnon
Organization: Georgia Department of Natural Resources Coastal Resources Division
Project Type: Living shoreline implementation
Description: The living shoreline project at Wormsloe aims to develop and install nature based solutions to shoreline erosion. Using oysters and native plants, this project will serve as a template for other erosional shorelines as alternatives to traditional armoring. The state of Georgia is interested in learning more about biological recruitment and physical stability of living shorelines while serving as a role model site for other landowners.

Project ID# 14
Name: Living Shoreline Ossabaw Island
Submitted by: Jan Mackinnon
Organization: Georgia Department of Natural Resources Coastal Resources Division
Project Type: Living shoreline implementation
Description: The living shoreline project on Ossabaw aims to develop and install nature based solutions to shoreline erosion along Newell Creek. Using oysters and native plants, this project will serve as a template for other erosional shorelines as alternatives to traditional armoring. The state of Georgia is interested in learning more about biological recruitment and physical stability of living shorelines while serving as a role model site for other landowners.

Project ID# 15
Name: Acquisition and ecological restoration of land adjacent to large drainage canals.
Submitted by: Laura Walker
Organization: City of Savannah
Project Type: Community resilience planning, Green infrastructure implementations, Riparian and floodplain restoration
Description: The purchase and ecological restoration of land adjacent to large drainage canals.

Project ID# 16
Name: Wetland Restoration Bilbo Basin
Submitted by: Laura Walker
Organization: City of Savannah
Project Type: Community resilience planning, Wetlands restored/enhanced
Description: The Bilbo Basin includes a large wetland that has been channelized. This area would be integrated into the City's system and provide storage to reduce flooding and nitrogen uptake for improved water quality. It could also serve as an outdoor classroom and provide environmental education opportunities within the City's expanding urban core.

Project ID# 17
Name: Tybee Island Sea Level Rise Adaptation Plan
Submitted by: Jason Evans
Organization: Stetson University
Project Type: Beach or dune restoration, Community resilience planning
Description: Using a grant from the National Sea Grant, the University of Georgia Marine Extension and Georgia Sea Grant analyzed risks and vulnerabilities from tidal flooding and sea-level rise on Tybee Island over the next

50 years, developing a plan that enabled savings of $3 million on flood insurance for property owners. The plan has emerged as a model for other coastal communities across the country and has won several national awards.

Project ID# 18
Name: Hurricane Matthew Research on experiences, risk perceptions and decision making of coastal residents
Submitted by: Jill Gambill
Organization: University of Georgia Marine Extension and Georgia Sea Grant
Project Type: Community resilience planning, Emergency Preparation and Response, Storm Surge Risk Communication
Description: Hurricane Matthew produced storm surge that was 1.5 feet higher than any water level on record for the Savannah area—a tidal record that goes back to 1935. Following the storm, UGA Marine Extension and Georgia Sea Grant collaborated with the National Center for Atmospheric Research, UGA Graduate School and UGA College of Environment and Design on NSF and Georgia Sea Grant-funded research to study the experiences, risk perceptions and decision making of coastal residents in relation to hurricanes, storm surge and climate change. Over 60 people in 2 counties were interviewed, almost 1,000 people throughout coastal Georgia surveyed, and seven focus groups in Beaufort, SC; Savannah, GA; and Brunswick, GA were conducted.

Project ID# 19
Name: Hurricane Irma Research #1
Submitted by: Jill Gambill
Organization: University of Georgia Marine Extension and Georgia Sea Grant
Project Type: Beach or dune restoration, Community resilience planning, Green infrastructure implementations
Description: Following Hurricane Matthew, the National Center for Atmospheric Research developed a prototype 3D GIS storm surge animation that we tested in focus groups within Savannah, GA, Beaufort, SC, and Brunswick, GA. When Hurricane Irma threatened the SE United States, the animation was viewed almost 50,000 times in just a few days. The NWS Jacksonville and NWS Charleston Forecast Office would like to collaborate with us on fine-tuning this 3D animation for post-Irma hurricane education in Florida, Georgia and South Carolina. They would like to use the modeling technique to develop visualizations for several key landmarks in their regions and modify the graphics so that it looks more like the actual conditions of a hurricane, with wind action, whitecaps, waves, rain and cloudy skies. They would use the 3D animations in their briefings and push them out to TV stations throughout Florida, Georgia and South Carolina during the next hurricane season. NWS Jacksonville survey results following Hurricane Irma indicated that people did not take the storm surge threat serious. They feel that seeing potential impacts could not only help people understand how storm surge occurs, but motivate them to follow evacuation orders.

Project ID# 20
Name: Hurricane Irma Research #2
Submitted by: Jill Gambill
Organization: University of Georgia Marine Extension and Georgia Sea Grant
Project Type: Community resilience planning, Hurricane planning and response
Description: National Center for Atmospheric Research (NCAR) and the University of Georgia propose studying risk perceptions and decision making in the wake of Hurricane Irma along the Georgia and South Carolina coasts. This effort would build off two NSF-funded projects to analyze 1) risk perception and decision making among authorities charged with protecting people from storm surge and hurricane impacts and 2) longitudinal risk perceptions of residents within the three pilot communities featured in the NCAR HazardSEES project—Beaufort, SC, Savannah, GA and Brunswick, GA—to determine how experiencing two hurricanes in less than one year has impacted their knowledge, perspectives and decision making. For 1) we would conduct 5 interviews each in

Beaufort, SC, Savannah, GA and Brunswick, GA with emergency managers, school superintendents, elected officials and other authorities. The goal will be to understand what storm surge and hurricane information they used or could have used as Hurricane Irma approached and how individual risk perceptions filtered this information to inform storm-related decisions. For 2) we would host one focus group each in Beaufort, SC, Savannah, GA and Brunswick, GA, resampling the same residents who participated in the NCAR HazardSEES focus groups following Hurricane Matthew. The goal will be to understand longitudinal perceptions of risk, what information people saw, and the role of experience on formulating perceptions of risk following Hurricane Irma. We will also revisit our prototype storm surge maps/visualizations and initial results from the Hurricane Matthew focus groups to see if people respond differently post-Irma. This research will enable improved planning, communication and emergency response by giving a fuller picture of the intertwined public risk perceptions and official decision making during hurricane threats.

Project ID# 21
Name: Culvert Assessment for culverts in high flood risk areas
Submitted by: Carrie Straight
Organization: USFWS
Project Type: Restoration of aquatic connectivity, Flood Resiliency and Emergency Response
Description: A catalog and assessment of coastal culverts or culverts in high risk flood areas is needed because the state does not have a catalog of culvert locations. This would serve multiple purposes: to identify all culverts, assess culvert for risk of failure during flooding events, assess fish passage and identify and prioritize culverts for replacement to minimize future damage to road substructure.

Project ID# 22
Name: Tybee Island Causeway/US 80 project looking at inundation of road and future road impacts on marsh species such as diamondback terrapin
Submitted by: Kimberly Andrews (biologist submitting information); DOT Ecologist contacts available upon request
Organization: University of Georgia
Project Type: Community resilience planning, Transportation improvements
Description: Tybee Island Causeway (US Highway 80) has localized points of "sag" where the road periodically floods from tidal and storm surges. These points of lower elevation are a result of the Causeway experiencing accelerated rates of sinking as influenced by bank erosion and the adjacency of tidal creeks and other natural features that influence flooding and degradation over time. Additionally, due to the intersection of marsh features that are critical habitats for species of concern, such as diamondback terrapins, the Causeway road shoulder is used seasonally as nesting habitat for terrapins. This habitat use has resulted in conflicts between wildlife and vehicles producing sustained rates of mortality that are concerning for retaining the viability of this important population in Georgia. Current designs for mitigating both the flooding and wildlife mortality along the Causeway are still in progress; therefore, design files are not being provided at this time. It is a certainty that the Georgia Department of Transportation will elevate parts of the Causeway along a 5.67 - 5.98 mile extent that are experiencing the most severe and frequent flooding and will instate temporary measures to reduce impacts to nesting terrapins during that construction period. It has not yet been determined whether any action to implement seasonal or permanent mitigation features for terrapins will be part of the design plan. Further, I am not aware of any mitigation needs being discussed to resolve any impacts to snakes, as these impacts have not been measured or provided to the state natural resource or transportation agencies.

Project ID# 23
Name: Savannah River Clean Water Fund
Submitted by: Braye Boardman
Organization: Savannah River Clean Water Fund
Project Type: Green infrastructure implementations, Wetlands restored/enhanced, Source Water Protection
Description: Our mission is to protect the water supply for communities and businesses along the Savannah River in Georgia and South Carolina. We make smart science-based investments in the management, and protection of land which pays dividends in cleaner water for generations to come. The Fund arranges financing and uses partnerships to stretch and multiply conservation investments and reach conservation goals on a regional or watershed scale.

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**
Georgia State Wildlife Action Plan 2015 Georgia Department of Natural Resources. September 2015. Georgia State Wildlife Action Plan. Social Circle, GA: Georgia Department of Natural Resources. http://georgiawildlife.com/sites/default/files/wrd/pdf/swap/SWAP2015MainReport_92015.pdf	State of Georgia	Birds, amphibians and reptiles, mammals, fishes and aquatic invertebrates, terrestrial invertebrates; 640 high-priority animal (and plant) species: critically imperiled species, habitat indicator species known to be in decline, species endemic to Georgia, and rare or uncommon species in need of further research to determine conservation objectives.	Anthropogenic or human-altered habitats (e.g., agricultural fields and fallow fields, pine plantations, suburban forests, utility rights of way, harvested timberlands); private lands; vegetated stream buffer; unpaved roads; row crop agriculture; reservoirs; water supply impoundments.	Increased and more extreme temperatures; greater rates of evaporation and evapotranspiration; uncertain frequency changes in precipitation with greater flood amplitude and deeper and longer droughts; predicted increases in rainfall variability; fewer but larger hurricanes and major storms; sea level rise; increased stream drying; habitat shift, reduction, elimination or fragmentation; trophic asynchrony; negatively impacting forage availability and wintering habitat suitability for whales; critical marsh habitat loss for estuarine dependent species; poorer water quality; increased infestations and damage from invasive species; exacerbated wildlife diseases.

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	Taxa: 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, and pasture lands; managed woodland; urban green spaces (parks, gardens, 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.
Chatham County – Savannah Comprehensive Plan MPC [Chatham County - Savannah Metropolitan Planning Commission]. August 2016. Chatham County – Savannah Comprehensive Plan. Chatham County - Savannah Metropolitan Planning Commission, Savannah, GA. http://www.thempc.org/docs/lit/CompPlan/2016/Dec/CompPlan.pdf	Chatham County and Savannah	A wide variety of amphibians, insects, birds, and fish inhabiting wetlands.	The Port of Savannah; manufacturing facilities; transportation facilities; oyster beds; bridges; berms; municipal separate storm sewer systems (MS4s); river corridors and riparian buffers; coastal marshlands and beaches; natural and scenic amenities; open space; parks, greenways, wildlife corridors; landfills; tree canopied and walkable communities; historic architecture; cultural resources.	Sea level rise; periodic and permanent inundation due to sea level rise; the higher than normal tides occurring more frequently which can impact infrastructure and mobility, as well as access to the islands.
Identifying and Evaluating the Distribution of Fishes, Crab, and Shrimp in the Savannah River Estuary	The Savannah River Estuary	Fish, crab, and shrimp species (fishes from 39 species and 24	Savannah Harbor area; Savannah National Wildlife	Sea level rise

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Guillermo Sanchez-Rubio and Cecil A. Jennings. June 2015. Identifying and Evaluating the Distribution of Fishes, Crab, and Shrimp in the Savannah River Estuary. Prepared for US Army Corps of Engineers. https://usgs-cru-individual-data.s3.amazonaws.com/jennings/tech_publications/Revised%20Final%20Report%20Savannah%20River%20Marsh%20Edge%20Survey%20-%20Sanchez-Rubio%20and%20Jennings%20June%2011%202015%20--1.pdf	(SRE) of GA/SC	families, crab from 5 species and 4 families, and shrimp from 4 species and 2 families).	Refuge (NWR) and adjacent lands.	
Tybee Island Sea-Level Rise Adaptation Plan Evans, J.M., J. Gambill, R.J. McDowell, P.W. Prichard, and C.S. Hopkinson. April 2016. Tybee Island sea-level rise adaptation plan. National Oceanic and Atmospheric Administration (NOAA) National Sea Grant College Program. https://www.researchgate.net/publication/289999590_Tybee_Island_Sea-Level_Rise_Adaptation_Plan	The City of Tybee Island in the State of Georgia	N/A	Municipal infrastructure such as stormwater management system; private property; roads: US Highway 80, the sole road connecting Tybee Island to the Savannah Metropolitan area; the Savannah Harbor channel; Works Project Administration (WPA) sea wall; large-scale sand renourishment under the Tybee Island Shore Protection Project; vegetated sand dunes.	Sea-level rise; increasing coastal flooding; increasing nuisance tidal floods; increased shoreline erosions; decreased stormwater drainage and increased back-up of stormwater systems; replacement of upland ecosystems with intertidal marsh and estuarine mudflats systems; increasing saltwater contamination risks for drinking water wells and underground aquifers; larger storm surge events and hurricanes.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Resilience Dialogues Final Synthesis Report: Savannah, GA Resilience Dialogues. March 2017. Resilience Dialogues Final Synthesis Report: Savannah, GA. https://drive.google.com/file/d/0B_f2XEFqZp8tXzV0VnE1OWNYNW8/view	Savannah, GA	N/A	Cultural and natural resources; historic infrastructure; key industries: the Port of Savannah, manufacturing plants, higher education institutions.	Sea level rise; increasing sea surface temperatures; increasing global air temperatures; altering coastal flooding and tropical storm hazards; increasing heat, drought, and saltwater intrusion.
Comprehensive Spatial Data on Biological Resources and Uses in Southeastern Coastal Waters of the U.S. 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	Coastal waters off North Carolina, South Carolina, Georgia, and Florida from the beach out to the 200m bathymetric contour	Shallow water finfish; crustacean species; deep water groundfish; reef fish; ichthyoplankton; coastal pelagic fishes; marine mammals: North Atlantic right whale, fin whale, minke whale, sperm whale, bottlenose dolphin; loggerhead sea turtle, green and leatherback turtles, Hawksbill and Kemp's turtles; seabirds: brown pelican, laughing gull, royal tern, sandwich tern, least tern, gull-billed tern, and black skimmer); piping plover.	N/A	N/A
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., Fuller, P.L., Birdsong, T., Wieferich, D.J., McClees-Funinan, R., Stedman,	Southeastern Atlantic states: North Carolina, South Carolina, Georgia	Pinewoods Darter (Etheostoma mariae); Shoal Bass (Micropterus cataractae); native black bass; Robust Redhorse; Shortnose Sturgeon. The Savannah River Basin is home to 110 fish species, 18 federally listed and 55 state-listed or of special concern.	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**
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/				
Savannah Harbor Expansion Project SHEP Progress Report February 1st – February 28th 2017 http://www.shep.uga.edu/docs/reports/2017-02%20Sturgeon%20Distribution%20Monthly%20Progress%20Report.pdf	Savannah River Estuary; Front, Middle, and Back Rivers	Atlantic sturgeon; shortnose sturgeon; Striped bass, Robust redhorse; American shad.	New Savannah Bluff Lock and Dam (NSBL&D) area	N/A
Savannah Harbor Expansion Project http://www.sas.usace.army.mil/Missions/Civil-Works/Savannah-Harbor-Expansion/		The summary of the report is broken down into relevant chapters below.		Sea level rise; adversely impacting freshwater marsh and wetland in the Savannah River Estuary; saltwater intrusion.
Environmental Impact Statement Appendix B: Biological Assessment of Threatened and Endangered Species US Army Corps of Engineers. Revised July 2012. Environmental impact statement appendix B: biological assessment of threatened and	Chatham County, Georgia and Jasper County, South Carolina	Impacted species: (GA) spotted turtle; American oystercatcher; black-necked stilt; black-crowned night heron; false killer whale; black skimmer; least tern; seaside sparrow; Wilson's plover; eastern diamond backed rattlesnake; bald eagle; migrant	Savannah Harbor navigation Project: navigation channel; inner harbor; outer harbor/ocean bar channel; dredged material disposal sites and unconfined placement sites; turning basins; upland Confined Disposal Facilities	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
endangered species. http://www.sas.usace.army.mil/Missions/Civil-Works/Savannah-Harbor-Expansion/Final-Environmental-Impact-Statement/		loggerhead shrike; northern yellow bat; robust redhorse; yellow crowned night heron; painted bunting; gopher frog; many lined salamander; eastern mudminnow; (SC) Bachman's sparrow; barrel floater; spotted turtle; bluebarred pygmy sunfish; Carolina slabshell; striped mud turtle; pygmy sperm whale; yellow lampmussel; dwarf siren; Gulf coast mud salamander; eastern floater; black swamp snake; least tern; paper pondshell; eastern creekshell; (federally listed) red-cockaded woodpecker; American chaffseed; pondberry; Canby's dropwort; Kirtland's warbler; Bachman's warbler; eastern indigo snake; flatwoods salamander; wood stork; piping plover; west Indian Manatee; North Atlantic right whale; finback whale; humpback whale; Sei whale; blue whale; sperm whale; sea turtles; Atlantic sturgeon; shortnose sturgeon.	(CDFs); sediment control system; freshwater control system.	

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Environmental Impact Statement Appendix S: Essential Fish Habitat Evaluation US Army Corps of Engineers. January 2012. Environmental Impact Statement Appendix S: Essential Fish Habitat Evaluation. http://www.sas.usace.army.mil/Missions/Civil-Works/Savannah-Harbor-Expansion/Final-Environmental-Impact-Statement/	Chatham County, Georgia and Jasper County, South Carolina	(Snapper grouper) black sea bass; crevalle jack; sheepshead; gray snapper; lane snapper; (Coastal migratory pelagics) cobia; Spanish mackerel; (Shrimp) brown shrimp; white shrimp; pink shrimp; (Highly migratory species) Atlantic sharpness shark; blacknose shark; bonnethread shark; bull shark; dusky shark; finetooth shark; lemon shark; sandbar shark; sandtiger shark; scalloped hammerhead; spinner shark; (others) striped bass; bluefish; summer flounder.	Savannah National Wildlife Refuge; essential fish habitat.	Sea level rise
Environmental Impact Statement Appendix Y: Stakeholders Evaluation Group Summary Report US Army Corps of Engineers. January 2012. Environmental impact statement appendix Y: stakeholders evaluation group summary report. http://www.sas.usace.army.mil/Missions/Civil-Works/Savannah-Harbor-Expansion/Final-Environmental-Impact-Statement/	Chatham County, Georgia and Jasper County, South Carolina	Endangered shortnose sturgeon; striped bass.	N/A	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Final General Re-evaluation Report US Army Corps of Engineers. Revised July 2012. Final General Re-evaluation Report. http://www.sas.usace.army.mil/Portals/61/docs/SHEP/reports/GRR/SHEP_GRR_Exec_Summ_JUL_2012.pdf	Chatham County, Georgia and Jasper County, South Carolina	Striped bass; shortnose sturgeon.	City of Savannah's water treatment plant; Savannah National Wildlife Refuge; the New Savannah Bluff Lock and Dam; Striped bass spawning and nursery habitats; raw water impoundment	N/A
Decline and Potential Recovery of Striped Bass in a Southeastern U.S. Estuary Reinert T.R., C.A. Jennings, T.A. Will, J.E. Wallin. March 2005. Decline and potential recovery of striped bass in a southeastern U.S. estuary. Fisheries 3003: 18-25. http://www.tandfonline.com/doi/abs/10.1577/1548-8446%282005%2930%5B18%3ADAPROS%5D2.0.CO%3B2	The Savannah River estuary, Georgia–South Carolina	Striped bass (Morone saxatilis) and striped bass hybrids (crossed with white bass, M. chrysops).	N/A	N/A
Biological Assessment 2015/2016 Hilton Head Island Beach Renourishment Project Town of Hilton Head Island, SC. October 2014. Biological Assessment 2015/2016 Hilton Head Island Beach Renourishment Project.	The Town of Hilton Head Island, SC	Listed species: piping plover; rufa red knot; loggerhead sea turtle; green sea turtle; Kemp's ridley sea turtle; leatherback sea turtle; least tern; shortnose sturgeon; West Indian manatee.	Beach shorelines and shoals	Sea level rise; Arctic warming; increased frequency and severity of asychronies in the timing of annual migrations for endangered species;

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Distribution of Shortnose Sturgeon in the Lower Savannah River Collins, M.R., W.C. Post, and D.C. Russ. 2001. South Carolina Department of Natural Resources. http://www.shep.uga.edu/docs/Wildlife%20and%20Fisheries/Distribution%20of%20Shortnose%20Sturgeon%20in%20the%20Lower%20Savannah%20River.pdf	Lower Savannah River	Shortnose sturgeon (Acipenser brevirostrum), especially juveniles.	Kings Island Turning Basin (KITB); Middle River; Front River; Back River.	N/A
Characteristics of the Adult Segment of the Savannah River Population of Shortnose Sturgeon Collins, M.R. and T.I.J. Smith. 1993. Characteristics of the adult segment of the Savannah River population of shortnose sturgeon. Proc. Annu. Conf. SEAFWA 47:485-491	The Savannah River	Shortnose sturgeon (Acipenser brevirostrum).	Impoundments; the New Savannah Dam near Augusta, GA; two major nuclear facilities; heavily industrialized port and harbor area of the city of Savannah.	N/A
Wetland/Marsh Impact Evaluation February 2007. http://www.sas.usace.army.mil/Portals/61/docs/SHEP/Reports/GRR/37%20Wetland%20Marsh%20Impact%20Evaluation%20February%202007.pdf		This report is not summarized. It is part of the results of the wetland/marsh EFDC modeling and focuses on the effect of deepening the navigation channel on the salinity values throughout the marshes linked		

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
		to the estuary. No wildlife information is provided.		
Evaluation of Juvenile Shortnose Sturgeon (Winter) Habitat Impacts with Proposed Mitigation Plan March 9, 2011. http://www.sas.usace.army.mil/Portals/61/docs/SHEP/Reports/GRR/53%20Juvenile%20SNS%20Win%20Habitat%20Impacts%20w_Prop%20Mitigation%20Plan%20Mar11.pdf		This report is an addendum to the report titled Evaluation of Fishery Habitat Impacts with Proposed Mitigation Plan included in the Draft GRR and EIS documents. This document provides habitat suitability impact predictions for juvenile Shortnose Sturgeon in January due harbor deepening and mitigation using the revised habitat suitability criteria.		
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.	The Southeast and Caribbean	Coral reefs.	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.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
http://nca2014.globalchange.gov/report/regions/southeast				
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.
Draft Biological Assessment of Threatened and Endangered Species (BATES) for Maintenance Dredging Atlantic Intracoastal Waterway (AIWW) November 2015. Draft Dredged Material Management Plan Atlantic Intracoastal Waterway. Appendix B: Biological Assessment of Threatened and Endangered Species (BATES). http://www.sas.usace.army.mil/Portals/61/docs/Planning/Plansandreports/AIWW/2016/Appendix%20B%20BATES%20-%20AIWW%20-%20Nov%202015.pdf		This report is not summarized due to the volume.		

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Elba Island Expansion Project Environmental Assessment Federal Energy Regulatory Commission (FERC). February 2003. Elba Island Expansion Project Environmental Assessment. http://infohouse.p2ric.org/ref/36/35525.pdf	Elba Island in Chatham County, Georgia	This report is not summarized due to lower priority in the date.		
Evaluation of Shortnose Sturgeon Spawning Habitat, Savannah River, Georgia and South Carolina U.S. Army Corps of Engineers, Savannah District (USACE). September 2010. Evaluation of Shortnose Sturgeon Spawning Habitat, Savannah River, Georgia and South Carolina. Dial Cordy and Associates Inc. Jacksonville Beach, Florida. http://www.sas.usace.army.mil/Portals/61/docs/Planning/Plansandreports/SNS%20Spawning%20Habitat.pdf	Savannah River	This report is not summarized due to limited time.		

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)[9]
- A species with a NatureServe global imperilment rank of G1, G2, or G3[10]
- 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 [11]

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.

EPA: Environmental Protection Agency

[9] 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)

[10] 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)

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

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: is 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

SWAP: State Wildlife Action Plan

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.