Coastal Resilience Assessment of the Delaware Bay and Coastal Watersheds

NFWF

NatureServe

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Cover Image: Cape May Point State Park, New Jersey

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Abstract

The Delaware Bay and Coastal Watersheds Coastal Resilience Assessment focuses on identifying areas of open space where the implementation of restoration or conservation actions could build human community resilience and fish and wildlife habitat in the face of increasing storms and flooding impacts. The study is important to the coastal areas of Delaware and southern New Jersey since both areas have large expanses of low-lying areas adjacent to coastal rivers, the Delaware Bay, and the Atlantic Ocean. In recent years, the area has experienced extensive damage to human assets from episodic and chronic flooding events. Human assets are also damaged due to land loss as a result of exposure to high wave energy and high levels of erosion around the Maurice River and other river systems in the area.

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

As part of the assessment process, 30 resilience-related project ideas were submitted through the stakeholder engagement process, of which two are described in detailed case studies in this report. In addition, a third case study features the mouth of the Maurice River, which represents four of the projects submitted. The case studies illustrate how proposed actions could benefit fish and wildlife habitat and human communities that face coastal resilience challenges such as storm surge during extreme weather events.

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

Executive Summary

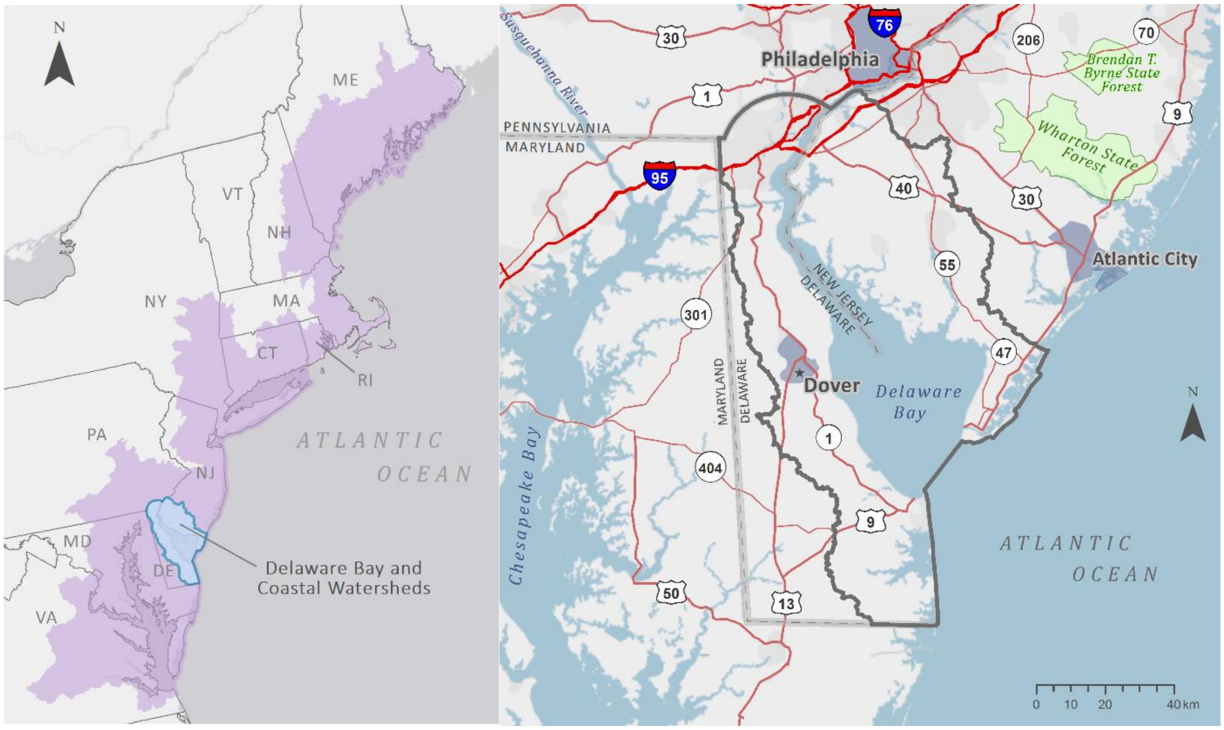
In response to increasing frequency and intensity of coastal storm events, the National Fish and Wildlife Foundation (NFWF) is committed to supporting programs and projects that improve community resilience by reducing communities' vulnerability to these coastal storms, sea-level rise, and flooding through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

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

This assessment focuses on the Delaware Bay and Coastal Watersheds in Delaware and New Jersey, including some adjacent watersheds to cover all of coastal Delaware. 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.

Delaware Bay and Coastal Watersheds

The Delaware River drains into Delaware Bay. Its expansive watershed includes parts of New Jersey and Delaware as well as much of eastern Pennsylvania and a small section of New York State. However, for the purposes of this assessment, the study area is limited to the immediate watersheds of coastal and bay waters of Delaware and southern New Jersey through Cape May (see figure below for map). The upland region of the study area is primarily composed of agricultural and forest lands. Closer to the Bay there are extensive tidal and non-tidal wetland areas that not only provide important fish and wildlife habitat but are also home to over one million people (Partnership for the Delaware Estuary 2017). The Delaware side of the study area is more densely populated than the New Jersey side, though both areas contain extensive forested and agricultural areas. The City of Wilmington, Delaware is the most populous city within the study area, with significant sections of the city built on fill near sea level that is protected by aging infrastructure. This leaves the city vulnerable to extreme storm scenarios and future sea level rise. The area considered in this assessment also includes three hydrological sub-basins adjacent to Delaware Bay.



Location and boundary of the Delaware Bay and Coastal Watersheds study area*. The map on the left shows the watershed in the context of the North Atlantic Coast Regional Assessment area (purple). In the map on the right, the study area is shown in detail bounded by the dark gray line.*

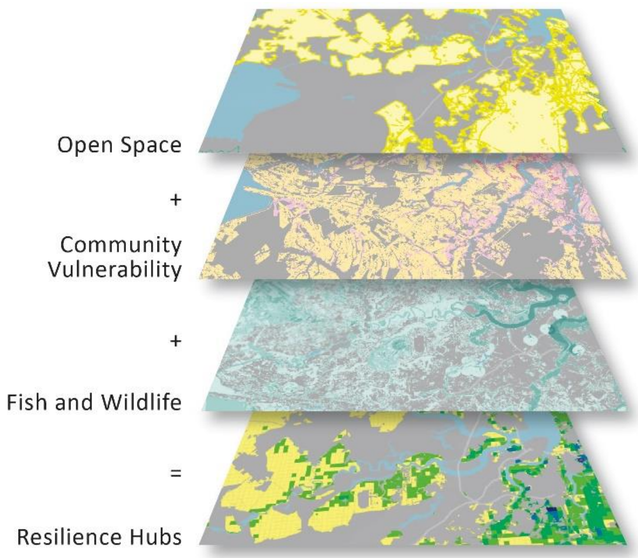
Assessment Objectives

The objectives of this assessment were to:

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

Assessment Approach

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



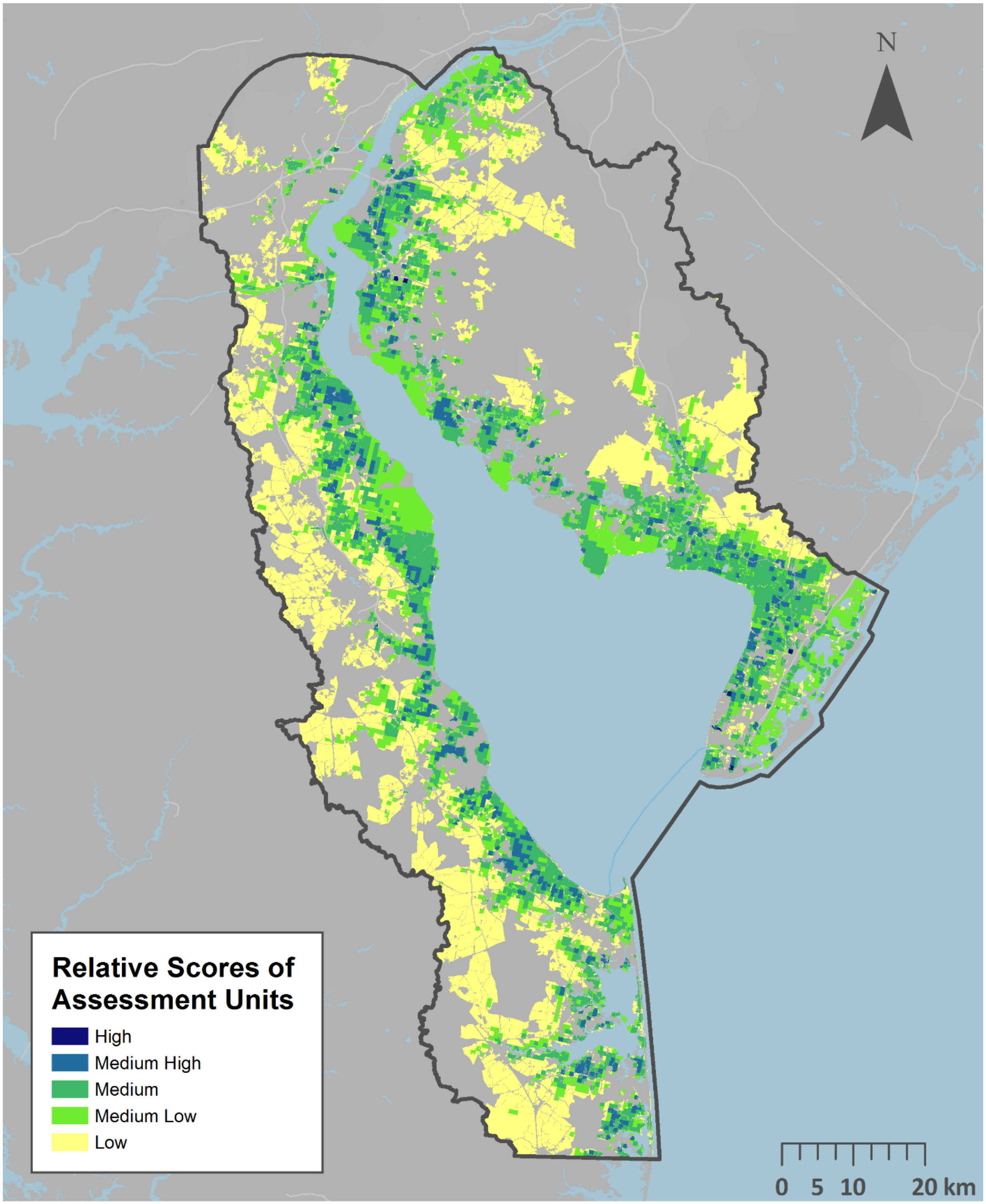
***Left**: Diagram of the overall approach of this assessment.* *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas in proximity to HCAs with high vulnerability **and** high fish and wildlife richness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

Results

Resilience Hubs

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

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



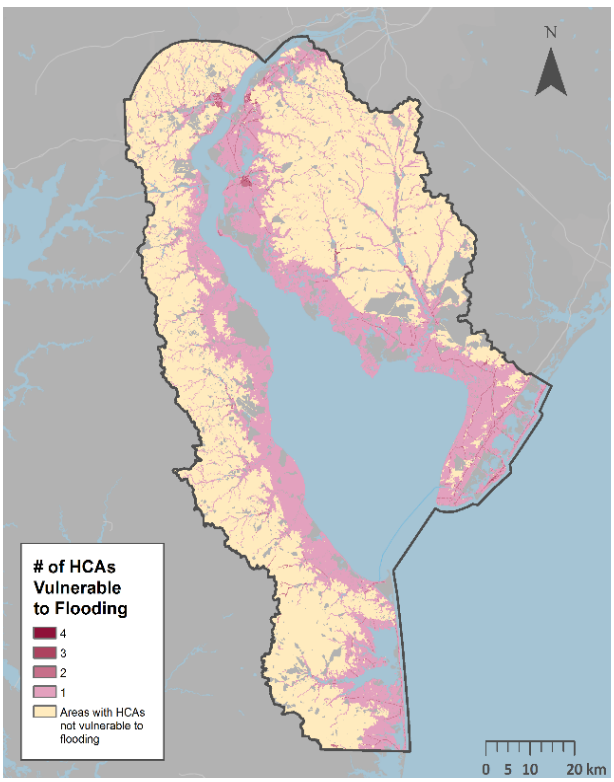
Resilience hubs assessment unit scores for the Delaware Bay and Coastal Watersheds*. Assessment units are 100-acres grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieve both community resilience and fish and wildlife benefits. Gray areas are outside of Hubs.*

Community Vulnerability

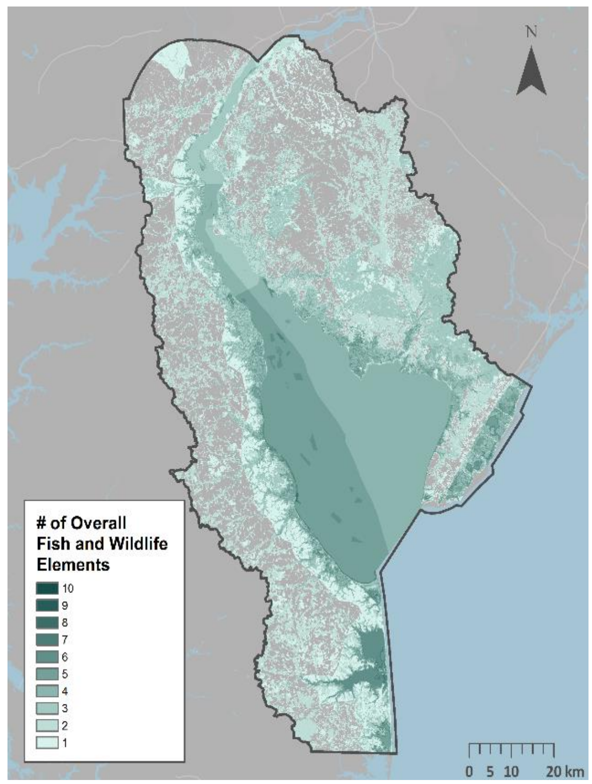
The Community Vulnerability Index (see map below) accounts for approximately half of the scoring of the Resilience Hubs. This index communicates threats to human community assets wherever they occur as well as concentrated areas of threat. Vulnerability is highest in the immediate coastal areas where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

Fish and Wildlife

A total of 26 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. The differences in richness within the Bay are a factor of element input map differences between Delaware and New Jersey so element richness in the Bay should be assumed to be more uniform than depicted.



Community Vulnerability Index for the Delaware Bay and Coastal Watersheds*. 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 Delaware Bay and Coastal Watersheds*. Green shades indicate the number of elements found in a location. Gray areas within the project boundary have no mapped fish or wildlife elements considered in this assessment.*

Resilience Projects

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

- Case Study 1: Port Mahon Road and Kelly Island Restoration Project and Plan
- Case Study 2: South Wilmington Wetland Park
- Case Study 3: Mouth of Maurice River Resilience Projects

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

Products may be used to:

1. Assist funders and agencies to identify where to make investments in conservation and restoration practices to achieve maximum benefits for human community resilience and fish and wildlife.
2. Inform community decisions about where and what actions to take to improve resilience and how actions may also provide benefits to fish and wildlife.
3. Distinguish between and locate different flooding threats that exist on the landscape
4. Identify vulnerable community assets and the threats they face
5. Identify areas that are particularly rich in fish and wildlife species and habitats

6. Understand the condition of fish and wildlife where they are exposed to environmental stressors and how that condition may be impacted by flooding threats.
7. Inform hazard planning to reduce and avoid exposure to flooding threats.
8. Jump start additional assessments and planning using the decision support system.

Introduction

Background

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

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

Regional Assessment

Developed through a separate but similar effort, the Regional Assessment (Dobson et al. 2019) explored resilience in five geographic regions of the conterminous United States (**Figure 1**) and aimed to identify areas where habitat restoration, installation of natural and nature-based features (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.

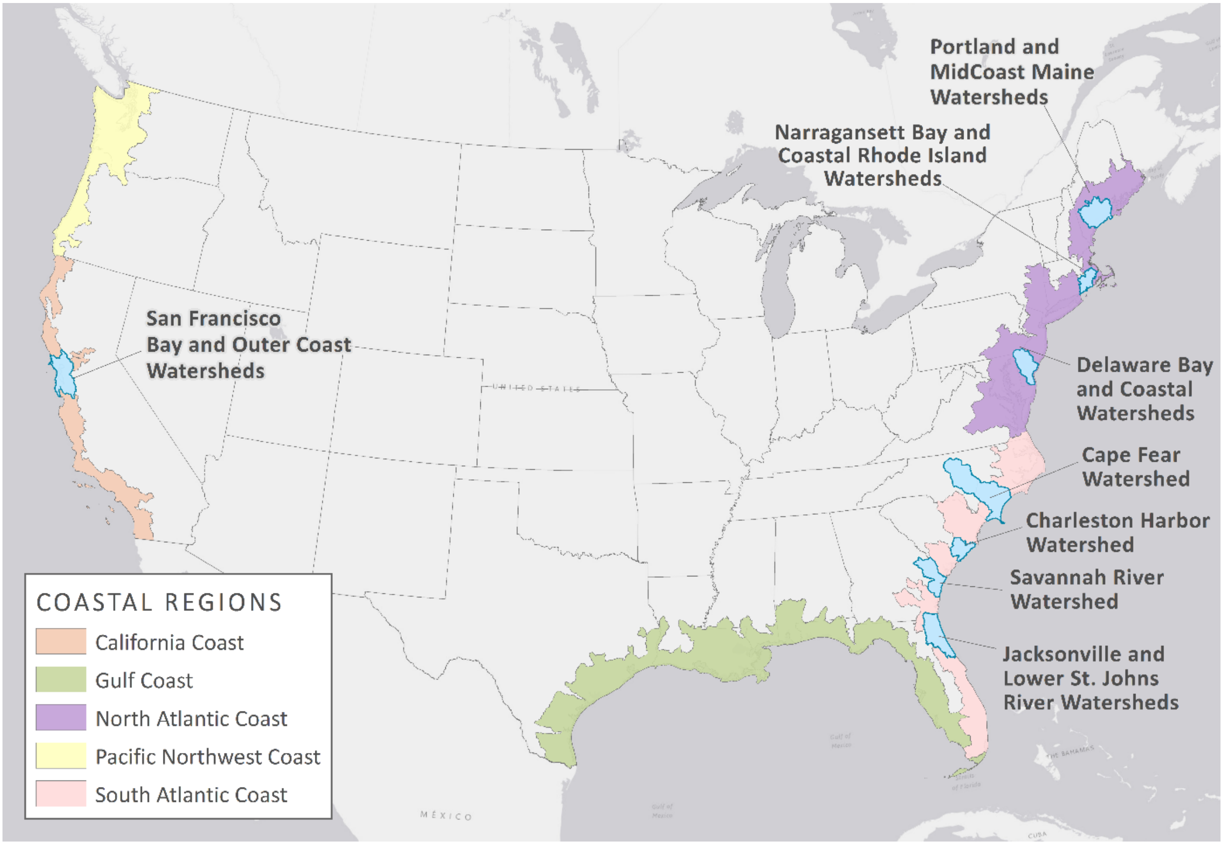


Figure 1. Map showing study areas for the Regional and Targeted Watershed Assessments. *The broad Regional Assessment included five coastal regions. High resolution resilience assessments were carried out in eight coastal Targeted Watershed Assessment study areas (in blue); the Cape Fear Watershed was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

Targeted Watershed Assessments

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

Resilience Hubs

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

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

Targeted Watershed Assessment Objectives

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

Assessment Products

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

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

Application of the Assessment

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

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

Delaware Bay and Coastal Watersheds

The Delaware Bay and Coastal Watersheds study area includes the entire lower Delaware Bay drainage area in New Jersey and Delaware, in addition to the Atlantic coastal regions of Delaware and southern New Jersey (**Figure 2**). The Delaware River itself provides drinking water to five percent of the population of the United States (Kauffman 2016). Dover and Wilmington, Delaware, and the suburbs of Philadelphia, Pennsylvania are the most densely populated portions of the study area, though there are also pockets of heavy tourist infrastructure and coastal development along the Delaware and New Jersey coasts along the Atlantic Ocean. Based on population estimates of the counties within the study area, the population is well over one million, although 8.5 million live in the entire Delaware River watershed (which includes portions of Pennsylvania and New York State). The region has a diverse economy that includes agriculture, tourism, military installations, medical facilities, and manufacturing. Much of the economy in the area is reliant on the economic value of nature, from forestry operations to tourism and recreation (Kauffman 2016). The Port of Wilmington is within the study area and is the first major port along the Delaware River; other larger ports upstream within the Delaware River watershed are outside of the study area.

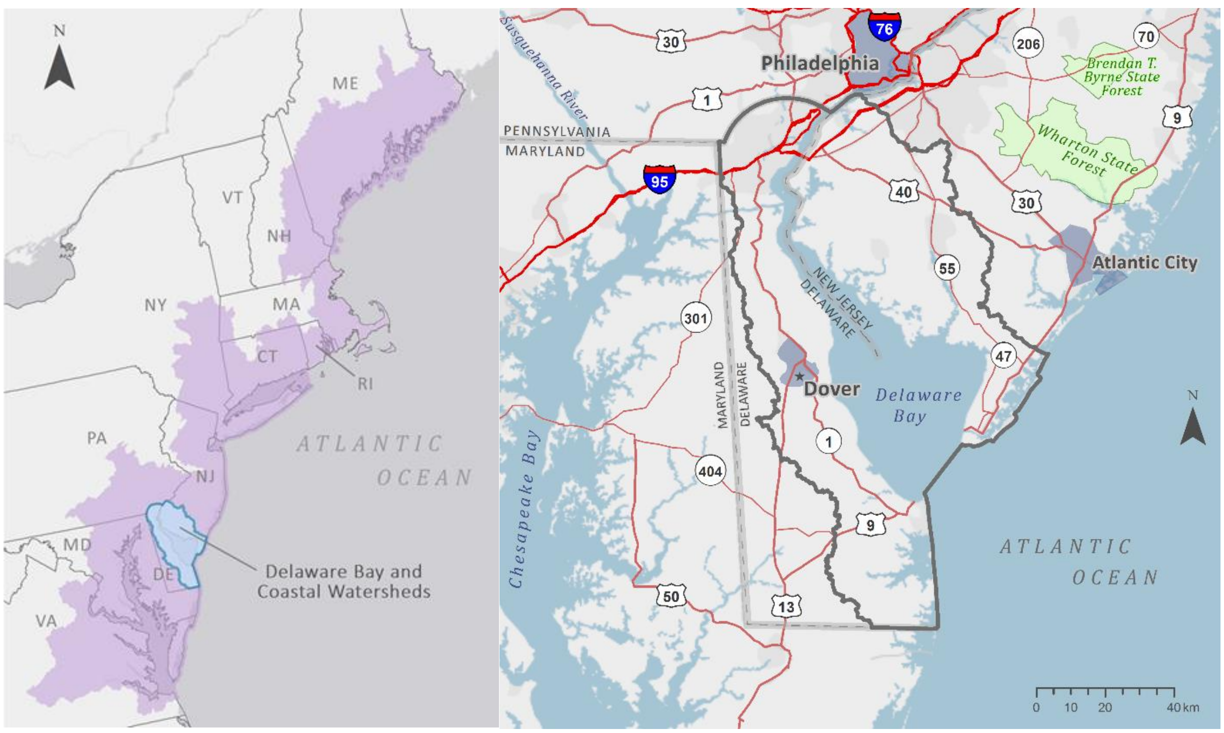


*Figure 2. **Location and boundary of the Delaware Bay and Coastal Watersheds study area.** The map on the left shows the watershed in the context of the North Atlantic Coast Regional Assessment area (purple). In the map on the right, the study area is shown in detail bounded by the dark gray line.*

The boundary of the watershed follows those of the three United States Geological Survey (USGS) level 4 hydrological units[1] adjacent to Delaware Bay. The dominant watershed feature is Delaware Bay, the estuary outlet of the Delaware River. The headwaters of the Delaware River originate in New York State, and the river ultimately drains over 14,000 square miles of land.

Although the river itself runs through several inland ecoregions, the study area is mainly situated in two ecoregions: the North Atlantic Coast and the Chesapeake Bay Lowlands. The Delaware River has flooded repeatedly during hurricanes and other high precipitation storm events due to a combination of riverine flooding and storm surge. According to the latest State of the Estuary Report (Partnership for the Delaware Estuary 2017), there has been a statistically significant increase in the days of unusually high precipitation within the Delaware Bay area, and current predictions indicate that this trend is likely to continue.

The Delaware Bay contains extensive areas of tidally influenced marsh habitat, both within the Bay itself and in the parts of the study area that front the Atlantic Ocean. In addition to native-dominated tidal marshes, there are large extents of the invasive exotic common reed, which is estimated to cover over 1/3 of the tidal wetlands along the U.S. Atlantic Coast. The rich complex of high-quality tidal habitats also supports nursery habitat for commercially important species, especially crabs and bivalves, as well as iconic birds such as great blue herons and egrets. Inland areas include both forested wetlands and upland hardwood forests (as well as small patches of Atlantic white cedar forest) harboring a diverse array of fish and wildlife species. Also located within the study area are critical beach and wetland habitats along the Delaware Bay that constitute one of the most important migratory bird stopovers along the Atlantic Flyway.

Historic Impacts from Flooding

The Delaware River Basin Commission (DRBC) maintains records on historic flooding of the Delaware River and adjacent parts of the Bay. Their records show a long history of severe flooding along the river caused by extreme rain events and impacts from storm surge along the Atlantic Coast and the Bay itself.

Significant floods have occurred in the last several decades although an approximate 40-year period between 1955 and 2004 experienced more drought than flooding[2]. A serious flood in August 1955 was one of the primary reasons for creation of the DRBC in 1961. According to the DRBC[2] "In September 2004, April 2005, and June 2006, three major floods caused devastation along the main stem Delaware River, repeatedly damaging property and disrupting tens of thousands of lives. These were the worst floods to occur on the main stem since August 1955 (which is still considered the flood of record in the Delaware River Basin). The last known occurrence of three main stem floods of comparable magnitude within so short a time span was the period from March 1902 to March 1904."

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

[2] Delaware River Basin Commission https://www.state.nj.us/drbc/programs/flood/.

According to the latest State of the Estuary Report (Partnership for the Delaware Estuary 2017), there has been a statistically significant increase in the days of unusually high precipitation within the Delaware Bay area, and current predictions indicate that this trend is likely to continue. In particular, the low elevation of extensive areas around the bay will be increasingly threatened by sea level rise as well as storm-induced flooding with rising sea levels extending the range and impact of flooding events (Partnership for the Delaware Estuary 2017).

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 land or unprotected privately owned lands), Human Community Vulnerability, and Fish and Wildlife Species and Habitats. Bringing these data together generated many useful assessments, which culminated in the mapping and scoring of Resilience Hubs.

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

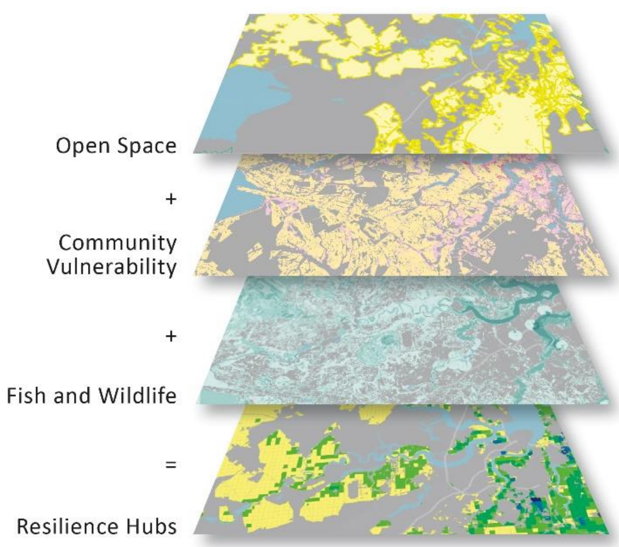


Figure 1. Diagram of the overall approach of this assessment. *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas with high HCA vulnerability and high fish and wildlife richness are mapped as Resilience 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

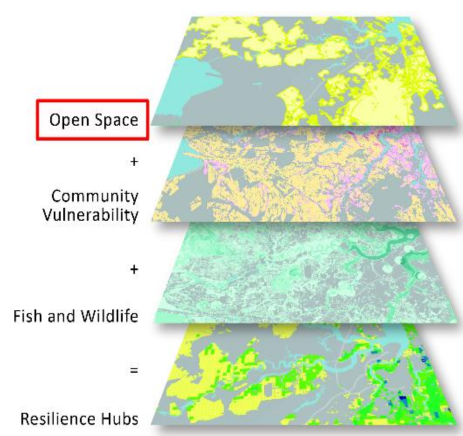
A fundamental part of this Targeted Watershed Assessment was to engage and work with individual and organizational stakeholders and partners within the Delaware Bay and Coastal Watersheds. Stakeholder involvement can improve the quality of decisions and policy—especially in the context of complex environmental and social challenges (Elliott 2016, Reed 2008). The stakeholder engagement process for the Delaware Bay and Coastal Watersheds 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 Delaware Bay and Coastal Watersheds Committee was formed consisting of local experts from the National Oceanic and Atmospheric Administration (NOAA), Partnership for the Delaware Estuary, New Jersey Department of Environmental Protection, U.S. Fish & Wildlife Service, 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 90 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 1** above is repeated, identifying in red outline the component being described in relation to the other three components.



Open Space

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

Mapping Open Space

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

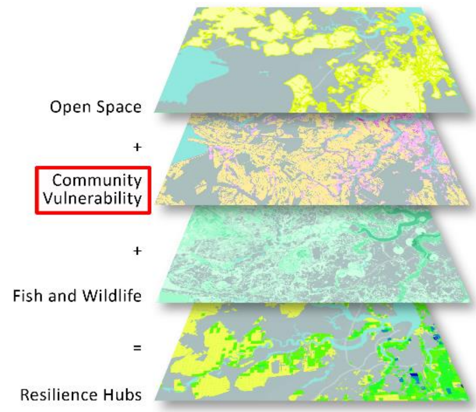
1. Protected areas, which are defined as lands that are part of the USGS Protected Areas Database of the United States (PAD-US).
2. Unprotected privately owned lands with contiguous habitat, as identified from the USGS National Land Cover Database (NLCD). The open space areas were further processed to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

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

1. Protected areas were augmented with local The Nature Conservancy (TNC) data on protected properties. All protected area polygons were intersected with the Resilience Hubs as identified in the Regional Assessment to distinguish protected from unprotected areas.
2. Hubs with shorelines (rivers or coastal) were supplemented with the National Hydrography Dataset (NHD) to include waters within a 50-meter (164 feet) buffer to add nearshore habitat areas that could provide locations for aquatic resilience projects such as oyster reefs or marsh protection/restoration.
3. Impervious surfaces were deleted from the Hubs using the National Land Cover Database (Homer et al. 2011) and Topologically Integrated Geographic Encoding and Referencing (TIGER) roads data (U.S. Census 2016). The removed areas might be protected, but have pavement or structures in place that would limit restoration actions.
4. Tracts that were less than five acres (mostly slivers resulting after deleting impervious surfaces and splitting polygons) were removed from consideration. For the purposes of this assessment, areas under this threshold were assumed to have significantly less potential for improving community resilience or supporting fish and wildlife in meaningful, measurable terms.

Community Vulnerability

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



Human Community Asset Weighted Richness Index

For the purposes of this assessment, Human Community Assets (HCAs) data were selected to represent: 1) critical infrastructure and facilities essential for community recovery post-storm event, 2) areas of dense human population, and 3) socially vulnerable populations. They are not intended to be comprehensive; for example, not all roads are included and instead focus on storm escape routes. The Regional Assessment identified a suite of HCAs that were used in this Targeted Watershed assessment. The selected HCAs are defined below (see also the Regional Assessment Report [Dobson et al. 2019]). **Table 1** (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 of infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.).	0.2
Critical Infrastructure (Rank 2)	**Medium** spatial concentration of infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.).	0.4
Critical Infrastructure (Rank 3)	**High** spatial concentration of infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.)	0.6
Critical Infrastructure (Rank 4)	**Very High** spatial concentration of infrastructure (i.e., dams, evacuation routes, water treatment plants, energy plants, etc.)	0.8
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[3] 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 summarized below and illustrated in **Figure 4**. Additional details and assumptions in their use in the vulnerability assessments is provided in Appendix 2.

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

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

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

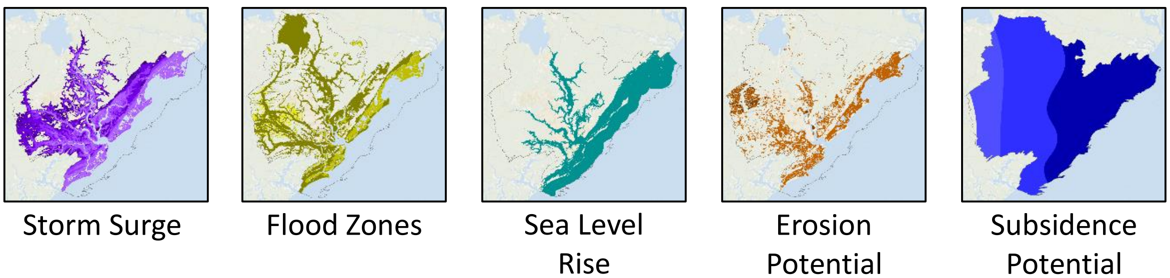


Figure 4. Flooding threats used to assess community vulnerability. *Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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 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 five feet of sea level rise. 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.

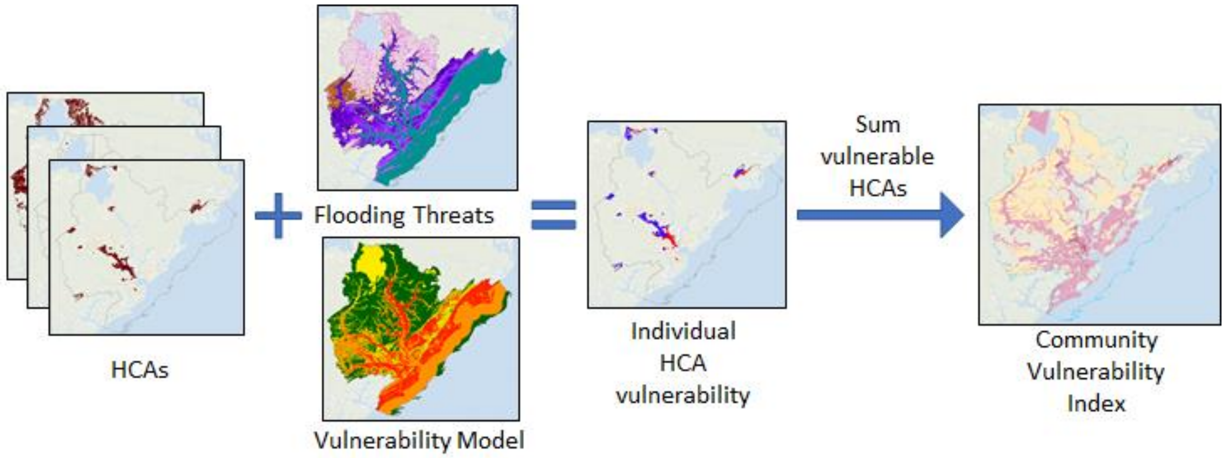
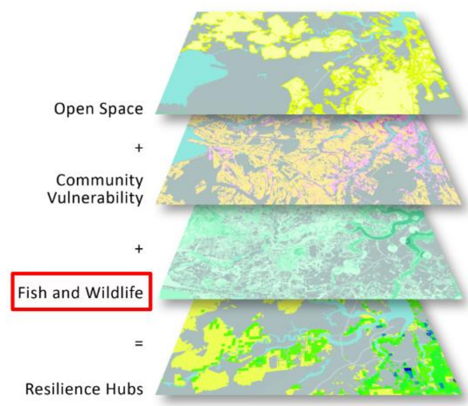


Figure 5. Community vulnerability assessment process. *Human Community Assets (HCAs) are intersected with the flooding threats, a vulnerability model is applied, and individual HCA results are summed to create the Community Vulnerability Index. Diagram represents the Charleston, SC region as an example 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 Hubs characterization and scoring used in the Targeted Watershed Assessment (see section below): 1) a Fish and Wildlife Richness Index, and 2) a Fish and Wildlife Condition-Weighted Index. Though not used directly in the hub prioritization, a Fish and Wildlife Vulnerability Index was also conducted and is likely to be of significant interest to stakeholders wanting to extend or further explore coastal resilience and fish and wildlife vulnerability. The Fish and Wildlife Vulnerability Index is described in Appendix 4.

Selection of Fish and Wildlife Elements

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

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

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

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

- A NOAA Trust Resource[4]
- A formally recognized at-risk species based on its inclusion in one of the following categories at the time of this assessment including:
    - A species listed as ‘endangered’, ‘threatened’, or ‘candidate’ under the provisions of Endangered Species Act (ESA)[5]
    - A species with a NatureServe global imperilment rank of G1, G2, or G3[6]
    - A species with a NatureServe state imperilment rank of S1, S2, or S3
    - A State Species of Greatest Conservation Need (SGCN) as recorded in current State Wildlife Action Plans
- A distinctive ecological system or species congregation area that represents habitat important to at-risk species and/or species of significance to stakeholders in the region. Examples might

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

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

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

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

Current fish and wildlife stressors were identified during stakeholder workshops and available data were identified to represent each. These stressors include land use and infrastructure, roads, 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.

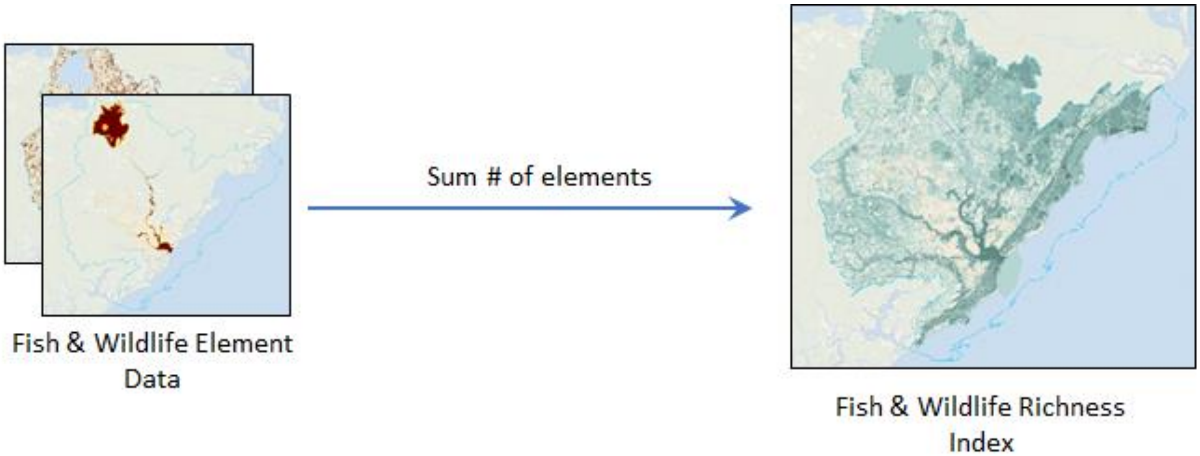


Figure 7. Method for generating the Fish and Wildlife Richness Index. *All elements are overlaid and the sum of elements occurring in a location is calculated. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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.

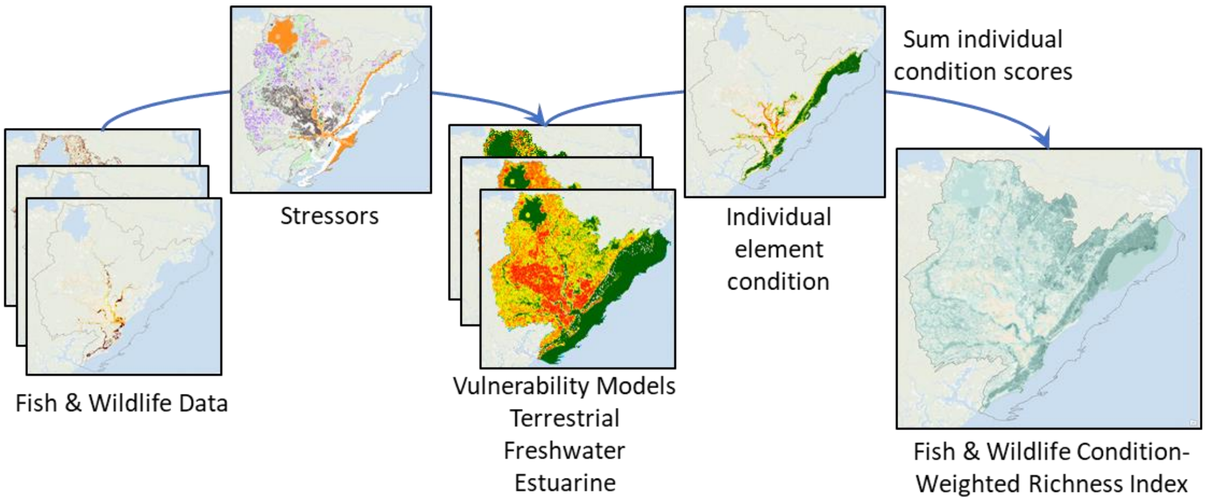
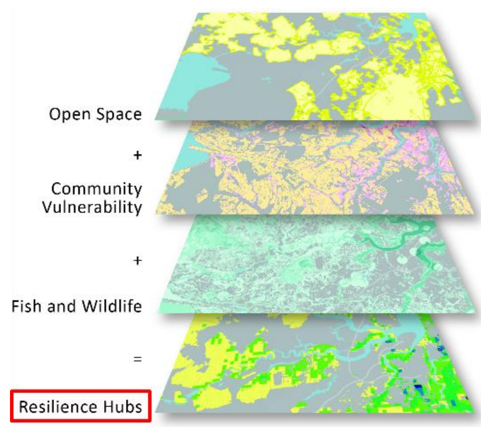


Figure 8. Method for generating the Fish and Wildlife Condition-Weighted Richness Index. *Fish and wildlife elements are intersected with stressors, the vulnerability model is applied, and individual element condition results are summed. Diagram represents the Charleston, SC region as an example and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

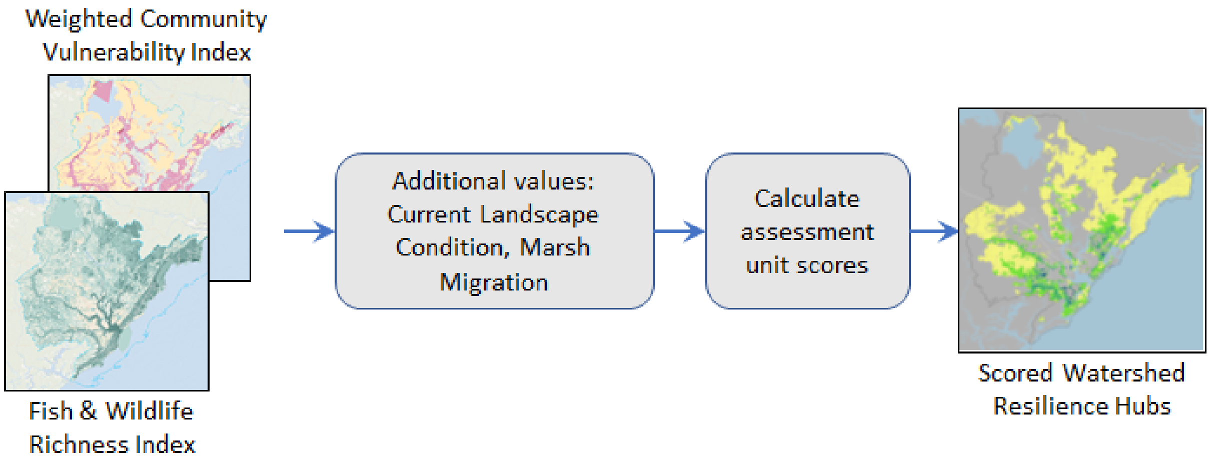


Figure 9. Method for scoring watershed Resilience Hubs. *Resilience Hub assessment units were scored based on their community resilience and fish and wildlife. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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. The index has a value of zero if the HCA Flooding Threats Exposure Index is zero, otherwise it is the value from the HCA Weighted Richness. Focal statistics were used to summarize this combined map using a 1km (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 scores the value of an assessment unit based on the average current condition as modeled from the existing fish and wildlife stressors as well as its protection status. Scores the value of an assessment unit based on the average.
    - The protected areas assessment units are of interest for ***restoration*** to improve the viability of elements within them (as they are already protected from conversion to more intensive uses). Therefore, they were scored as:

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

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

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

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

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

Resilience Projects

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

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

- Calculated size in acres: The size in acres of the polygon representing the project area. Alternatively, submitters could enter an estimated size if project boundaries had not been developed.
- Alignment with NOAA's mission, programs, and priorities
- Alignment with USACE's mission, programs, and priorities
- Addressing stressors and threats mapped in the project polygon
- Project addresses the main threats: Assessed by comparing the list of threats to the proposed actions of the project
- Project proximity to a resilience hub: A Yes/No indicator for whether the project falls within 1 km (0.62 mi) 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

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

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

Results

This section portrays the key set of products primarily focused on the resulting Resilience Hubs and key indices. Many map and tabular products were generated for this Targeted Watershed Assessment. In addition to this report, key results may be viewed in the Coastal Resilience Evaluation and Siting Tool (CREST), which is an interactive online mapping tool that includes results for this Regional Assessment and each of the eight Targeted Watersheds (available at resilientcoasts.org). CREST can also be used to download data including the Delaware Bay and Coastal Watersheds NatureServe Vista decision support project, 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 Delaware Bay and Coastal Watersheds. The Threats Index used in the Regional Assessment is a combination of the number and probability of occurrence of the flooding threats in each location (see Dobson et al. 2019 for more information).

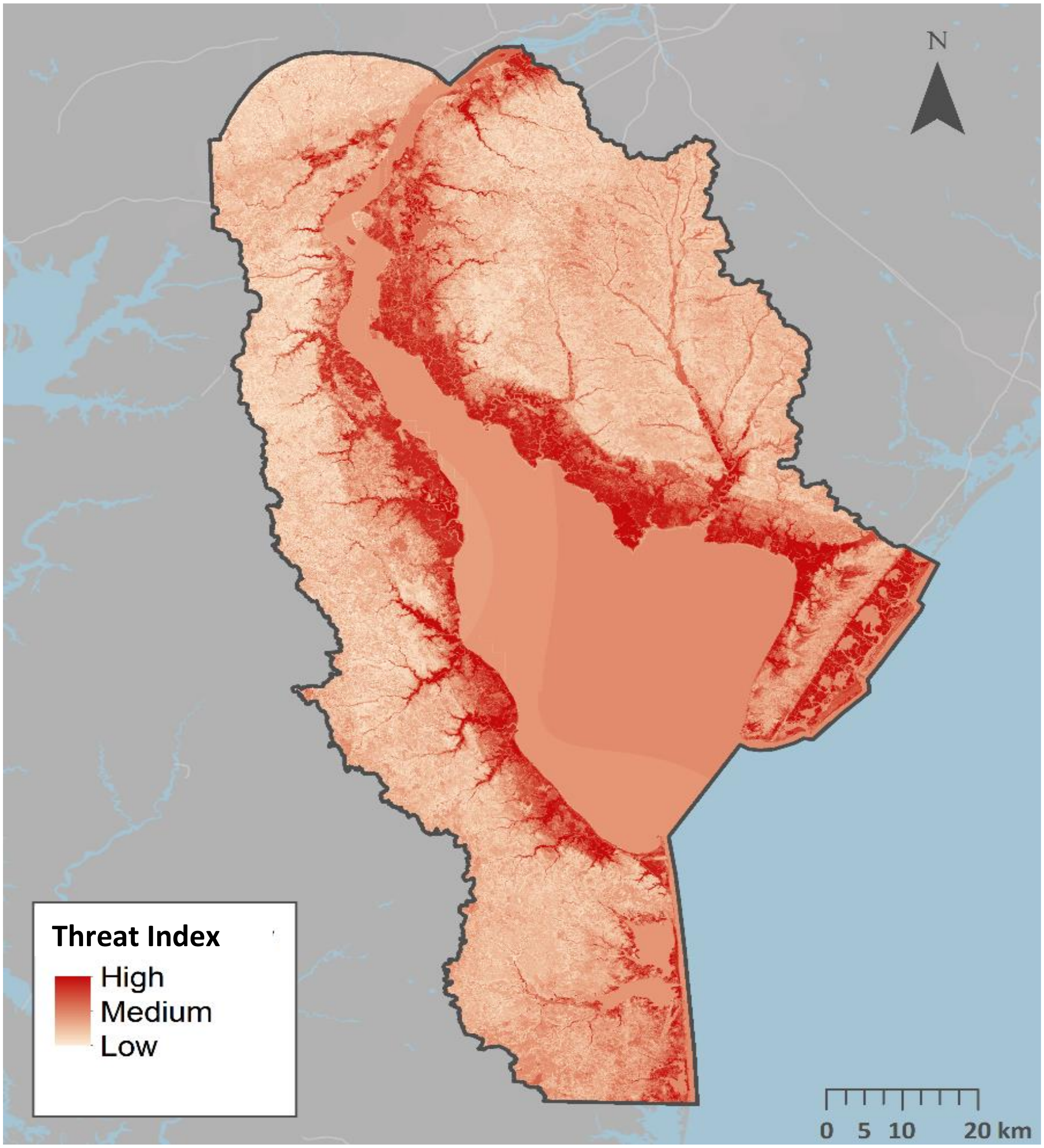


Figure 10. Weighted Threat Index for the Delaware Bay and Coastal Watersheds. *Map shows the number of overlapping threats modified by a weighting based on their probability of occurrence.*

Suggested Uses

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

Human Community Assets

HCA Weighted Richness Index

This index indicates areas of HCA concentrations (**Figure 11**). Darker shades can be an indication of overlapping HCAs, higher or lower importance weightings, or both. The rural character of the Delaware Bay and Coastal Watersheds is evident from the predominance of light shaded area, although some urban centers, particularly Wilmington, DE, are clearly observable as the darker-shaded areas.

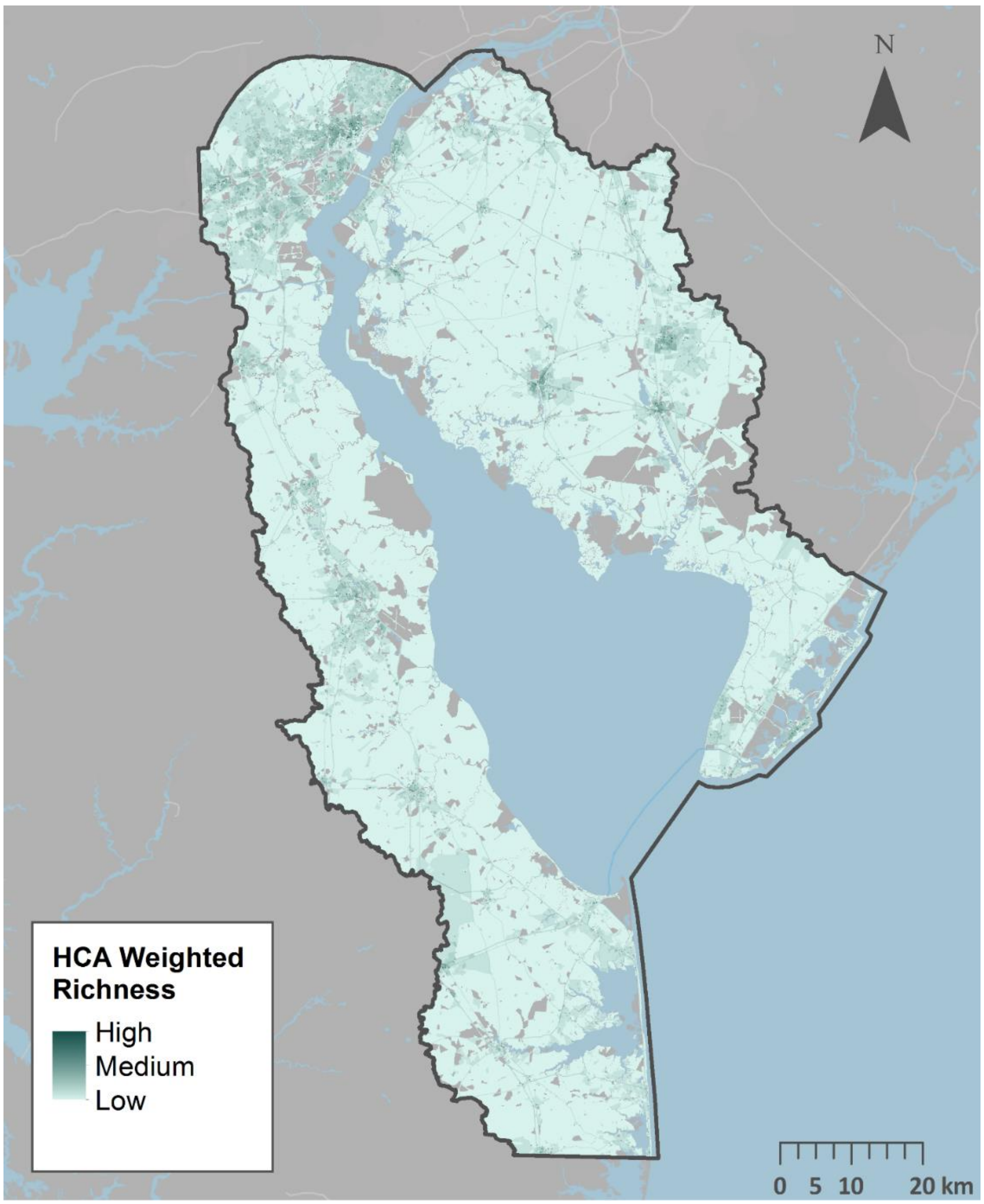


Figure 11. Human Community Asset (HCA) Weighted Richness Index for the Delaware Bay and Coastal Watersheds*. Darker shades indicate higher value based on the number and importance weightings of HCAs in each location. Gray areas within the project boundary represent areas with no mapped HCAs.*

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**).

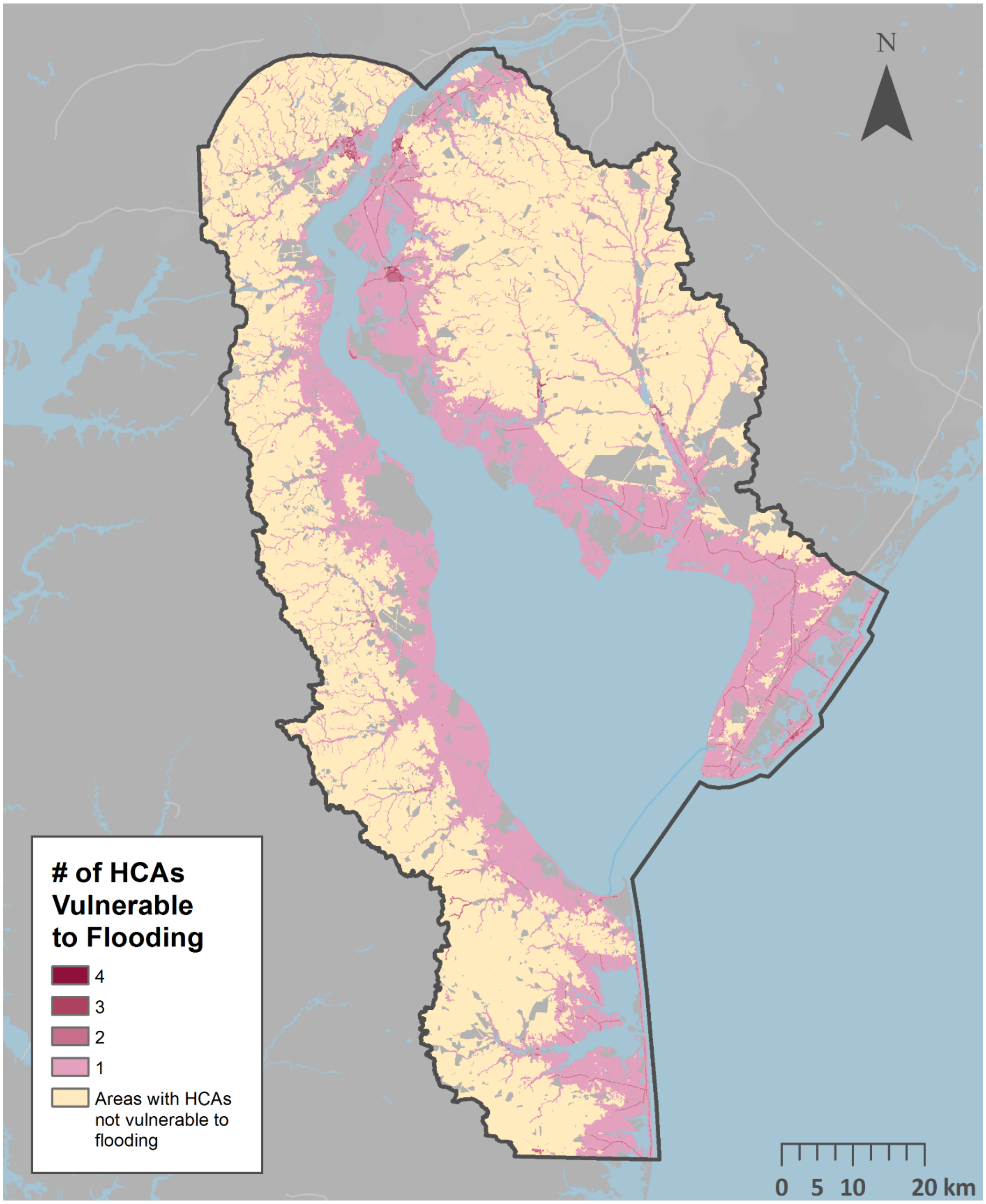


Figure 12. Community Vulnerability Index results for the Delaware Bay and Coastal Watersheds. *Pink to red shades indicate the number of Human Community Assets (HCAs) exposed to threats. Tan areas indicate areas of low to no impact from the flooding threats. Gray within the project boundary represents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

The entire coastal and Bay shoreline areas are vulnerable to a variety of flooding threats but are particularly susceptible to storm surge and sea level rise. Vulnerability is highest 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) along stream courses. Areas of Wilmington, DE along the Christina (dark red area at top of map on west side of Delaware River) and Maurice rivers and Penns Grove (across the river from Wilmington) and Salem, NJ (dark spot south of Penn's Grove on east side of river) are hotspots of vulnerability. Outer coastal areas like Wildwood, NJ are also vulnerable due to high exposure to storms and sea level rise. Fortunately, the coast along much of this watershed contains extensive beaches and wetlands that currently provide some buffering from storms. Protecting these areas and restoring other beaches and wetlands may provide resilience-building opportunities.

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).

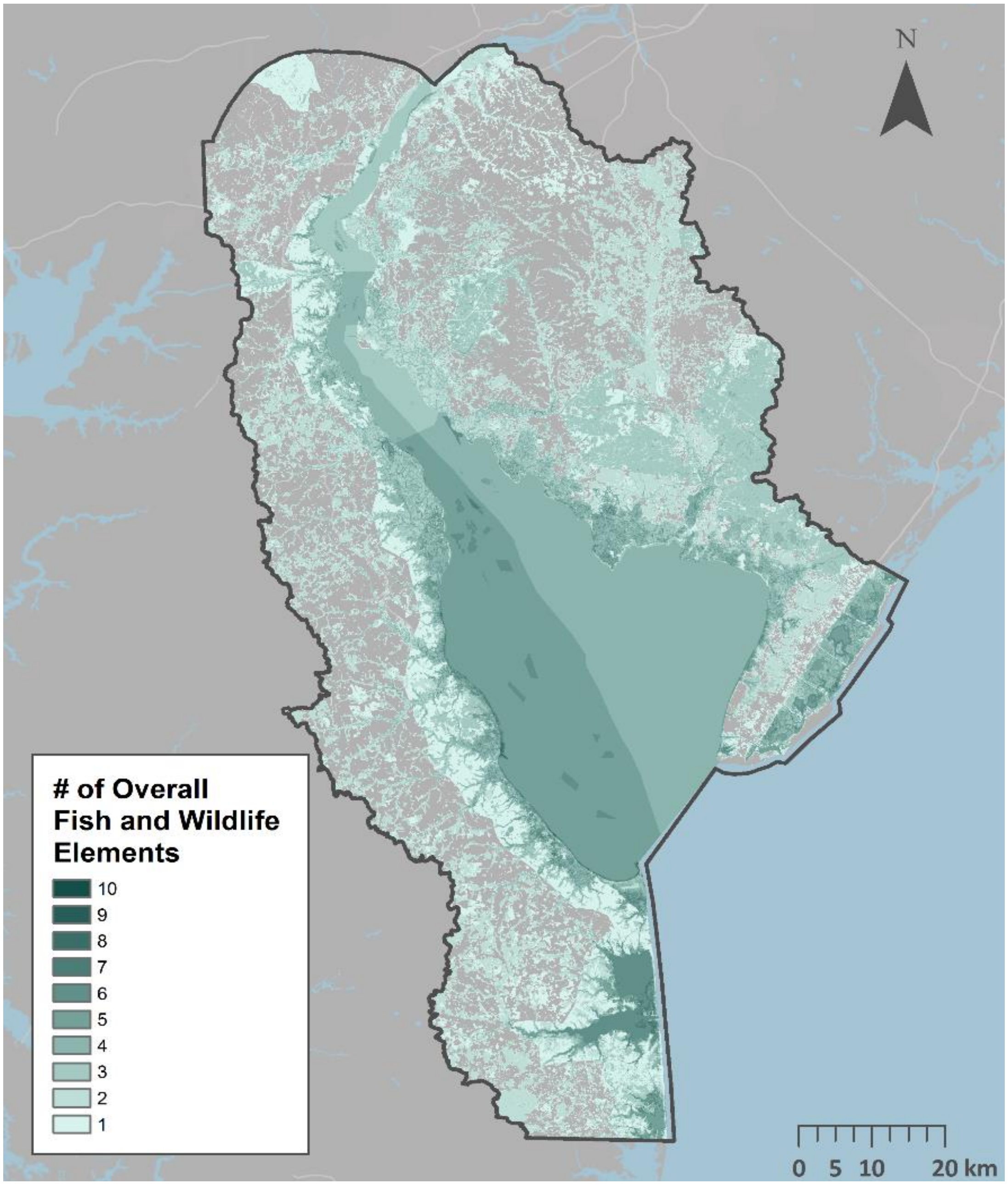


Figure 13. Richness of fish and wildlife elements in the Delaware Bay and Coastal Watersheds. *Green shades indicate the number of elements found in a location. Gray within the project boundary are areas with no fish and wildlife elements considered in this assessment.*

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.

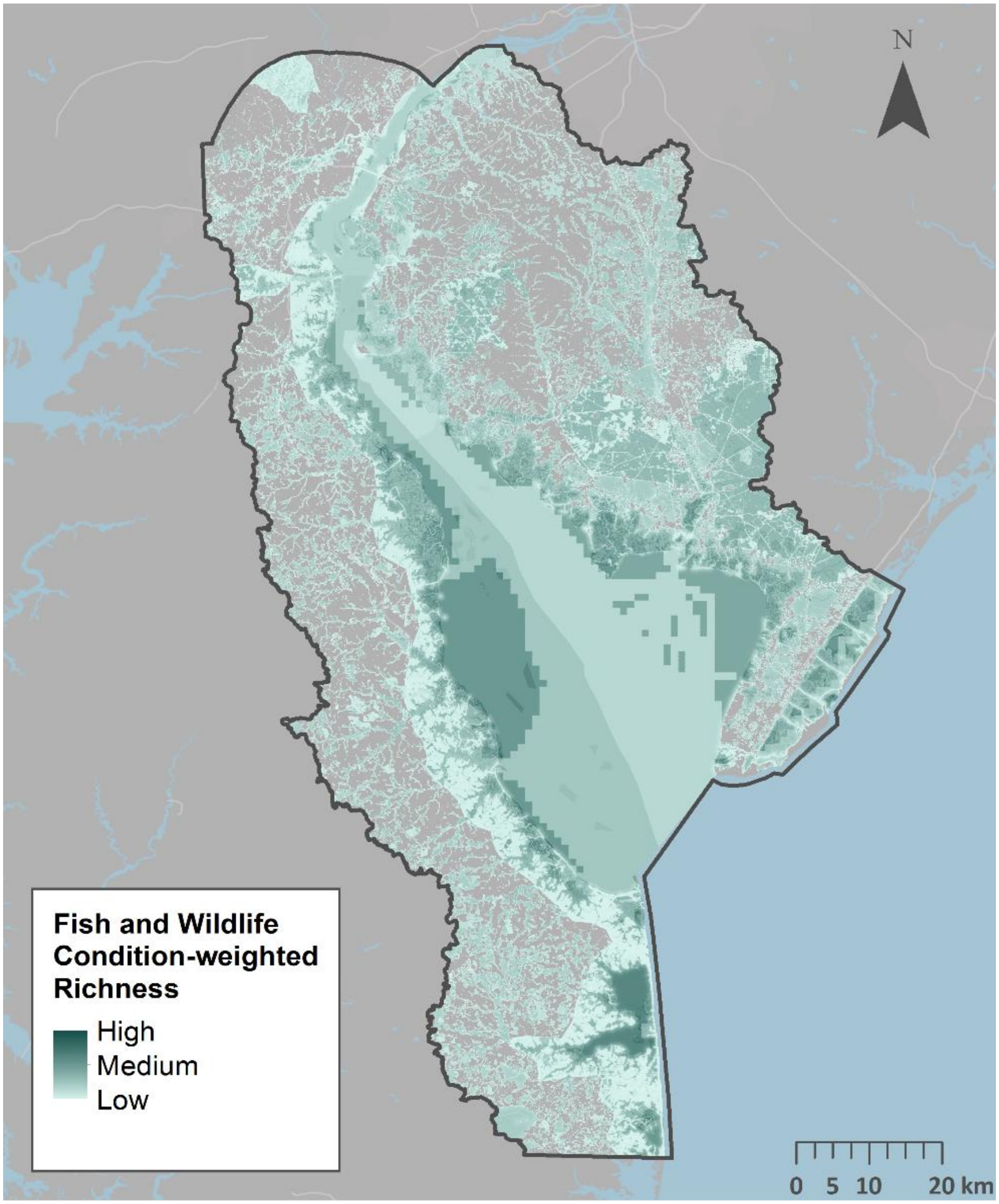


Figure 14. Fish and Wildlife Condition-weighted Richness Index results for the Delaware Bay and Coastal Watersheds. *Green shades indicate the added condition scores of the elements found in a location, with a maximum value of one per element. Grey areas within the project boundary signify areas with no mapped fish and wildlife elements. *Note that a globally important Bird Area runs along the entire Delaware side of the bay, as can be seen by the increased richness score on the Delaware half of the bay.*

Richness is highest in the immediate coastal areas and inland bays, especially Rehoboth and Indian River Bays (just south of the Bay mouth), areas around Prime Hook National Wildlife Refuge (just inside the south side of the Bay mouth), Egg Island (west of the mouth of the Maurice River), and coastal estuaries on the New Jersey Atlantic coast. The differences within the Bay are a factor of an Important Bird Area on the Delaware side but element richness in the Bay should be assumed to be more uniform than depicted. The different patterns of value between the richness and condition-weighted richness indices occur primarily in the bays and sounds. The condition weighted richness index highlights the higher values in the less developed Rehoboth and Indian River Bays versus the higher development on the Cape May peninsula and subsequent reduced water quality in the sounds. Within the Bay, shipping traffic is a key stressor.

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.

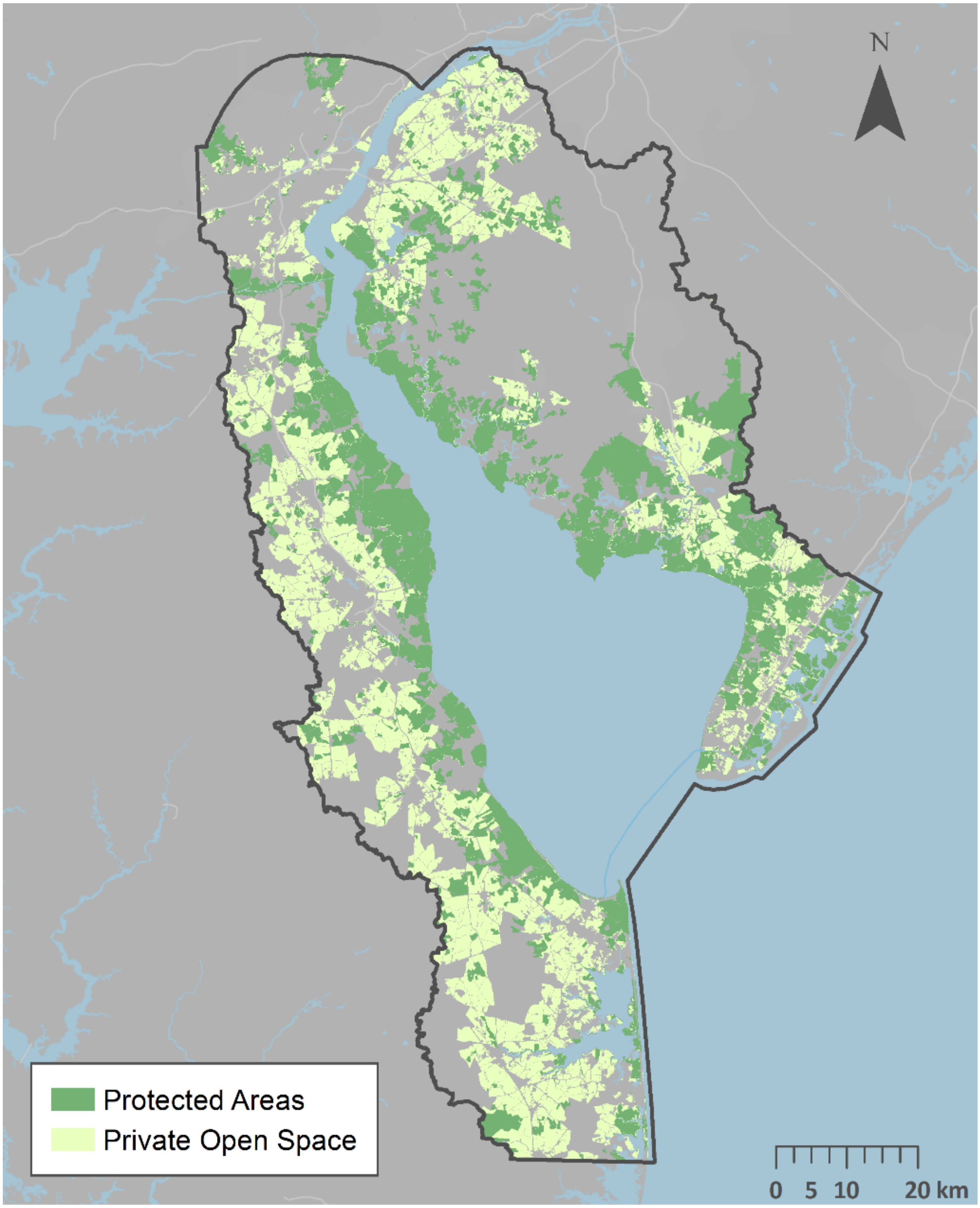


Figure 15. Undeveloped protected areas and unprotected privately-owned areas of open space in the Delaware Bay and Coastal Watersheds. *Map displays the distribution these areas within Resilience Hubs identified in the study area and therefore does not include all such areas within the study area.*

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

Resilience Hubs Assessment Unit Scores

The scoring of the assessment units of the Resilience Hubs, as described in the Methods Overview, was intended to convey the differing values for providing resilience and fish and wildlife benefits within the Hubs. In total, 18,990 assessment units were analyzed and scored within the Delaware Bay and Coastal Watersheds. 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**).

Medium-to-high scoring resilience hub areas are scattered throughout the coastal portions of the watershed on both the Delaware and New Jersey sides of the Bay, occurring primarily in the wetland areas between the Bay and human development. Notable high-scoring areas are visible on the New Jersey side along the Cape May Peninsula and up the Route 347 corridor, up the Maurice River near Millville, by Greenwich, and generally in the northern portion along the Delaware River. On the Delaware side, areas around Indian River Bay, in the northern end of the Bay from Dover to Middletown, and some small patches in the Wilmington area such as the wetland complex at the interchange of the 95/495 and 295 interstates. Some of these areas are further highlighted in the example hub areas below.

Suggested Uses

The Resilience Hubs map for the Delaware Bay and Coastal Watersheds 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.

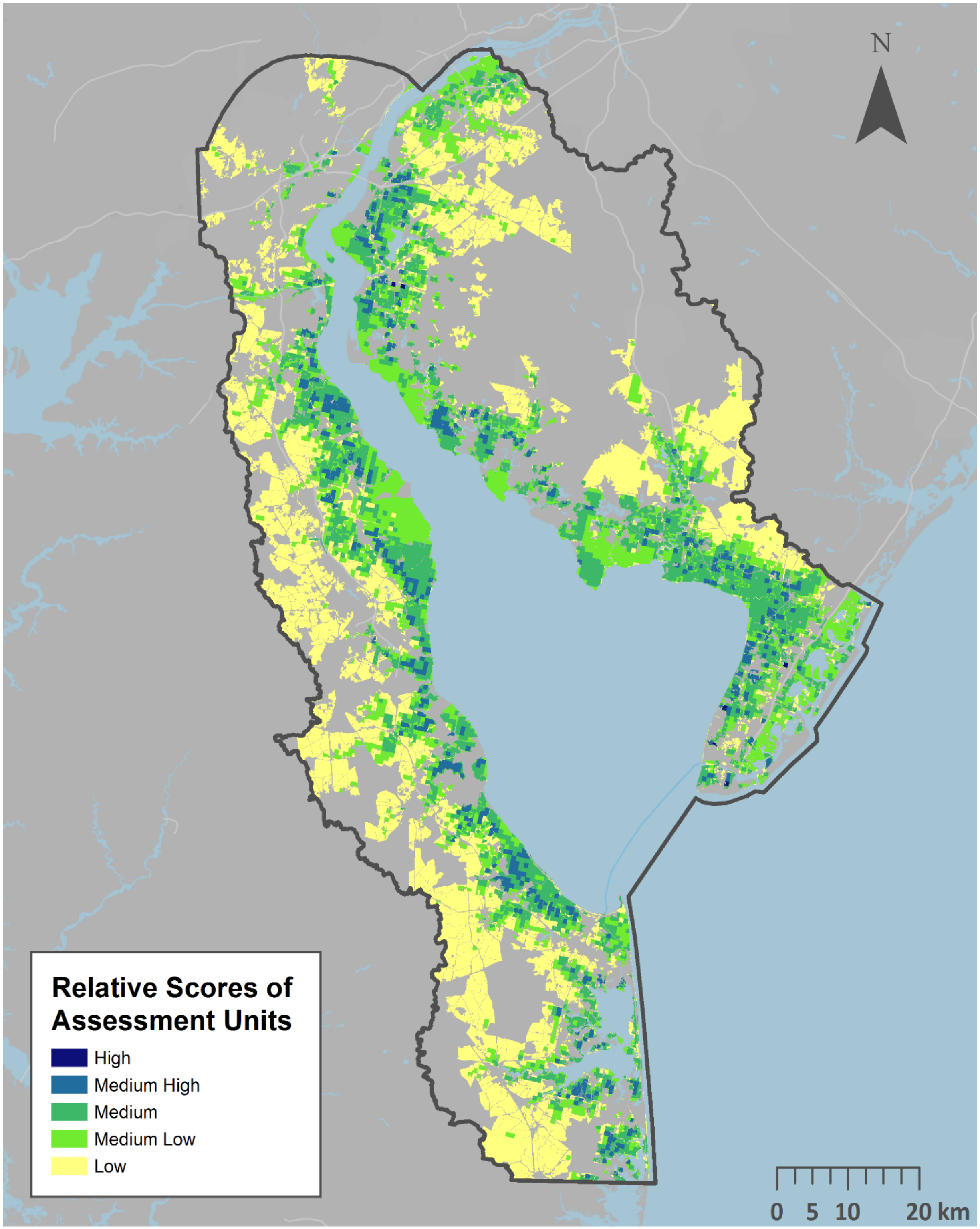


Figure 16. Resilience Hubs assessment unit relative scores for the Delaware Bay and Coastal Watersheds. *Assessment units are 100-acre grids or smaller parcels. Darker shades have higher scores or greater potential for community resilience and fish and wildlife benefits.*

Resilience Hubs Example Areas

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

Maurice River Resilience Hub Area Example

This hub area scored in the top one percent of all assessment units for resilience potential because its location between the flood prone areas of the Maurice River and the town of Millville and key transportation routes (**Figure 17**). The area has very high HCA vulnerability, moderate fish and wildlife richness and is a good candidate for both restoration and protection projects. This area is also likely to retain at least a portion of the fish and wildlife benefits under three feet of sea level rise because it was modeled to be a site for marsh migration. This area is near the Maurice River Restoration Project (#29). See the Resilience Projects Portfolio section for a map of that project area and case study for the mouth of the Maurice River.

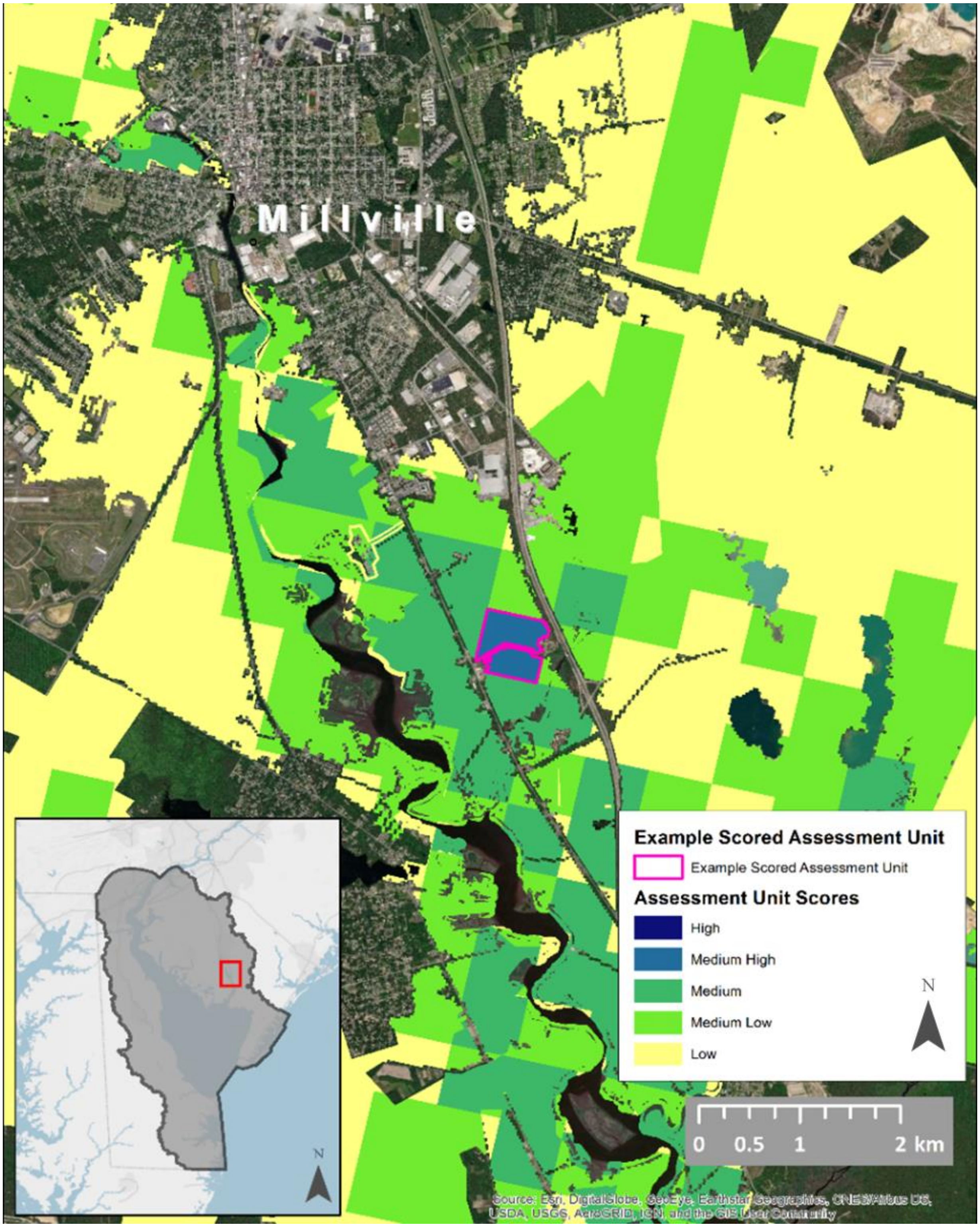


Figure 17. Maurice River Resilience Hub area example. *The yellow-blue shaded areas are the scored resilience hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- G1G3 ESA
- Coastal forest
- Forested wetland
- Freshwater marshes
- Wading bird and ally colonies

HCA elements in or near assessment unit:

- Critical Infrastructure Ranks 1, 2 and 3 (Route 55 and Route 47)
- Population Density Ranks 1 and 2

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

Description of Scoring Attributes	Score
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	5
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with 1 meaning high vulnerability. Mean 0.08, SD 0.12)	0.57 (very high)
Restorability Index	1 (good candidate for protection)
Average Condition (1 = current very high condition)	0.82 (high)
Final score	**3.57 (rank #215 out of 18,990 units)**

Cape May Peninsula Resilience Hub Area Example

Nearly the entire Cape May Peninsula is vulnerable to flooding threats (**Figure 12**), which can come from both the outer coast and Bay. The large number of high scoring assessment units on the peninsula (**Figure 18**) includes the highest scoring unit in the watershed. That unit is near the mouth of Fishing Creek on agricultural land between the wetlands of Cape May County Park South and the development of Miami Beach and the important Bay Shore Road. Typical of many resilience hub areas around the Bay, this area is strategically located to offer resilience improvements, has high restorability, and potential to offer fish and wildlife values well into the future with marsh migration under sea level rise. The bay side of the peninsula generally featured higher assessment unit scores than the ocean side due to the fact that available sites and results of the aquatic element condition model depressed the value of the coast-side Sounds and associated wetlands. While little area exists for hubs along the outer coastal strip, the wetland complex around the Sounds is a logical place for conservation and restoration projects. Projects there could increase resilience for the key transportation routes and development along the spine of the peninsula.

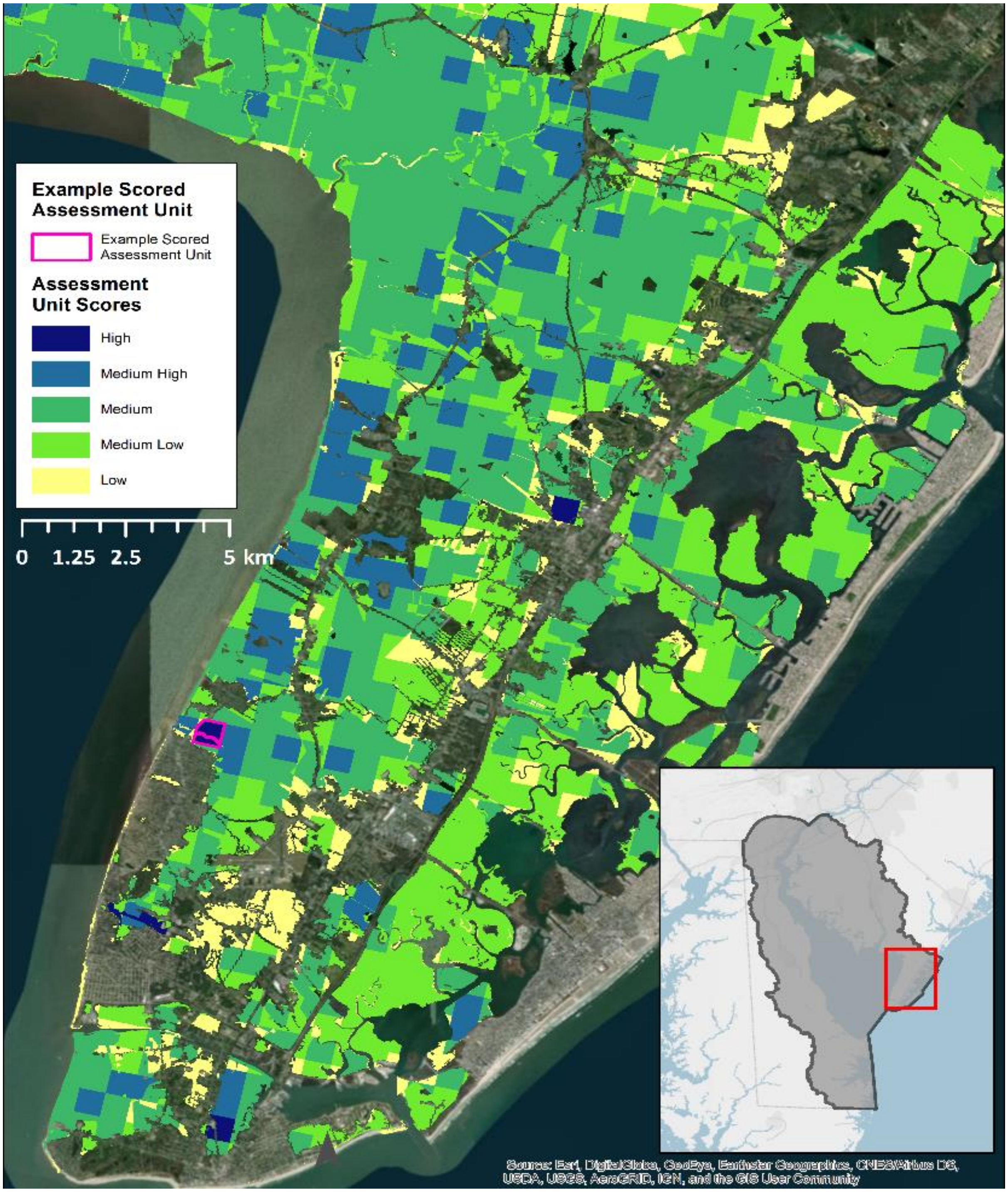


Figure 18. Cape May Peninsula Resilience Hub area example. *The yellow-blue shaded areas are the scored resilience hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Forested wetlands
- Fresh water marshes
- Wading bird and ally colonies
- G1G3 ESA
- Important river mussel habitat
- Black duck

HCA elements in or near assessment unit:

- Critical Infrastructure Rank 1 and 2 (Bay Shore Rd/603)
- Population Density Ranks 1, 2, 3 and 4.

Table 4. Attributes used to calculate the final score for the Cape May Peninsula 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)	6
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with 1 meaning high vulnerability. Mean 0.08, SD 0.12)	0.87 (very high)
Restorability Index	1 (highly restorable)
Average Condition (1 = current very high condition)	0.60 (moderate)
Final score	**5.35 (rank #1 out of 18,990 units)**

Little Creek Wildlife Area Resilience Hub Area Example

This high scoring area (top 16) could be viewed as the first line of defense for the Dover, DE area (**Figure 19**). It is comprised of relatively intact wetlands interspersed with agricultural areas between the Bay and Dover and is inclusive of the area represented in the Port Mahon resilience project case study (presented in the Resilience Projects Portfolio section). It is characterized by high HCA vulnerability, high fish and wildlife diversity (especially for migratory birds), high restorability potential despite moderately low habitat condition, and high potential for supporting marsh habitat under future sea level rise. This area exemplifies many remaining open space areas around the Bay that can provide resilience for adjacent communities and infrastructure.

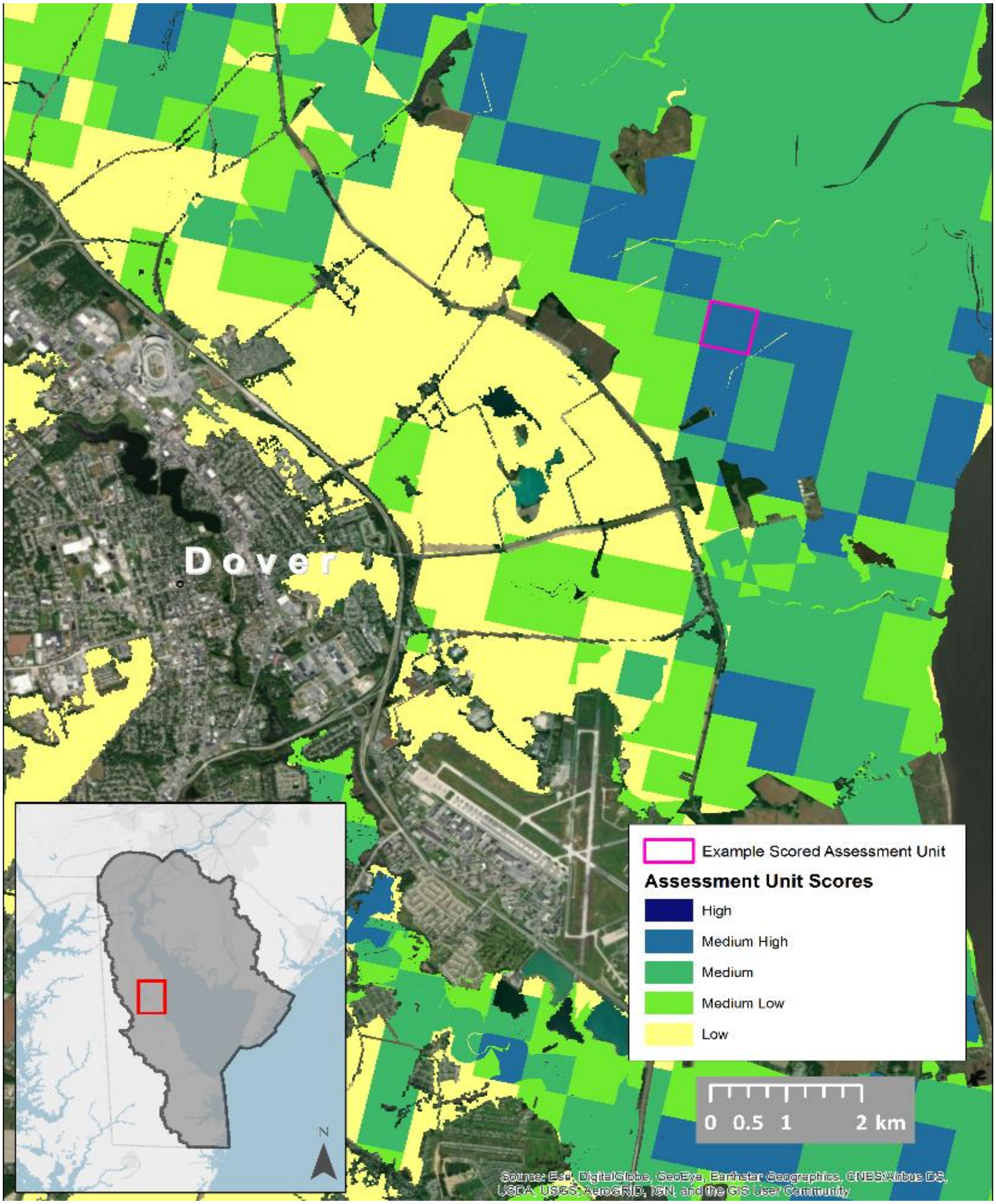


Figure 19. Little Creek Resilience Hub area example. *The yellow-blue shaded areas are the scored resilience hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Atlantic white cedar swamp forest
- Coastal forest
- Forested wetlands
- Fresh water marshes
- G1G3 ESA
- Important Bird Area
- Important river mussel habitat
- Northern diamondback terrapin
- Tidal marsh and tidal creek
- Wading bird and ally colonies

HCA elements in or near assessment unit:

- Pop Density Ranks 1, 2, 3, and 4

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

Description of Scoring Attributes	Score
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	10
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with 1 meaning high vulnerability. Mean 0.08, SD 0.12)	0.48 (high)
Restorability Index	1 (very high)
Average Condition (1 = current very high condition)	0.44 (moderately low)
Final score	**4.05 (rank #16 out of 18,990 units)**

Fish and Wildlife Elements

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

Table 6. Final list of elements used in the Delaware Bay and Coastal Watersheds assessment.

Fish/Wildlife Element	*Description/Significance*
NOAA Trust Resources	
Diadromous fish habitat	This element represents sturgeon spawning grounds/hotspots as well as other diadromous fish priority habitat (such as shad, alewife, blueback herring, American eel, and striped bass).
Important river mussel habitat	Includes potential habitat for native river mussels within the watershed.
Tidal marsh and tidal creek (includes open water)	This element is an extremely important nursery area for fish species (including some NOAA trust resources), as well as for some oysters, blue crab, juvenile sandbar sharks, summer flounder, and numerous wading birds.
Oyster beds/reefs	Oyster beds/reefs are an iconic and commercially important habitat that also harbors habitat for numerous key species (blue crab, oysters, juvenile fish species).
Summer flounder Essential Fish Habitat	Those waters and substrate necessary for summer flounder for spawning, breeding, feeding or growth to maturity. NOAA summer flounder essential fish habitat covers the entire bay, so this element also represents other key recreational and commercial fish species found in the bay and near coastal areas.
Important horseshoe crab areas	These areas are considered the most important areas for collection of horseshoe crabs.
Sea turtles	Represents key summer foraging habitat for sea turtles.
Sharks	Those waters and substrate necessary to the sandbar and sand tiger shark species for spawning, breeding, feeding or growth to maturity. This layer is also a useful surrogate for shark species habitat in general.
At-Risk Species, Species of Special Interest, and Multi-species Aggregations	
At-risk terrestrial species	This composite element includes species that are listed as Threatened or Endangered under the Endangered Species Act and/or assigned as G1-G3 or S1-S3 by state heritage programs.
Ovenbird	Key forest interior habitat for ovenbirds is a good surrogate for high quality habitat for forest interior-dependent species.

Fish/Wildlife Element	*Description/Significance*
At-Risk Species, Species of Special Interest, and Multi-species Aggregations	
Wood thrush	Key forest interior habitat for wood thrush is a good surrogate for high quality habitat for forest interior-dependent species.
Northern diamondback terrapin	Northern diamondback terrapins are particularly rare species associated with salt marsh and adjacent habitats, so this model of probably of occurrence helps pinpoint areas of particular importance for terrapin conservation.
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Submerged aquatic vegetation	These areas are important nursery grounds for some species of fish and shellfish as well as a food source for numerous species. Summer flounder are particularly dependent on submerged aquatic vegetation.
Atlantic white cedar swamp forest	This element is a rare and distinctive habitat type and provides key ecosystem services related to water quality and buffering. In South Jersey, Atlantic white cedar (AWC) swamps are critically important to Black-throated green warblers, saw-whet owls, boreal redback vole, Hessel's hairstreak butterfly and numerous invertebrate species such as a recently discovered species of stonefly.
Cypress swamp	This element is a rare and unique habitat type that provides key ecosystem services related to water quality and buffering. It is at its northern range in the watershed, only occurring on the Delaware side of the bay.
Freshwater marshes	Included in part to represent the habitat distributions of a different suite of bird and herpetofauna species than forested wetlands.
Salt marsh sparrow habitat	This element is considered a proxy for high quality salt marsh habitat.
Wading bird and ally colonies	This element includes areas that are currently utilized by wading birds as colonies. These areas are important to include because the nesting requirements of some species are fairly rigorous, and changes may threaten current colonies, forcing them into substandard habitat in the future.
Vernal pools	Vernal pools provide key habitat for important amphibian species, especially salamanders and frogs that rely on vernal pools for breeding.
Forested wetlands	This element serves as a coarse filter that adds value to all forested wetland types, apart from the cypress and Atlantic white cedar swamps, since they provide such important forest habitat for the suite of species we are most interested in representing.

Fish/Wildlife Element	*Description/Significance*
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Black duck habitat	This is a distinctive and high-quality wetland habitat of limited distribution.
Atlantic beach and dune / priority near shore habitat	This element includes open sandy coastal expanses that provide habitat for a large set of high priority wildlife species.
Coastal forests	These areas represent a distinctive and iconic forest type in this region. These habitats buffer communities from the effects of wind and water from storms and include habitat for a variety of species. This layer is based on mapped information from NatureServe's Terrestrial Ecosystems.
Grassland bird habitat	This element provides habitat for declining species of grassland birds in the Northeast.
Artificial reefs	This element provides nursery habitat for many commercially and recreationally important fish species.
Cross-cutting Elements	
Continental and global Important Bird Areas	These are areas identified to be of key importance for a number of continentally and globally important bird species.

Resilience Projects Portfolio

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

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

1. Agency, NGO, and extension staff in this region have a great deal of capacity to implement coastal resilience projects where funding is available. In particular, there are opportunities to work across agencies and NGOs to complete comprehensive projects within the Maurice River watershed.
2. Project leaders recognize the need to engage neighbors and community stakeholders upfront in planning and decision-making for projects that directly affect their areas of interest to ensure there is initial and ongoing support for long-term projects.
3. Impacts of sea level rise and storm surge are being acutely felt by residents of bay front and coastal communities. These impacts have led to an increased awareness of potential future flooding and storm impact issues and an interest in resilience projects.

Table 7. Summary of resilience-related projects identified for the Delaware Bay and Coastal Watersheds study area. *Table shows the implementation stage of each project at the time of compilation.*

Project Type	**Project Phase**				
	Conceptual	**Planning Complete**	**Design Complete**	**Ready to Implement**	**Total**
Living shorelines		2	5	1	8
Aquatic connectivity		1			1
Beach or dune restoration			2	4	6
Wetland and/or marsh restoration		4	2	2	8
Green infrastructure		2	1		3
Community resilience planning		1		1	2
Oyster reef creation/enhancement		1		1	2
Totals	**0**	**11**	**10**	**9**	**30**

As can be seen in **Figure 20**, the submitted resilience projects are distributed throughout the study area, with a focus on the near-coastal areas. 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 27 project ideas, demonstrating that the stakeholder engagement process was effective in attracting project ideas from local stakeholders. There were two submissions from federal agencies and one from state agencies. Project sizes ranged from 0.23 acres to over 360,000 acres.

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

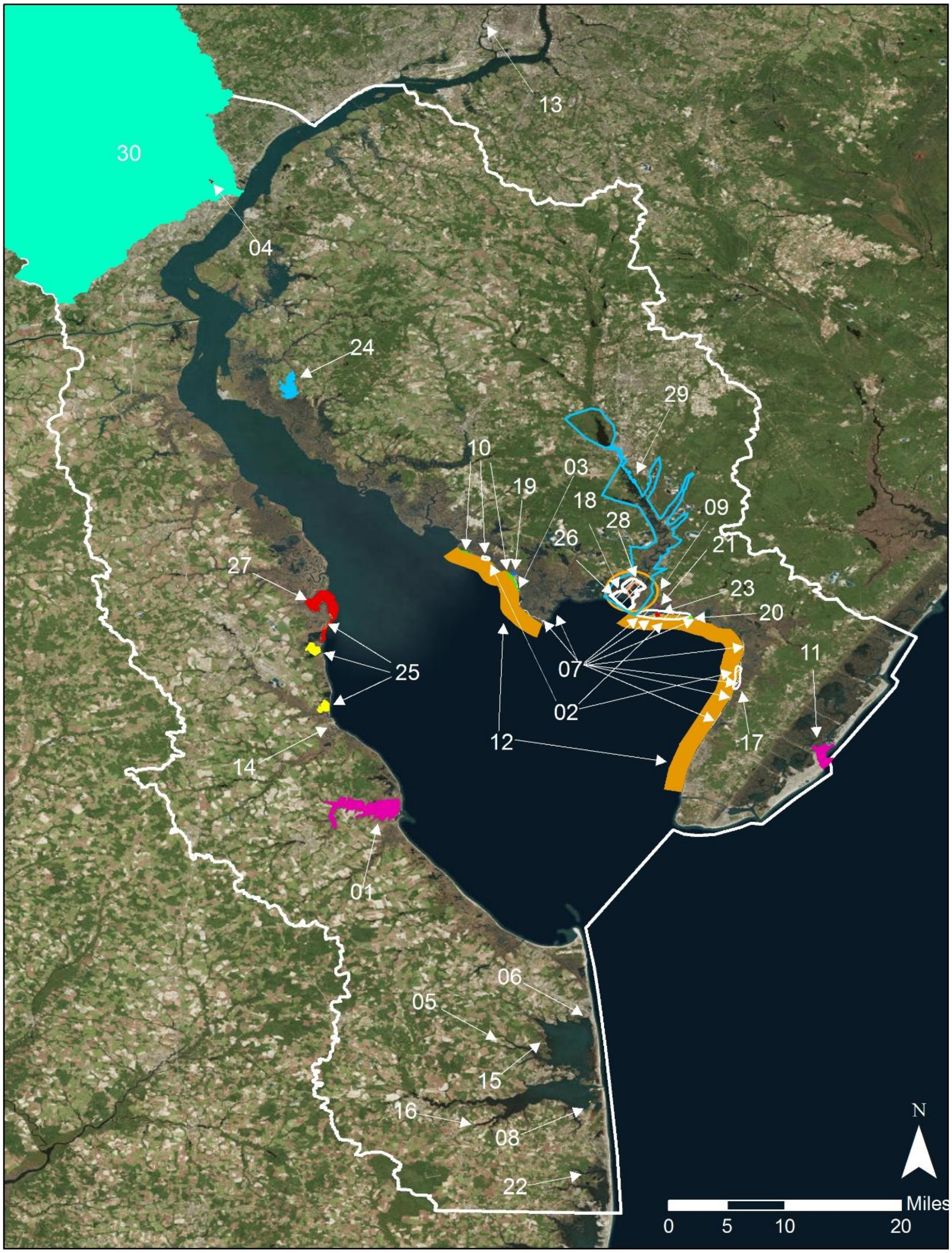


Figure 20. Map showing the boundaries of resilience projects compiled for the Delaware Bay and Coastal Watersheds. *Note that key to project numbers and names is provided on following page. Projects #25 and #27 were combined into a detailed case study, as were projects #9, #18, #26, #28, and #29. A case study was also developed for project #4. See Appendix 6,* ***Table A6-1*** *for a full list of projects.*

Delaware Bay Resilience Projects
Map ID and Project Name

01: Milford Neck Saltmarsh Restoration
02: Expansion of Oyster Reefs at Six Different Sites
03: Continuing Fortescue Beach Habitat Restoration and Living Shoreline
04: South Wilmington Wetland Park (SWWP)
05: Angola by the Bay
06: Sunset Park Living Shoreline
07: Adaptive Management Beaches
08: VFW
09: Sustainable Solutions for a Resilient Maurice River
10: Downe Township NJ Beach Resiliency and Sustainability
11: Habitat Restoration and Resilience at Hereford Inlet Cape May Co
12: DE Bay Sediment Transport Analysis and Web Tool Development
13: Bartrams Garden
14: Murderkill Oyster Breakwater Project
15: Bayfront at Rehoboth
16: Botanical Gardens
17: Cooks and Kimbles Source Beach Habitat Restoration Living Shoreline
18: Developing a Resilience Mouth of Maurice River
19: Fortescue Marsh Platform and Shoreline Stabilization
20: Moores Beach Habitat Restoration and Living Shoreline Creation
21: Restore Marsh Damaged by Salt Hay Farming and Dredged Fill
22: Sassafras Landing
23: Thompsons Beach Habitat Restoration and Living Shoreline Creation
24: Silver Lake Tidal Marsh Restoration
25: Port Mahon Road Restoration
26: Mouth of Maurice River
27: Port Mahon and Kelly Island
28: Maurice River Mouth
29: Weland Restoration on the Maurice River
30: Aquatic Connectivity in the Christina River Basin

Figure 20 (continued). Key to project numbers presented in map on previous page.

Suggested Uses

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

Case Studies

The three case studies that follow illustrate how proposed resilience projects may benefit fish and wildlife habitat and human communities faced with coastal resilience challenges such as storm surge during extreme weather events. The case studies described for the Delaware Bay and Coastal Watersheds share the following traits:

- Each of the projects has the potential to reduce flooding and/or storm surge effects to adjacent human assets such as boat access areas, homes, schools, hospitals, and places of business.
- All projects have potential benefits for either wetland bird habitat and/or fish nursery areas for key species that support recreational and commercial activities in the region.

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

Case Study 1: Port Mahon Road and Kelly Island Restoration Project and Plan

Figure CS1-1. Area of former marsh and beach that is now open water with large "dilapidated bulkhead/rip-rap" structure installed to protect Port Mahon Road. *During storms, water overtops the rocks and inundates the road.*

Project Overview

Location: Dover, Delaware

Date Visited: July 24, 2018

Contact: Brian Marsh, US Fish and Wildlife Service and Jeremy Ashe, DNREC

Port Mahon Road and the adjacent area of Kelly Island are located along the Delaware Bay shore within Kent County (**Figure CS1-2**). The shoreline facing Delaware Bay was formerly a mixture of coastal wetlands and sandy beach habitat utilized by numerous shoreline species, including spawning horseshoe crabs and the shorebirds that forage on their eggs, particularly the federally threatened red knot. Recent storms and increased wave-driven erosion and coastal flooding have resulted in nearly complete loss of marsh and beach habitat along the bay side of Port Mahon Road and extensive erosion of beach and marsh habitat along Kelly Island. This has also led to the conversion of high-quality high marsh into low marsh habitat, which provides less coastal resilience value and less habitat value to marsh and nesting birds such as the salt marsh sparrow. As a result, the area now provides minimal habitat for horseshoe crab spawning, foraging shorebirds, and nesting marshland birds. Additionally, the Port Mahon Road and its associated infrastructure has become increasingly vulnerable. Unabated erosion will result in the following:

- Continued absence of the foraging habitat previously provided by the area to many shorebird species of conservation concern.
- Continued loss and degradation of Kelly Island of the U.S. Fish and Wildlife Service-owned Bombay Hook National Wildlife Refuge (e.g., high marsh to low marsh, low marsh to mudflat, and marsh edge erosion).
- Loss or degradation of wildlife habitat of the Delaware Division of Fish and Wildlife-owned Little Creek Wildlife Area to the west of Port Mahon Road (e.g., high marsh to low marsh).
- Continued costly armoring with rip-rap and clearing of flood debris along the Port Mahon Road, which is owned by the Delaware Department of Transportation.
- Potential impacts to an unloading pier and pipeline for jet fuel relied upon by the Dover Air Force Base.
- Reduced or no access to the Delaware Division of Fish and Wildlife-owned public fishing pier along Port Mahon Road.
- Reduced or no access to the popular Delaware Division of Fish and Wildlife-owned public boat ramp and dock at the end of Port Mahon Road.
- Loss of public recreation opportunities of the area, including ecotourism, fishing, hunting, and boating.

There are two potential resilience projects that could help to mitigate the damage and provide for increased resilience in the future. First, a pilot breakwater project has been designed by Delaware Division of Fish and Wildlife to begin restoration and shoreline protection along Port Mahon Road. The second is to develop a comprehensive plan among stakeholders for restoration of subtidal and intertidal habitat and protection of current human assets in the area.

The Delaware Division of Fish and Wildlife was awarded a National Fish and Wildlife Foundation grant to engineer and design a hybrid green/gray infrastructure pilot breakwater project to restore a 900-foot section of habitat along Port Mahon Road. The basic design involves installing several offshore breakwaters ("gray structures") to dissipate wave energy and restore a beach/dune ("green structures") along the shoreline. The goal of this pilot effort is to create and protect habitat along this section of the road, but importantly, the pilot will also provide valuable insight into potential restoration measures along the remaining 1.6-mile section of the road.

Protecting Port Mahon Road will provide several benefits. Currently Port Mahon Road helps to prevent significant erosion from occurring on adjacent saltmarsh habitat within the Little Creek Wildlife Area. If the road were lost or damaged due to erosion, this saltmarsh habitat would become vulnerable to rapid erosion and habitat loss. Furthermore, if the Port Mahon Road was lost or damaged in a storm event, it could also significantly compromise the military's access to an important pipeline that runs adjacent to the road and carries jet fuel to the Dover Air Force Base.

Restoring marsh and beach habitat along the eastern side of the road will not only protect the road itself but will also restore the important horseshoe crab and shorebird habitat for which the site is known. Protection of the road and its adjacent habitat are important to support a thriving tourism industry in the region. In particular, protecting the road will allow for the creation of a planned highlight stop along the Delaware Bayshore Byway. This will support ecotourism and outdoor recreation, offering opportunities to view Delaware Bay's world-renowned spring migratory shorebird stopover, maintain use of the Port Mahon Road public fishing pier and boat launch, and access waterfowl hunting and fishing opportunities on state and federal lands. DelDOT has repeatedly installed over mile of hardened stone shoreline, which has temporarily protected the road from wave energy, but horseshoe crabs and diamondback terrapins get caught and killed in the rip-rap and the stones create a high energy hardened shoreline that prevents the formation of beach. The pilot breakwater project design replaces the rip-rap with more effective breakwaters, beach, and dune thereby supporting the many benefits described above.

The entire area of Port Mahon Road and Kelly Island requires a detailed restoration plan based on a technical examination of the high energy dynamic coastal environment in this area of the bay shore. The plan must not only consider the multiple human uses of the site, but also those natural resources that depend on the area, such as horseshoe crabs, oyster beds, shorebirds, marsh birds, and finfish. Ultimately, restoration measures could include a combination of subtidal and intertidal living shoreline techniques, beach and marsh renourishment, and debris removal. Developing a comprehensive plan would be an opportunity for stakeholders to come together and develop an agreed upon strategy for the area allowing them to be responsive to future funding opportunities.

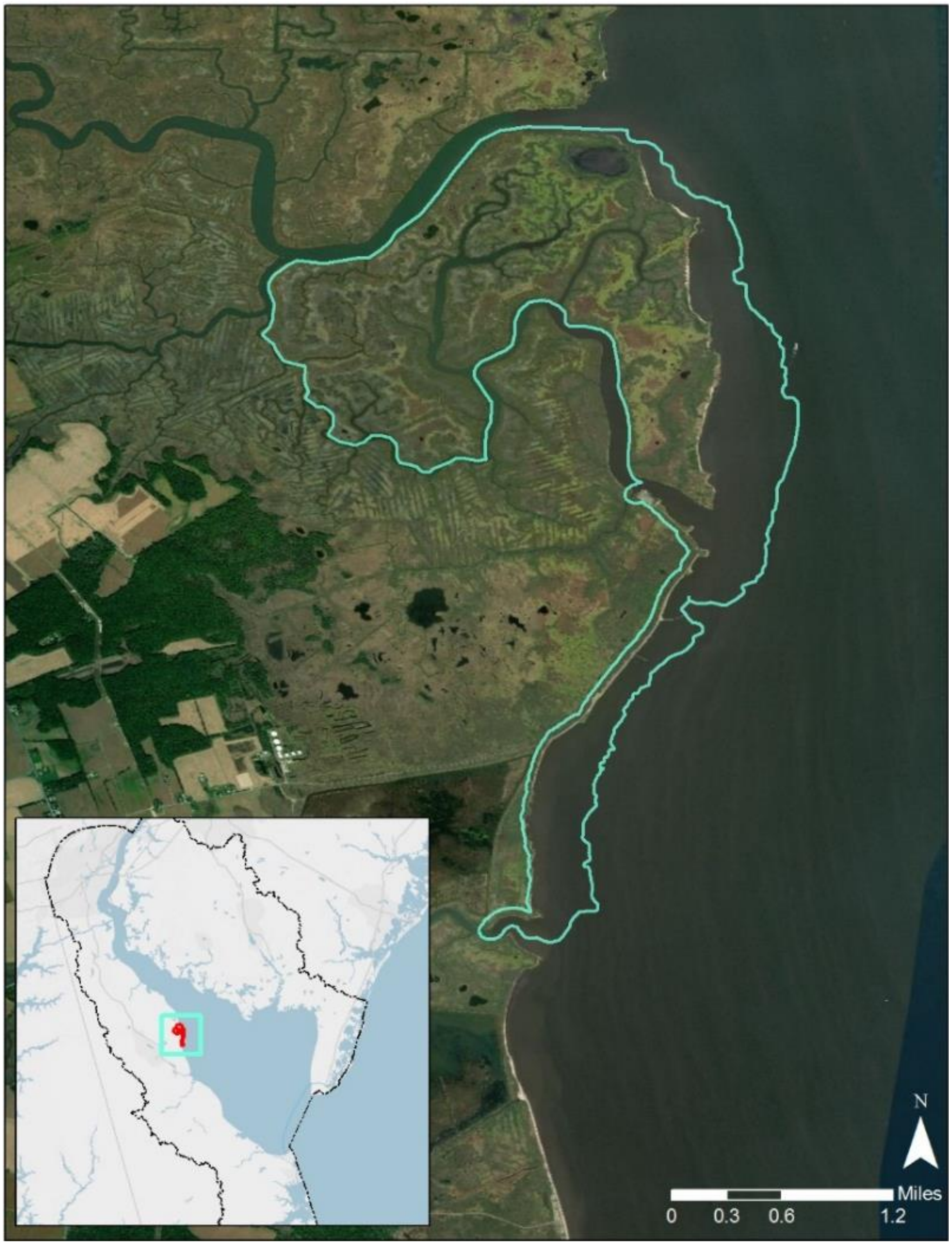


Figure CS1-2. Approximate project area. *The blue outline is the project boundary, with the aerial imagery taken in 2014 and the blue boundary based on the historic shoreline position in 1954 (note the high loss of acreage since 1954).*

Estimated Cost of the Project

The pilot breakwater project is estimated to cost around $2 million. The overall restoration plan for the area is estimated to be approximately $200,000. For more detailed numbers, please contact the project sponsors.

Stressors and Threats

This site has several existing stressors for fish and wildlife and flooding threats that could impact fish/wildlife and human community assets (HCAs) in the project area. **Table CS1-1** contains a list of the identified stressors and flooding threats. Storm surge and sea level rise are particularly important flooding threats in the project area.

Figure CS1-3. Port Mahon Road is frequently inundated when storms hit the area. *In this photo, debris including dead horseshoe crabs has washed onto the road after the latest storm.*

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

Existing Stressors
Developed Open Spaces (low imperviousness <20%)
Commercial & Industrial Areas
Local neighborhoods and connecting roads, bridges/culverts
Low Density Housing (moderate imperviousness 20%-49%)
High Density Housing (high imperviousness > 49%)
Water Quality - Low (EPA impaired waters, high commercial vessel traffic)
Water Quality - Moderate (moderate commercial vessel traffic)
Developed Open Spaces (low imperviousness <20%)
Commercial & Industrial Areas
Local neighborhoods and connecting roads, bridges/culverts
Flooding Threats
Sea Level Rise
Storm Surge (Category 1)
Storm Surge (Category 2)
Storm Surge (Category 3)
Storm Surge (Category 4)
Storm Surge (Category 5)

Human Community Assets

Wave action and flooding have severely degraded the beach and tidal marsh communities both on Kelly Island and between Port Mahon Road and the open water of Delaware Bay. This has put several key human assets at risk of being cut off from the mainland if/when the road is washed away. Assets most at risk include the jet fuel pipeline that parallels Port Mahon Road, Port Mahon Road itself, a fishing pier, and a dock and boat ramp that currently serves as the home port for emergency boats used by the nearby township. **Figure CS1-4** shows areas where the vulnerable human community assets are concentrated, and identified assets are described in **Table CS1-2**.

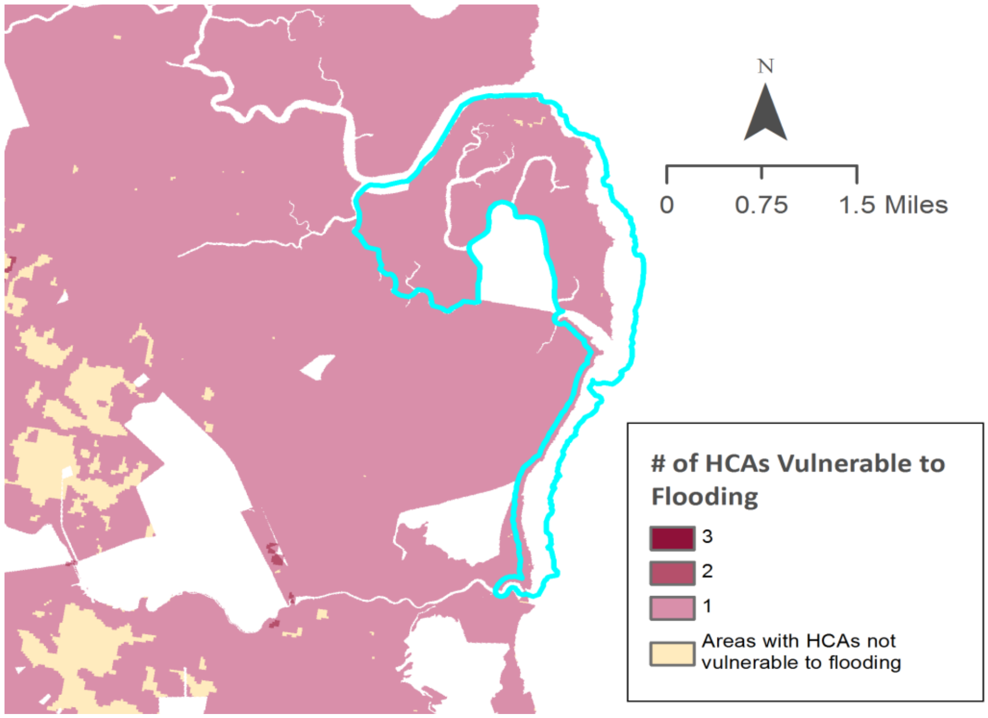


Figure CS1-4. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements) within and around the Port Mahon Road project. Tan color indicates areas with HCAs that are not categorized as vulnerable for the purposes of this assessment. Blue outline is the proposed project area.*

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

Categories of Human Assets Identified within Project Boundary
Densely populated areas (from NLCD; area not populated but has infrastructure serving human population)
Mapped Community/Human Assets within Project Boundary
No standard features used in the assessment but has important road, dock, and fuel pipeline.

Fish and Wildlife

Fish and wildlife elements mapped for this site are listed in **Table CS1-3**. Before the beaches eroded back to Port Mahon Road, this site was an important horseshoe crab spawning area, which attracted large numbers of migratory shorebirds during the spring stopover (Brian Marsh, personal comm. 2018). Every year, Delaware Bay hosts the world's largest concentration of spawning horseshoe crabs and one of the world's largest concentration of shorebirds, including the federally threatened red knot. The red knot is one of six shorebird species where most of their population in the western hemisphere rely on Delaware Bay as a spring migratory stopover. Delaware Bay is the last and most important migratory stopover for red knots during spring migration. Red knots rely on the beaches of Delaware Bay to forage on horseshoe crab eggs allowing the birds to nearly double their weight and accumulate the energy needed to complete their migration to the arctic to breed. However, these important beaches no longer exist at Port Mahon. Partners hope that restoration of the site will allow the horseshoe crab spawning to increase and provide habitat once again for red knot and other shorebirds. In addition, the pilot breakwater project and overall restoration plan will attempt to address the high mortality of diamondback terrapins along Port Mahon Road and the restoration of tidal marsh habitat behind Port Mahon Road and on Kelly Island, thereby providing more habitat for key tidal marsh dependent species such as saltmarsh sparrow.

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	American oystercatcher, horseshoe crab, Northeastern tiger beetle, piping plover, red knot
Submerged aquatic vegetation	Nursery habitat for key fish species, bay scallop
Tidal marsh and tidal creek	Northern diamond-backed terrapin, saltmarsh sparrow, winter flounder, forage fish species
Essential fish habitat	Sharks, eels

**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.*

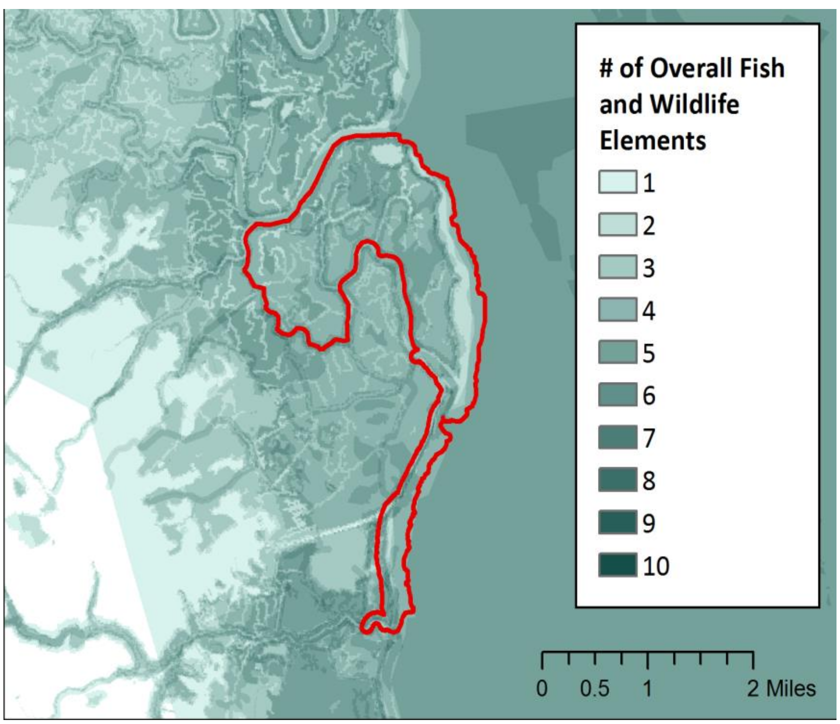


Figure CS1-5. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements richness (darker green signifies a higher number of elements co-occurring in the same place). Red outline is the project boundary.*

Expected Project Impact

It is hoped that these two projects (the overall conservation plan for Port Mahon/Kelly Island) and the pilot breakwater project will lead to protection of key HCAs by keeping the road, pipeline, piers, and dock protected during extreme storm events and rising sea levels. The breakwater pilot project will also increase habitat for species like horseshoe crabs and red knot.

These projects will also serve as a demonstration for other communities in the Delaware Bay facing similar challenges with eroding habitat and threatened infrastructure. By showing the value of a restoration project, work at this site could increase community buy-in for the implementation of resilience projects elsewhere.

Case Study 2: South Wilmington Wetland Park

Figure CS2-1. View showing eastern ridge of future wetland park area and nearby housing that is currently prone to flooding.

Project Overview

Location: Wilmington, Delaware

Date Visited: July 24, 2018

Contact: Leah Kacanda, City of Wilmington, DE

The neighborhood of South Wilmington, DE has suffered from backups within the city's sewer and stormwater system due to the combined effects of heavy rainfall events co-occurring with high water levels in the Christina River. This has occurred for decades, leading to flooding of the lower levels of residential structures. The purpose of the South Wilmington Wetland Park (SWWP, **Figure CS2-2**) is to re-establish an historical freshwater tidal wetland that was recently filled to support development and therefore is currently hydrologically disconnected from the adjacent Christina River. Under this project, the sewer and stormwater will be separated so that, during heavy rainfall events, stormwater will be diverted to the wetland park for short-term storage, thereby minimizing future risk of flooding to the adjacent neighborhood.

The development of the park will create a complex of freshwater ponds, tidal freshwater wetlands, and vegetated buffers that can better support stormwater management, alleviating flooding, restore and enhance existing wetland habitats in the area, and creating a new park for the community. The SWWP includes the restoration of 14 acres of low-quality wetlands to highly functioning tidal wetlands via habitat enhancements and the creation of additional high-quality wetlands adjacent to the tidal wetlands. To help reduce chronic flooding in the neighborhood during heavy rain events, the SWWP will also be hydrologically modified in ways that provide flood storage and water quality enhancements for the newly separated storm water system flows from the Southbridge neighborhood of Wilmington. To provide recreation for surrounding communities, the SWWP will also include a trail, boardwalk, and other recreational features.

The property within the project area is controlled or owned by the City of Wilmington, which making the project easy to implement. The project itself is “shovel ready”, with some pre-construction phases already underway.

Key benefits from this project are expected to include:

- Improved tidal marsh habitat, which is expected to support marsh-dependent birds and fish species (e.g., forage fishes and American eel).
- Reduced flooding to adjacent neighborhoods by diverting stormwater into the marsh area.
- Project could serve as a model for other restoration projects in the community, especially as an example of proactive solutions developed by residents and municipalities to prepare for future changes.

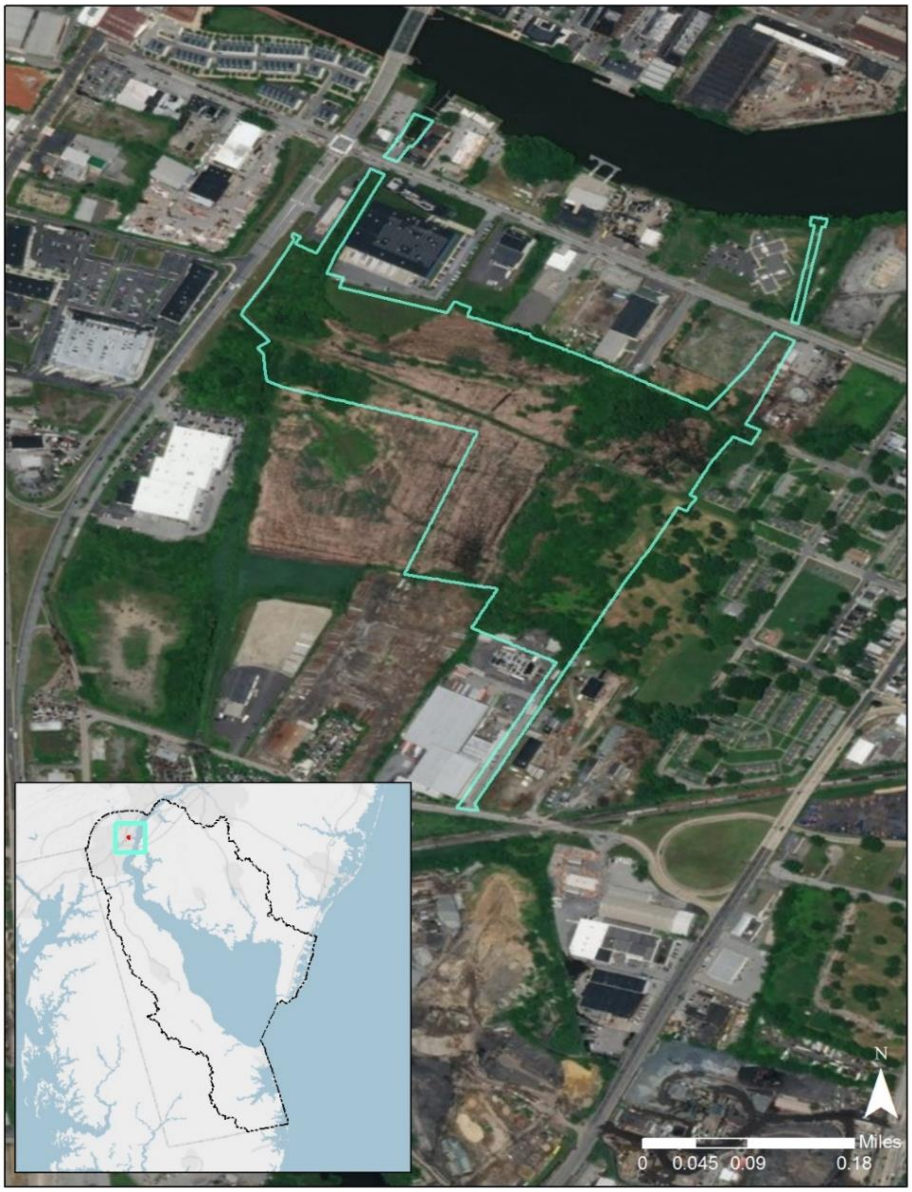


Figure CS2-2. Approximate project area (blue boundary). *Project area includes a proposed wetland park. During storm events much of the stormwater from the adjacent neighborhood to the east would be diverted to this wetland park. Tan color indicates areas with HCAs that are not categorized as vulnerable for the purposes of this assessment. Blue outline is the proposed project area.*

Estimated Cost of the Project

The first phase of the project is estimated to cost $21 million, much of which will be covered by the city. However, there is a need for additional funding to ensure that the wetland restoration and plantings are appropriate, incorporating the native plant species that have the best ability to thrive and provide valuable wildlife habitat for the particular conditions created by the restoration work. In addition, there are opportunities for additional restoration of adjacent wetland tracts in the near future should the city of Wilmington obtain purchase or easement rights on the land.

Stressors and Threats

This site has several existing stressors and flooding threats affecting fish and wildlife and nearby human community assets (HCAs). **Table CS2-1** contains a list of the identified stressors and flooding threats. Storm surge, high erosion potential, 100-year floodplain, poor drainage, and sea level rise all combine to create conditions at the site that put fish and wildlife and HCAs at risk.

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

Existing Stressors
Developed Open Spaces (low imperviousness <20%)
Railroads, Bridges/Culverts
Local neighborhoods and connecting roads, bridges/culverts
Low Density Housing (moderate imperviousness 20%-49%)
High Density Housing (high imperviousness > 49%)
Water Quality - Low (EPA impaired waters, high commercial vessel traffic)
Water Quality - Moderate (moderate commercial vessel traffic)
Flooding Threats
Storm Surge (Category 1)
Storm Surge (Category 2)
Storm Surge (Category 3)
Storm Surge (Category 4)
Storm Surge (Category 5)
Soil Erodibility (High, Very High)
Flat, Poor or Very poorly drained
100 Year Floodplain
500 Year Floodplain

Human Community Assets

Flooding adjacent to the site is a perennial problem. Flooding is caused by backups within the current combined sewer and stormwater system that occur when river levels are high and the stormwater Combined Sewer Overflow (CSO) is unable to discharge into the Christina River. Under this project, the sewer and stormwater will be separated so that, during heavy rainfall events, stormwater will be diverted to the wetland park for short-term storage, thereby minimizing future risk of flooding to the adjacent neighborhood. Since this neighborhood is a traditionally underserved community with a high environmental justice score, it is particularly important to address this flooding issue, especially as flooding becomes worse under sea level rise scenarios. **Figure CS2-3** shows areas where the vulnerable HCAs are concentrated, and identified assets are described in **Table CS2-2**.

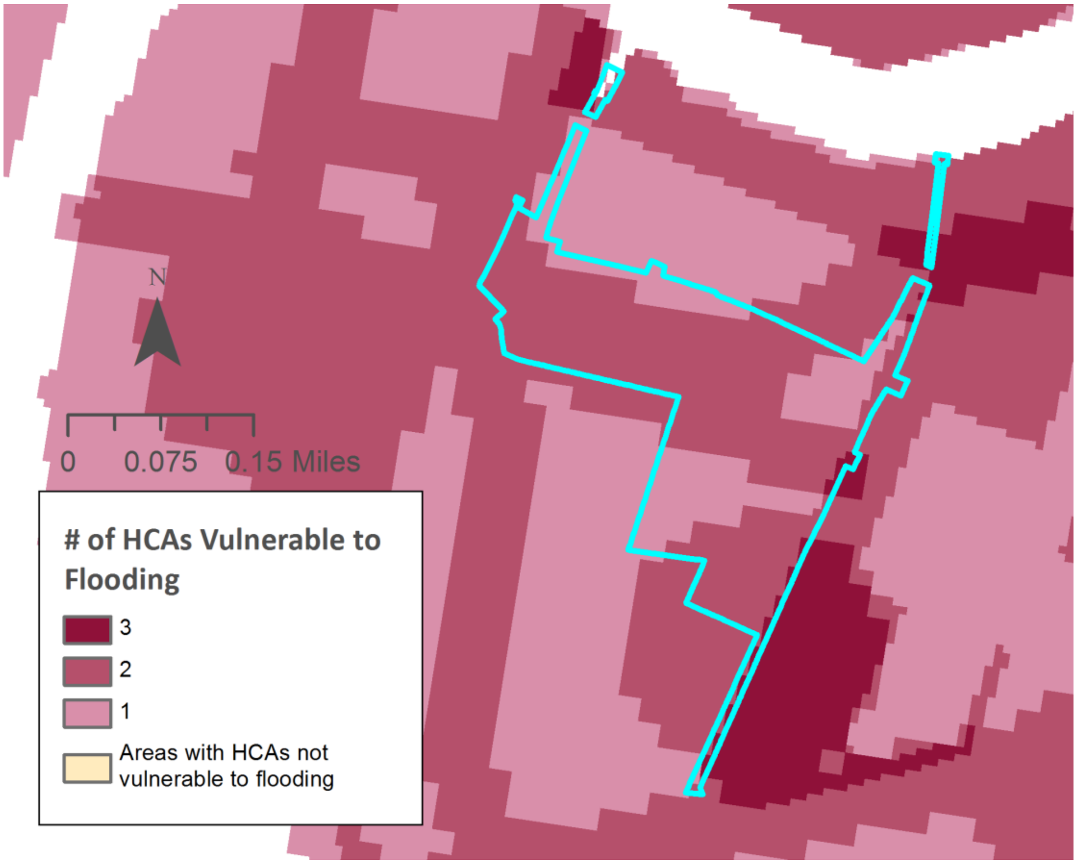


Figure CS2-3. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements) within and around the South Wilmington Wetland Park project. Tan color indicates areas with HCAs that are not categorized as vulnerable for the purposes of this assessment. Blue outline is the proposed project area.*

Table CS2-2. Human Community Assets identified within the project boundary.

Categories of Human Assets Identified within Project Boundary
Densely populated areas Environmental Justice Area Critical facilities
Mapped Community/Human Assets within Project Boundary
Dugan Park and Elbert Playground Multi-family housing along Buttonwood, Locust, and other neighborhood streets

Fish and Wildlife

This site contains potential habitat for priority fish and wildlife species, including many species highly valued by regional stakeholders, like forest, shrubland, and marsh bird species and forage fishes (**Table CS2-3, Figure CS2-4**). The site currently is of low quality and value for these species, but the restoration effort that are planned should allow for improvement of habitat for key species.

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 ****
Coastal forest / shrubland	American woodcock, black-crowned night heron rookeries, willow flycatcher, migratory stopover habitat for songbirds
Freshwater marshes	King rail, marsh wren, least bittern
Tidal marsh and tidal creek	Forage fish, American eel, saltmarsh sparrow
Essential fish habitat	

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

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

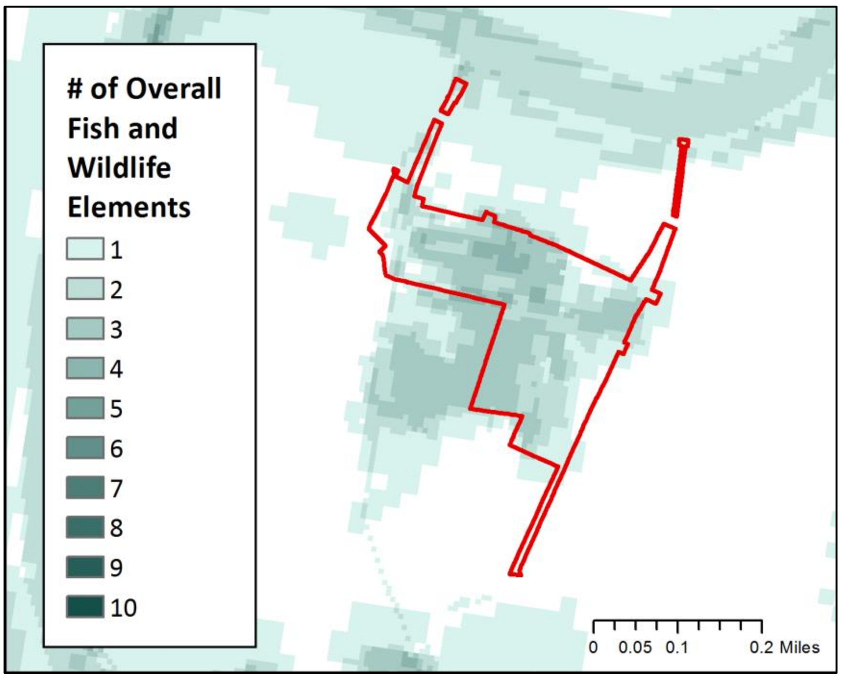


Figure CS2-4. Density of fish and wildlife elements in project area. *Map of fish and wildlife element richness (darker green signifies more elements). Red outline is the project boundary.*

Expected Project Impact

This project is expected to have clear dual benefits for both human assets and fish and wildlife. In addition to addressing current flooding and reducing future flooding risk, the project will restore a key tidal wetland near the center of the city that has the potential to provide habitat for declining tidal marsh dependent bird species and a limited set of fish species (like eels). This project will also serve as a demonstration project for others interested in effectively combining important ecological and stakeholder considerations to increase resilience to sea level rise and storm surge.

Case Study 3: Mouth of Maurice River Resilience Projects

Figure CS3-1. Aerial imagery of the mouth of the Maurice River in 1935 (left) and in 2018 (right).

Project Overview

Location: Maurice River Township, New Jersey

Date Visited: July 25, 2018

Contacts: Multiple projects that include the following partners: American Littoral Society, Citizens United Maurice River, Delaware Bayshore Council, Getting to Resilience LLC, Maurice River Township, Niles Smith Ecological Design and Management, and Partnership for Delaware Estuary.

The mouth of the Maurice River (**Figure CS3-1**) was the subject of numerous project proposals received as part of this assessment, all with potentially complementary outcomes that would serve to build resilience to future storms and erosion for both fish and wildlife and human communities. Four potential projects are highlighted in this case study, each proposed by different partners in the region. Three of these projects propose engineering and design components to address wind and wave energy that are disrupting and destroying key wetland habitat with the end goal of building both habitat and community resilience. The four projects proposed are briefly outlined below:

1) *<u>Developing a Resilient Mouth of Maurice River</u>*. This habitat-oriented project proposes to address the impacts of wind-driven wave action on the mouth of the Maurice River by designing and installing an offshore breakwater/artificial oyster reef that would reduce future salt marsh and beach loss. This would improve habitat for horseshoe crab, juvenile fish, and oysters. This would also provide an opportunity to begin to address the conversion of land to open water within the Basket Flats area.
2) *<u>Maurice River Mouth Restoration</u>*. This wetlands and sediment-focused project proposes to address the impacts of wind-driven wave action at the current mouth of the Maurice River by

designing an offshore breakwater. This is intended to create conditions whereby sediment would deposit behind the created structures, filling former wetland areas that had eroded to open water habitat, and thereby stabilizing the oxbow feature at Basket Flats and surrounding wetlands. This could help convert open water back to productive tidal marsh habitat.

3) *Sustainable Solutions for a Resilient Maurice River*. This engineering-focused project would create an engineering plan for installation of an artificial reef structure that could help preserve the lowest oxbow of the Maurice River, which is eroding away due to wave action.
4) *Whole watershed planning for the Maurice River*. There is also interest in acquiring funding to develop a watershed restoration plan for the entire Maurice River watershed that could tie into the three specific efforts outlined above and others to create a coordinated strategy to restore the mouth of the Maurice River.

Most of the property within this project area is currently open water or tidal marsh controlled by the state. The mouth of the Maurice River protects several human assets including the historic port areas that exist within and near the mouth of the river, as well as salt hay farmlands that are either currently open water or will be soon without action. Upstream towns could also be affected should the mouth continue to erode to open water.

Combined benefits from these projects are expected to include:

- Slowing erosion of marsh and farmlands caused by wave action and continued loss of sediment due to tidal exchange and water velocity.
- Improvement of ecological integrity of tidal marsh, inter-tidal flats, and submerged lands.
- Potential for providing more habitat for oysters, horseshoe crabs, and juvenile fishes.

Estimated Cost of the Project

Cost estimates vary widely, ranging from $500,000 to $50 million depending upon the final scope and scale of the project(s) that are undertaken. For more detailed numbers, please contact the project proponents for each project.

Figure CS3-2. Approximate outline of the mouth of the Maurice River (blue boundary). *Note that much of the area currently in open water was historically in salt hay or tidal marsh.*

Stressors and Threats

This site has a number of existing stressors and flooding threats that could impact both fish and wildlife and the human community assets (HCAs) in the area. **Table CS3-1** contains a list of the identified stressors and flooding threats. Storm surge and sea level rise combine to create conditions at the site that put fish and wildlife and HCAs at risk.

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

Existing Stressors
Developed Open Spaces (low imperviousness <20%)
Dams/Reservoir
Local neighborhoods and connecting roads, bridges/culverts
Low Density Housing (moderate imperviousness 20%-49%)
High Density Housing (high imperviousness > 49%)
Water Quality - Low (EPA impaired waters, high commercial vessel traffic)
Water Quality - Moderate (moderate commercial vessel traffic)
Commercial & Industrial Areas
Flooding Threats
Sea Level Rise
Storm Surge (Category 1)
Storm Surge (Category 2)
Storm Surge (Category 3)
Storm Surge (Category 4)
Storm Surge (Category 5)

Human Community Assets

Continued erosion at the mouth of the Maurice River could disrupt and threaten business operations, tourism, commercial fishing, and farming, and could displace residents or damage property. As the erosion continues to eat away at bends in the river, more areas further upstream will become exposed to direct wave action from the Bay, thereby increasing the chance that they will be impacted by future storms. As more water enters the upper system, the river may be threatened by impaired water quality (e.g., changes in salinity gradient, temperature, invasive species, etc.). **Figure CS3-3** shows areas where the HCAs are concentrated, and identified assets are described in **Table CS3-2**.

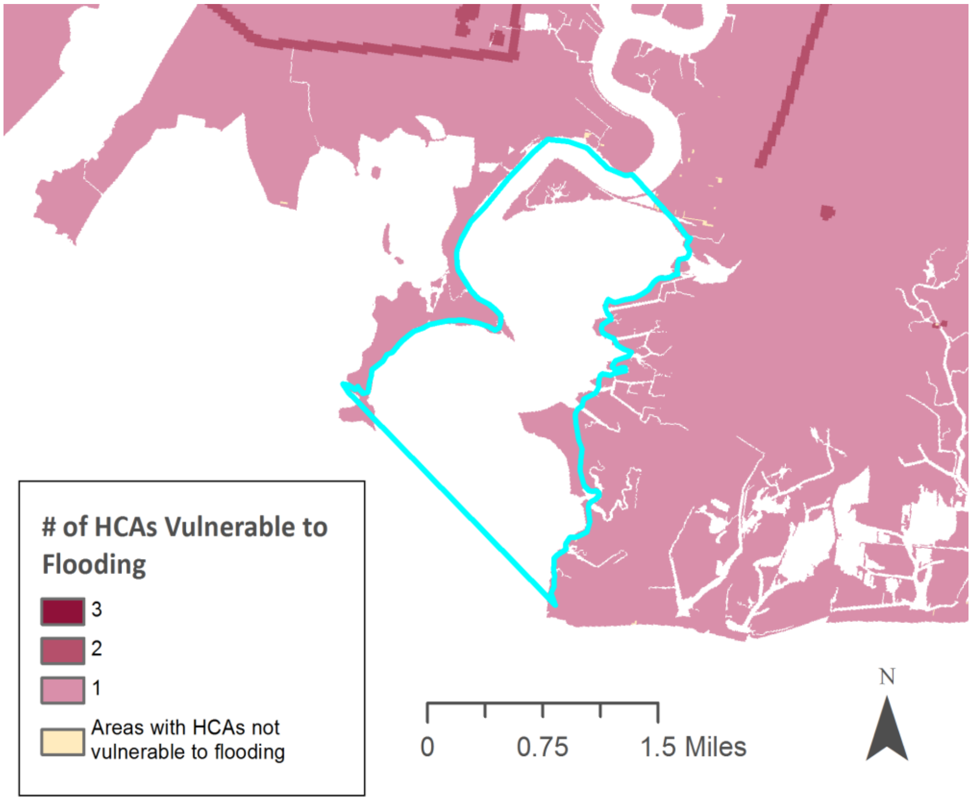


Figure CS3-3. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements) within and around the Maurice River area. Tan color indicates areas with HCAs that are not categorized as vulnerable for the purposes of this assessment. Blue outline is the proposed project area.*

Table CS3-2. Human Community Assets within the project boundary.

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

Fish and Wildlife

This site contains habitat for priority fish and wildlife species including many species highly valued by the regional stakeholders, including horseshoe crabs, eelgrass, and marine finfish and shellfish (**Table CS3-3, Figure CS3-4**). Restoration work at the site has the potential to positively impact species richness and diversity, especially for tidal marsh-dependent species as well as those that benefit from oyster beds.

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

Fish/Wildlife Habitat *	**Species of Interest to Stakeholders that may be Represented by these Habitat Types ****
Beaches and dunes	Horseshoe crab, red knot
Fresh water marshes	Rails (king and Virginia), least bittern, saltmarsh sparrow, ducks (various species)
Tidal marsh and tidal creek	Northern diamond-backed terrapin, saltmarsh sparrow, striped bass, river herring, shad, seatrout, forage species, ducks (various species)
Essential fish habitat	Flounder species, bluefish, black sea bass,
Oyster beds	Oysters, nursery habitat for fish species
Oyster tributaries	Oysters, nursery habitat for fish species

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

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

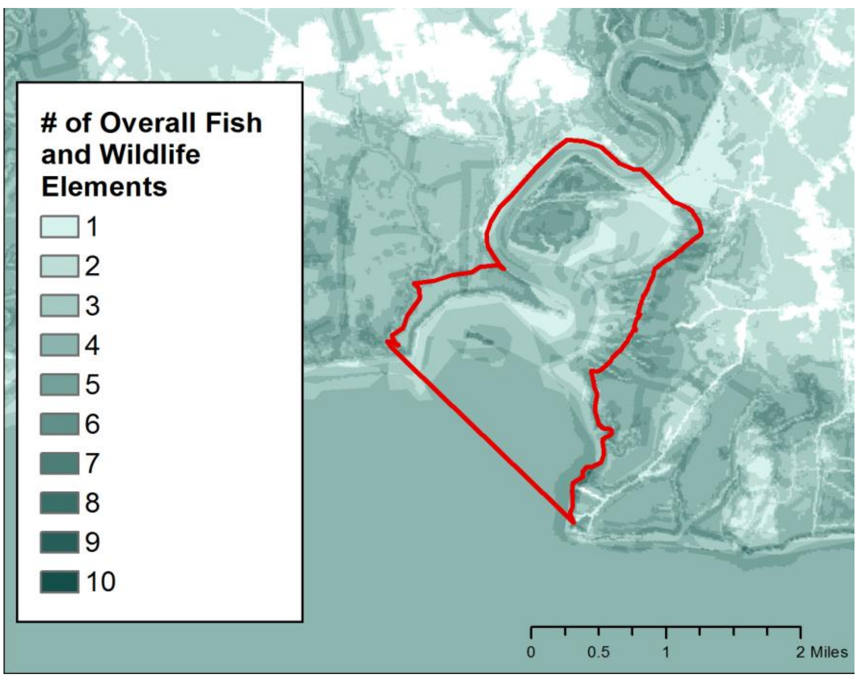


Figure CS3-4. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements combined (darker green signifies more elements/value). Red outline is the project boundary.*

Expected Project Impact

These projects will all serve a dual benefit by potentially preventing additional erosion of low-lying areas due to wave action, while also restoring tidal marsh habitat. In addition, these projects would potentially preserve and improve water quality in the face of emerging coastal threats in the region.

Conclusions

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

The mapping of the Resilience Hubs is intended to inform potential new locations for resilience projects that can provide mutual benefits to community resilience and fish and wildlife. The large spatial extent of open space areas in the Delaware Bay 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 Delaware Bay and Coastal Watersheds 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 this Delaware Bay and Coastal Watersheds—that the entire coastal area at the seashore and around the Bay are vulnerable to a variety of flooding threats but are particularly vulnerable to storm surge and sea level rise. Areas of vulnerability farther inland are largely due to precipitation-caused flooding threats along stream courses. Areas of Wilmington, DE along the Christina and Maurice Rivers and Penns Grove and Salem, NJ are hotspots of vulnerability. Outer coastal areas like Wildwood, NJ are also, vulnerable with their high exposure to storms and sea level rise. Fortunately, the coast along much of this watershed contains extensive beaches and wetlands that currently provide some buffering from storms. Protecting these areas and restoring other beaches and wetlands will provide resilience-building opportunities.

While the dense, urbanized areas such as Wilmington and the coastal strip development on the Cape May peninsula offer few nature-based resilience opportunities, such opportunities are common in the natural shorelines, marshes, and adjacent low uplands around the Bay and extending along key waterways. These nature-based resilience opportunities are best illustrated via the three case studies featured in this report, which highlight several important opportunities for improving resilience while benefiting fish and wildlife, such as:

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

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

Summary of Limitations

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

1. This assessment is not a plan and is not intended to assess or supplant any plans for the area (such as those summarized in Appendix 6. 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 4. 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 Delaware Bay and Coastal Watersheds. 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 the Bayshore Center at Bivalve (Port Norris, NJ) and the St. Jones Reserve / Delaware National Estuarine Research Reserve (Dover, DE).

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Additional Stakeholders

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American Littoral Society
Arcadis US
Association of NJ Environmental Commissions
Bayshore Center at Bivalve
Cape May County
Cattus Island County Park
Citizens United
Clean Ocean Action
Coalition for the Delaware River Watershed
Coastal Delaware NWR Complex
Coastal Zone Management Program
Cohansey Area River Preservation
Conserve Wildlife Foundation of NJ
CU Maurice River
Cumberland County
DE Valley Regional Planning Commission
Delaware Center for the Inland Bays
Delaware Department of Natural Resources and Environmental Control (DNREC)
Delaware National Estuarine Research Reserve
Delaware Natural Heritage Program
Delaware Nature Society
Delaware River Basin Commission
Delaware River Basin Commission
Department of Agriculture
DNREC - DE Bayshore Initiative

DNREC - Div. Fish & Wildlife
DNREC - Division of Energy and Climate
Downe Township
Downe Township Rutala Association
Ducks Unlimited - Delaware Chapter
Ducks Unlimited - New Jersey Chapter
Endangered and Nongame Species Advisory Committee
Federal Emergency Management Agency (FEMA)
Fordham University
Jacques Cousteau Coastal Education Center
Jacques Cousteau National Estuarine Research Reserve
Jenkinson's Aquarium
Jersey Coast Anglers Association
Kreitler Research & Consulting, LLC
Marine Mammal Stranding Center
National Fish and Wildlife Foundation (NFWF)
National Marine Fisheries Service - Northeast Regional Office
National Marine Fisheries Service - Office of Protected Resources
National Oceanic and Atmospheric Association (NOAA)
National Wildlife Foundation
Natural Resources Conservation Service
NatureServe
New Jersey Audubon Society
New Jersey Audubon Society - Cape May Bird Observatory
New Jersey Audubon Society - Sandy Hook Bird Observatory
New Jersey Conservation Foundation
New Jersey Department of Environmental Protection (NJDEP)
New Jersey Department of Transportation
New Jersey Farm Bureau
New Jersey Forest Association
New Jersey Marine Sciences Consortium
New Jersey Waterflowers Association
Niles and Associates
NJ Conservation Foundation
NJ Farm Bureau
NJDEP - Bureau of Coastal Engineering
NJDEP - Bureau of Marine Fisheries
NJDEP - Bureau of Water Monitoring and Standards
NJDEP - Coastal Management Program
NJDEP - Coastal Management Program
NJDEP - Division of Fish and Wildlife
NJDEP - Division of Water Quality
NJDEP - Endangered and Nongame Species Program
NJDEP - Green Acres
NJDEP - New Jersey Natural Heritage Program
NJDEP - NJ Natural Lands Trust
NJDEP - Office of Natural Lands Management
NJDEP - Office of Science, Research & Environmental Health
NJDEP State Forestry Service & NJDEP Natural Resources Restoration
NOAA - National Ocean Service
NOAA - Office of Restoration
NOAA - Sea Grant
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Partnership for the Delaware Estuary
Prime Hook NWR
Public Service Energy Group
Regional Planning Association
Richard Stockton College of New Jersey
Rummel Klepper & Kahl
Rutgers Cooperative Extension
Rutgers University
Rutgers University - Institute of Marine and Coastal Sciences
South Jersey Land & Water Trust
Stockton University - Marine Field Station
Stroud Water Research Center
Surfrider Foundation - Jersey Shore Chapter
The Nature Conservancy (TNC)
The Wetlands Institute
Tidewater Gateway Partnership, Inc.
TNC - Endangered and Nongame Species Advisory Committee
U. S. Fish and Wildlife Service (USFWS)
U. S. Army Corps of Engineers (USACE)
U. S. Department of Transportation - Division of Project Planning & Development
U. S. Environmental Protection Agency

(USEPA) - Region 2
University of North Carolina at Asheville - National Environmental Modeling and Analysis Center (NEMAC)
USEPA - Region 3
USFWS - Delaware Bay Estuary Project
USFWS -NJ Field Office
Woodbine Public Works

Appendices

Appendix 1. Watershed Committee and Stakeholder Engagement Mechanisms and Process

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

Watershed Committee

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

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

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

Stakeholders

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

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

Representatives from federal and state agency personnel, non-profit organizations, local government agencies, academic institutions, and interested private citizens were all invited to participate in the assessment process. Of 194 invited participants, 48 participated in the in-person stakeholder workshops, but many others followed up with additional information and input after the workshops, providing critical data leads and resilience project ideas. (See Acknowledgments section for a list of the agencies represented in the stakeholder process.)

Project Outreach and Coordination Resources

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

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

Watershed Webinars and Stakeholder Workshops

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

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

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

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

Name of Engagement Activity	Participation	Date
First Watershed Committee meeting (by webinar)	Watershed Committee	July 11, 2017
Pre-stakeholder webinar	Stakeholders, Watershed Committee	November 9, 2017
In-person stakeholder workshops	Stakeholders, Watershed Committee	November 15-16, 2017
Post workshop follow-up to summarize workshop results	Watershed Committee	December 19, 2017
Review of fish and wildlife and vulnerability assets	Watershed Committee	March 9, 2018
Draft results webinar to discuss GIS analysis and obtain final input from all stakeholders that wish to participate	Stakeholders, Watershed Committee	September 6, 2018

Post-workshop Activities

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

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

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

Gathering Candidate Projects

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

Appendix 2. Condition and Vulnerability Technical Approach and Modeling Methods

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

GIS Tools

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

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

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

Modeling Approach

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

The process steps used are listed and described below.

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

Definition of Scenarios

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

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

Scenarios were built within the Vista DSS using the Scenario Generation function where data attributes were cross-walked to a classification of scenario stressors and threats. Data layers were added and grouped as to whether a feature overrode or dominated stressors and threats below it or combined with other stressors and threats. The objective of that process is to provide the most accurate scenario in terms of whether scenario stressors and threats co-occur in the same location or the presence of a feature precludes the presence of another feature (e.g., where there is a road there is not also agriculture). A large volume of stressor and threat data were gathered, evaluated, and integrated in the Vista DSS to map each of the scenarios. Details on scenario data are described below and the use of individual stressors and threats in each scenario is shown in **Table 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
Energy, including oil and gas extraction and renewable energy	X		X
Terrestrial and aquatic invasive species	X		X
Water quality or stressors that can affect water quality	X		X
Dredge Material Placement Areas	X		X
Flooding Threats	**Baseline**	**Threats**	**Combined**
Sea level Rise		X	X
Storm surge potential		X	X
Subsidence		X	X
Erosion potential		X	X
Flat and poorly drained soils		X	X
Flood prone areas		X	X

Stressor and Threat Data

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

Soil Erodibility

To assess the erodibility of soils throughout the coastal watersheds, the USDA-NRCS Soil Survey Geographic Database (SSURGO) classification kffact was used. The kffact score represents the susceptibility of soil particles to detachment by water. Soil erosion resulting from flooding can drastically alter the landscape and impact wildlife habitat. Erosion can be devastating in extreme flood events. In this assessment, soil erodibility varies tremendously across regions and is dependent on soil type. Also highlighted in this input are beaches and dunes that are migratory by nature. Although these landforms can help buffer a community from flooding, the risk of erosivity is fairly high.[7]

[7]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.

Impermeable Soils

This input was included because it influences the period of time that coastal lands are inundated after a storm event. Poorly drained soils are typically wetland soils or clays and high density development is also considered very poorly drained because of pavement and rooftops. In many cases the USDA-NRCS SSURGO database is lacking data in urban areas. To account for the obvious impermeable nature of these areas, the National Land Cover Database developed land cover classes are included. To be considered a "very high" rank, the landscape must be a poorly or very poorly drained soil type and mapped as a developed land use.

Sea Level Rise

Sea level rise is occurring at different rates across the U.S. Coasts, for example relative sea level rise along the western portion of the Gulf Coast and a large portion of the North Atlantic Coast will be greater than the Pacific Northwest Coast as a result of groundwater and fossil fuel withdrawals.[8] 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.[9] Scenarios for a 1-5 foot rise in sea level were used in the Regional Assessment but a lower level was used in this Targeted Watershed Assessment (see Methods Overview).

Storm Surge

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

Areas of Low Slope

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

Additional stressors on fish and wildlife were identified by stakeholders in the workshops (Appendix 1). Distribution data were submitted by stakeholders and evaluated against data criteria and other regional/national datasets known to the GIS team. The best available data were then used to build each scenario based on currency, completeness, and resolution. Stakeholders, Watershed Committee

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

[9] 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.

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. Requirements for data submissions included:

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

All data sources were further evaluated according to project data requirements. Evaluation included completeness of data across the watershed, precision of data, and accuracy of data compared to other sources or imagery. Where necessary, data were projected to the project standard, clipped/masked to the project boundary, and rasterized if necessary. For readers interested in using these datasets, they can be found in the 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, cemeteries, 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	NatureServe Systems Map (Comer 2009)	Baseline, Combined
	Intensive Agriculture		
	Ruderal (maintained pasture, old field)		
	Aquaculture	No data	N/A
Energy Production and Mining	Solar Arrays	No data	N/A
	Wind		
	Oil and Gas Fields		
	Mining		
Transportation and Service Corridors	Primary Roads	Tiger roads (U.S. Census 2016)	Baseline, Combined
	Secondary Roads		
	Local, neighborhood and connecting roads, bridges/culverts		
	Dirt/Private roads/culverts		
	Railroads, bridges, culverts	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later); Federal Highway Administration, NBI v.7, NTAD (2015 or later)	
	Utility & Service Lines (overhead transmission, cell towers, etc.)	No data	N/A

Stressor/Threat Primary & Secondary Categories		Data Sources	Scenarios
Dredge Material Placement Areas		USACE (Michael Sarhan pers. comm.)	Baseline, Combined
Dams & Reservoirs		USDOT/Bureau of Statistics's NTAD (2015 or later)	Baseline, Combined
Sea Level Rise – 1 ft		NOAA Sea-level Rise Scenarios	Flooding Threats, Combined
Storm Surge	Category 1	FEMA National Flood Hazard Layer	Flooding Threats, Combined
	Category 2		
	Category 3		
	Category 4		
	Category 5		
Water Quality	Moderate	EPA Impaired Waters AIS Commercial Vessel Traffic Density (*citation needed*, obtained from Rua Mordecai pers. comm.)	Baseline, Combined
	Low		
Invasive Species	Terrestrial	No data	N/A
	Aquatic		
Landslide Susceptibility	High Susceptibility, Moderate Incidence	USGS Landslide Susceptibility Data	Flooding Threats, Combined
	High Incidence		
Subsidence	Moderate	UNAVCO Subsidence Data	Flooding Threats, Combined
	High		
	Very High		
Poorly drained areas	Flat & Somewhat Poorly Drained	NRCS SSURGO	Flooding Threats, Combined
	Flat & Poorly or Very Poorly Drained		
Erosion	High Erodability	NRCS SSURGO Soil Erodibility Data	Flooding Threats, Combined
	Very High Erodability		
Flood Prone Areas	Occasional Flooded Soils	FEMA National Flood Hazard Layer	Flooding Threats, Combined
	Frequent Flooded Soils		
	500 Year Floodplain		
	100 Year Floodplain		
	Floodway*		

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

Building Element Response Models

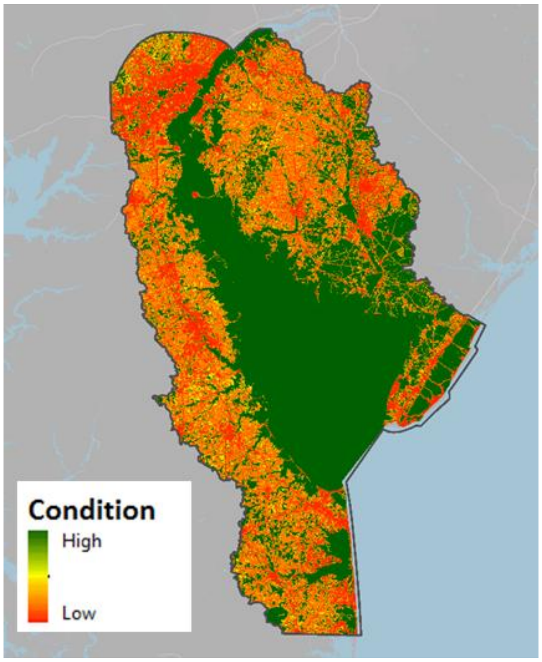
Response models reflect how each element responds in the presence, or within a certain distance, of a scenario feature. Four response models were developed to model element condition and assess their vulnerability. One model was developed for HCAs; fish and wildlife elements were put into three groups, assuming that the elements within a group respond similarly to the stressors and threats: a Terrestrial Elements model (models condition of all terrestrial wildlife elements), a Freshwater

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

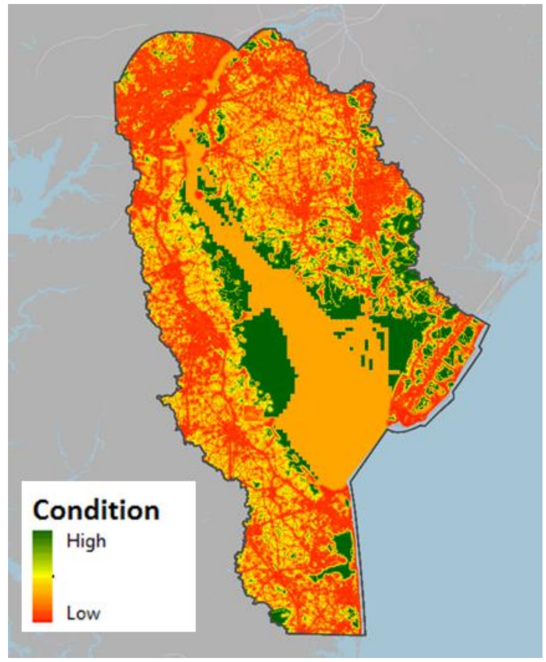
Model Element Condition

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

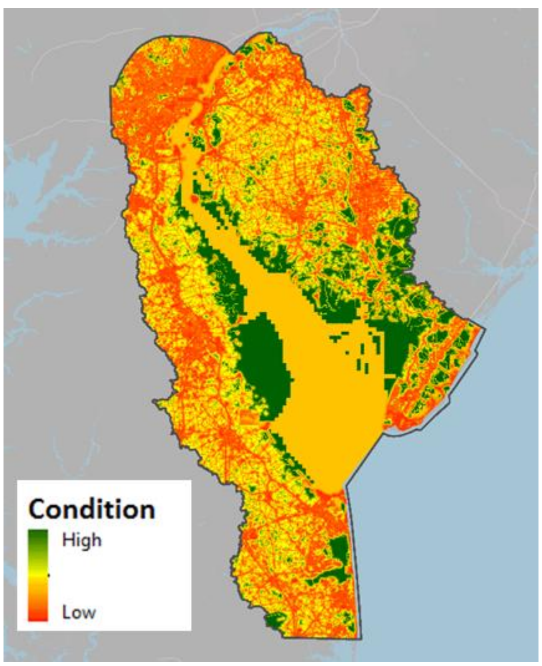
The LCM calculates the condition score of every pixel in the watershed as depicted in the four maps below (**Figure A2-1**) using the relevant response models per above without regard to locations of elements to which the scores will be applied. The LCM first calculates the response scores on each individual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



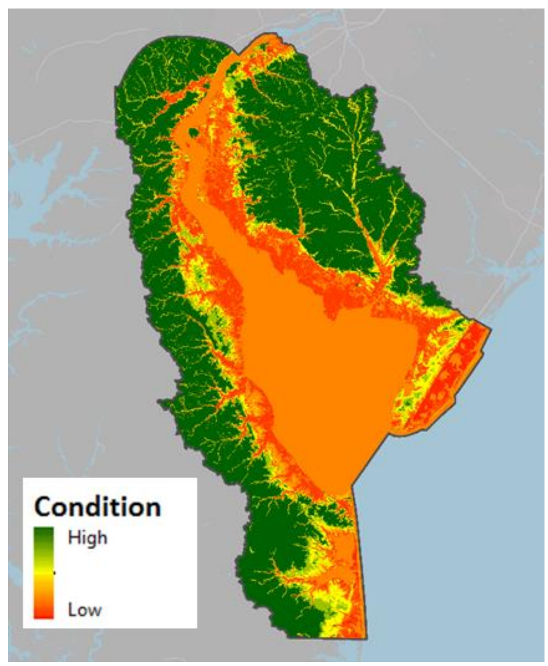
Terrestrial Elements Condition



Freshwater Elements Condition



Estuarine Elements Condition



HCA Elements Condition

Figure A2-1. Landscape condition model outputs for the Delaware Bay and Coastal Watersheds. *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 (0.65) x category 2 (0.7) x category 3 (0.75) x category 4 (0.8) x category 5 (0.85) = a cumulative impact score of 0.23 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	N/A
		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	N/A	N/A
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response	N/A	Assume slightly less impact than for Very High Erodibility below.
		LCM Site Intensity	0.95	
		LCM Distance	N/A	N/A
	Very High Erodibility	Categorical Response	N/A	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	N/A	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	N/A
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.6	N/A
		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	N/A
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	N/A
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.9	N/A
		LCM Distance	0	Assume no offsite effect.

Table A3-1. Freshwater Exposure Model structure and assumptions.

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

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)	Categorical Response	Negative	Developed/armored shorelines, heavy runoff of freshwater and pollutants may include effects such as waterfowl hazing and noise impacts that would greatly reduce condition Very low potential for restoration.
		LCM Site Intensity	0.2	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
Agriculture and Aquaculture	Silviculture - Intensive	Categorical Response	Neutral	Periodic clearing with high impacts on habitat, some impacts on hydrology through sedimentation and potential chemical application. In-wetland harvesting occurs in the Delaware 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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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.
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.

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, and pollutant runoff.
		LCM Site Intensity	0.05	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
Transportation and Service Corridors	Secondary roads, e.g., moderate traffic/volume state highways, bridges	Categorical Response	Negative	Assume over water assume bridge with in water and shoreline structures, and clearing leading to altered hydrology, shading, and noise impacts. Assume these impacts will drop immediate area to just below viability threshold.
		LCM Site Intensity	0.6	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Local, neighborhood and connecting roads, bridges/culverts	Categorical Response	Negative	Assume culvert instead of bridge with in water and shoreline structures, and clearing, altered hydrology, shading, and noise impacts, in addition to the loss of ecological connectivity. Likely denser than other road types. Assume these impacts will drop immediate area to just below viability threshold.
		LCM Site Intensity	0.6	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Dirt/Private roads/culverts	Categorical Response	Negative	Assume culverts with intensive onsite impact, shoreline structures, and clearing, altered hydrology, shading, noise, dirt runoff, and impacted connectivity. Assume some restorability.
		LCM Site Intensity	0.5	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Railroads, bridges, culverts	Categorical Response	Negative	Over water assume bridge with in-water and shoreline structures, and clearing, altered hydrology, shading, and noise impacts. Assume these impacts will drop immediate area to just below viability threshold and low restorability.
		LCM Site Intensity	0.6	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Utility & Service Lines (overhead transmission, cell towers, etc.)	Categorical Response	Neutral	Assume over water feature with in-water support structures, infrequent maintenance, and noise impacts. High restorability.
		LCM Site Intensity	0.9	
		LCM Distance	20	Very small distance effect.

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 that offsite effects would include chemical and sediment runoff. Moderate restorability to vegetative cover that would reduce impacts to adjacent aquatic systems.
		LCM Site Intensity	0.3	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
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 the 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, understanding that in some cases individual structures might be removed for purposes such as allowing for marsh expansion in the future.
		LCM Site Intensity	.9	
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Projects with on-the-ground actions focused on improving beach or dune conditions may reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

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.

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

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

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

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Local, neighborhood and connecting roads, bridges/culverts	Categorical Response	Negative	Assume mostly culverts instead of bridges with in-water and shoreline structures, clearing, altered hydrology, shading, and noise impacts, and loss of ecological connectivity. Likely more dense than other road types causing the immediate area to drop just below the viability threshold.
		LCM Site Intensity	0.5	
		LCM Distance	50	Relatively small distance effect.
	Dirt/Private roads/culverts	Categorical Response	Negative	Assume culverts with intensive onsite impact, shoreline structures, clearing, altered hydrology, shading, noise impacts, dirt runoff, and impacted connectivity. Assume some restorability possible.
		LCM Site Intensity	0.5	
		LCM Distance	50	Relatively small distance effect.
	Railroads, bridges, culverts	Categorical Response	Negative	Assume bridge with in-water and shoreline structures, clearing, altered hydrology, shading, and noise impacts. Assume these impacts will drop immediately affected area to just below viability threshold.
		LCM Site Intensity	0.5	
		LCM Distance	50	Relatively small distance effect.
	Utility & Service Lines (overhead transmission, cell towers, etc.)	Categorical Response	Neutral	Assume over-water feature with some in-water support structures, but infrequent maintenance or noise. High restorability.
		LCM Site Intensity	0.9	
		LCM Distance	20	Relatively small distance effect.
Dredge Material Placement Areas		Categorical Response	Negative	Assume dredge materials will not be placed within aquatic systems. Offsite effects could include chemical and sediment runoff. Moderate restorability for vegetative cover that would reduce impacts to adjacent aquatic systems.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
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 assumes greater dilution/flushing action. Restorability is possible if sources impairing water quality are addressed.
		LCM Site Intensity	0.5	
		LCM Distance	100	Extrapolates incomplete water quality data to surrounding waters.
	Invasive Species - Aquatic	Categorical Response	Negative	Assume aquatic species are much more difficult to control in an open marine/estuarine system compared to streams/lakes. Restorability is low because it is difficult to manage and effectively remove aquatic species from a given habitat.
		LCM Site Intensity	0.3	
		LCM Distance	300	Indicates a potentially large distance of spread of invasives depending on species and conditions.
	Invasive Species - Terrestrial	Categorical Response	Neutral	No anticipated effect.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Subsidence	Moderate Subsidence (Rank 3)	Categorical Response	Neutral	Assume minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect. Restoration generally not feasible.
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.
	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 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 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	

<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="6"></td><td rowspan="3">Upland restoration</td><td>Categorical Response</td><td>Positive</td><td rowspan="2">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.</td></tr>
<tr><td>LCM Site Intensity</td><td>1</td></tr>
<tr><td>LCM Distance</td><td>0</td><td>Assume no offsite effect.</td></tr>
<tr><td rowspan="3">Riparian and floodplain restoration</td><td>Categorical Response</td><td>Positive</td><td rowspan="2">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.</td></tr>
<tr><td>LCM Site Intensity</td><td>1</td></tr>
<tr><td>LCM Distance</td><td>0</td><td>Assume no offsite effect.</td></tr>
</table>

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

Key Assumptions of this Model			
Applies to all human community assets		Responses to stressors focused on physical damage/loss from flooding	
Note: elevated roads/bridges were not separated from surface roads is the source data, so they are treated equally.			
Importance Weighting (Optional, used only for the CVS)	Values range from: 0.0 (Low) to 1.0 (High). These ratings were approximated from those used in the regional coastal resilience assessment.	0.2	Critical Infrastructure (Rank 1)
		0.2	Environmental Justice Rank 1
		0.2	Population Density (Rank 1)
		0.4	Critical Infrastructure (Rank 2)
		0.4	Population Density (Rank 2)
		0.6	Critical Infrastructure (Rank 3)
		0.6	Population Density (Rank 3)
		0.8	Population Density (Rank 4)
		1.0	Critical Facilities
		1.0	Population Density (Rank 5)
Element Condition Threshold	Values range from: 0.0 (Low) to 1.0 (High). This value will determine the LCM result threshold under which a species is no longer viable in a pixel. Nearing 0.0 indicates increasing resilience and nearing 1.0 indicates increasing sensitivity.	0.5	Assume human assets have moderate sensitivity owing to their ability to repair/rebuild vs. ecological features that can rarely be restored to original type/health or take a very long time to recover naturally.
Land Use Intents (term used in Vista 3.x for all land uses, infrastructure, other stressors and threats, and conservation management and practices anticipated under any scenario). The IUCN/CMP classification list (v3.1, 2011) of direct threats and conservation practices was modified to meet the needs of this project.			

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions *(Restorability is not included because assets are not natural features to be restored.)*
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.7	
		LCM Distance	0	Assume no offsite effect.
	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	N/A	N/A
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.
	High Subsidence (Rank 4)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Flat (Slope <=0.75%) & Poor Drainage	Flat & Somewhat poorly drained	Categorical Response	N/A	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	N/A	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.

Primary Category	Secondary Category	Response Types	Responses	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
Erosion	High Erodibility	Categorical Response	N/A	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	N/A	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.
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.

Primary Category	**Secondary Category**	**Response Types**	**Responses**	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
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.
Resilience Project Protection/ Restoration Actions *(categories needed for Scenario breakouts)*	Living shoreline implementation	Categorical Response	N/A	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.

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

Appendix 4. Fish and Wildlife Vulnerability Index

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

Methods

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

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

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

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

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

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

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

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

Steps to model element vulnerability under each scenario:

1. Select fish and wildlife elements to be assessed.
2. Select the stressors and threats scenarios to assess the elements vulnerability.
3. Populate vulnerability (condition) models 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 condition maps.
5. Intersect fish and wildlife distributions with the resulting watershed condition maps to generate condition 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.

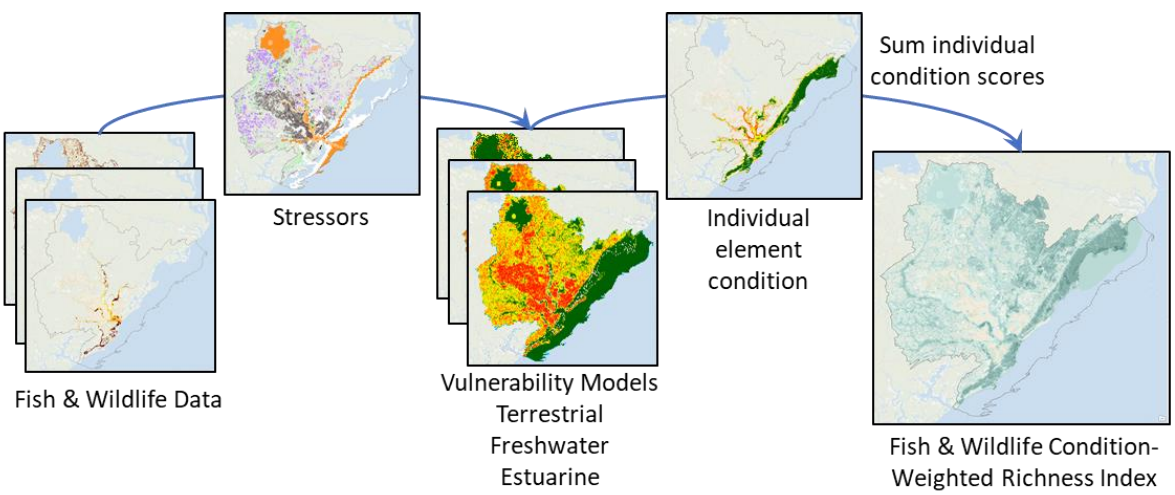


Figure A4-1. Method for calculating fish and wildlife vulnerability indices. *Elements are intersected with stressors and/ or threats, the vulnerability model is applied, and individual element vulnerability results are summed to create each index. Diagram represents the Charleston, SC region as an example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

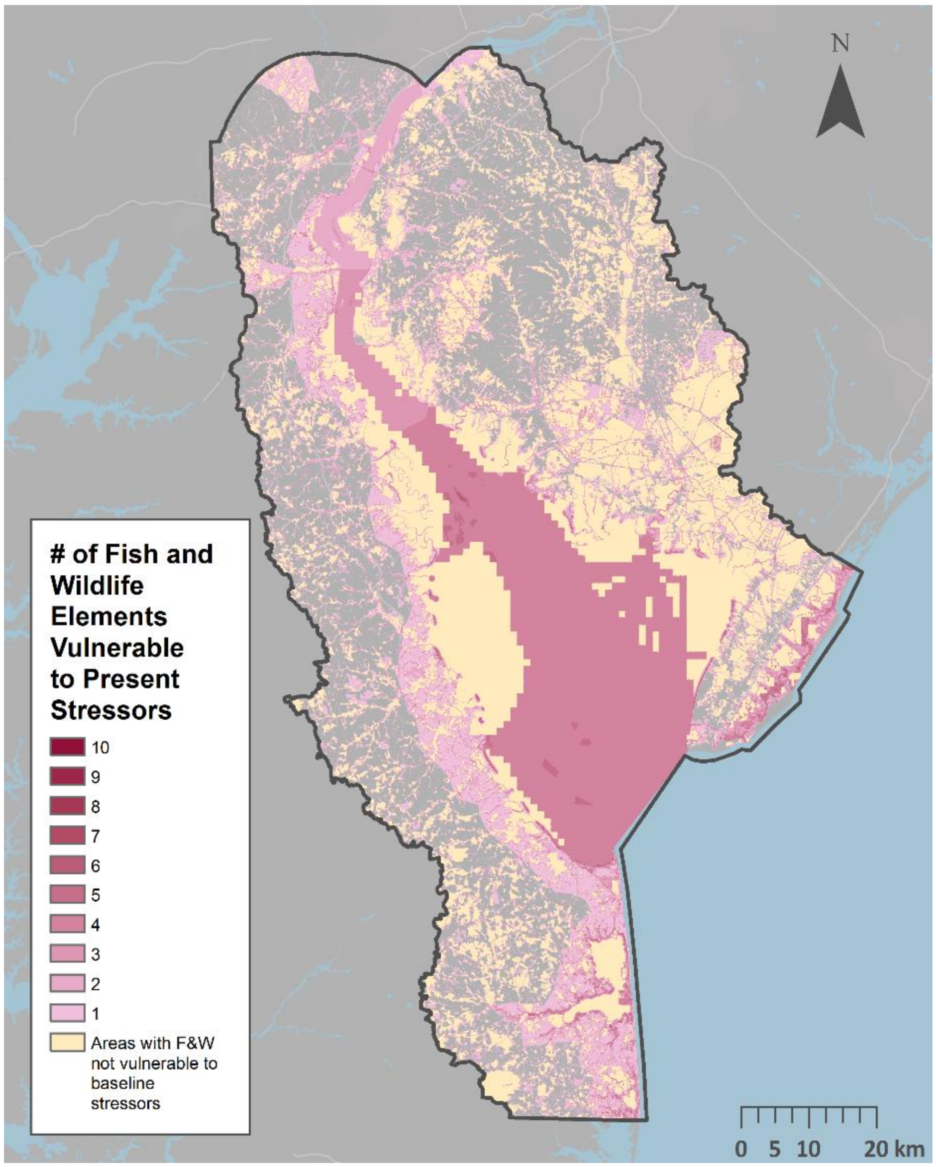


Figure A4-2. Fish and Wildlife Baseline Vulnerability for the Delaware Bay and Coastal Watersheds. *This map is an overlay or index of all fish and wildlife elements that are vulnerable to the existing mapped stressors. Gray areas within the project boundary represent areas with no mapped fish and wildlife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

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

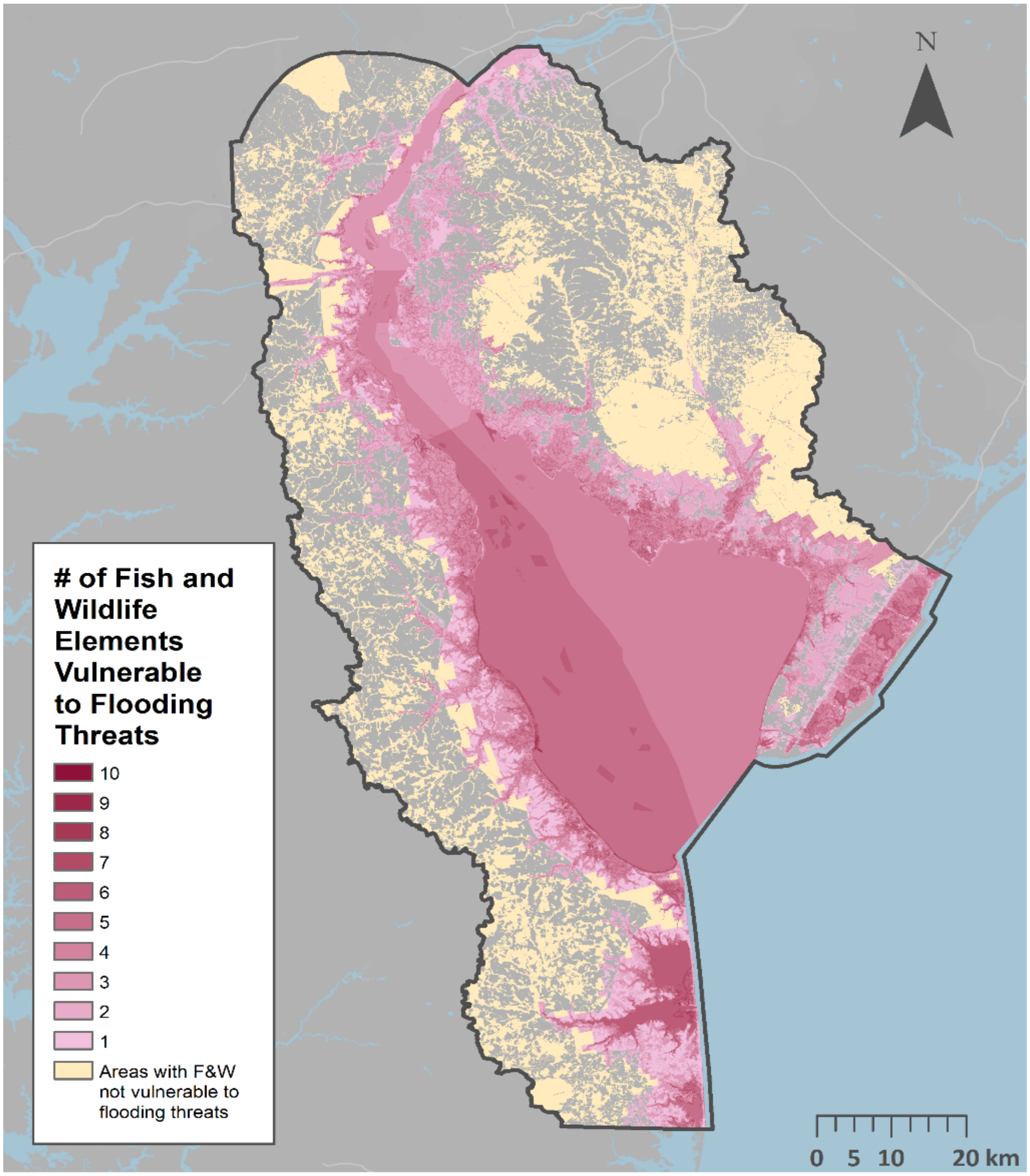


Figure A4-3. Fish and wildlife vulnerability to flooding threats in the Delaware Bay and Coastal Watersheds. *Pink to red shades indicate the number of elements vulnerable to flooding threats. Tan areas indicate areas of low to no impact. Gray areas within the project boundary represent areas with no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

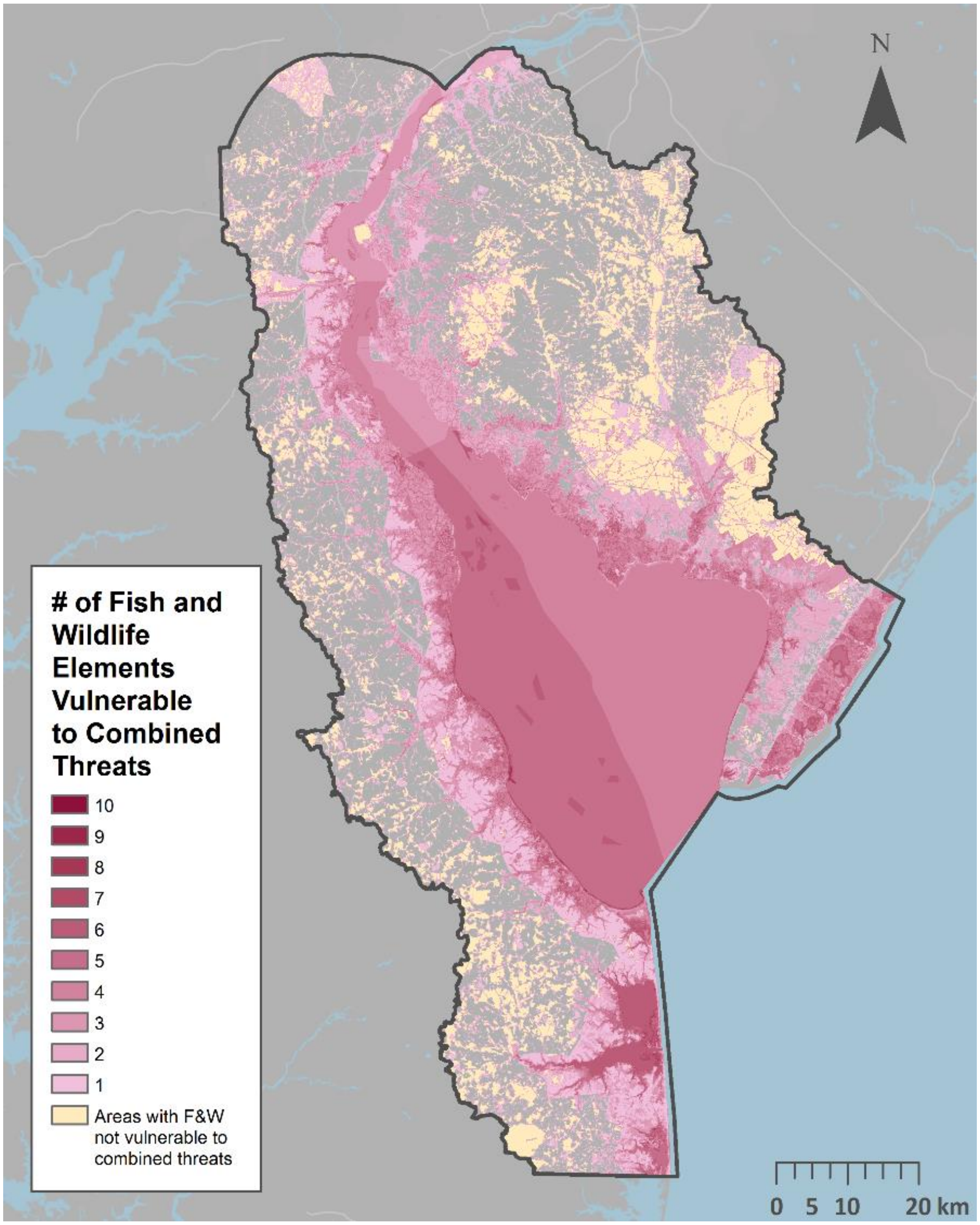


Figure A4-4. Fish and wildlife elements vulnerability to combined stressors and flooding threats for the Delaware Bay and Coastal Watersheds*. Pink to red shades indicate the number of elements vulnerable to threats. Tan areas indicate areas of low to no impact from the baseline threats. Gray areas within 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 (Score Agency or Organization) [Attributes used].

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
NOAA Trust Resources		
Diadromous fish habitat	Merged: • NE Aquatic Connectivity Assessment - Anadromous Fish presence / absence (TNC) [50m buffer] as intersected with TNC flowlines_habguide.shp, • DSL_lotic_cores_HUC6_2010_v3.0_shape.shp • DSL_lentic_cores_HUC6_2010_v3.0_shape.shp • Important_Anadromous_Fish_Habitat.shp	BEST RegionAnadFish_032513; RegionAnadFish_032513
Important river mussel habitat	Merged: • Predicted Best Ribbed Mussel Habitat in NJ (Partnership for the Delaware Estuary) • Data from Stream and River Aquatic Habitat Guide (TNC) [Desc_58 = "Tidal Headwater/Creek"]	• Active River Area (Open Space Institute) • Predicted Best Ribbed Mussel Habitat in NJ (Partnership for the Delaware Estuary) → Data only covers partial study area boundary (NJ) • Landscape Project (NJDEP) → Data only covers part of study area boundary (NJ) • NJ Freshwater Mussel Streams (New Jersey Conservation Foundation) → Data only covers partial study area boundary (NJ)
Tidal marsh and tidal creek (includes open water)	Merged: • Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) ['Northern Atlantic Coastal Plain Tidal Salt Marsh'] • NJ - Land_lu_2012_hu02040204_206 = 'Tidal Marsh and tidal creek'	• Salt Marsh Integrity Rating (TNC) → Data does not provide additional information beyond primary proposed data sources. • Terrestrial and Aquatic Habitat Map (DSLland) (NALCC) → Data does not provide additional information beyond primary proposed data sources.

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
NOAA Trust Resources		

Oyster beds/reefs	Merged:
	• Delaware River Basin Initiative - 2011 Analysis:
	  ○ Designated Target Oyster Beds (Partnership for the Delaware Estuary (PDE))
	  ○ Designated Hard Bottom - Potential Reef Creation (PDE)
	  ○ Tributary Oysters (NJDE) [buffered by 90m]
	• DE Oyster Bed Locations (Wildlife Species Conservation & Research Program, Division of Fish & Wildlife, Delaware Department of Natural Resources and Environmental Control)
		• PDE Climate Oyster Planting Area (TNC) → Data does not provide additional information beyond primary proposed data sources; data too coarse for the resolution of this analysis.

Essential Fish Habitat/important habitat for key fish species	Essential Fish Habitat for Summer Flounder (NOAA) [DDBOX = 'Summer Flounder']	• Atlantic Sturgeon Critical Habitat Rivers (NOAA) → Distribution does not extend beyond primary proposed data sources. • Atlantic Sturgeon GARFO Section 7 Consultation Areas (NOAA Fisheries) → Distribution does not extend beyond primary proposed data sources. • Delaware Special Management Zone Areas ('artificial reefs') → Distribution does not extend beyond primary proposed data sources. • Management Units for summer flounder, scup, and black sea bass (NOAA) → Distribution does not extend beyond primary proposed data sources. • New Jersey Fish Index of Biotic Integrity Sampling Points (2000 - 2011) → Data does not intersect project area. • Weakfish Relative Abundance (Michael Greco, Delaware Division of Fish & Wildlife, from data collected from the Coastal Finfish Assessment Survey) → Distribution does not extend beyond primary proposed data sources.

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
NOAA Trust Resources		
Important horseshoe crab areas	Dissolved: • Beach Segment Dataset (inclusive of DE and NJ) (Delaware Bayshore mapping project) [buffered 30m on each side of all segments (60 total)]	• Horseshoe Crab Habitat Suitability dataset (Rutgers CRSSA) → Distribution does not extend beyond primary proposed data sources. • DE Horseshoe Crab Beaches (from Bill McAvoy) → Distribution does not extend beyond primary proposed data sources. • DE Bay Spatial Data with "COMMUNITY" = 'Beach and Dune Communities' (Wildlife Species Conservation & Research Program, Division of Fish & Wildlife, Delaware Department of Natural Resources and Environmental Control)→Distribution does not extend beyond primary proposed data sources.
Sea turtles	NOAA Section 7 Consultation Areas for Sea Turtles (NOAA)	N/A
Sharks	Sandbar and sand tiger shark distributions (NOAA)	N/A
At-Risk Species and Multi-species Aggregations		
At-risk terrestrial species	Habitat importance for imperiled species (Nature's Network) [**Important** ('IMPT_SUM' >= 77)	• Natural Heritage Grid Map (NJDEP) → No comparable data to be utilized in state of Delaware. • Natural Heritage Grid Map (NJDEP) →No comparable data to be utilized in state of Delaware.
Ovenbird	NALCC (Landscape Capability for Wood Thrush and Ovenbird, Northeast) and Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe). Issues accurately representing this element were encountered and an update to this data is encouraged for any assessments using this element.	N/A
Wood thrush	NALCC (Landscape Capability for Wood Thrush and Ovenbird, Northeast) and Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe). Issues accurately representing this element were encountered and an update to this data is encouraged for any assessments using this element.	N/A

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
At-Risk Species and Multi-species Aggregations		
Northern diamondback terrapin	Northern Diamondback Terrapin Probability of Occurrences model for the Northeastern U.S. (Rutgers University) [10th percentile probability threshold]	N/A
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species		
Atlantic white cedar swamp forest	Merged: • Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) ["Atlantic white cedar swamp forest"] • In NJ only: ○ Land use/land cover map (NJ DEP) ["Atlantic white cedar forest"] for New Jersey ○ Land_lu_2012_hu02040204_206 [LU12 = 6221] • Cypress swamps and AWC swamps are mapped as part of the habitat vegetation map removed as covered by Cypress Swamp • Land Use / Land Cover 2012 (2015) (NJ DEP) ['ATLANTIC WHITE CEDAR WETLANDS'] • Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) [System_Name = Northern Atlantic Coastal Plain Basin Peat Swamp, Northern Atlantic Coastal Plain Tidal Swamp, (Great Cyprus swamp areas subtracted)]	• Terrestrial and Aquatic Habitat Map (DSLland) (NALCC) → Data does not provide additional information than the proposed data source
Cypress swamp	Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) [System Name = "Northern Atlantic Coastal Plain Tidal Swamp" clipped to Great Cypress (managed area) only]	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		

Freshwater marshes	Merged:
	• Land Use / Land Cover 2012 (2015) NJDEP [DECIDUOUS SCRUB/SHRUB WETLANDS, CONIFEROUS SCRUB/SHRUB WETLANDS, MIXED SCRUB/SHRUB WETLANDS (DECIDUOUS DOM.), MIXED SCRUB/SHRUB WETLANDS (CONIFEROUS DOM.), HERBACEOUS WETLANDS, PHRAGMITES DOMINATE INTERIOR WETLANDS, DISTURBED WETLANDS (MODIFIED)]
	• (For DE only):
	  ○ Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) [Laurentian-Acadian Freshwater Marsh, Laurentian-Acadian Wet Meadow-Shrub Swamp]
	  ○ National Wetlands Inventory (USFWS) [‘Freshwater’]
		Terrestrial and Aquatic Habitat Map (DSLland) (NALCC)

Salt marsh sparrow habitat	Landscape Capability for Saltmarsh Sparrow-Version 3.0, Northeast (NALCC) [capability score > 0.136584598 (2nd quartile and above)]	N/A
Wading bird and ally colonies	Wading habitat (NJDE)	N/A
Vernal pools	Species Based Habitat - NJDEP Landscape Project v3.3 (NJDEP) [Vernal Habitat layer] Augmented NWI dataset (DNREC) ["COMMUNITY" = 'Coastal Plain Seasonal Pond']	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		
Forested wetlands	Merged: • Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) [Northern Atlantic Coastal Plain Pitch Pine Lowland, North-Central Appalachian Acidic Swamp, Central Interior and Appalachian Rich Swamp, Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest] • NJDEP Land Use / Land Cover 2012 (2015) [DECIDUOUS WOODED WETLANDS, CONIFEROUS WOODED WETLANDS, MIXED WOODED WETLANDS (DECIDUOUS DOM.), MIXED WOODED WETLANDS (CONIFEROUS DOM.)]	N/A
Black duck habitat	North Atlantic LCC Habitat Capability model for American Black Duck (non-breeding habitat layer for this region) [Applied threshold of 0.391767609]	N/A
Atlantic beach and dune / priority near shore habitat	Merged: • Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) [System_Name = Northern Atlantic Coastal Plain Dune and Swale] • Land Use / Land Cover 2012 (2015) (NJDEP) [VEGETATED DUNE COMMUNITIES, BEACHES] Land_lu_2012_hu02040204_206; LU12 = 6130 & 7100	• Northwest Atlantic Marine Ecoregional Assessment Coastal Habitats (TNC) → Data does not provide additional information than the proposed data source • Terrestrial and Aquatic Habitat Map (DSLland) (NALCC) → Data does not provide additional information beyond primary proposed data source
Coastal forests	• Terrestrial Ecological Systems and Land Cover of the Conterminous United States v35 2018 (NatureServe) [System_Name = Northern Atlantic Coastal Plain Hardwood Forest, Southern Atlantic Coastal Plain Mesic Hardwood Forest, Northern Atlantic Coastal Plain Maritime Forest] • Land Use / Land Cover 2012 (2015) (NJDEP) (Used in place of the above in NJ) [Land_lu_2012_hu02040204_206; LU12 = 4110,4120,4210,4220,420,411,4312,421,422,4410,4411,4420,4430,4440]	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		
Grassland bird habitat	Grass bird core areas (Nature's Network) [Grassland Bird Core Areas, Northeast U.S.]	N/A
Artificial reefs	Artificial Reefs (NOAA NMFS Northeast Fisheries Science Center)	• FSSI and Non-FSSI Stock Status Table (NOAA) (status accessed on June 20 2018 on this webpage: http://www.nmfs.noaa.gov/sfa/fisheries_eco/status_of_fisheries/status_updates.html: → Documentation in progress • DE Artificial Reef Locations (DEDNREC) → Data does not provide additional information than the proposed data source, and it is also too coarse • Artificial Reef Sites (NJ DEP) [category='Beach segments']→Data only covers partial study area boundary (NJ))
Cross-cutting Elements		
Continental and Global Important Bird Areas	Important Bird Areas (Audubon) • Global • Continental	N/A

***Table A5-2. Fish and wildlife elements proposed but ultimately <u>not included</u> in this assessment**. For each element, a brief description is provided explaining why it was not included.*

Fish/Wildlife Element Proposed for Inclusion	Reason Not Included in Assessment
Bogs/fens	Given the 'nesting' of this ecological system within a more general 'Freshwater marshes' category, this element was 'collapsed' into that category.
Northern long-eared bat	Insufficient data– the range is probably the whole DE Bay region, which wouldn't be helpful.
Submerged aquatic vegetation	Data did not cover entire study area boundary.
Bald eagle (nests)	Species now too common to serve the goals of this assessment.
Black rail	No specific data available beyond surrogate habitat data which is already represented in the analysis.
Osprey	No data found suitable for the resolution of this analysis.
Purple martin	No data found suitable for the resolution of this analysis.
Bee species	No data found suitable for the resolution of this analysis.
Monarchs and other butterflies	No data found suitable for the resolution of this analysis.
Tubeworms	No data found suitable for the resolution of this analysis.
Brown coral	No data found suitable for the resolution of this analysis.
Bobwhite quail	No data found suitable for the resolution of this analysis.
Delmarva/Carolina bays	No data found suitable for the resolution of this analysis.
Interdunal wetlands/swales	Considered represented by the 'Atlantic beach and dune' element.
Wild rice	No specific data available beyond surrogate habitat data which is already represented in the analysis.
Coastal impoundments	No explicit datasets found to represent this target.
Managed dunes (as separate from natural dunes)	No specific data available beyond more general habitat data which is already represented in the analysis.
Forest core/travel corridors	No specific data available beyond more general habitat data which is already represented in the analysis.
Bog/fen habitat	Considered represented by the 'Freshwater marshes' element.
At-risk aquatic species	No adequate data identified for Delaware.

Appendix 6. Resilience Project Information

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

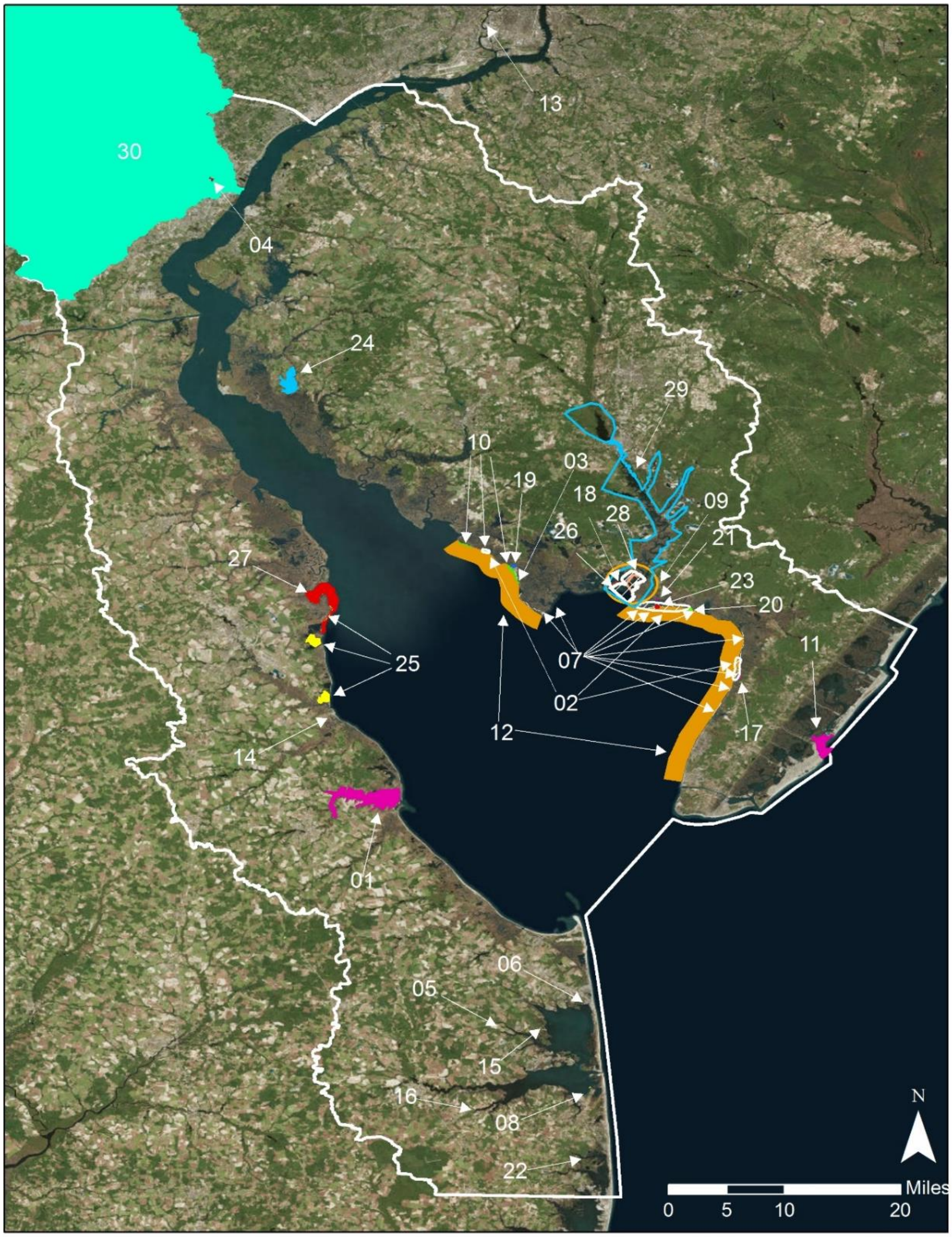


Figure A6-1. Map showing the boundaries of resilience projects compiled for the Delaware Bay and Coastal Watersheds. *Note that key to project numbers and names is provided on following page. Projects #25 and #27 were combined into a detailed case study, as were projects #9, #18, #26, #28, and #29. A case study was also developed for project #4. See Appendix 6,* ***Table A6-1*** *for a full list of projects.*

Figure A6-1 (continued). Key to project numbers presented in map on previous page.

Resilience Projects Information as Submitted by Stakeholders

A summary of all resilience project submitted for the Delaware Bay and Coastal Watersheds can be found in **Table A6-1**. More detailed information about each project are also included below.

Table A6-1. All resilience projects submitted for Delaware Bay and Coastal 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
Continuing Fortescue Beach Habitat Restoration and Living Shoreline Creation, Delaware Bay, NJ	4.20 / 5.14	2	12	7
South Wilmington Wetland Park (SWWP)	5.61	4	8	25
Angola by the Bay	5.00	1	7	2
Sunset Park Living Shoreline	4.17	1	7	26
Adaptive Management of Beaches important to horseshoe crab breeding and shorebird foraging	3.32	4	15	1
VFW	3.30	1	7	29
Sustainable Solutions for a Resilient Maurice River - Communities and Living Resources	3.13	4	20	27
Downe Township NJ Beach Resiliency and Sustainability Project	3.09	3	13	11
Habitat restoration and resilience at Hereford Inlet, Cape May Co., NJ	3.03	4	11	14
Delaware Bay Sediment Transport Analysis & Web Tool Development	3.00	4	14	9
Bartram's Gardens	3.00	N/A	0	4
Murderkill Oyster Breakwater Project	3.00	2	6	19
Bayfront at Rehoboth	3.00	1	8	5
Botanical Gardens	3.00	1	7	6
Cooks and Kimbles Source Beach Habitat Restoration and Living Shoreline Construction	3.00	1	6	8
Developing a resilient mouth of Maurice river	3.00	1	11	10
Fortescue Marsh Platform and Shoreline Stabilization Project	3.00	1	6	13

Project Name	Community Exposure Index	Number of Human Assets Mapped	Fish/Wildlife Elements within project boundary	Map ID Number
Moores Beach Habitat Restoration and Living Shoreline Creation, Delaware Bay, NJ	3.00	1	9	17
Restore Marsh Damaged by Salt Hay Farming with Dredged Fill and Thin Layer Deposition (Thompson's Marsh)	3.00	1	5	22
Sassafras Landing	3.00	1	7	23
Thompsons Beach Habitat Restoration and Living Shoreline Creation, Delaware Bay, NJ	3.00	1	11	28
Silver Lake Tidal Marsh Restoration	3.00	1	10	24
Port Mahon Road Restoration Project	3.00	2	15	21
Mouth of the Maurice River	3.00	3	16	18
Expansion of Oyster Reefs at six different sites Dyers, Thompsons, Moores, Reeds, Cooks and Kimbles Beaches	3.00	2	11	12
Port Mahon / Kelly Island	2.99	2	13	20
Maurice River Mouth Restoration	2.98	2	12	15
Milford Neck Saltmarsh Restoration	2.95	2	16	16
Wetland Restoration on the Maurice River	2.78	9	21	30
Aquatic Connectivity in the Christina River Basin	2.75	10	16	3

Project ID# 1
Name: Adaptive Management of Beaches important to horseshoe crab breeding and shorebird foraging
Submitted by: Lawrence Niles
Organization: Niles Smith ecological design and management / American Littoral Society
Project Type: Beach or dune restoration
Description: As part of the ALS and CWF sandy grant we successfully restoration 2.3 miles of beach for horseshoe crabs and shorebirds. The beaches need a periodic sand recharge to maintain viability. Our work has shown a need direction to do this at a relatively small cost by adding large grain sand to key beaches that supply sand to other downdrift beaches. We propose and experimental beach management to refine these methods. This project was submitted to the RFP for the Delaware Watershed Business plan but was not funded.

Project ID# 2
Name: Angola by the Bay
Submitted by: Marianne Walch
Organization: Delaware Center for the Inland Bays
Project Type: Living shoreline implementation, Research project on biochar
Description: This area is predominantly low energy, and is impacted by boat wakes. The project would consist of traditional techniques such as coir logs and toe logs, with plantings behind to stabilize sediment. The project would also include the application of biochar to investigate its effectiveness at improving water quality. It would be among the first projects to include biochar in higher salinity areas.

Project ID# 3
Name: Aquatic Connectivity in the Christina River Basin
Submitted by: Brian Marsh
Organization: Delaware Bay Estuary Project, US Fish and Wildlife Service
Project Type: Dam removal/fish passage, Restoration of aquatic connectivity, Riparian and floodplain restoration
Description: In Delaware, many of the dams that effect both ecological health and threats to human communities are concentrated in the Christina River basin, a tributary of the Delaware River. The dams throughout the basin are low head dams that in many cases are dilapidated and in need of repair or removal. The dams prevent American shad, river herring, and other anadromous fish species from accessing spawning grounds; represent a safety hazard; exacerbate flooding; and contribute to creating broad unstable river corridors with degraded water quality. Dam removal is the preferred method of restoring fish passage and it has the most benefits to restoring ecological function to the rivers of the basin, improving water quality, reducing safety issues, and reducing flooding. However, in some instances in the Christina River basin where dam removal is unacceptable due to water supply needs, infrastructure restrictions, and historical values other means can be used to restore some of the ecological function particularly fish passage through fish ladders and other methods. Partners in Delaware are pursuing funding to remove or modify dams in the Cristina River basin's two largest watersheds of Brandywine Creek and White Clay Creek. There are eleven dams of Brandywine Creek that block fish passage throughout the 320-square mile watershed, the first of which is slated to be removed in 2018. Six dams along White Clay Creek block fish passage throughout the 107-square mile watershed. A seventh dam and the lowest dam on White Clay Creek was removed in 2014. In 2000, 190 miles of the White Clay Creek and its tributaries were designated as a National Wild and Scenic River.

Project ID# 4
Name: Bartram's Gardens
Submitted by: Joshua Moody
Organization: Partnership for the Delaware Estuary
Project Type: Living shoreline implementation, Marsh restoration, Wetlands created
Description: Bartram's Garden is the oldest surviving botanic garden in North America. Located on the west bank of the Schuylkill River, it covers 46 acres and includes an historic botanical garden and arboretum. The shoreline along this portion of the river has been experiencing erosion from undercutting of large boat wakes and reflective energy from near-by hardened shorelines. A hybrid living shoreline consisting of off-shore energy attenuation materials, freshwater mussel housing, and lateral, bio-based shoreline stabilization materials aims to restore the natural look and function of this stretch of shoreline. With active, on-site outreach and educational programs, this living shoreline also presents opportunity of local engagement and enrichment.

Project ID# 5
Name: Bayfront at Rehoboth
Submitted by: Marianne Walch
Organization: Delaware Center for the Inland Bays
Project Type: Living shoreline implementation
Description: The site has a northeast to east fetch of approximately two the more than 3 miles. The northeast to east energy corridor is associated with coastal storms (tropical storms and nor'easters), making this site very high energy. A reef would be placed at the mouth of the cove to allow passive accretion behind and create a lower energy system, reducing erosion to the shoreline and to a high quality marsh.

Project ID# 6
Name: Botanical Gardens
Submitted by: Marianne Walch
Organization: Delaware Center for the Inland Bays
Project Type: Living shoreline implementation, Wetlands created, Wetlands restored/enhanced
Description: This project involves preventing erosion along a low energy shoreline with traditional techniques such as coir logs and spartina plantings. The wetlands behind the project will also be restored by a landscape architect with the Botanical Gardens.

Project ID# 7
Name: Continuing Fortescue Beach Habitat Restoration and Living Shoreline Creation, Delaware Bay, NJ
Submitted by: Capt. Al Modjeski
Organization: American Littoral Society
Project Type: Beach or dune restoration, Living shoreline implementation
Description: Our team placed 35,000 to 40,000 cy of sand at Fortescue South Beach in 2015 and would like to continue that restoration moving forward. We originally intended to place much more, but due to funding constraints, we had to cut back and were unable to maximize the project footprint. To complete the project, we would like to add coarse-grained (from 0.3-0.5 mm to >0.8 mm). We would also like to add a reef to promote accretion and wave attenuation as well as improve biodiversity. We would place an additional 19,500 cy. The reef would be built with volunteers and US military veterans.

Project ID# 8
Name: Cooks and Kimbles Source Beach Habitat Restoration and Living Shoreline Construction
Submitted by: Capt. Al Modjeski
Organization: American Littoral Society
Project Type: Beach or dune restoration, Living shoreline implementation, Intertidal oyster reef creation
Description: Place up to 20,000 cy of coarse-grain sand and build two intertidal oyster reefs. These beaches have received sand two times in the life of our project and our studies indicate that these beaches are source beaches and provide sand to adjacent beaches. Although highly successful, over 14,000 knots used these beaches in each of the last three years, the beaches lose sand to adjacent creeks. Both are exposed to westerly winds and the consequent damaging waves. As is the case with other Delaware Bay beaches in New Jersey, the losses add sand to important shoals in the adjacent creeks but we propose to create greater resiliency by adding relatively small amount of large grain sand and to add two new oyster reefs to keep that sand on the beach.

Project ID# 9
Name: Delaware Bay Sediment Transport Analysis & Web Tool Development
Submitted by: Steven Hafner
Organization: Stockton University Coastal Research Center
Project Type: Community resilience planning, Habitat restoration and ecological resilience planning
Description: The Stockton University Coastal Research Center (CRC) is proposing a two-year program to continue and refine the sediment transport analysis it conducted along the New Jersey shoreline throughout the lower reaches of the Delaware Bay from 2015 to 2017. The previous efforts resulted in creation of a network of 44 topo-bathymetric profile lines, seasonal Littoral Environmental Observation (LEO) data collected by veteran citizen-scientists, quantification of morphologic features and seasonal changes throughout the network, the quantification of nearshore currents and wave climates at 5 measurement locations, the quantification of sediment transport at the different locations, and the creation of a sediment budget model for the area. All of this information was then compiled into a user-friendly web-based application, Delaware Bay Sediment Transport Analysis Tool (DBSTAT). The proposed project will continue data collection throughout the profile line network, continue data collection at the 5 current and wave climate sites, add an additional 9 sites to bring the total number of current and wave climate measurement sites to 14, and refine the sediment budget analysis in order to better understand the movement of sediment throughout the system. All new data will then be made available through the web application in order to guide future development and implementation of habitat restoration and community resilience projects along the New Jersey Delaware Bay shoreline.

Project ID# 10
Name: Developing a resilient mouth of Maurice river
Submitted by: Lawrence Niles
Organization: Niles Smith Ecological Design and Management / American Littoral Society
Project Type: Green infrastructure implementations, Living shoreline implementation, Hybrid living shoreline breakwater
Description: The mouth of the Maurice river has been the subject of numerous project proposals, none moving any further than unfunded proposals and without any engineering or permitting action. We are developing a new shovel ready proposal to build hard core living breakwaters using our experience with building small oyster reefs and with help from Drexel engineering experts. We have already done preliminary bathymetric, design drawings and have permitting experience. This project is being developed as the last part of the ALS sandy grant. We will need implementation funds for the first part and design funds for an expansion to other problem areas

Project ID# 11
Name: Downe Township NJ Beach Resiliency and Sustainability Project
Submitted by: Jim Rutala
Organization: Rutala Associates
Project Type: Beach or dune restoration, Community resilience planning, Green infrastructure implementations, Living shoreline implementation
Description: The purpose of this project is to extend a resiliency and habitat enhancement plan that was developed for the northwestern beachfront area of Gandy’s Beach in Downe Township. This proposed project will increase resiliency and habitat for the remainder of Gandy’s Beach, all of Fortescue’s shoreline and other bayfront areas within the township. The project will evaluate structural and living shoreline options to protect the communities’ beaches, dunes, and coastal marshes, and provide for greater resiliency from coastal storms, sea level rise, and chronic erosion. Once optimized, the designs will be implemented to provide ecosystem services and socio-economic benefits through enhancement of the eco-tourism based economy of Downe Township. This plan and design will enhance the estuarine habitat, storm damage protection and coastal resiliency.

Project ID# 12
Name: Expansion of Oyster Reefs at six different sites Dyers, Thompsons, Moores, Reeds, Cooks and Kimbles Beaches
Submitted by: Capt. Al Modjeski
Organization: American Littoral Society
Project Type: Living shoreline implementation, Intertidal oyster reef creation
Description: Over the last three years our team has experimented with protecting restored beaches by reproducing historic oyster reefs in the inter-tidal shore in front of three restored beaches. We tested the concept of construction a reef so that it did not restrict horseshoe crab breeding but still provided beach protection. We also developed permitting that would allow us to expand if necessary with an existing Army Corp permit. Therefore, we propose expanding protected reefs throughout the Delaware Bay by approximately 2.2 miles. First we will expand existing experimental reefs to cover most of Moores, (0.7 miles) Thompsons (0.6 miles) and Dyers Cove (0.4 miles), Reeds, Cooks and Kimbles Beach (0.5 miles). In each location we would create reef designs to protect the areas most vulnerable to wind driven waves. Reefs would be built by volunteers and US military veterans.

Project ID# 13
Name: Fortescue Marsh Platform and Shoreline Stabilization Project
Submitted by: Joshua Moody
Organization: Partnership for the Delaware Estuary
Project Type: Living shoreline implementation, Wetlands restored/enhanced
Description: Beach and marshes along the town of Fortescue, NJ have been eroding at an alarming rate resulting in enhance flooding and property damage to the town and its businesses. Additionally, marsh erosion in the mouth of the river results in channel-infilling which requires frequent maintenance to allow for boat access, one of the major commercial businesses in the town. Data collection along the site in 2014 showed central regions of the marsh were sitting at a lower elevation than required by the high marsh vegetation community, resulting in water logging and habitat conversion in the marsh interior. In some areas, the increased water logging was resulting in enlarged denuded areas (increasing percentage relative to whole of marsh). The combination of sediment export from the marsh eroding edge and interior were contributing to not only a loss in net marsh acreage, but also the channel in-filling. This project would aim to enhance the elevation of the marsh interior to an appropriate elevation for high marsh persistence and stabilize the eroding shoreline, which would also help to retain sediment in the interior as well as along the edge of the marsh

Project ID# 14
Name: Habitat restoration and resilience at Hereford Inlet, Cape May Co., NJ
Submitted by: David Mizrahi
Organization: NJ Audubon
Project Type: Beach or dune restoration
Description: Hereford inlet is one of few unimproved inlets along the New Jersey and mid-Atlantic coastline and a highly dynamic system, influenced by sand input through longshore drift and by erosion due to storms. A large portion of inter-tidal marsh, mudflat and beach habitat from North Wildwood to the south and Stone Harbor Point to the north, drains into the inlet. This complex is comprised primarily of open, sandy beaches and sparsely vegetated dunes, with mudflats and a large, undeveloped saltmarsh system and is designated an Important Bird Area by the NJA and a Natural Heritage Priority Site by NJ DEP (NJA 2013). As part of a NFWF Sandy project, we conducted small-scale back passing of sand to manage for high-elevation nesting and roosting areas for beach nesting birds and shorebirds including Piping Plover, American Oystercatcher, Black Skimmer, Least Tern and Red Knot. Here we propose to build upon the knowledge gained during that project to restore coastal habitat and manage for an expanded suite of coastal wildlife including not only nesting birds and shorebirds, but also

wintering Ipswich sparrows and the dune ghost tiger beetle, both species of special conservation concern in NJ and elsewhere. All of these species depend on dynamic elements of waves, flooding and wind which create disturbances that maintain key habitat features. While coastal protection projects may replenish beaches and dunes, they often use designs that maximize stability and shoreline protection at the expense of wildlife habitat. For example, many species depend on vegetation-free areas, while the goal for constructed dunes is often to achieve high vegetation coverage as quickly as possible. Our project is designed to reconcile these potentially competing objectives by developing low-cost recurrent wildlife habitat management strategies that can be employed in concert with beach and dune replenishment projects. We will partner with NJ Department of Transportation, Office of Maritime Resources who can provide a recurring source of sand through dredging for navigation within the inlet, and we will coordinate their activities with ecological restoration at the site. The management practices developed as part of this project can be applied to any site where there is active beach management to increase community resilience.

Project ID# 15
Name: Maurice River Mouth Restoration
Submitted by: Ben Stowman
Organization: Delaware Bayshore Council; Maurice River Township LUB
Project Type: Community resilience planning, Living shoreline implementation, Marsh restoration, Riparian and floodplain restoration, Wetlands created, Wetlands restored/enhanced
Description: Wave attenuation in Maurice River Cover; Rock/Seawall Adjoined to Land on Basket Flats; Restoration/stabilization of Northwest Reach northern bank; sediment building in marsh between Northwest Reach and Matt's Landing; redredging of Maurice River Mouth; stabilization of NFWF dike at Heislerville/Matt's Landing. Vast acreage of marsh will be restored and the communities of Maurice River and Commercial Townships will be preserved. Financial impact preservation $100-200 million per year.

Project ID# 16
Name: Milford Neck Saltmarsh Restoration
Submitted by: Jessica Hammond
Organization: The Nature Conservancy
Project Type: Marsh restoration
Description: Anthropogenic influences have greatly altered the hydrology of saltwater marsh complex at the Milford Neck Conservation Area, resulting in the conversion of hundreds of acres of Spartina marsh to open water. The conversion to open water reduces the resilience of the marsh system and adjacent upland farms, forests, and residents, from future storms and sea level rise. The project models the hydrology of the marsh and designed restoration alternatives to increase tidal exchange and encourage the re-establishment of Spartina.

Project ID# 17
Name: Moores Beach Habitat Restoration and Living Shoreline Creation, Delaware Bay, NJ
Submitted by: Capt. Al Modjeski
Organization: American Littoral Society
Project Type: Beach or dune restoration, Living shoreline implementation, Oyster reef extension
Description: Moores Beach was once one of the most important shorebird and horseshoe crab habitats on the Bay. In 2013 and 2014 our team restored sand to two sections of Moores Beach, both immediately providing new habitat for crabs with egg densities greater than unrestored beaches. In 2016 the team added an experimental oyster reef. Over the last two years the western section of Moores Beach has eroded and much of the sand was lost to the adjacent creek. This was assessed as an acceptable outcome as the goal was to improve conditions for horseshoe crabs and shorebirds. The adjacent creek is now one of the most productive for horseshoe crabs in the Bay. We propose to return to Moores, however, to experiment with new methods of

extending beach life. First by adding up to 35,000 cy of sand of much greater sand grand size (from 0.3-0.5 mm to >0.8 mm) and to add an additional oyster reef to reduce the impact of wind-driven waves. We also propose adding an additional 0.3-mile beach segment of Moore’s for restoration.

Project ID# 18
Name: Mouth of the Maurice River
Submitted by: Joshua Moody
Organization: Partnership for the Delaware Estuary
Project Type: Green infrastructure implementations, Living shoreline implementation, Marsh restoration, Wetlands created, Wetlands restored/enhanced
Description: The mouth of the Maurice has been experiencing high rates of erosion since the 1930s that has resulted in a large loss in salt marsh habitat, private land, and valuable commercial infrastructure. To restore lost acreage of salt marsh habitat, and to protect the local community from increased storm severity and tidal inundation, a comprehensive restoration protection plan needs to be developed. Implementation will require a combination of off-shore wave attenuation, in-filling of historical marsh areas that have been converted to open water, and the stabilization of existing marsh shorelines that have been measured to be eroding at a rate of >2 m (6.56 ft) per year. Many NJ partners are interested in implementing projects in this area that span the public, p private, and academic sectors. Even though interest has been high regarding projects in this area, funding has been virtually non-existent due to low population densities and a prioritization of NJ's Atlantic coastline.

Project ID# 19
Name: Murderkill Oyster Breakwater Project
Submitted by: Joshua Moody
Organization: Partnership for the Delaware Estuary
Project Type: Living shoreline implementation, Oyster reef enhancement for shoreline protection
Description: The mouth of the Murderkill River is located in Bower's Beach, DE, a summer tourist destination and home to many commercial and recreational fishing outfits. This project would aim to enhance naturally occurring oyster reefs in the mouth of the Murderkill River. The expanses of salt marsh surrounding the mouth of the river have been experiencing large scale erosion from increased boat traffic and a changing hydrologic regime. These reefs currently provide minimal shoreline protection from the large boat wakes produced from commercial and recreational traffic in the river. As intertidal oyster reefs become more prevalent at northern latitudes, they present an opportunity to utilize a natural form of energy attenuation, that also provide water quality uplift through enhanced filtration capacity, to fortify eroding salt marsh shorelines.

Project ID# 20
Name: Port Mahon / Kelly Island
Submitted by: Brian Marsh
Organization: U.S. Fish and Wildlife Service
Project Type: Beach or dune restoration, Green infrastructure implementations, Living shoreline implementation, Marsh restoration, Wetlands restored/enhanced, DOD infrastructure protection, Country road protection, Ecotourism enhancement
Description: The Kelly Island and Port Mahon area of the Delaware Bayshore has experienced erosion resulting in the loss of salt marsh and beach habitat. Continued erosion threatens wildlife habitat of Little Creek State Wildlife Area and Bombay Hook National Wildlife Refuge and threatens Port Mahon Road, a pier and pipeline used by the Air Force as the sole source of jet fuel for Dover Air Force Base, a public fishing pier, and a public boat ramp. Marsh and beach habitat on the bayside of Port Mahon Road once important to migratory shorebirds and other wildlife has mostly eroded away and been replaced with riprap in an attempt to keep the road. Port Mahon Road currently acts as a barrier to further erosion occurring on saltmarsh to the west that is part of Little

Creek Wildlife Area. The road also protects the Air Force's pipeline. The gravel and asphalt road is impassable at high tides and frequently needs costly maintenance and repair work. The area requires restoration to create resilient and sustainable beach habitat on the bayside of Port Mahon Road, address marsh loss along Kelly Island, and stabilize Port Mahon Road. Restoring the habitat and improving the road would support populations of at-risk wildlife, create a highlight stop along the Delaware Bayshore Byway for ecotourism and outdoor recreation, and protect the military's uses of the area. The area requires a detailed restoration plan based on a technical examination of the high energy dynamic coastal environment in this area of the bayshore and that addresses the multiple uses of the site and most important natural resources such as horseshoe crabs, oyster beds, shorebirds, marsh birds, and finfish. Ultimately, restoration measures could include a combination of subtidal and intertidal living shoreline techniques, beach renourishment, and debris removal. Restoration in the Port Mahon and Kelly Island area would add to restoration already completed by Delaware Division of Fish and Wildlife at Little Creek Wildlife Area where a 450-acre impoundment was restored.

Project ID# 21
Name: Port Mahon Road Restoration Project
Submitted by: Jeremey Ashe
Organization: DNREC, DFW
Project Type: Beach or dune restoration
Description: Port Mahon Road is located along the Delaware Bayshore within Kent County. The shoreline used to be a beach with numerous species utilizing the shoreline including red knot and spawning horseshoe crabs. Recent storms and increased erosion due to waves and increased coastal flooding has resulted in complete loss of habitat. Red Knots are virtually extirpated form this location. To protect the road, DelDOT has installed over one-mile-long of harden stone shoreline. This has protected the road but has resulted in increased horseshoe mortality (caught in rocks) and more recently an increase of diamondback terrapin turtles getting caught in the rocks. To address these issues, the Division of Fish and Wildlife obtained a National Fish and Wildlife Foundation grant to engineer and design a solution. The solution developed was a hybrid approach to green/gray infrastructure. The basic design is installing several breakwaters to dissipate the wave energy and restore a beach/dune along the shoreline. The goal is to do a pilot section of the road first and monitor the success prior to implementing the entire road. This way lessons learned can be applied and the design modified if needed.

Project ID# 22
Name: Restore Marsh Damaged by Salt Hay Farming with Dredged Fill and Thin Layer Deposition (Thompson's Marsh)
Submitted by: Capt. Al Modjeski
Organization: American Littoral Society
Project Type: Living shoreline implementation, Marsh restoration, Wetlands created, Wetlands restored/enhanced
Description: After almost 2 years, we have permits and approvals in hand to restores approximately 13.75 acres of marsh through containment and thin layer. Thin layer application will be contingent upon outcome of containment. This project was partially funded by NFWF to create experimental marsh restoration using both dredged fill and thin layer deposition to repair damage created by the unmanaged abandonment of salt hay farms. The goal of the work is to carry out the most ecologically effective method with the least cost so as to allow a complete evaluation. The ostensible goal for the project is to scale up a cost-effective method to tackle the nearly 10,000-acre restoration needed to rescue the Delaware Bay marsh. This is one of the most compelling problems on Delaware Bay. The unmanaged abandonment of salt hay farms not only destroyed productive marsh throughout the Bay but continues to reduce productivity created conditions that erode surrounding marsh. At present there is insufficient funding to pursue both the experimental dredge fill and thin layer deposition projects. Both are necessary. Dredge fill will help understand the best method and most cost-

effective way to increase elevation by 1.8 feet, the average deficit found in most salt hay damaged marsh. Thin layer deposition will aim at creating new high marsh in existing *Spartina alterniflora* marsh. High marsh (i.e. Spartina patens) marsh is one of the Delaware Bay's most endangered habitat and serves as breeding habitat for several species of conservation concern. Monitoring would need to be funded for 5 years.

Project ID# 23
Name: Sassafras Landing
Submitted by: Marianne Walch
Organization: Delaware Center for the Inland Bays
Project Type: Living shoreline implementation
Description: This project will stabilize an eroding shoreline and help replenish the small sandy beach currently existing. The sandy shoreline in question is the only barrier between a managed pond for waterfowl and the open waters of the Bay.

Project ID# 24
Name: Silver Lake Tidal Marsh Restoration
Submitted by: Jim Feaga
Organization: Ducks Unlimited, Inc.
Project Type: Marsh restoration, Restoration of aquatic connectivity, Wetlands restored/enhanced
Description: The Thorofare Creek Meadowbank Company (Meadowbank Company) was established in 1967 and consists of a group of landowners who jointly make decisions regarding marsh habitat management (i.e. water level manipulation) for their properties (collectively known as Silver Lake) in Lower Alloways Creek, NJ. Silver Lake itself consists of approximately 1,200-acre marsh offshoot of the Lower Alloway Creek that is impounded at both its north and south ends. Water control structures allow the Meadowbank Company to control water levels via changes to the amount of inflow and outflow of the impounded area. Based on discussions with members of the Meadowbank Company and review of historic aerials, Silver lake was likely a transition zone of plant communities that began as saltmarsh at its southern end before changing to brackish and freshwater marsh proceeding upstream. Once the area was impounded, most tidal (saltwater) influence was eliminated and the area slowly converted to an entirely freshwater marsh. At present, the majority of vegetation within Silver Lake consists of the invasive common reed (*Phragmites australis*). The Service, in partnership with Ducks Unlimited, Inc. and the Salem County Mosquito Control, recommend reintroducing tidal flow to the impounded Silver Lake. Reintroducing saltwater would stress, reduce, and locally eliminate this species and allow recolonization by native saltmarsh species as observed directly adjacent to the southern dike boundary of the Silver Lake. These native species provide better habitat for migrating birds and open tidal flow will allow additional fish and invertebrate species to utilize the Silver Lake interior. The reestablishment of the salt marsh will add to the overall health of the marsh system, making it resilient to sea level rise and marsh migration (via accretion). In turn, the marsh will be better suited to mitigate flooding and storm surges, protecting the nearby residential and agricultural lands and infrastructure. Partnering agencies and landowners are currently monitoring the vegetation, elevation, and salinity within Silver Lake to evaluate measures needed to transition back to saltmarsh habitat. This may include ditch plugging, additional water control structures, herbicide treatments, and more active forms of water level management (Integrated Marsh Management).

Project ID# 25
Name: South Wilmington Wetland Park (SWWP)
Submitted by: Leah Kacanda
Organization: City of Wilmington
Project Type: Community resilience planning, Green infrastructure implementations, Restoration of aquatic connectivity, Upland restoration, Wetlands created, Wetlands restored/enhanced
Description: The purpose of the South Wilmington Wetland Park (SWWP) is to create a stormwater management facility, restore and enhance existing wetlands, and create a new park for the community. The SWWP includes the restoration of 14 acres of low-quality wetlands to highly functioning tidal wetlands with habitat enhancements and the creation of additional high quality wetlands. The SWWP will also be hydrologically modified to provide flood storage and water quality enhancements for the newly separated storm water system flows from the Southbridge neighborhood of Wilmington prior to discharge to the Christina River. To provide passive recreation for surrounding communities, the SWWP will include a trail, boardwalk, and other recreational features.

Project ID# 26
Name: Sunset Park Living Shoreline
Submitted by: Marianne Walch
Organization: Delaware Center for the Inland Bays
Project Type: Living shoreline implementation, Wetlands restored/enhanced
Description: Sunset Park, located on Rehoboth Bay in the Town of Dewey Beach, Delaware has experienced extensive erosion due to winds and wave activity that has resulted in a loss of beach and wetland, and simultaneously increased flooding in the community surrounding the park. The proposed project would install approximately 270 feet of wave attenuating devices (WAD's), and install approximately 500 to 600 square feet of oyster castles to reduce the wave energy before it can interact with the nearshore environment. The site would then have approximately 0.50 acres of tidal wetland and approximately 0.40 acres of sandy beach restored, behind the WAD's and oyster habitat. The wetland creation areas would be buttressed with 550 feet of coir fiber logs, to stabilize the sediments until the tidal wetlands attain the desired levels of above-ground and below-ground biomass production, which will require two to three growing seasons. A stormwater outfall of concern (in Sunset Beach Cove) would be incorporated into the restoration design, through a redesign to potentially extend the outfall and install a one-way tide gate. The stormwater along Dagsworthy Street currently does not adequately drain, due to rising water levels exceeding the pipe opening elevation, and would experience increased effectiveness in removing flood waters along Dagsworthy Street through these retrofits.

Project ID# 27
Name: Sustainable Solutions for a Resilient Maurice River - Communities and Living Resources
Submitted by: Dorina Frizzera
Organization: Getting to Resilience LLC
Project Type: Community resilience planning, Green infrastructure implementations, Living shoreline implementation, Marsh restoration, Restoration of aquatic connectivity, Riparian and floodplain restoration, Wetlands created, Wetlands restored/enhanced, Living breakwater
Description: This project proposes to build upon the collaboration of multiple stakeholders, including state, federal and local agencies. This project also proposes to implement ecosystem-based restoration strategies that will result in enhancements to wetlands, living resources and the communities (commercial and residential assets) impacted by the loss of wetlands and ecosystem services, changes to the structure of the river system, sea level rise, storm surges and flooding caused by extreme weather events.

Project ID# 28
Name: Thompsons Beach Habitat Restoration and Living Shoreline Creation, Delaware Bay, NJ
Submitted by: Capt. Al Modjeski
Organization: American Littoral Society
Project Type: Beach or dune restoration, Living shoreline implementation, intertidal oyster reef creation
Description: Restore remaining portions of Thompsons Beach to pre-Sandy conditions with 42,250 cy sand and build two reefs. Our team conducted all preliminary work to restore for 4 sections of Thompson's beach. In 2015 we restored two sections with great success. These beaches had the highest density of horseshoe crab eggs in the Bay and shorebird use has been gradually building. The restored Thompsons Beach segments are also among our most resilient beaches because of sheltering peninsulas that are the remains of past development. We propose to restore the remaining two sections of Thompson beach with higher grade sand of larger particle size, and to improve access for observation in conjunction with the Maurice River Township. We will also add two new oyster reefs to Thompsons to improve resiliency.

Project ID# 29
Name: VFW
Submitted by: Marianne Walch
Organization: Delaware Center for the Inland Bays
Project Type: Living shoreline implementation
Description: The VFW site location is an ideal candidate for hybrid energy attenuation reef to reduce focused wave energy and promote natural accretion. Reefs in the form of Wave Attenuation Devices would be placed in front of the shoreline, to allow accretion behind and in between the WADS. Storms would then push the accretion material onto shore, helping to build of the shoreline.

Project ID# 30
Name: Wetland Restoration on the Maurice River
Submitted by: Karla Rossini
Organization: CU Maurice River
Project Type: Community resilience planning, Marsh restoration, Wetlands restored/enhanced
Description: The Maurice River watershed has vast wetland complexes that are critical to a great many fish and avian species in various stages of migration. In fact, the area is on the RAMSAR inventory of important wetlands. The Maurice River's wetlands are supported by thousands of protected forested uplands. Such that not only our obligate wetland species able to benefit but a much larger number of species. Large portions of wetlands are being compromised by invasive species. Phragmites intrusion has been taking over hundreds of acres of what was formerly predominately *Spartina alterniflora* and *Zizania aquatic*. Both are keystone species in the river's ecology. We have seen a decline is waterfowl use and fish species abundance. The Maurice's wetlands protect many historic Pineland Villages of national significance and support traditional trades such as fishing and crabbing. We would advocate for an inventory showing the phased encroachment by phragmites and the development of a restoration plan. The study should be conducted within the Wild & Scenic designation area including the three Wild and Scenic tributaries Manumuskin, Menantico and Muskee Rivers (all in the watershed). Sites would then be selected, and restoration commenced.

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 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**
The Delaware Wildlife Action Plan 2015-2025 Department of Natural Resources and Environmental Control. 2015. The Delaware Wildlife Action Plan 2015-2025. Division of Fish and Wildlife, Department of Natural Resources and Environmental Control. Dover, DE. http://www.dnrec.delaware.gov/fw/dwap/Pages/WAP-Progress.aspx	Delaware	More than 450 animal "species of greatest conservation need" (184 bird, 43 herpetofauna, 23 mammal, 105 fish, and 333 invertebrate species); 86 animal species are listed as State Endangered, including 21 birds, 8 reptiles, 3 amphibians, 9 mammals, 7 fish, 7 freshwater mussels, and 31 insects.	Coastal impoundments; hard and living shorelines; dams and water management systems; residential and commercial development; piers and docks; transportation and service corridors.	Sea level rise; projected increases in annual and seasonal temperatures; changes in annual and seasonal precipitation; increased frequency of extreme events; changes to hydrological regimes; changes to fire regimes; ocean acidification; increases in ocean stratification; changes in coastal upwelling and/or ocean temperatures; storms and floods; saltwater intrusion; habitat shifting and alteration; changes in the distributions of animals and plants, phenology, and community compositions and structures.
New Jersey Wildlife Action Plan NJ Department of Environmental Protection. January 23, 2008. New Jersey Wildlife Action Plan. Division of Fish and Wildlife, NJ Department of	New Jersey	Over 900 vertebrate species and innumerable invertebrates; species that are federal or state listed (9 mammals; 60 birds; 17 reptiles; 11 amphibians; 9 mollusks; 16 insects; 1 fish).	Caves and mines as bat habitats; beaches; public lands; reservoirs and impoundments; offshore wind structures; water intake systems; roads;	Sea level rise; increased air and water temperatures; increase in the frequency and intensity of flooding; changes in the coastline; declining air quality; detrimental changes in vegetation composition; decreasing

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Environmental Protection. Trenton, NJ. http://www.njfishandwildlife.com/ensp/wap/pdf/wap_draft.pdf			private and conserved lands and waters; open spaces.	food resource availability; disadvantageous changes in bird migration routes and timing; the appearance and disappearance of climate sensitive species.
NJ WAP: Atlantic Coastal Cape May Chapter VI. Landscape Assessments and Conservation Strategies, NJWAP.	Atlantic Coastal Cape May Zone	7 federal endangered or threatened species, 8 state endangered, 5 state threatened, and 44 special concern or regional priority species.	N/A	N/A
NJ WAP: Delaware Bay Landscape Chapter VI. Landscape Assessments and Conservation Strategies, NJWAP.	Delaware Bay	8 federal endangered or threatened species, 13 state endangered, 14 state threatened, and 128 special concern and regional priority wildlife species.	N/A	N/A
NJ WAP: Southern Piedmont Plains Chapter VI. Landscape Assessments and Conservation Strategies, NJWAP.	Southern Piedmont Plains zone	1 federal endangered, 1 federal threatened, 14 state endangered, 15 state threatened, 76 special concern and regional priority species, and 13 additional harvested species of regional priority.	N/A	N/A
National Fish and Wildlife Foundation: Delaware River Watershed Business Plan National Fish and Wildlife Foundation. January 23, 2017. Delaware River Watershed Business Plan. National Fish and Wildlife Foundation. Washington, D.C.	Delaware River Watershed	(Nearshore, aquatic, and forest habitats) shorebirds; shellfish, migratory fish; red knot; horseshoe crab; semipalmated sandpiper; ruddy turnstone; fringing eastern oyster; ribbed mussels; alosine species: American shad, river herring; eastern brook trout; forest birds; cerulean warbler; golden-	Agriculture; canals, roadways, dams and culverts; ports; coal mines; aquaculture; living shorelines; septic systems; green stormwater infrastructure (GSI); fish passage; residential, commercial, and energy-	Sea level rise; increased stream temperatures; altered stream hydrology; high storm surge; warmer climate; salt water intrusion.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
https://web.tplgis.org/NFWF_Delaware/pdfs/DelawareRiverWatershedBusinessPlanDraftJanuary2017.pdf		winged warbler; wood thrush; salt marsh sparrow; peregrine falcon.	related development; municipalities.	
Technical Report for the Delaware Estuary and Basin 2017 Partnership for the Delaware Estuary. 2017. Technical Report for the Delaware Estuary and Basin 2017. L. Haaf, S. Demberger, D. Kreeger, and E. Baumbach (eds). PDE Report No. 17-07. 379 pages. https://s3.amazonaws.com/delawareestuary/TREB+douments/TREB+2017+complete.pdf	Delaware Estuary and River Basin	American shad, alewife, blueback herring, striped bass, sea lamprey, American eel; tessellated darter; freshwater mussels; Atlantic sturgeon; blue crab; osprey; white perch; striped bass; weakfish; horseshoe crab; eastern oyster; freshwater benthic macroinvertebrates.	Green infrastructure and landscape buffers; public open space (lands of federal, regional authority, state, local, and private ownership); public access points; water supply and wastewater utilities; maritime transportation systems; navigational channels; dams; fish ladders.	Sea level rise; increased air temperature; warming water and oxygen deficits; increasing winter and spring precipitation; changes in the intensity and frequency of extreme temperature and precipitation events, storms, and associated tidal surges; changes in snow cover and diminishing snowpack; changes in stream and river flows; increase in tidal and storm energy; change in salinity regime.
Recommendation of Sea-Level Rise Planning Scenarios for Delaware: Technical Report Callahan JA, Horton BP, Nikitina DL, Sommerfield CK, McKenna TE, Swallow D. 2017. Recommendation of Sea-Level Rise Planning Scenarios for Delaware: Technical Report, prepared for Delaware Department of Natural Resources and Environmental Control (DNREC) Delaware Coastal Programs. 114 pp. http://www.dgs.udel.edu/sites/defaul	State of Delaware and the U.S. mid-Atlantic coast	N/A	Public infrastructure (e.g., roads, septic tanks, water supply lines); private property; irrigation systems; agricultural fields and forested lands; beaches and dunes; hospitals; evacuation routes; fire house; electric power substation; historic sites; state parks; wildlife refuges; DE Bayshore and beach communities; piers; utilities.	Sea-level rise resulting in shoreline erosion, inundation of wetlands and uplands, saltwater contamination, changes to natural habitat, and flood damage to infrastructure; saltwater intrusion to groundwater supply; increasing coastal storms; increased frequency and duration of nuisance flooding and exacerbated impacts of extreme coastal flooding.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
t/files/projects-docs/de%20slr%202017%20technical%20report%20final.pdf				
Delaware Climate Change Impact Assessment Delaware Department of Natural Resources and Environmental Control. February 2014. Delaware Climate Change Impact Assessment. Division of Energy and Climate, Delaware Department of Natural Resources and Environmental Control. Dover, Delaware. http://www.dnrec.delaware.gov/energy/Pages/The-Delaware-Climate-Impact-Assessment.aspx	State of Delaware	This report includes analysis of historic trends and future projections for temperature and precipitation indicators, as well as chapters on climate impacts to resources (Ch. 8—ecosystems and wildlife; Ch. 9—natural infrastructure). More than 1,000 animal species of invertebrates, native and nonnative species; more than 200 resident and migrant fish species; 58 species classified as game animals by Delaware Division of Fish and Wildlife.	Food systems (agricultural infrastructure); water infrastructure (supply, distribution, treatment, wastewater & stormwater systems); commerce networks; energy and transportation infrastructure (roads, bridges, rail lines, public transit, evacuation routes, public boat ramps); piers, dams, levees; homes, businesses, schools, public buildings; industrial facilities; communication and natural infrastructure.	Sea level rise; exacerbated inland and coastal flooding; greater storm surges; increasing average annual and seasonal temperatures; changes in temperature extremes; projected increasing average precipitation and rainfall extremes; increased frequency and/or duration of drought; increasing stressors on wildlife species including changes in habitat quality, timing and availability of food sources, abundance of pests and diseases, etc.
Partnership for the Delaware Estuary PDE. February 2013. Partnership for the Delaware Estuary Strategic Plan 2013-2018. Wilmington, DE. https://s3.amazonaws.com/delawareestuary/pdf/2013_strategic_plan.pdf	Delaware Estuary	Shellfish: freshwater mussels and oysters.	Tidal wetlands; living shorelines; schools; green infrastructure such as rain gardens, stream buffers and naturalized basins.	Sea level rise; storm surge, flooding, and erosion.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Cumberland County Delaware Bayshore Recovery Plan Cumberland County. December 2013. Cumberland County Delaware Bayshore Recovery Plan. Bridgeton, NJ. https://www.mauricerivertwp.org/pdfdocs2014/RecoveryPlanFEMAfinal.pdf	Cumberland County, southern New Jersey	Menhaden; weakfish; flounder; stripers; bluefish; Atlantic sturgeon; red-shouldered hawk; peregrine falcon; upland sandpiper; resident and migratory birds (red knot, sanderlings, bald eagles); horseshoe crabs.	Water supply and wastewater management facilities; roads; marinas; telecommunications infrastructure; beaches, sand dunes; flood control structures; navigational channels; public boat ramps, water access points; homes; fishing beds; oyster seed beds; mussel and oyster reefs; fisheries; shipyard; farmland; living shorelines; cultural and historic sites.	More extreme weather events (e.g., Superstorm Sandy); sea level rise; salt water intrusion; storm surges; flooding.
Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment for the State of Delaware Delaware Coastal Programs. July 2012. Preparing for Tomorrow's High Tide: Sea Level Rise Vulnerability Assessment for the State of Delaware. Delaware Coastal Programs, Department of Natural Resources and Environmental Control. Dover, DE. http://www.dnrec.delaware.gov/coastal/Documents/SeaLevelRise/AssesmentForWeb.pdf [SLR Vulnerability	State of Delaware	(This report describes the results of GIS and stakeholder analysis to identify the natural, social, public safety and infrastructure resources at risk of SLR impacts.) Animals, insects, migratory birds, and a multitude of other terrestrial and aquatic wildlife; approximately 20% of the state's native fauna is considered rare and uncommon (e.g., black rails)—54% could be impacted at the 1.5 m sea level rise scenario which represents 11% of the entire state fauna.	79 statewide resources assessed and 16 resources of high concern identified: beaches and dunes; coastal impoundments; dams, dikes, levees; evacuation routes; future development areas; heavy industrial areas; protected lands statewide; transportation and port infrastructure; resort areas, coastal historic sites; wildlife refuges; wells; also food system; water facilities; residential areas; landfills.	Sea level rise; inundation of low-lying land and structures, saltwater intrusion into ground and surface waters, increased coastal flooding from storm events.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Climate Change and the Delaware Estuary: Three Case Studies in Vulnerability Assessment and Adaptation Planning. Kreeger D, Adkins J, Cole P, Najjar R, Velinsky D, Conolly P, Kraeuter J. 2010. Climate Change and the Delaware Estuary: Three Case Studies in Vulnerability Assessment and Adaptation Planning. Partnership for the Delaware Estuary, PDE Report No. 10-01. 1 –117 pp.	Delaware River and Estuary	An assessment of the vulnerabilities and adaptation options for three key resources of the Delaware Estuary: tidal wetlands, drinking water, and bivalve shellfish (sixty species of bivalves in the Delaware Estuary). Freshwater mussels; marine bivalves; invasive clams; oyster; horseshoe crabs; migratory shorebirds; rare and endangered shellfish; over 200 resident and migrant fish species.	Living shorelines; drinking water infrastructure; communication and emergency response systems (e.g., Delaware Valley Early Warning System); oyster reefs/beds; forested streamside areas and undeveloped wetland buffer migration areas; climate monitoring systems; rain gardens; green infrastructure; structural impoundments; port system (world's largest freshwater port); refining petrochemical center; dikes, bulkheads, and tide gates; reservoirs.	Rising temperatures with more warming in summer than in winter and more extreme heat days; increasing precipitation; sea-level rise; storm surges; larger tidal volumes and increasing salt water up the estuary; salinity rise and intrusion; increasing rates in storms; drowning of the brackish/saltwater wetlands; flooding; decreased river discharge and stream flow; increased number and intensity of wild fires.
Marine Bivalve Shellfish Conservation Priorities for the Delaware Estuary Partnership for the Delaware Estuary (PDE). September 2011. Marine Bivalve Shellfish Conservation Priorities for the Delaware Estuary. D. Kreeger, P. Cole, D. Bushek, J. Kraueter, J. Adkins. PDE Report #11-03. 54 pp. http://delawareestuary.s3.amazonaws.com/pdf/ScienceReportsbyPDEandD	Delaware Estuary	Native species of marine and estuarine bivalves (excluding tidal freshwater mussels): American oysters (*Crassostrea virginica*); ribbed mussels (*Geukensia demissa*); northern quahog (*Mercenaria mercenaria*); blue mussel (*Mytilus edulis*); Atlantic rangia (*Rangia cuneate*); hooked mussel (*Ischadium recurvum*); softshell clam (*Mya arenaria*); stout tagelus (*Tagelus plebeius*); Atlantic jackknife clam	Shellfish reefs; living shorelines (shellfish-based living shorelines or subtidal breakwaters); artificial reefs; hatcheries; shellfish gardening structure; oyster fishery.	Sea level rise; salinity rise from climate change; warmer water temperature and saltier conditions causing oysters to shift habitats up-Bay; saltier conditions causing oyster populations to have higher disease levels; ribbed mussels threatened with the loss of marsh habitats.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
ELEP/PDE-Report-11-03-NFWF%20Bivalve%20Shellfish%20Conservation%20Priorities_FINAL.pdf		(*Ensis directus*). Non-native species: Asian clam (*Corbicula fluminea*).		
River ecosystem processes: A synthesis of approaches, criteria of use and sensitivity to environmental stressors von Schiller D, et al. April 2017. River ecosystem processes: A synthesis of approaches, criteria of use and sensitivity to environmental stressors. Science of the Total Environment. 596–597, pp 465-480. http://dx.doi.org/10.1016/j.scitotenv.2017.04.081	Within the stream channel	This paper presents a synthesis of key river ecosystem processes, a description of the main characteristics of each process, including criteria guiding their measurement and their respective sensitivity to stressors. Current limitations, potential improvements and future steps for the use of functional measures in rivers are discussed.	N/A	N/A
Delaware River Basin Priority Conservation Areas and Recommended Conservation Strategies The Nature Conservancy. September 2011. Delaware River Basin Priority Conservation Areas and Recommended Conservation Strategies. The Nature Conservancy, Partnership for the Delaware Estuary and Natural Lands Trust. New Jersey. http://www.state.nj.us/drbc/library/d	Delaware River Basin	A suite of freshwater, estuarine, and bay-related ecosystems and habitat-forming species including floodplains, headwaters, non-tidal wetlands, freshwater tidal marsh, brackish and salt marsh, and oysters and ribbed mussels; major benthic habitat types and benthic organisms. Twenty-five focus species; by taxa: fish, reptiles and amphibians, freshwater mussels, estuarine invertebrates, birds, mammals. Migratory shorebirds (red knot);	Human communities adjacent to tidal marshes; shellfish reefs (oyster reefs); hatcheries; fisheries; agricultural lands; forests; natural shorelines; sand mining sites; headwaters, tributaries, floodplains, tidal marshes; groundwater aquifers; living shorelines; industries; conservation easements; protected lands.	Sea level rise; impacts on water supply; increased water temperature; salinity change in the estuary; threats to tidal marshes and to human communities adjacent to them; threats to climate sensitive species; down-bay oyster populations reduced due to increased disease mortality in saltier conditions; threats to freshwater ecosystems and aquatic organism.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
[ocuments/DEbasin-priority-areas_2011NFWF.pdf]()		horseshoe crab; black duck; saltmarsh sparrow.		
City of Cape May: Municipal Coastal Vulnerability Assessment City of Cape May. December 2016. Municipal Coastal Vulnerability Assessment. City of Cape May, Cape May, NJ.	Cape May City, NJ	N/A	Community assets (4 categories): critical facilities & infrastructure systems; community resources & amenities; natural resources & ecosystems; districts, neighborhoods, & population clusters; 44 assets included in the assessment. Living shorelines.	Increasing rate of sea level rise and extreme storm events; coastal flooding.
Borough of Cape May Point: Getting to Resilience Recommendation Report Borough of Cape May Point. January 2016. Getting to Resilience Recommendation Report. Borough of Cape May Point. Cape May Point, New Jersey.	Borough of Cape May Point, NJ	N/A Wetland complex (meadows, freshwater wetlands, ponds)	Residential areas; civic buildings; evacuation routes; emergency facilities; civic and ecosystem locations; beach front and dune areas; shorelines; riparian buffer; South Cape May Point Meadows and Cape May Point State Park.	Sea level rise; flooding; coastal storms.
Comprehensive Conservation and Management Plan for the Delaware Estuary	Delaware Estuary	Neotropical migrant birds and migrating waterfowl; migrating shore birds (sandpiper, ruddy turnstone, red knot, sanderling, and dunlin); wading birds (herons,	Heavy industry; freshwater port; refining petrochemical center; municipalities; water supply and	Sea level rise; potential coastal flooding; increasing storms.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
A Management Plan for The Delaware Estuary. September 1996. U.S. Environmental Protection Agency, Washington, D.C. https://s3.amazonaws.com/delawareestuary/pdf/CCMP.pdf		egrets, and ibis); horseshoe crabs; fish and shellfish; oysters and crabs; minnows and sturgeon; benthic communities.	treatment systems; commercial fisheries; shellfish beds; oyster seed beds; sandy beaches and intertidal mudflats; riparian forests.	
Charting a Course for the Delaware Bay Watershed Honigfeld HB. 1997. Charting a Course for the Delaware Bay Watershed. New Jersey Conservation Foundation, Far Hills, NJ.	New Jersey's Delaware Bay Watershed	Sora rail; migrating birds, shorebird; scarlet snake; horseshoe crabs; menhaden, weakfish, blue crab, striped bass, shad, sturgeon; oyster…	N/A	Sea-level rise
Delaware Bay Watershed Habitat and Wildlife Inventories Kane, R., P. Kerlinger, and K. Anderson. 1992. Delaware Bay Watershed Habitat and Wildlife Inventories. New Jersey Conservation Foundation, Far Hills, NJ.		Not summarized.	N/A	N/A
New Jersey Landscape Project Version 3.3 New Jersey Division of Fish and Wildlife. 2017. New Jersey Landscape Project, Version 3.3. New Jersey Department of Environmental		Not summarized.	N/A	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Protection, Division of Fish and Wildlife, Endangered and Nongame Species Program. pp. 33.				
The Scientific Characterization of the Delaware Estuary Sutton CC, O'Herron, II JC, Zappalorti RT. 1996. The Scientific Characterization of the Delaware Estuary. The Delaware Estuary Program (DRBC Project No. 321; HA File No. 93.21). 200 pp. and appendices.		Not summarized.	N/A	N/A
Living Resources of the Delaware Estuary Dove LE, and R.M. Nyman, eds. July 1995. Living Resources of the Delaware Estuary. The Delaware Estuary Program. 530 pp. & appendices.		Not summarized.	N/A	N/A
A Guide to the Natural Communities of the Delaware Estuary: Version 1 Westervelt K, Largay E, Coxe R, McAvoy W, Perles S, Podniesinski G, Sneddon L, Strakosch Walz K. 2006. A Guide to the Natural Communities of		Not summarized.	N/A	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
the Delaware Estuary: Version 1. NatureServe. Arlington, Virginia.				
Key to the Delaware Estuary Ecological Systems and Natural Communities Sneddon L, Gawler S, Largay E. 2006. Key to the Delaware Estuary Ecological Systems and Natural Communities. Version 1. NatureServe. Arlington, Virginia.		Not summarized.	N/A	N/A
2011 Strategic Plan: New Jersey Coastal Heritage Trail Route National Park Service. 2011. 2011 Strategic Plan: New Jersey Coastal Heritage Trail Route. Division of Interpretation and Education, National Park Service, Northeast Region. Philadelphia, PA. https://parkplanning.nps.gov/document.cfm?parkID=258&projectID=35779&documentID=42791		Not summarized.	N/A	N/A
From Marsh to Farm: The Landscape Transformation of Coastal New Jersey		Not summarized.	N/A	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Sebold KR. 1992. From marsh to farm: the landscape transformation of coastal New Jersey. National Park Service. Washington, D.C.				
Regional Reports				
The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA Narayan S. et al. August 31, 2017. The value of coastal wetlands for flood damage reduction in the northeastern USA. Nature Scientific Reports 7, 9463 (2017). https://www.nature.com/articles/s41598-017-09269-z	Northeastern USA (regional:12 states affected by Hurricane Sandy)	N/A	Coastal townships (at the upstream and downstream end of estuaries); coastal roads (highways); coastal properties (housing), exclusively private assets; high urbanized areas; artificial defenses (seawalls, levees); critical facilities and infrastructure.	Damages from Hurricane Sandy: storm surge flooding, wave-induced damages, debris, etc. Rising sea-levels.
Ch. 16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment Horton R, Yohe G, Easterling W, Kates R, Ruth M, Sussman E, Whelchel A, Wolfe D, Lipschultz F. 2014: Ch. 16: Northeast. 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	Northeast states: ME, NH, VT, MA, CT, RI, NY, PA, NJ, DE, MD, D.C., WV	Commercially important fish and shellfish species such as cod, lobster, brook trout, and bass. Ecosystems: forests, grasslands, coastal zones, beaches and dunes, wetlands, rich marine and freshwater fisheries.	Communications, energy, transportation, water and waste infrastructure; cultural and historical landmarks; agricultural lands; green spaces; evacuation routes; lifelines; low-lying coastal metropolitan areas; rural areas; culverts and the structures they protect.	Rising temperatures; sea level rise; coastal flooding; storm surges; extreme precipitation events; declining water quality and clarity; saltwater intrusion; increasing frequency, intensity, and duration of heat waves; increasing risk of seasonal droughts; negatively impacting public health; increased vulnerability of the region’s most disadvantaged residents; warmer winters with increased risk of frost and freeze damage; increased weed and

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Research Program, 16-1-nn. http://nca2014.globalchange.gov/report/regions/northeast				pest pressure; agriculture, fisheries, and ecosystems increasingly compromised by climate change impacts.
Resilient Sites for Species Conservation in the Northeast and Mid-Atlantic Region Anderson MG, Clark M, Olivero Sheldon A. 2011. Resilient Sites for Species Conservation in the Northeast and Mid-Atlantic Region. The Nature Conservancy, Eastern Conservation Science. 122pp. http://www.fwspubs.org/doi/suppl/10.3996/062016-JFWM-044/suppl_file/fwma-08-01-28_reference+s02.pdf	United States Northeast and Mid-Atlantic Region, from Maine to Virginia.	234 species of greatest conservation need (SGCN) that includes 1) high responsibility species and 2) high concern species.	Natural lands; agricultural or modified lands; developed lands.	Altering species distribution, and ecological processes and flows.
Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans Staudinger MD, Morelli TL, Bryan AM. 2015. Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans. DOI Northeast Climate Science Center Report, Amherst, Massachusetts. Available at: http://necsc.umass.edu/	22 Northeast Climate Science Center (NE CSC) states from Maine to Virginia, and Minnesota and Missouri in the eastern U.S.	Major taxonomic groups including amphibians (56), birds (421), fish (freshwater 346 and marine 83), freshwater mussels (83), insects (259), marine invertebrates (22), other invertebrates (73), mammals (112), and reptiles (69).	In multi-scale (national, ecoregional, state, and local).	(General threats) Increasing warming effects in every season, esp. in winter, at higher latitudes, elevations, and inland; more frequent, intense, and longer heatwaves; increasing precipitation amounts and intensity; snow shifting to rain, with reduced snowpacks (harder and crustier) and extent of snow cover; increased atmospheric moisture content; declining wind speeds; intensifying wind gusts; intensifying streamflows; increasing water temperature; more

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
				severe thunderstorms; intensifying floods and droughts; longer dry periods; more frequent blizzards and ice storms. (U.S. Atlantic coast) Accelerating sea level rise; intensifying tropical cyclones and hurricanes; storm tracks shifting northward along the coast. Oceans are warming and becoming more acidic.
Other References				
http://www.udel.edu/udaily/2017/november/new-sea-level-rise-planning-scenarios/				
http://www.dgs.udel.edu/projects/determination-future-sea-level-rise-planning-scenarios-delaware				
http://www.delawareestuary.org/data-and-reports/science-reports/				
http://www.njadapt.org/				
This link from the Army Corps of Engineers addresses risks to infrastructure and various possible methods of dealing with climate change and sea level rise and flood risk reduction. The Corps is targeting doing more natural and nature-based resiliency projects for flood risk reduction (that also benefit natural resources).				

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
http://www.nad.usace.army.mil/CompStudy.aspx (From Barbara E. Conlin)				

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)[10]
- A species with a NatureServe global imperilment rank of G1, G2, or G3[11]
- 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 [12]

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.

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[10] 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)

[11] 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)

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

EO: See Element Occurrence.

EPA: Environmental Protection Agency

ESA: Endangered Species Act

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

GIS: Geographic information system

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

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

HCA: See Human Community Asset.

HUC: See Hydrologic unit code.

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

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

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

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

LCC: See Landscape conservation cooperative.

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

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

LCM: See Landscape condition model.

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

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

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

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

NEMAC: National Environmental Modeling and Analysis Center

NFWF: National Fish and Wildlife Foundation

NHD: see National Hydrography Dataset.

NOAA: National Oceanic and Atmospheric Administration

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

NWI: National Wetlands Inventory (USFWS product)

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

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

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

SGCN: See Species of Greatest Conservation Need.

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

SLR: Sea level rise

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

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

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

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.