Coastal Resilience Assessment of the Narragansett Bay and Coastal Rhode Island Watersheds

Suggested Citation: Crist, P.J., R. White, M. Chesnutt, C. Scott, P. Cutter, and G. Dobson. Coastal Resilience Assessment of the Narragansett Bay and Coastal Rhode Island Watersheds. 2019. National Fish and Wildlife Foundation.

Cover Image: Fishing port in Jamestown, Rhode Island

Table of Contents

Abstract

The Narragansett Bay and Coastal Rhode Island 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. Although a majority of the watershed is on higher ground not vulnerable to one-foot of sea level rise and other flooding threats assessed for this project, there are some notable areas of vulnerability. Areas vulnerable to storm surge and/or sea level rise are found in low-lying areas of the outer coast and around the bays and tidally-influenced rivers, while some inland areas are subject to precipitation-based flooding from extreme storm events.

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

As part of the assessment process, 34 resilience-related project ideas were submitted through the stakeholder engagement process, of which three are described in detailed case studies in this report. The case studies illustrate how proposed actions could benefit fish and wildlife habitat and human communities that face coastal resilience challenges such as storm surge during extreme weather events.

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

Executive Summary

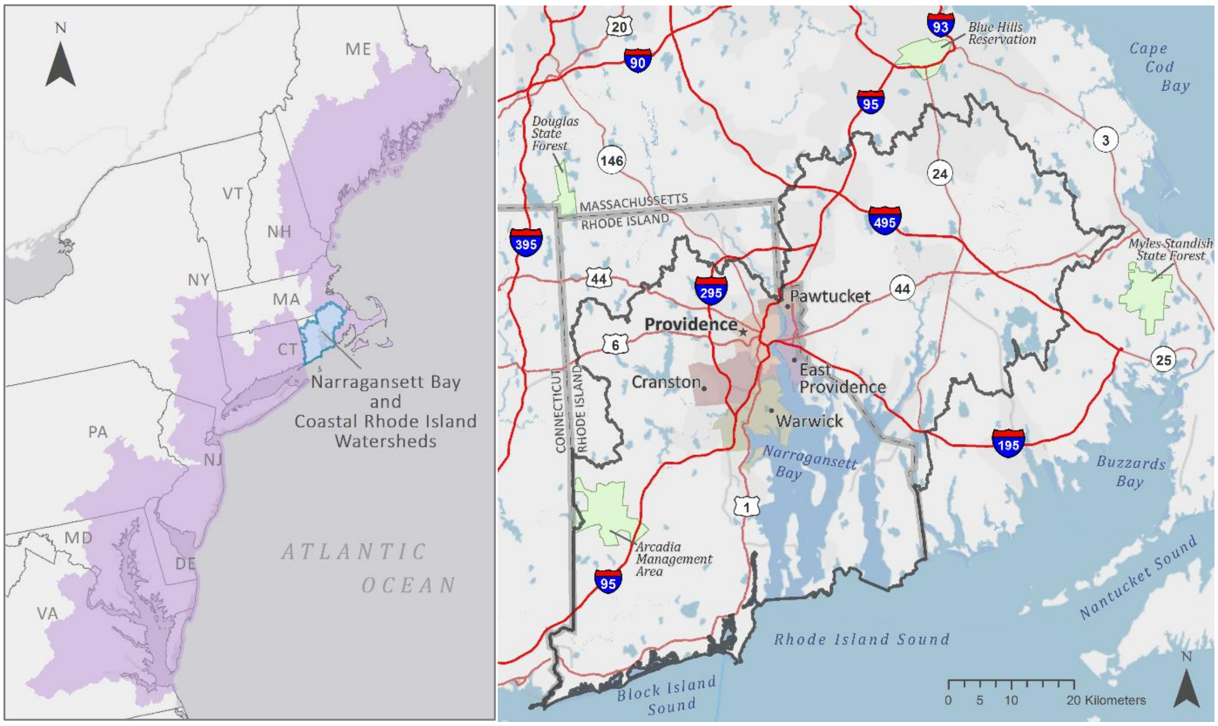
In response to increasing frequency and intensity of coastal storm events, the National Fish and Wildlife Foundation (NFWF) is committed to supporting programs and projects that improve community resilience by reducing communities' vulnerability to these coastal storms, sea-level rise, and flooding through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

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

This assessment focuses on the Narragansett Bay and Coastal Rhode Island Watersheds and adjacent areas of coastal Rhode Island. 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.

Narragansett Bay and Coastal Rhode Island Watersheds

The Narragansett Bay and Coastal Rhode Island Watersheds study area consists of the lower watersheds of Narragansett Bay and adjacent areas of coastal Rhode Island, including all of the Pawtuxet and Taunton River watersheds. The Taunton River watershed extends into Massachusetts and comprises a large inland area just south of Boston and east of Providence. The majority of the study area is in the North Atlantic Coast ecoregion and although the highest elevations in this ecoregion are generally quite low (the highest elevation in all of Rhode Island is just over 800 feet) and the low-lying coastal plain is very narrow. Many communities and human assets are located within vulnerable locations near the outer and bay shores and along tidally-influenced rivers. Many large storms recorded over the last several centuries have caused catastrophic damage and increasing sea levels and storm intensity ensure increasing vulnerability in the future.



Location and boundary of the Narragansett Bay and Coastal Rhode Island 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, composed of the primary Narragansett watershed and other neighboring watersheds including coastal salt ponds and part of the Pawcatuck watershed, is shown with the dark gray outline.*

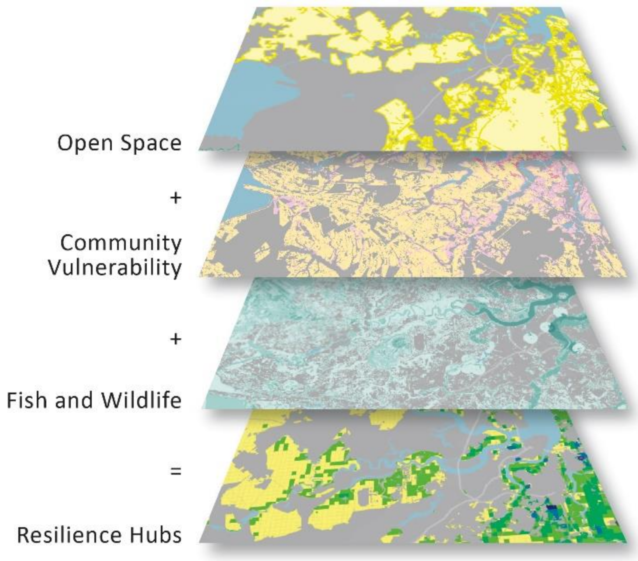
Assessment Objectives

The objectives of this assessment were to:

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

Assessment Approach

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



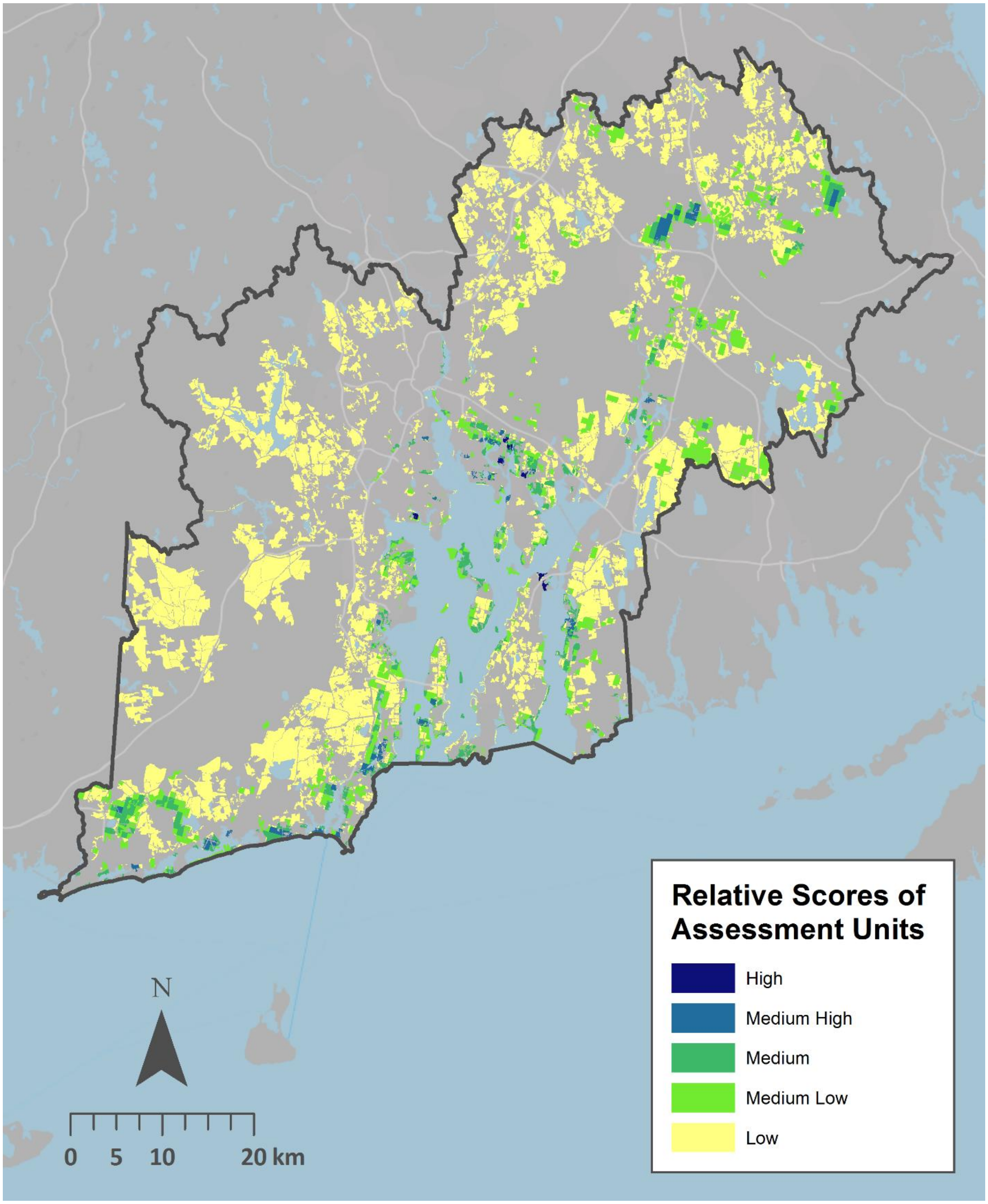
Left: Diagram of the overall approach of this assessment. *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas in proximity to HCAs with high vulnerability **and** high fish and wildlife richness are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

Results

Resilience Hubs

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

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



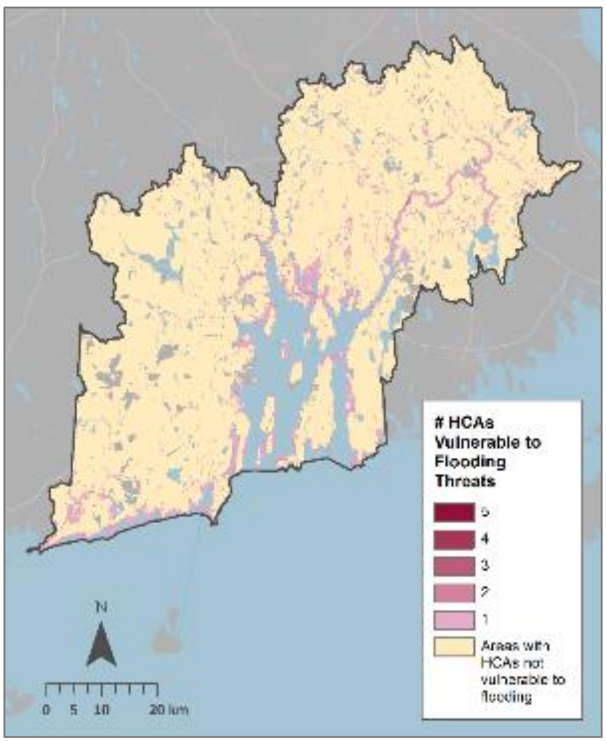
Resilience Hubs assessment unit relative scores for the Narragansett Bay and Coastal Rhode Island Watersheds*. Assessment units are 100-acres grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieve both community resilience and fish and wildlife benefits. Gray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

Community Vulnerability

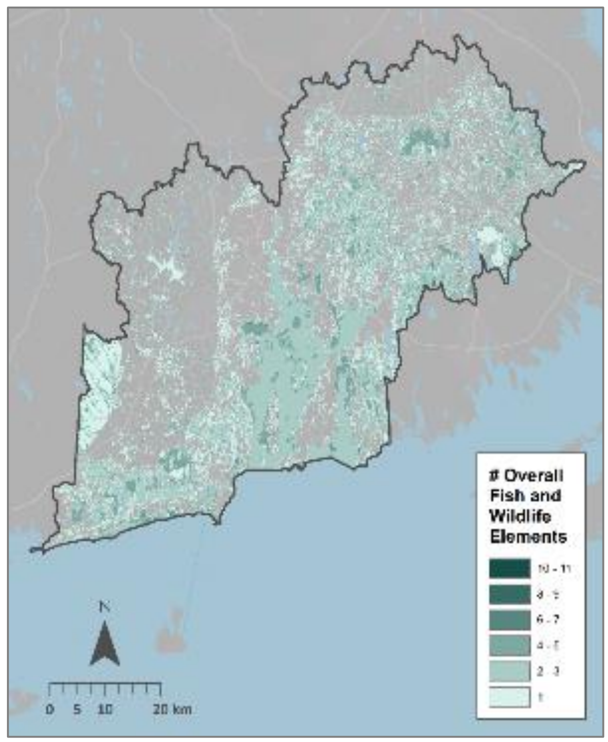
The Community Vulnerability Index (see map below) accounts for approximately half of the scoring of the Resilience Hubs. This index communicates threats to human community assets wherever they occur as well as concentrated areas of threat. As can be seen from the map, much of the watershed is on higher ground and not widely vulnerable to the flooding threats assessed for this project. Vulnerable areas are found in low-lying areas of the outer coast, around the bays and tidally-influenced rivers, as well as some inland areas subject to precipitation-based flooding from extreme storm events.

Fish and Wildlife

A total of 22 unique habitats, species, and species aggregations (referred to in this report as 'fish and wildlife elements' or simply 'elements') were included in this analysis. A Richness Index (see below) represents the concentration of fish and wildlife elements in each location.



Community Vulnerability Index for the Narragansett Bay and Coastal Rhode Island 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 Narragansett Bay and Coastal Rhode Island 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: Canada Pond Dam
- Case Study 2: Upper Kickemuit River Restoration Project
- Case Study 3: Wading River Culvert Replacement Project

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 Narragansett Bay and Coastal Rhode Island 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.

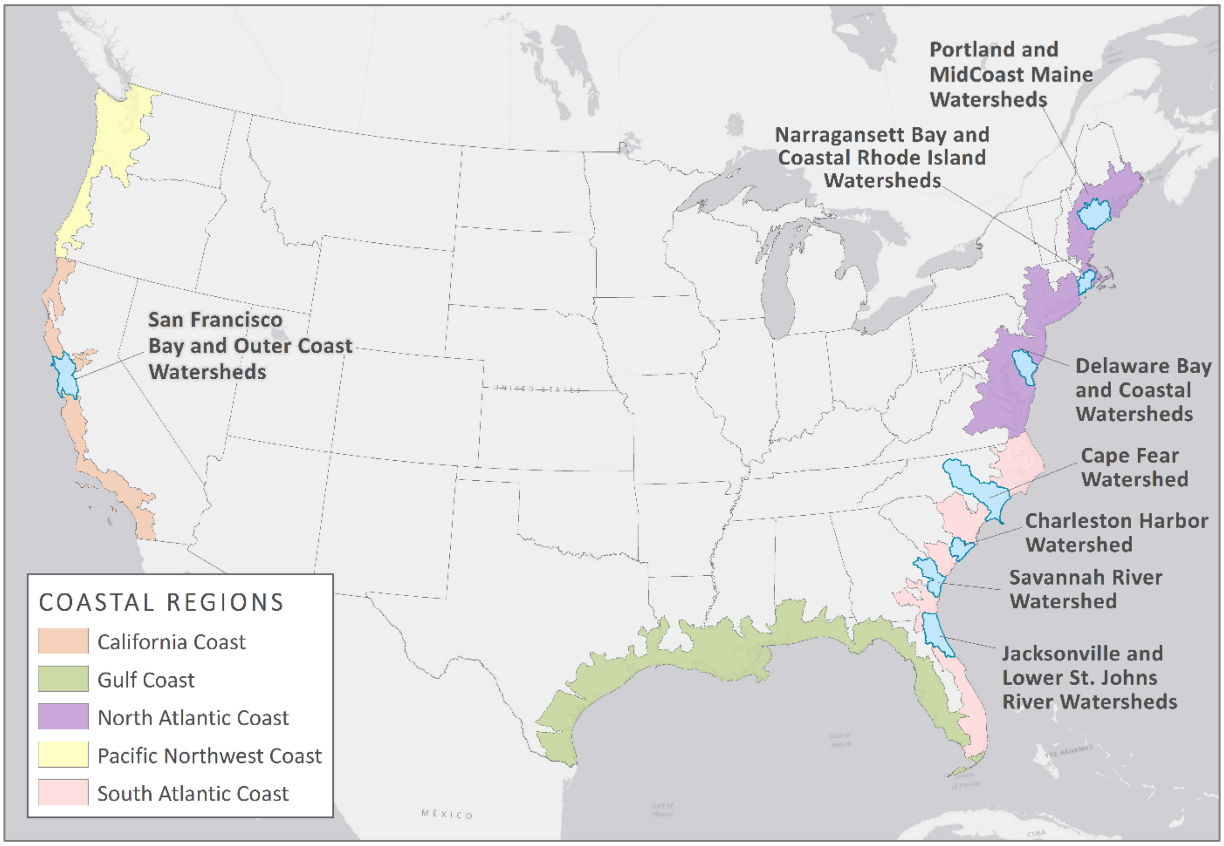


Figure 1. Map showing study areas for the Regional and Targeted Watershed Assessments. *The broad Regional Assessment included five coastal regions. High resolution resilience assessments were carried out in eight coastal Targeted Watershed Assessment study areas (in blue); the Cape Fear Watershed was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

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.**

Narragansett Bay and Coastal Rhode Island Watersheds

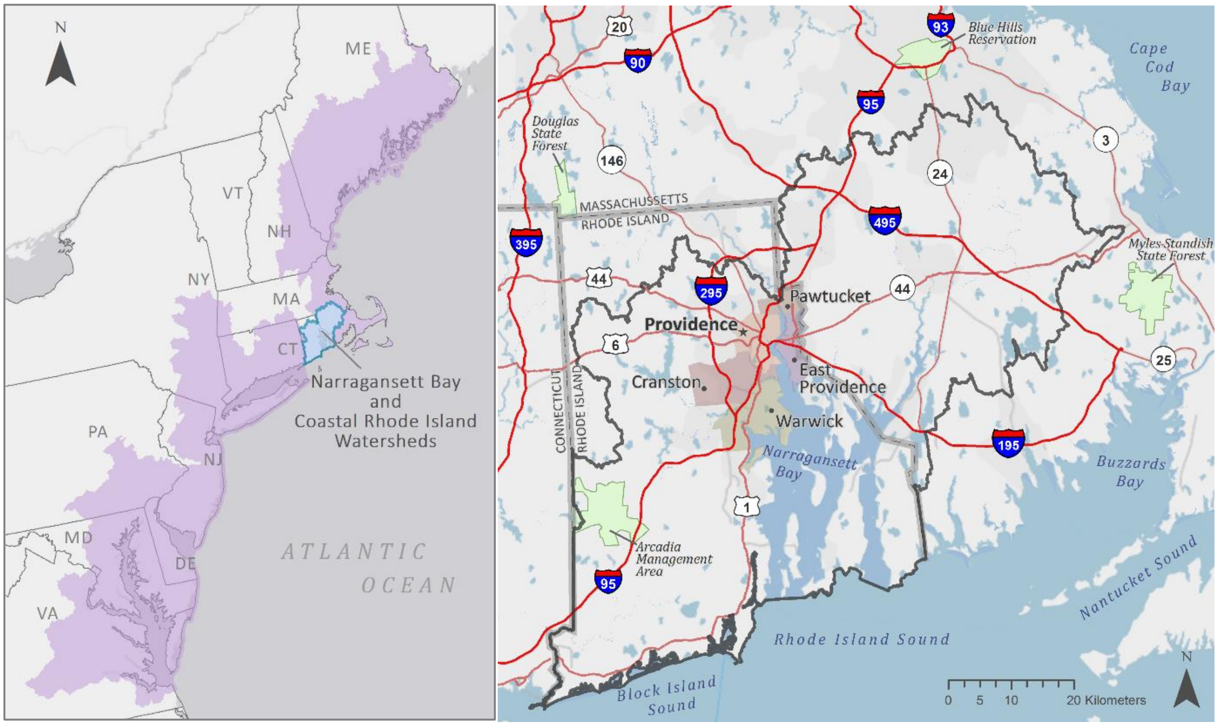


Figure 2. Location and boundary of the Narragansett Bay and Coastal Rhode Island Watersheds study area. *The map on the left shows the watershed in the context of the North Atlantic Coast Regional Assessment area (purple). In the map on the right, the study area, composed of the primary Narragansett watershed and other neighboring watersheds, is shown with the dark gray outline.*

The Narragansett Bay and Coastal Rhode Island Watersheds study area is centered around Narragansett Bay in Rhode Island. The study area encompasses the entire coastal region of Rhode Island and parts of adjacent Massachusetts[1]. The primary urban center of Providence, RI is located at the head of the bay, but other large cities and towns occur around the bay and coast, including East Providence, Pawtucket, Fall River, Taunton, Brockton, Middletown, Portsmouth, and Warwick. The study area is very densely populated with approximately 1.95 million residents as of 2017. The region has a strong and diversified economy. Although it's largest single employers are Brown University and Rhode Island Hospital, almost 20 percent of Providence's economy is based in trade, transportation, and utilities and another 13 percent from manufacturing (Advameg Inc. 2007). The Port of Providence is an important deep water seaport serving New England and providing a key transportation link for imports/exports to and from the region. The Port of Davisville in North Kingstown, RI, also serves the region. The Narragansett Bay Watershed study area is shown in **Figure 2**.

[1] The boundary of the study area is similar to that of the State of the Narragansett Bay and its Watershed report (NBEP 2017), which did not include the adjacent coastal watershed but did include the Blackstone River Basin not included in this study.

The boundary of the study area follows those of the three United States Geological Survey (USGS) level four hydrological units[2] adjacent to the Narragansett Bay and Coastal Rhode Island Watershed. The dominant watershed feature of the region is Narragansett Bay, one of New England's largest estuaries receiving waters from the Blackstone, Pawtuxet, and Taunton Rivers. The rivers that feed into Narragansett Bay drain from large portions of southeastern Massachusetts and Rhode Island. The study area also includes watersheds in western and southwestern Rhode Island and the entire coastal region of Rhode Island, which represents the largest proportion of low-lying land in the area. Unlike some regions of the U.S. with larger coastal plains, this area's very narrow low-lying coastal plain and its rolling topography means that exposure to sea level rise and storm threats is concentrated in relatively small geographic pockets. The population of the region is concentrated in and around Providence and its suburbs. Outside of the cities, the terrestrial portions of the watershed have a typical New England land use pattern of small towns and rural, agricultural development although recent population increase is encroaching on this, primarily in suburban and exurban areas (NBEP 2017). As the birthplace of the American Industrial Revolution (NBEP 2017), considerable alteration of the hydrology with canals and dams occurred, many of which still impact fish and wildlife resources. While the overall water quality has improved, impacts linger from legacy contamination and non-point source pollution runoff (NBEP 2017).

The watershed benefits greatly from the existence of the Narragansett Bay Estuary Program (NBEP) and the Narragansett National Estuary Research Reserve. The reserve includes 4,400 acres of protected land and water within four islands in the bay, preserving key salt marsh, eelgrass, rocky intertidal, pine barren, coastal hardwood forest, and coastal meadow habitats. Substantial salt marsh habitat has been lost in Narragansett Bay and is extremely vulnerable to sea level rise, so conservation of this habitat is vital to conserving the increasingly rare salt marsh-dependent species in this region. The NBEP's mission is to protect, restore, and preserve Narragansett Bay and its watershed. The State of the Narragansett Bay Watershed Report summarizes progress towards conservation goals as well as key challenges.

In addition to the Narragansett Bay proper, the study area includes very important coastal areas of Rhode Island that harbors the largest concentrations of coastal salt ponds, intertidal marshes, and coastal beaches in the region. As some of the lowest-lying areas in the region, they are particularly vulnerable to coastal storms. This area of coastal salt ponds and intertidal wetlands provides a rich complex of tidal habitats that support eelgrass beds, relatively high densities of migrating waterfowl and shorebirds (including piping plover stopover habitat), and commercially and recreationally-important fish species. The NBEP report (2017) found that climate change stressors are impacting the estuarine fish communities with declining cold-water species and increasing warm water species.

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

Historic Impacts from Flooding

The Narragansett Bay and Coastal Rhode Island region is subject to intense storms (hurricanes, gales, Nor'easters) with the first recorded gale in 1764. Providence was built at the confluence of the Providence and Seekonk Rivers at the head of the bay making it vulnerable to flooding originating upstream from heavy precipitation and storm surge. In addition to the 1764 storm that destroyed many developments including the Weybosset Bridge, several other storms are cataloged by Brown University[3]:

- The Great Gale of 1815 generated a tide of nearly 12-feet and flooded low lying areas of Providence to the second floor of buildings. The September Gale of 1869 caused similar damage.
- The Great New England Hurricane of 1938 caused extensive damage along the Atlantic Coast, but most severely impacted Providence in 262 deaths. This is considered the worst disaster in Rhode Island's history.
- Hurricane Carol landed in 1954 causing a 13-foot tide, killing 19 people and resulting in $90M in damage.
- Damage from Hurricane Carol spurred construction of the Fox Point Hurricane Barrier across the Providence River which was completed in 1966. That barrier helped reduce impacts from the subsequent storms, including Hurricane Gloria in 1985 and Hurricane Bob in 1992.
- In spring of 2010, the area was subject to heavy rains from several storms occurring over a month-long period. This caused soil saturation and heavy runoff from urban areas, which resulted in the Pawtuxet River cresting 11 feet above flood stage and resulting in extensive flooding.
- In October 2012, Superstorm Sandy ravaged the Northeast coast causing $11M in damages in Rhode Island alone. The storm revealed a need to quickly identify nature-based recovery projects that could increase future resilience in the region, which in part, contributed to the development of this assessment.

Resilient Rhody, the state of Rhode Island's climate adaptation strategy, addresses the impacts of changing environmental conditions to the state's critical infrastructure and utilities, natural systems, emergency preparedness, and community health and resilience. The goal of the strategy is to identify actions (e.g., projects, policies and legislation, or funding and financing opportunities) that the state can use to better prepare for a changing climate. The strategy has four focal areas: 1) critical infrastructure and utilities, 2) natural systems, 3) emergency preparedness, and 4) community health and resilience. It outlines priority assets, related climate vulnerabilities, and actionable recommendations for advancing adaptation and resilience. Building on the climate leadership of state government, municipalities, and organizations, the strategy leverages existing studies and reports to identify critical actions that move from planning to implementation.

[3] https://www.brown.edu/Departments/Joukowsky_Institute/courses/architectureandmemory/8084.html

Massachusetts created the Municipal Vulnerability Preparedness grant program (MVP)[4] which provides support for cities and towns in Massachusetts to begin the process of planning for changing environmental conditions and implementing priority projects. The state awards communities with funding to complete vulnerability assessments and develop action-oriented resiliency plans. Communities that complete the MVP program become certified as an MVP community and are eligible for MVP Action grant funding and other opportunities.

[4] https://www.mass.gov/municipal-vulnerability-preparedness-mvp-program

Methods Overview

This overview is intended to provide the reader with sufficient information to understand the results. Details on methods are provided in the appendices as referenced in each section below to provide deeper understanding and/or aid in the use of the available Vista decision support system (Vista DSS). Process diagrams (e.g., **Figure 4**) use the Charleston, SC region as an example and do not represent inputs or results for this watershed; they are only intended to illustrate methods.

Overall Approach

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

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

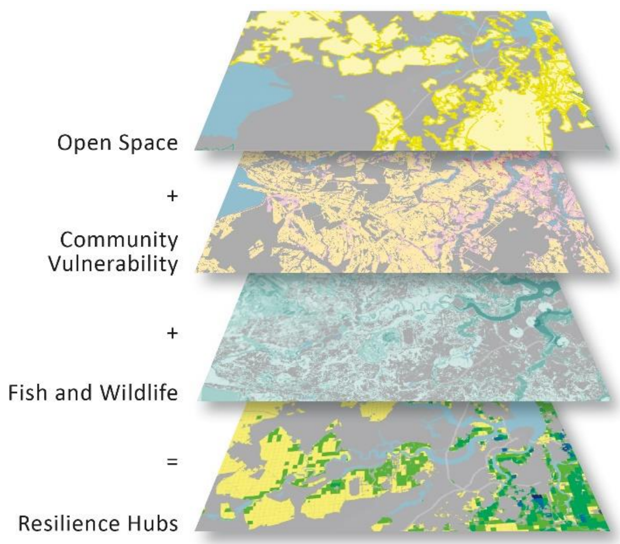


Figure 3. Diagram of the overall approach of this assessment. *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas with high HCA vulnerability <u>and</u> high fish and wildlife richness are mapped as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

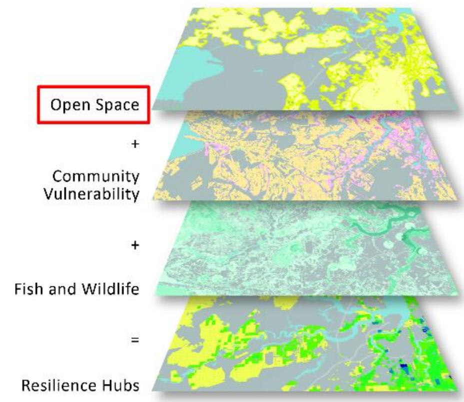
Stakeholder Participation

A fundamental part of this Targeted Watershed Assessment was to engage and work with individual and organizational stakeholders and partners within the Narragansett Bay and Coastal Rhode Island 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 Narragansett Bay and Coastal Rhode Island 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 Narragansett Bay and Coastal Rhode Island Watersheds Committee was formed consisting of local experts from the National Oceanic and Atmospheric Administration (NOAA), Save The Bay, Rhode Island Coastal Resources Management Council, Narragansett Bay National Estuarine Research Reserve, Narragansett Bay Estuary Program, Rhode Island Natural History Survey, North Atlantic Landscape Conservation Cooperative (LCC), 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 50 participants including federal and state agency representatives, NGO staff, local elected officials and municipal staff, and citizens representing their communities were engaged in the stakeholder process through web meetings, in-person workshops, and follow-up activities such as site visits to proposed resilience project sites. Additional details on key stakeholder inputs, details about the stakeholder process, and the committee structure that guided the assessment can be found in Appendix 1.

Components of the Assessment



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

Open Space

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

Mapping Open Space

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

1. Protected areas, which are defined as lands that are part of the USGS Protected Areas Database of the United States (PAD-US).
2. Unprotected, privately owned lands with contiguous habitat, as identified from the USGS National Land Cover Database (NLCD).

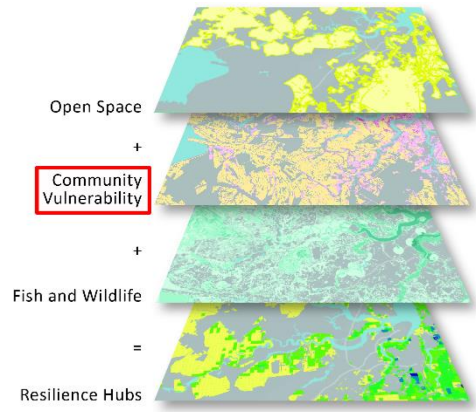
The open space areas were further processed to remove impervious surfaces and deep marine areas. Within the Regional Assessment methodology, these areas were also analyzed using a community exposure index to highlight areas of higher exposure and areas that are near or adjacent to communities.

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

1. Hubs with shorelines (rivers or coastal) were supplemented with the National Hydrography Dataset (NHD) to include waters within a 50-meter buffer to add nearshore habitat areas that could provide locations for aquatic resilience projects such as oyster reefs or marsh protection/restoration.
2. 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.

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. These categories were 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[5]	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

[5] Human Community Asset elements were provided by the regional assessment. Please refer to the regional report for details.

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)

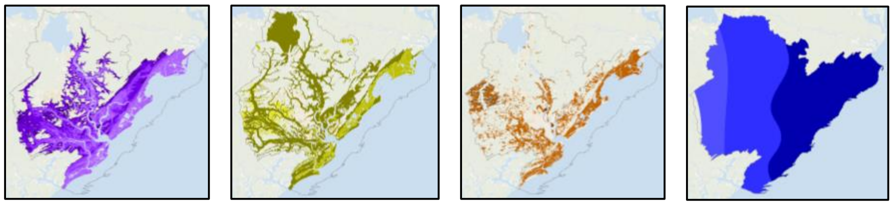
The HCA weighted richness index expresses values based on the number of HCAs present in a location and their importance weights. The HCAs were combined in the Vista DSS using its Conservation Value Summary function[6] by first assigning a weighting factor that approximated the ranked weights used in 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.

[6] 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.

- Storm surge (with values of 1-5, which are based on hurricane categories 1-5)
- Flood zones (100 and 500-year floodplains and flood-ways)
- Flood prone areas (flat topography with poorly draining soils)
- Moderate to high erosion potential
- Subsidence



Storm Surge | Flood Zones | Erosion Potential | Subsidence Potential

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

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

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.

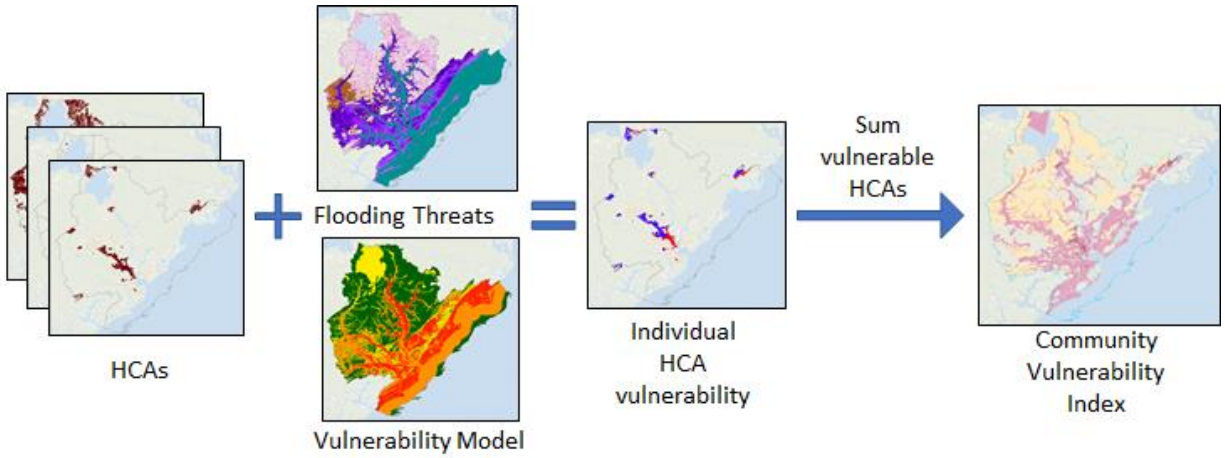
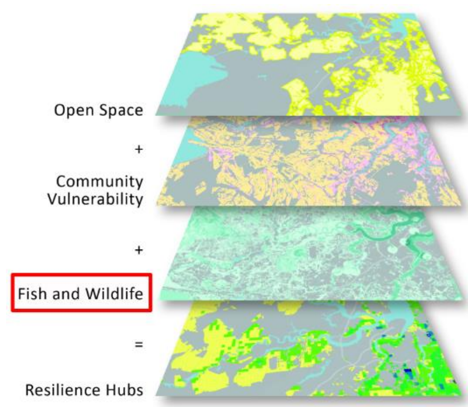


Figure 5. Community vulnerability assessment process. *Human Community Assets (HCAs) are intersected with the flooding threats, a vulnerability model is applied, and individual HCA results are summed to create the Community Vulnerability Index. Diagram represents the Charleston, SC region as an example 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[7]
- 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)[8]
  - A species with a NatureServe global imperilment rank of G1, G2, or G3[9]
  - 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

---

[7] 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 river herring and American shad 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, seagrass beds, coral reefs, and other coastal habitats; and Resources associated with National Marine Sanctuaries and National Estuarine Research Reserves (NOAA 2015).

[8] 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)

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

- A distinctive ecological system or species congregation area that represents habitat important to at-risk species and/or species of significance to stakeholders in the region. Examples might include heron rookeries that represent important wading bird habitat or tidal marsh representing shrimp nursery areas and diamondback terrapin habitat; or
- A species or population of commercial, recreational, or iconic importance in the watershed. This includes:
    - Fish or wildlife species or populations of significant commercial value (such as bay scallop habitat),
    - Fish or wildlife-related features that confer resilience to biodiversity or human assets (such as healthy examples of salt marshes/tidal creeks that may attenuate wave action)
    - 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 (quahogs).

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

The current fish and wildlife stressors were identified during stakeholder workshops and available data were identified to represent them. 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 are found in Appendix 2.

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

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

Fish and Wildlife Indices

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

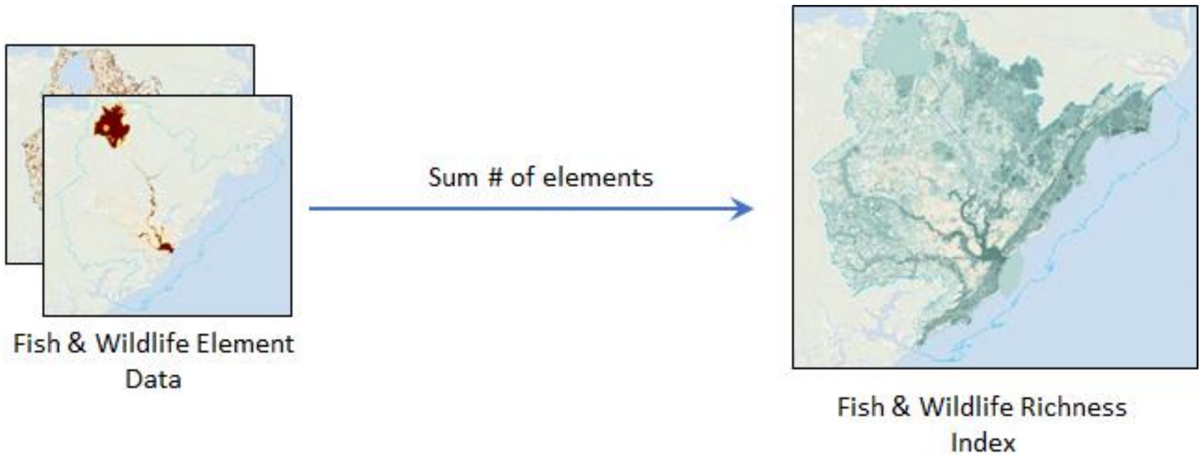


Figure 7. Method for generating the Fish and Wildlife Richness Index. *All elements are overlaid and the sum of elements occurring in a location is calculated. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

Condition-Weighted Fish and Wildlife Richness Index

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

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

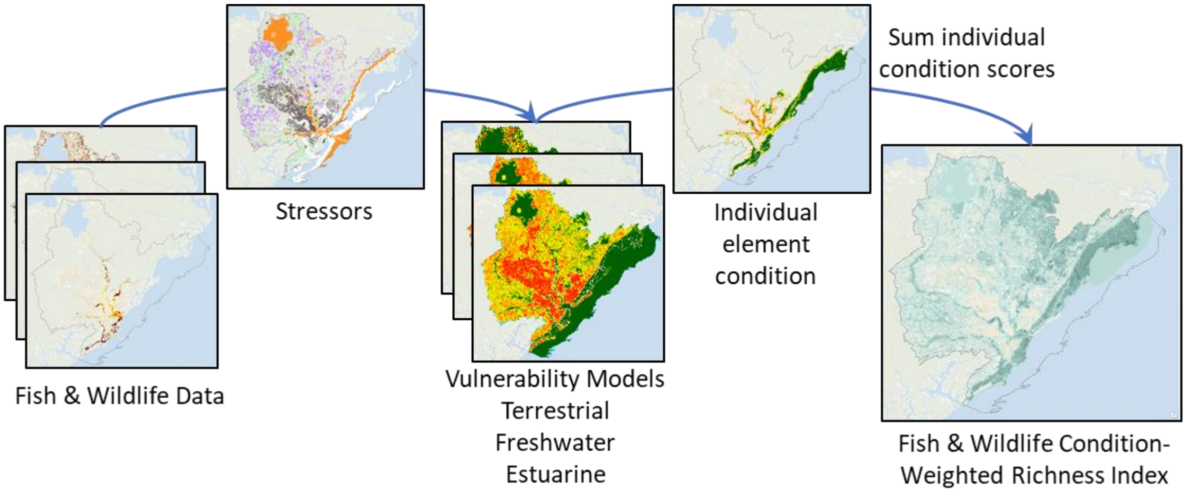
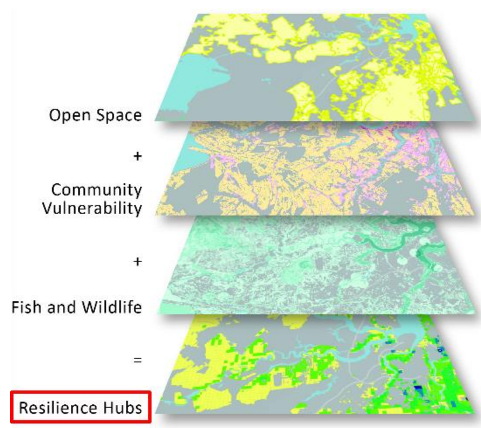


Figure 8. Method for generating the Fish and Wildlife Condition-Weighted Richness Index. *Fish and wildlife elements are intersected with stressors, the vulnerability model is applied, and individual element condition results are summed. Diagram represents the Charleston, SC region as an example and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

Resilience Hub Characterization and Scoring



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

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

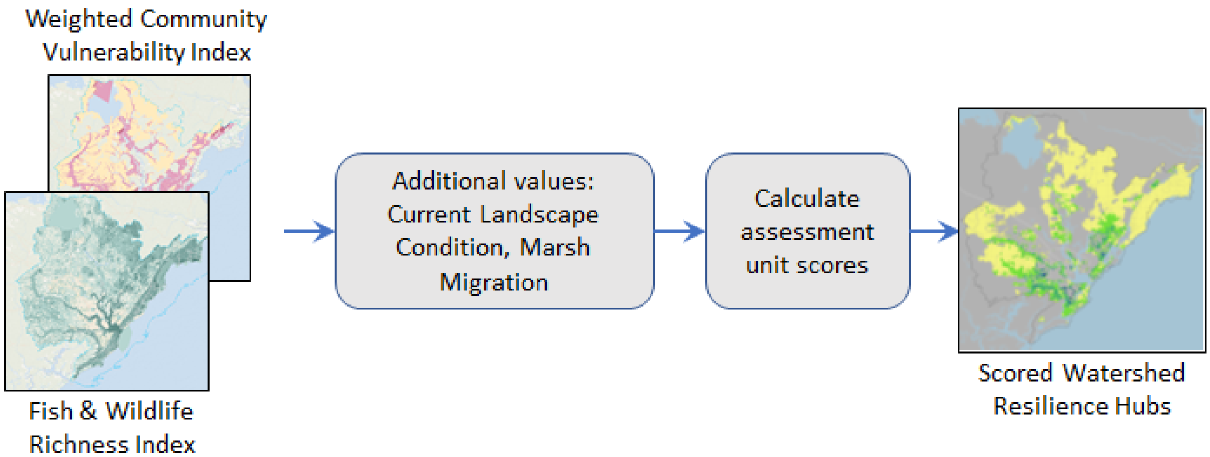


Figure 9. Method for scoring watershed Resilience Hubs. *Resilience Hub assessment units were scored based on their community resilience and fish and wildlife. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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

- **Weighted Community Vulnerability**: The weighted richness of HCAs with vulnerability to flooding threats falling within each assessment unit. This is a combination of the Community Vulnerability Index and HCA Weighted Richness Index. This attribute was used as a strong attractor of resilience projects to increase resilience to HCAs modeled to be vulnerable. The index has a value of zero if the HCA Flooding Threats Exposure Index is zero, otherwise it is the value from the HCA Weighted Richness. Focal statistics were used to summarize this combined map using a 1 km (0.62 mi) radius and these results were summed to each assessment unit using zonal statistics. This is an intermediate product used only to score Resilience Hubs and therefore not depicted in the Results section.
- **Fish and Wildlife Richness Index**: The number of fish and wildlife elements falling within each assessment unit. This attribute was used to increase the value of areas that could benefit more fish and wildlife elements relative to places with fewer elements.
- **Future Marsh Migration Index**: This attribute is based on NOAA's three-foot sea level rise marsh migration models (NOAA 2018). The rationale is that areas modeled to support future marsh habitat will be able to provide ongoing fish and wildlife value with at least three-feet of sea level rise. While changes (e.g., one foot of sea level rise) may not occur until well into the future, conservation and restoration of these areas should begin now to prepare for future changes. Areas were assigned a one (1) if the assessment unit was projected to have estuarine marshes.
- **Restorability Index:** This attribute is based on the current condition as modeled from the existing fish and wildlife stressors as well as its protection status. Scores the value of an assessment unit based on the average.

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

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

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

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

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

Resilience Projects

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

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

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

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

Site Visits

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

Results

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

Flooding Threats

The effects of the flooding threats on the vulnerability of Human Community Assets (HCAs) and fish and wildlife elements are treated individually in the assessment model (see Appendix 2); therefore, a separate threats index was not generated. An analog to a threats index can be found in Appendix 2, which contains the results of four models of how wildlife stressors and flooding threats may cumulatively impact the condition of HCAs, terrestrial wildlife, freshwater fish and wildlife, and estuarine fish and wildlife. The Threat Index generated in the Regional Assessment is provided below (**Figure 10**) to illustrate the accumulation of flooding threats across the Narragansett Bay and Coastal Rhode Island 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).

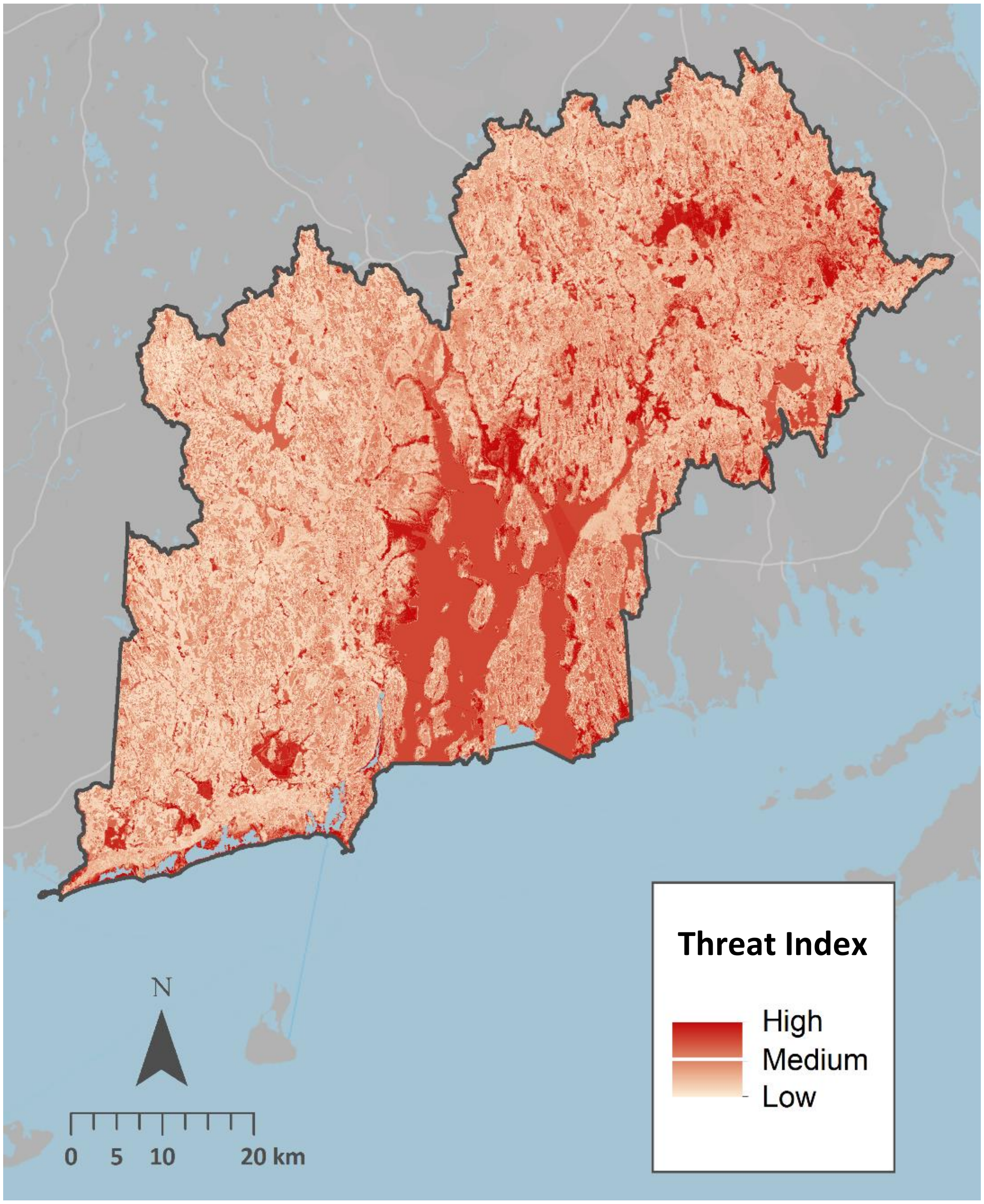


Figure 10. Weighted Threat Index for the Narragansett Bay and Coastal Rhode Island Watersheds. *Map shows the number of overlapping threats modified by a weighting based on their probability of occurrence.*

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.

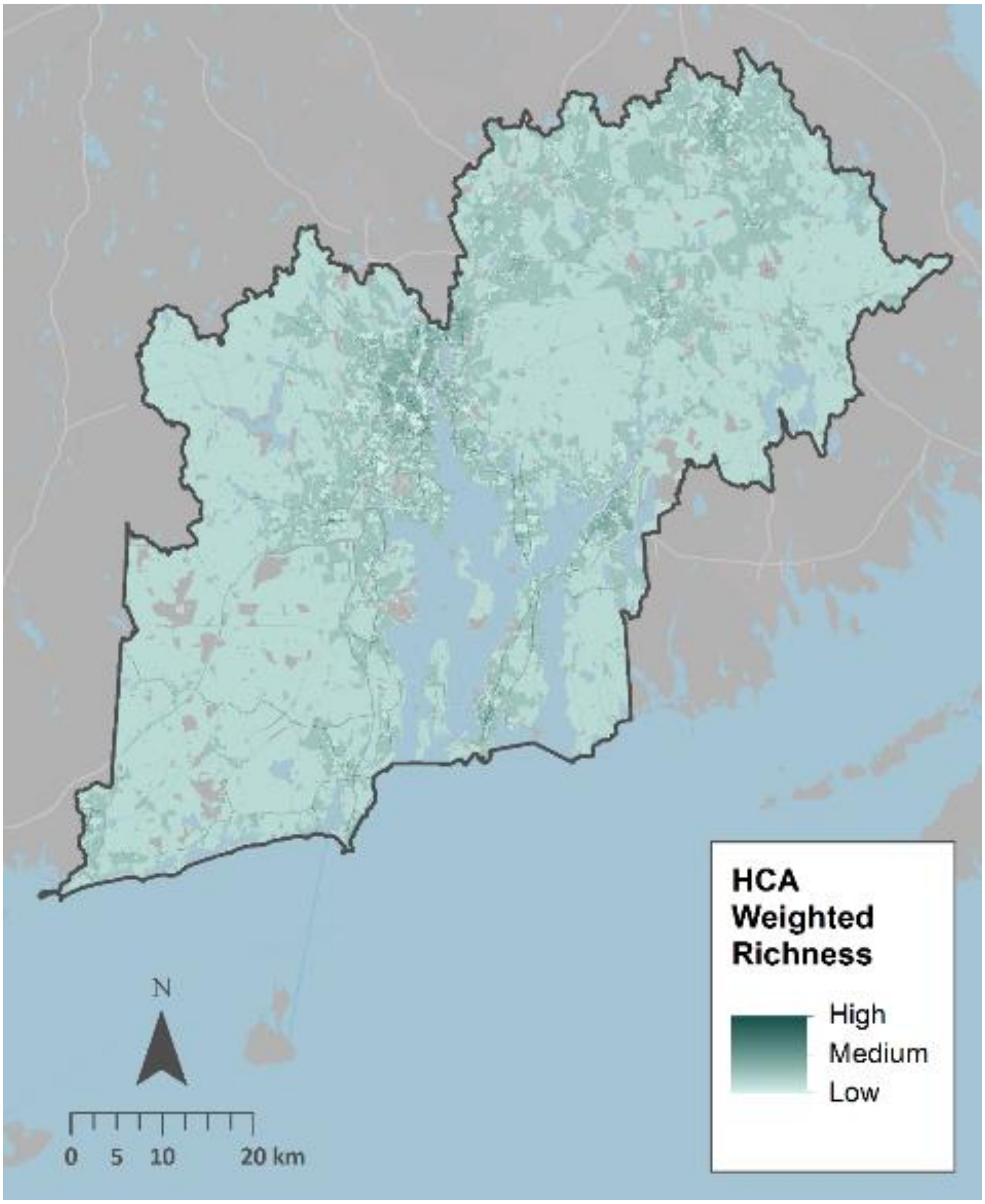


Figure 11. Human Community Asset (HCA) Weighted Richness Index for the Narragansett Bay and Coastal Rhode Island Watersheds. *Darker shades indicate higher value based on the number and importance weightings of HCAs in each location. Gray areas within the project boundary represent areas with no mapped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

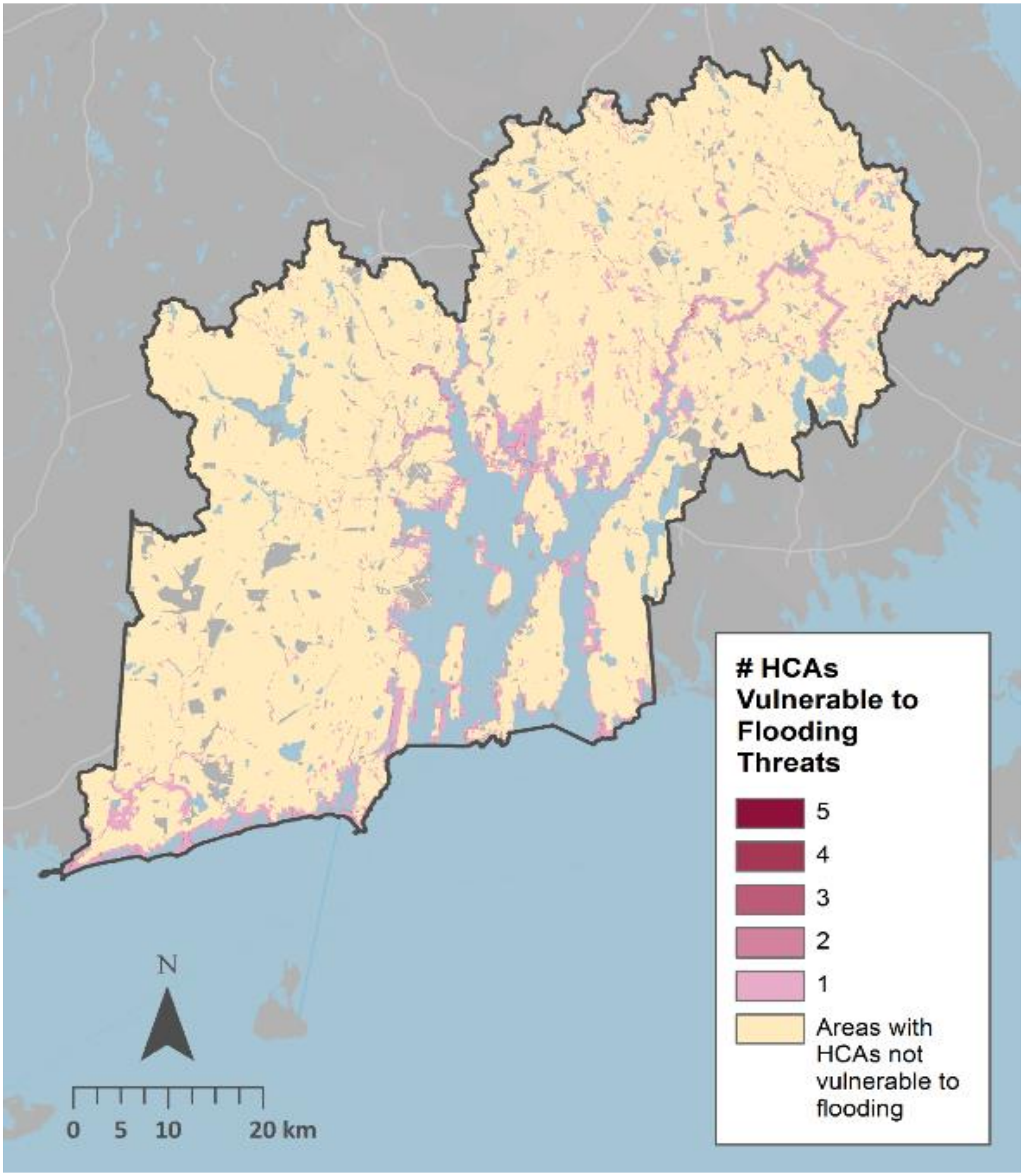


Figure 12. Community Vulnerability Index for the Narragansett Bay and Coastal Rhode Island Watersheds. *Pink to red shades indicate the number of Human Community Assets (HCAs) exposed to flooding related threats. Tan areas indicate areas of low to no impact from the flooding threats. Gray within the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

Vulnerability is highest in the immediate coastal areas (outer coast and around the bays) where there are concentrations of HCAs exposed to the largest number of overlapping threats, particularly in communities such as Barrington, Warren, North Kingstown, and Warwick in Rhode Island and Dighton and Freetown in Massachusetts. Areas of vulnerability farther inland are largely due to precipitation-caused flooding threats (flood zones and flat areas with poorly draining soils), such as Raynam near the Pine Swamp in Massachusetts. Within Providence, the major city in the watershed, areas on the west side of the Providence River such as Downtown, Washington Park, and the Jewelry District are vulnerable. These results are consistent with those of the Narragansett Bay Estuary Program report (2017).

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).

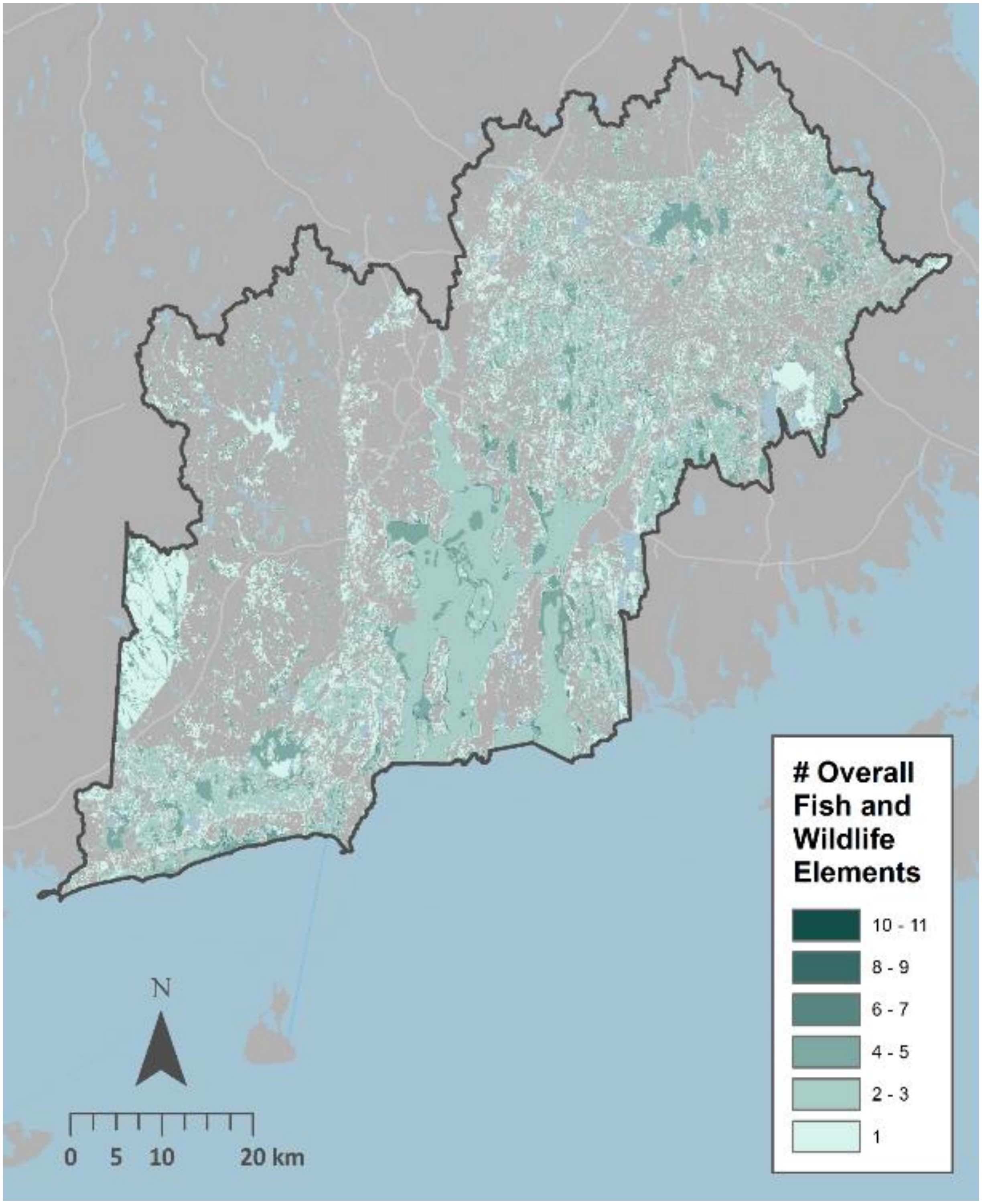


Figure 13. Richness of fish and wildlife elements in the Narragansett Bay and Coastal Rhode Island Watersheds. *Green shades indicate the number of elements found in a location. Gray areas within the project boundary have no mapped fish and wildlife elements considered in this assessment.*

Condition-weighted Richness of Fish and Wildlife Elements

The Fish and Wildlife Condition-weighted Richness Index (**Figure 14**) modifies the richness map above by incorporating the modeled condition of elements that overlap in any location. This analysis used a sum of the condition scores of all elements overlapping in a pixel. It conveys value through the concept that areas with more elements of higher condition are important to conserve, while areas with moderate scores may provide opportunities for restoration. Areas of low scores either have few elements[10] 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 13 and **Figure 14** above show similar patterns of value. Richness and condition are currently highest in the bay and coastal areas, which includes many important l fish species and aquatic habitats. Additionally, the upper watershed areas of Massachusetts include relatively rare intact forest and wetland habitats. The lighter shades of the condition-weighted richness map indicate reduced condition from current stressors to fish and wildlife from urban and agricultural land uses and reduced water quality. Examples include the Seekonk River and Belcher Cover, which have high fish and wildlife richness but low current condition scores. Other areas indicate both high richness and condition such as around Raynham in Massachusetts and Chapman Pond and Burlingame Management Area near the Rhode Island coast.

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.

[10] The selection process for fish and wildlife elements was influenced by the project's emphasis on coastal resilience and data availability. Some inland natural resource areas may not be fully represented in terms of fish and wildlife value.

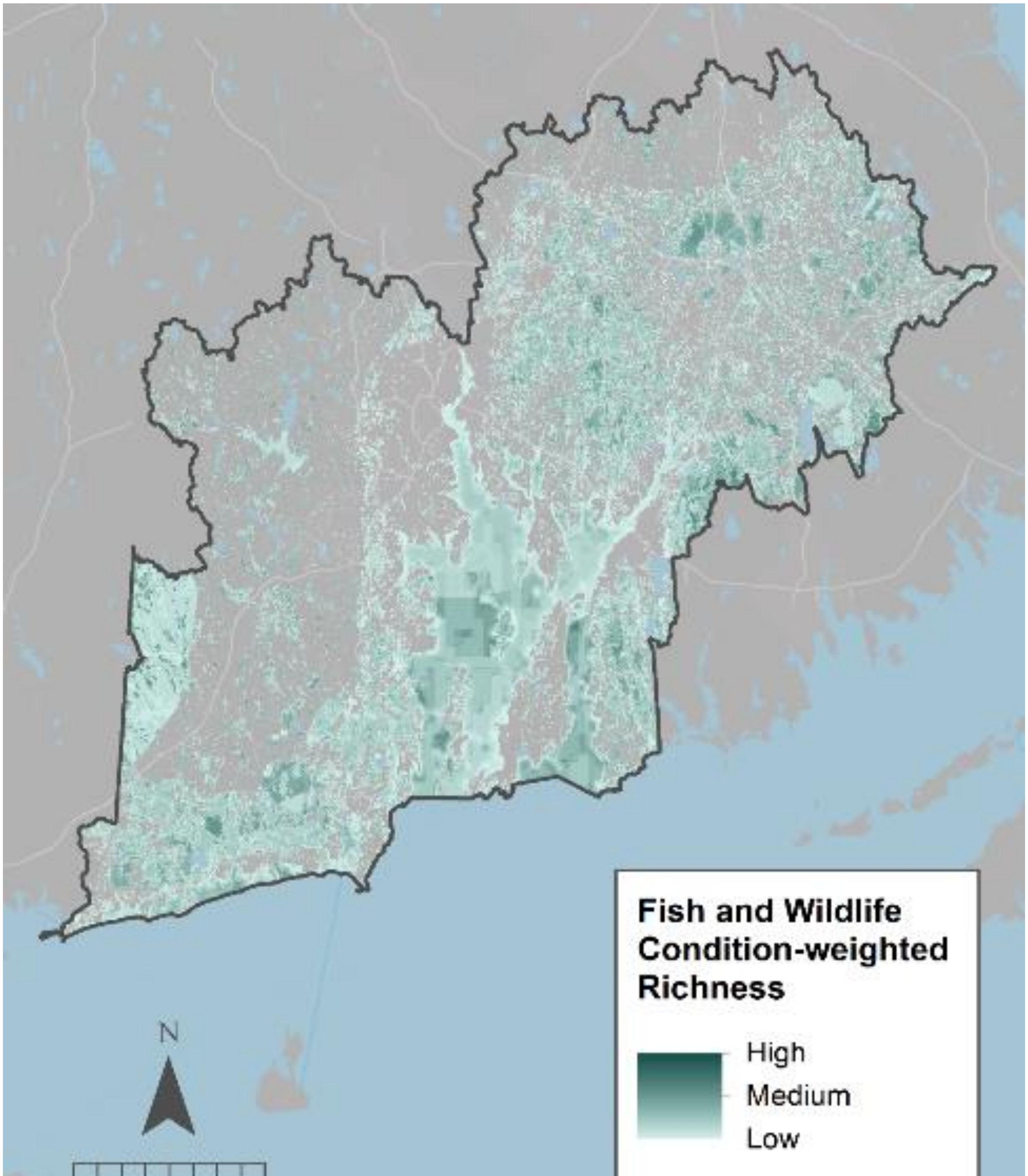


Figure 14. Fish and Wildlife Condition-weighted Richness Index results for the Narragansett Bay and Coastal Rhode Island Watersheds*. Green shades indicate the added condition scores of the elements found in a location, with a maximum value of one per element. Grey areas within the project boundary signify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

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.

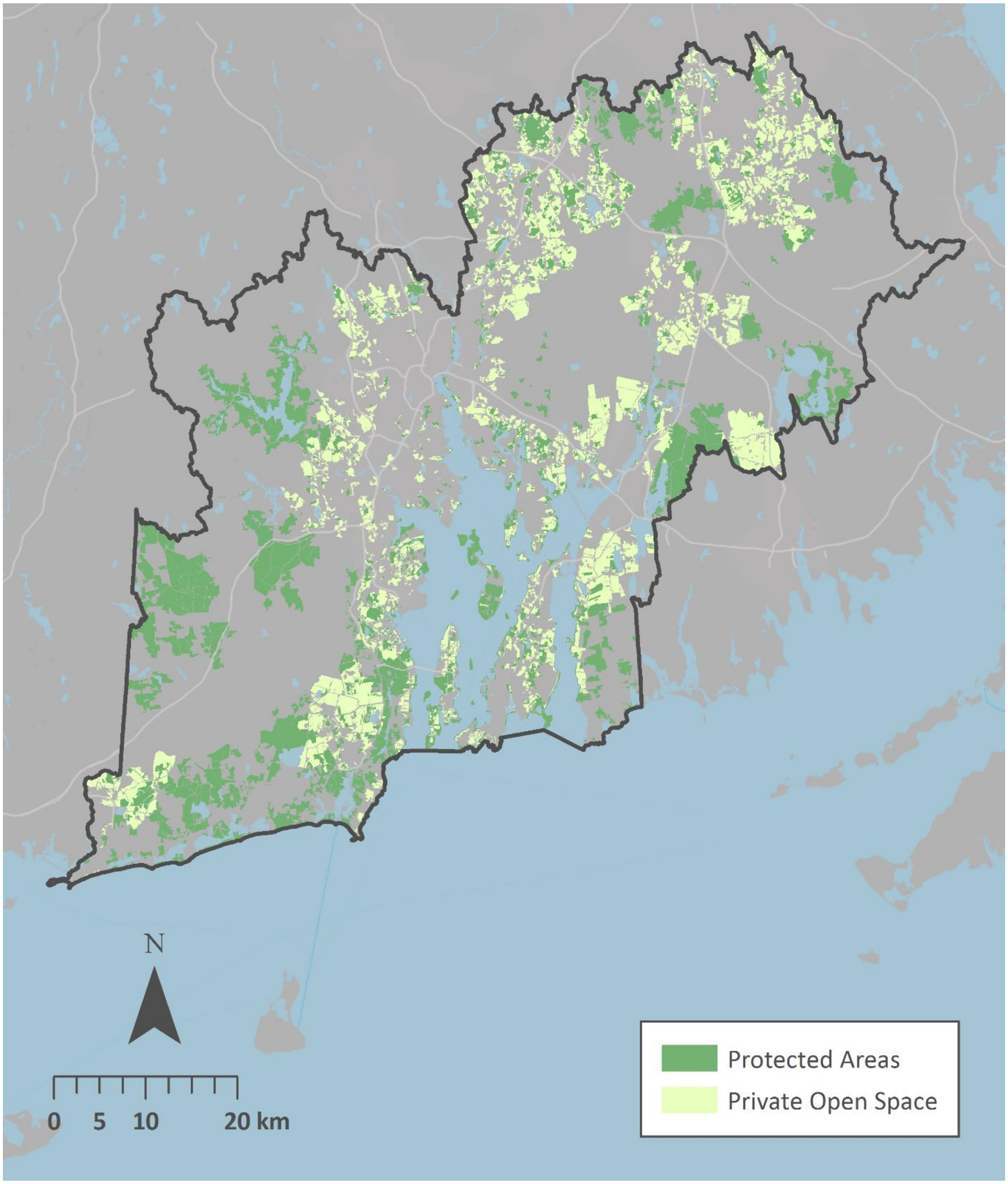


Figure 15. Undeveloped protected areas and unprotected privately owned areas of open space in the Narragansett Bay and Coastal Rhode Island Watersheds. *Map displays the distribution of these areas within Resilience Hubs identified in the study area and therefore does not include all such areas within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

By design, 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, 8,533 assessment units were analyzed and scored within the study area. 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**).

There are relatively few high scoring hub areas in this watershed reflecting the lack of open space near the areas of highest vulnerability (e.g., downtown Providence, which is also protected by the Fox Point Hurricane Barrier). However, clusters of high scoring areas are found along the outer coastal areas of Charlestown, Green Hill, Narragansett, and Westerly. Within the northern end of the bay, there are also high scoring areas around Brush Neck Cove, Island Park Cove, and Hundred Acre Cove. Inland, the large area around Raynham, MA stands out because of the relatively intact forest and wetlands in this area around flood-vulnerable towns and highways.

Suggested Uses

The Resilience Hubs map for the Narragansett Bay and Coastal Rhode Island 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.

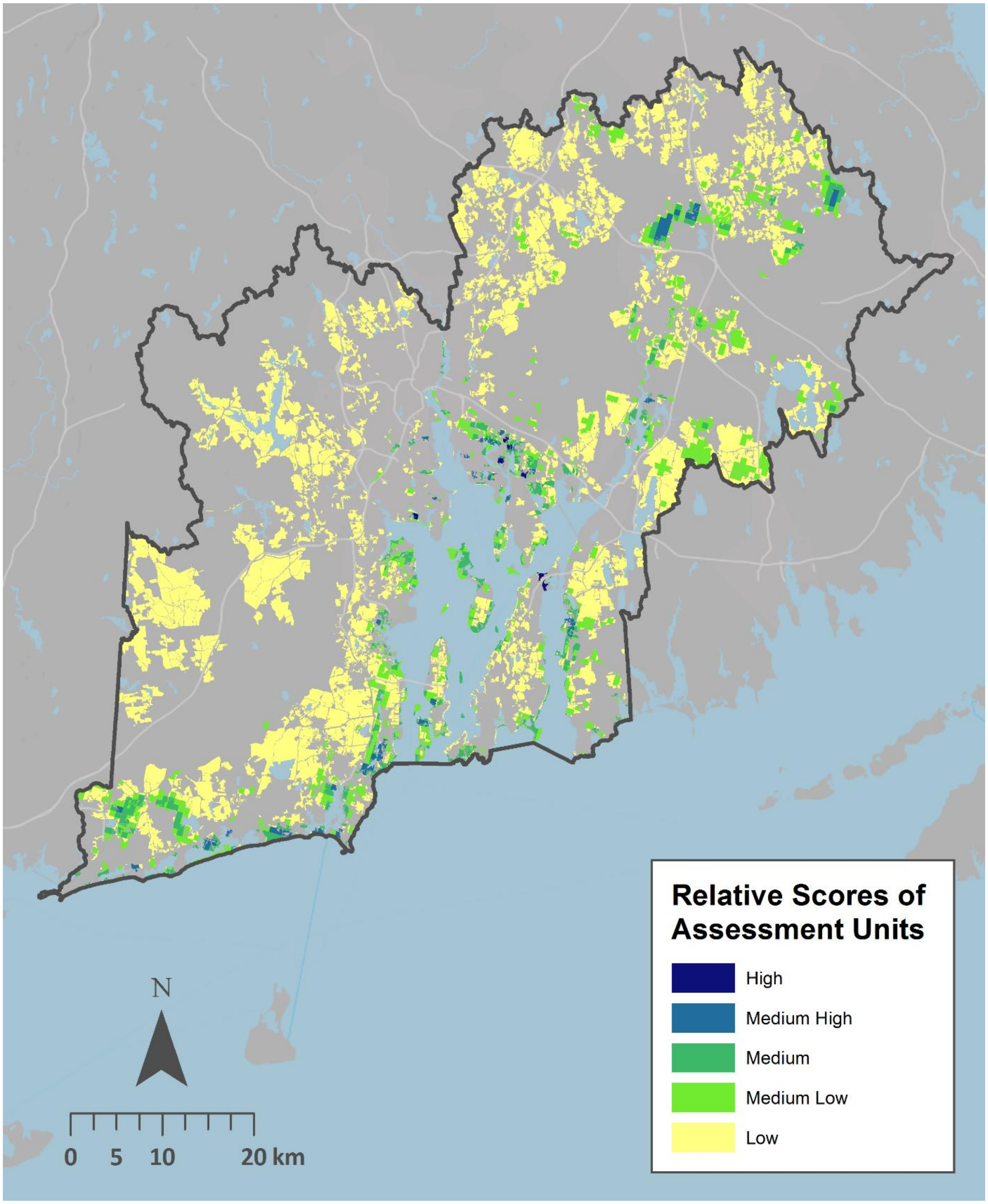


Figure 16. Resilience Hubs assessment unit relative scores for the Narragansett Bay and Coastal Rhode Island Watersheds. *Assessment units are 100-acre grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieve both community resilience and fish and wildlife benefits.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

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.

Ninigret National Wildlife Refuge Resilience Hub Area Example

This hub area includes the wildlife refuge (former Charlestown Naval Auxiliary Field), East Beach, and east side of Tautog Cove, which together have the potential to add resilience to the Charlestown area. This area scores high because of the juxtaposition of natural and open space areas with vulnerable human populations and key transportation routes. It is subject to all of the mapped flooding threats including storm surge over nine-feet in depth. Resilience projects in this hub area can benefit both human assets and fish and wildlife (**Figure 17**). This area is also likely to retain at least a portion of these benefits under three feet of sea level rise because it was modeled to be a site for marsh migration. This hub area's current fish and wildlife condition is moderate so could benefit from additional restoration projects and protection through land acquisition or easement acquisition of some privately owned open spaces.

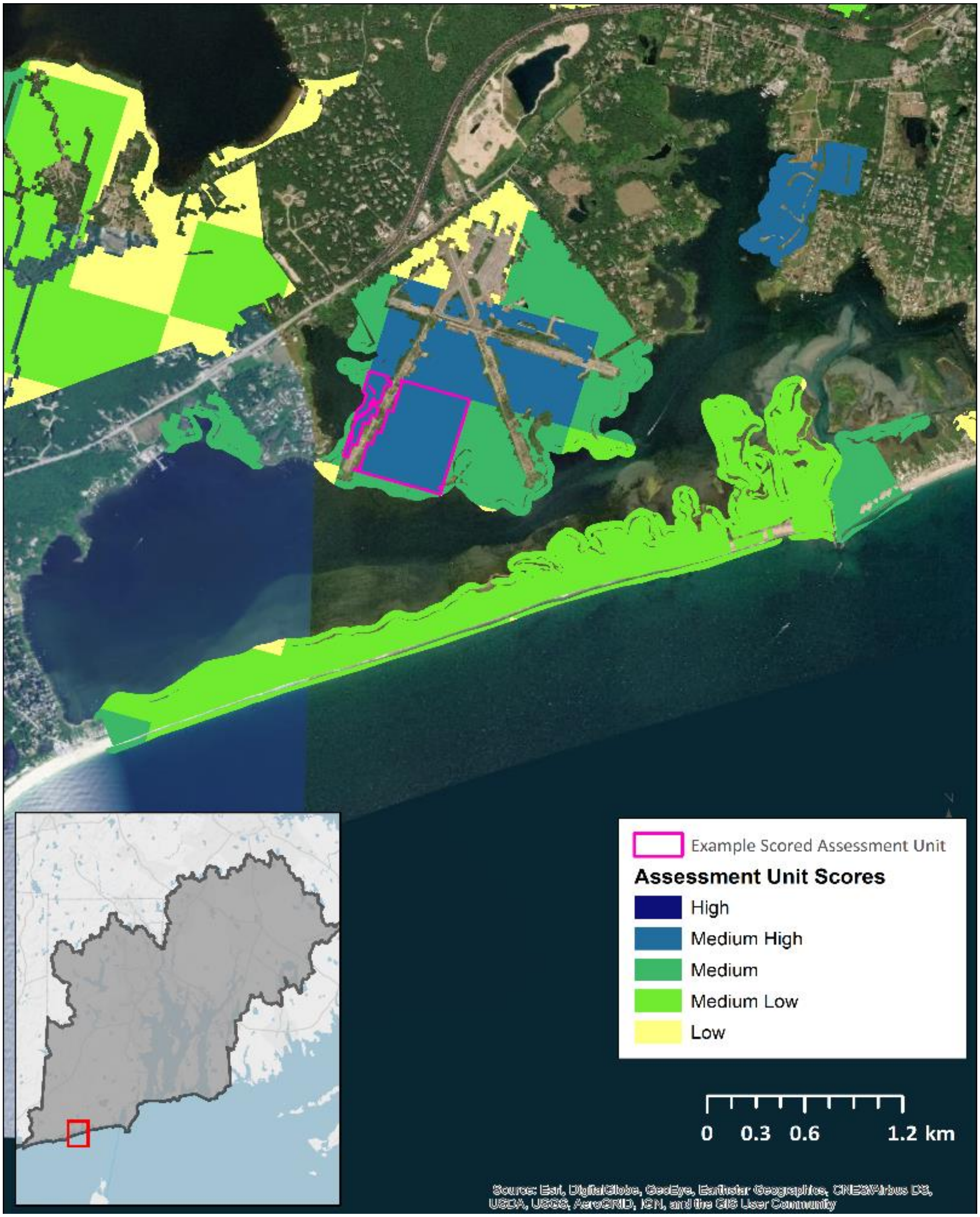


Figure 17. Ninigret National Wildlife Refuge Resilience Hub area example. *The yellow-blue shaded areas are the scored Resilience Hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Shrubland Nesting Bird Habitat
- Species of Greatest Conservation Concern
- Freshwater Meadows – Sedge Marshes – Forest – Shrub
- Freshwater Herbaceous and Shrubby Wetlands
- Coastal Salt Ponds
- Salt Marsh and Tidal Creek
- Winter Flounder
- Important Bird Area
- Diamondback Terrapin
- Diadromous Fish

HCA elements in or near assessment unit:

- Population Density Ranks 1 & 2
- Critical Facilities
- Critical Infrastructure Ranks 1 and 2 (U.S. Hwy 1, E Beach Rd)

Table 3. Attributes used to calculate the final score for the Ninigret National Wildlife Refuge 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 23 possible)	10
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with mean of 0.03 and standard deviation of 0.07)	0.44 (high)
Restorability index	1 (good candidate for restoration)
Average Condition (1= current very high condition)	0.59 (moderate)
Final score	**3.83 (rank #8 out of 8,533 units)**

Portsmouth/Island Park Cove Resilience Hub Area Example

This area contains the number one ranked hub assessment unit in the watershed due to very high HCA vulnerability, capability for future marsh under sea level rise, moderately high fish and wildlife value, and high restorability. The area around Island Park Cove includes the densely developed neighborhood of Island Park and contains high recreational value and assets including areas used for fishing and shellfish as well as developed recreation. The hub areas also bracket the intersection of key transportation routes including highways 114, 24, and 138 (**Figure 18**). This area is subject to several flooding threats including poorly drained soils, 500-year floodplain, storm surge over nine-feet in depth, and sea level rise. Resilience projects in this hub have the potential to benefit both human assets and fish and wildlife. There is high potential for restoring this area and modeled future marsh under three-feet of sea level rise indicate that it could support fish and wildlife benefits into the future. The northern unit has been restored (fill removal by USACE in late 2000s), but the southern area has little room for marsh migration due to fill for roads abutting it to the north and west.

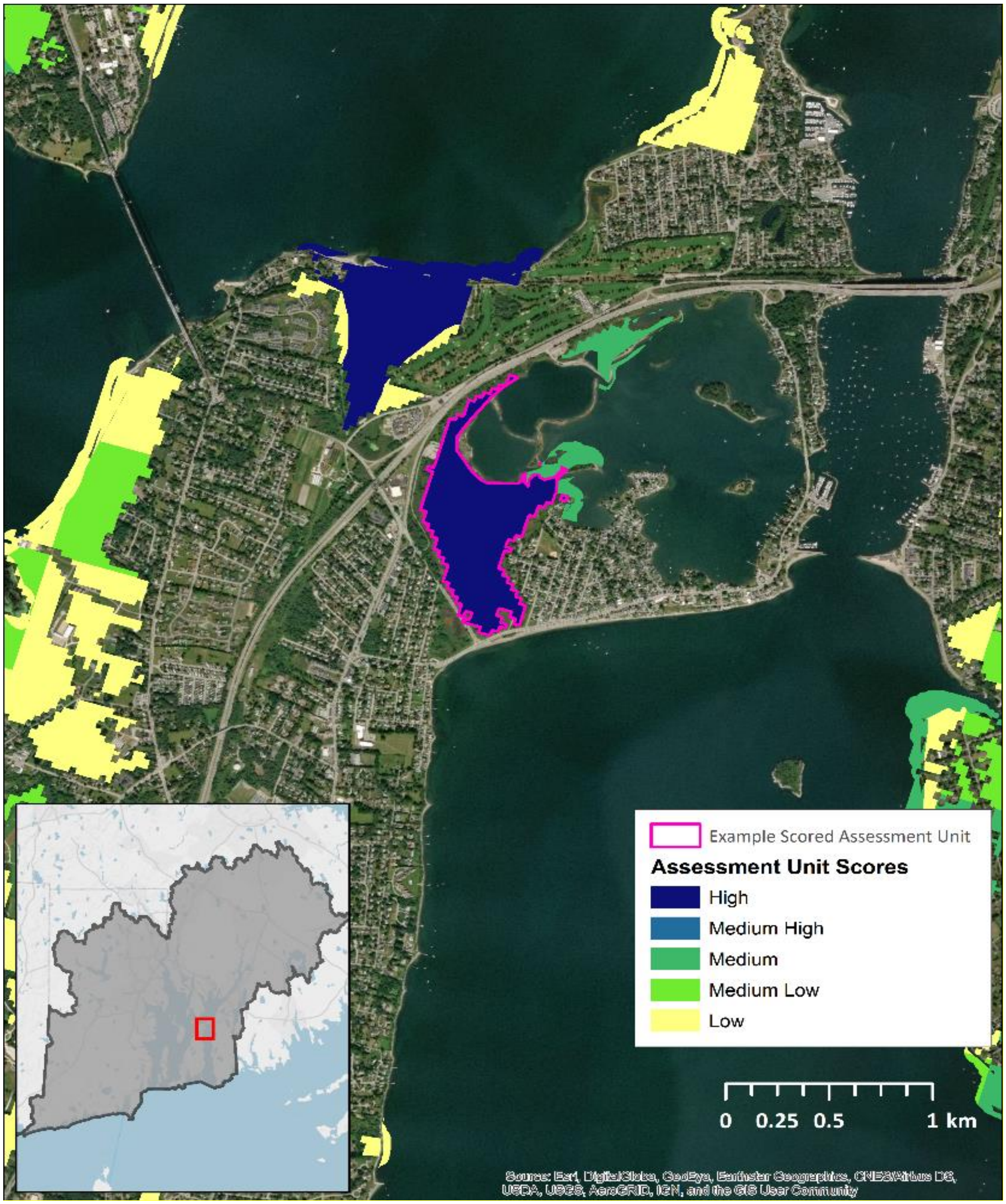


Figure 18. Portsmouth/Island Park Cove Restoration Hub area example. *The yellow-blue shaded areas are the scored Resilience Hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements mapped in this assessment unit:

- Diadromous Fish (freshwater spawning habitat not present)
- Shrubland Nesting Bird Habitat
- Freshwater Herbaceous and Shrubby Wetlands
- Freshwater Meadows – Sedge Marshes – Forest – Shrub
- Coastal Forest
- Shellfish Collection Areas
- Oyster Reefs
- Recreational Fishing Areas
- Salt Marsh and Tidal Creek
- Diamondback Terrapin (not known to nest in this area)
- Winter Flounder

HCA elements in or near assessment unit:

- Population Density Areas Ranks 1-5
- Critical Infrastructure Ranks 1 and 2
- Critical Facilities (Howard W Hathaway Elementary)

Table 4. Attributes used to calculate the final score for the Portsmouth/Island Park Cove Restoration Hub assessment unit example. *These 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 23 possible)	11
Presence of marsh under 3ft SLR	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with mean of 0.03 and standard deviation of 0.07)	0.8 (very high)
Restorability index	1 (highly restorable)
Average Condition	0.4 (moderate)
Final score	**4.8 (rank #1 out of 8,533 units)**

Kickemuit River Resilience Hub Area Example

This area represents a location within an urbanized context that, while having low habitat condition and restorability, retains moderate fish and wildlife value and very high HCA vulnerability. Therefore, it ranks as the fifth highest scoring hub assessment unit in the watershed. It is comprised of wetland and agriculture areas in the narrowest point of the Bristol peninsula between Belcher Cove and Warren Reservoir. These water bodies represent flooding sources for this area and the area is within the 500-year floodplain and subject to storm surge over nine-feet. Flooding threats can originate upstream from the Kickemuit River watershed and storm surge and sea level rise from the coves. Both the upper and lower reservoir dams are identified as “significant hazards” (Department of Environmental Management 2014) and the upper dam was being studied for removal (Department of Environmental Management 2016) and is the subject of a proposed resilience project (see Case Study 2). Rhode Island key transportation routes in and around this area include Routes 103, 136, and Schoolhouse Road. Although the area is not densely populated, there are suburban areas around the hub and the Bristol County Water Authority (treatment plant). Some areas along Belcher Cove are expected to be inundated by one-foot of sea level rise and the low-lying farm area is modeled to support future marsh under a three-foot sea level rise scenario. Marsh migration into this area would increase its value for fish and wildlife well into the future while possibly moderating storm surge impacts to adjacent areas. While no resilience project plans were identified for this area, it is directly downstream of the Upper Kickemuit Dam removal project and Schoolhouse Road elevation project as well as upstream of future potential project to remove the lower Kickemuit dam. Dam removal (similar to the Canada Dam removal described later), would be consistent with the DEM 2016 study above.

Given that this area is unprotected, land acquisition and/or the establishment of one or more easements would likely be effective actions for increasing resilience. While the restorability score was low owing to the developed context, the open spaces could be actively restored to marsh or left to restore on their own as sea level rises.

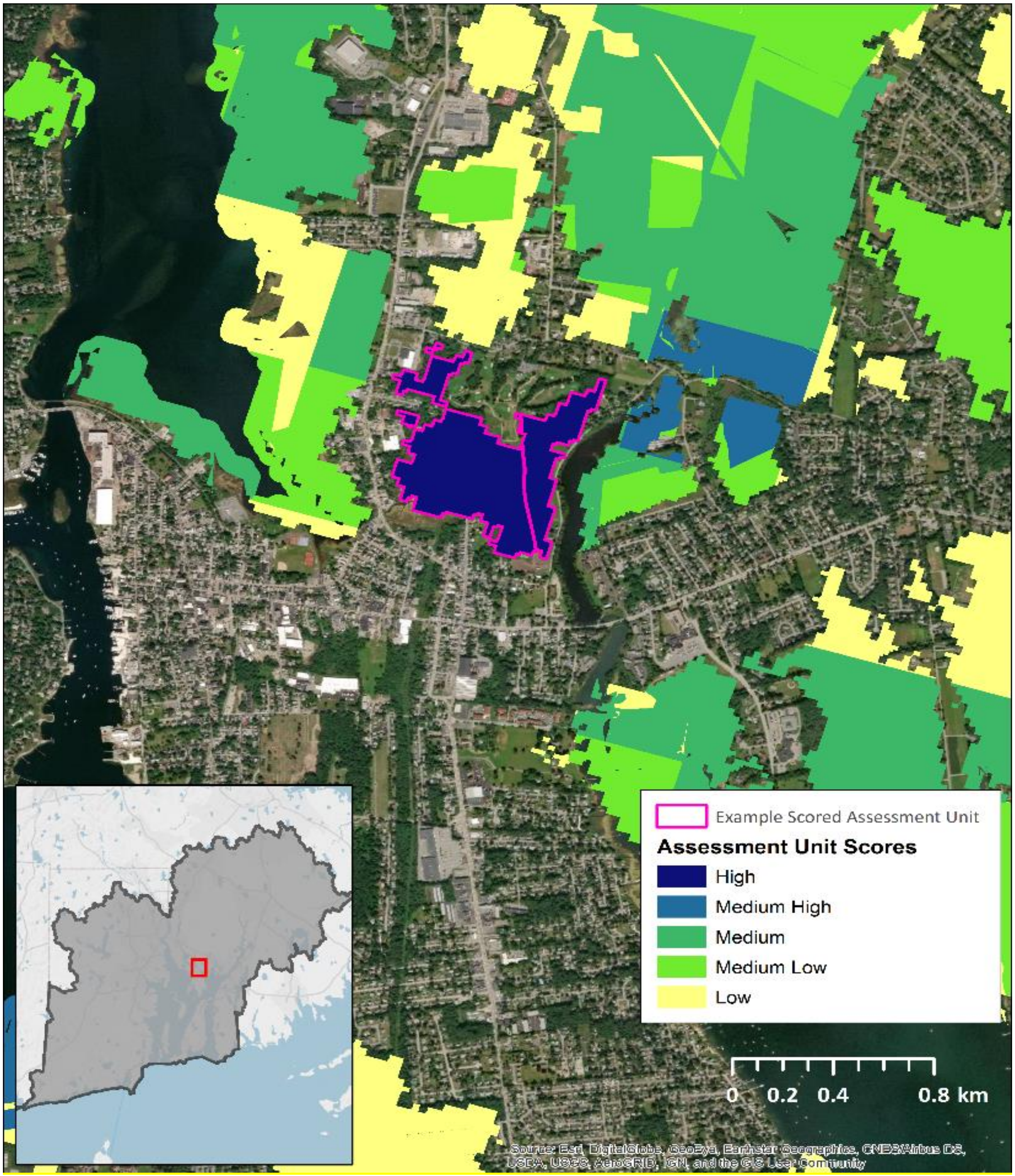


Figure 19. Assessment units in and around the Kickemuit River Resilience Hub example area. T*he yellow-blue shaded areas are the scored Resilience Hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Diadromous Fish
- Shrubland Nesting Bird Habitat
- Freshwater Herbaceous and Shrubby Wetlands
- Freshwater Meadows – Sedge Marshes – Forest – Shrub
- Coastal Forest
- Salt Marsh and Tidal Creek (not known to occur on this site)
- Diamondback Terrapin (not known to occur on this site)
- Winter Flounder (not known to occur on this site)[11]

HCA elements in or near assessment unit:

- Critical Infrastructure Ranks 1, 2, 3
- Critical Facilities
- Pop Dens Ranks 1, 2, 3, 4, 5

Table 5. Attributes used to calculate the final score for the Kickemuit 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 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 23 possible)	8
Presence of marsh under 3ft SLR	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1 with mean of 0.03 and standard deviation of 0.07)	1.0 (very high)
Restorability index	0 (low restorability)
Average Condition	0.29 (low)
Final score	**4 (Rank # 5 out of 8,533 units)**

[11] It has been noted that there is a dam blocking the tidal exchange downstream of this area at Ruta de Rhode Island 103— (where it looks like the pond starts on the map). That is a dam that has fish passage for diadromous fish, but not for flat fish like the Winter Flounder or other turtles. There are no marine habitats upstream (i.e., Salt Marsh and Tidal Creek). This is a ground-truthing “problem” and reflects the state of the data used for element distributions.

Fish and Wildlife Elements

The final list of elements explicitly represented in the Narragansett Bay and Coastal Rhode Island 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 Narraganset Bay and Coastal Rhode Island Watersheds assessment.

Fish/Wildlife Element	*Description/Significance*
NOAA Trust Resources	
Diadromous fish habitat	Represents key diadromous fish species in the watershed, including alewife, American and hickory shad, sturgeon (shortnose and Atlantic), striped bass, American eel, and blueback herring.
Salt marsh and tidal creek (including open water)	These habitats are an extremely important nursery area for fish species (including most NOAA trust species). Species that utilize this habitat as important nursery area include winter flounder, blue crab, bluefish, black sea bass). Many SGCN bird species are dependent on salt marsh habitat, including Nelson's sparrow, saltmarsh sparrow, seaside sparrow, American black duck, clapper rail, and willet.
Harbor seal haulout sites	Areas heavily utilized by seals when hauling out from the ocean.
Potential oyster reefs	Important because they were a historical feature of this region.
Recreational fishing areas	These areas are particularly important for recreational fishermen, serving as an important resource to many stakeholders in the region.
Atlantic cod habitat area of particular concern	Those waters and substrate particularly important for juvenile inshore Atlantic cod life history stage. feeding or growth to maturity. Atlantic cod are a NOAA managed species.
Summer flounder habitat area of particular concern	Those waters and substrate particularly important for juvenile and adult summer flounder life history phases. Summer flounder are a NOAA managed species.
Winter flounder essential fish habitat	Those waters and substrate necessary for winter flounder for spawning, breeding, feeding or growth to maturity. Winter flounder are a NOAA managed species.
Sandbar and sand tiger shark essential fish habitat	Those waters and substrate necessary to the sandbar and sand tiger shark species for spawning, breeding, feeding or growth to maturity.

Fish/Wildlife Element	*Description/Significance*
At-Risk Species and Multi-species Aggregations	
Atlantic beach and dune habitat	Includes open sandy coastal expanses that provide stopover and breeding habitat for high priority wildlife species.
Northern diamondback terrapin	This species' habitat includes portions of coastal estuaries, tidal rivers, salt marshes, and sandy beaches.
Brook trout	Although the main element is brook trout, this layer represents cool/cold-freshwater habitat in general for the study area.
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Submerged aquatic vegetation (SAV)	Represents habitat (for at least one life stage) for key fish and mollusk species.
Coastal salt ponds	Identified by stakeholders as important habitat for recreational fish, shellfish, and birds.
Freshwater herbaceous and shrubby wetlands	Covers freshwater wetland types that provide habitat for important species including sedge wrens and other species that are dependent on high-quality non-forested wetland habitats. This element also includes sea level fens and vernal pools. Sea level fens are important due to their rarity and high level of exposure to the effects of sea level rise, while vernal pools include habitat for rare/declining salamanders and invertebrates.
Grassland bird habitat	Grassland habitat supporting Savannah sparrow, horned lark, and Eastern meadowlark are three key grassland bird species found within the project footprint. Other grassland dependent species include barn owl, bobolink, Northern flicker, Northern harrier, short-eared owl, and grasshopper sparrow.
Shrubland-nesting bird habitat	Represents habitat for many declining bird species. Shrubland birds that are also SGCN include Eastern whip-poor-will, ruffed grouse, yellow-billed cuckoo, black-billed cuckoo, gray catbird, willow flycatcher, yellow-breasted chat, Nashville warbler, indigo bunting, Eastern towhee, American woodcock, prairie warbler, chestnut-sided warbler, field sparrow, brown thrasher, Eastern kingbird, and blue-winged warbler. Coastal shrubland dependent birds include blackpoll warbler and tree swallow.
Coastal forest (maritime forest)	Community types that harbor unique forests found in or near coastal areas of Rhode Island and Massachusetts. These forests are important for coastal resilience since they can help stabilize soils in the face of extreme storm events.
Wading bird and ally colonies	Areas utilized by wading birds (herons, etc.) as colonies. Significant because the nesting requirements of some species are fairly rigorous and changes may threaten current colonies, forcing them into substandard habitat in the future.

Fish/Wildlife Element	*Description/Significance*
Fish or Wildlife-related Areas of Key Economic, Cultural, Recreational Significance	
Shellfish collection areas (e.g., quahog)	Shellfish collection areas are near-shore areas that are traditional areas for both commercial and recreational collection of shellfish (especially digging of quahogs and other shellfish).
Cross-cutting Elements	
Continental and global important bird areas	Geographies of key importance for bird species.
Species of greatest conservation need	Areas with high levels of biodiversity, rare species, and/or imperiled species, and that are necessary for the persistence of these species.

Resilience Projects Portfolio

A portfolio of resilience projects within the Narragansett Bay and Coastal Rhode Island Watersheds was compiled from plans and other project documents submitted by stakeholders (**Table 7**). A total of 34 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. Government agencies and non-profits have already addressed some of the most pressing and logical resilience projects (such as removal of publicly owned failing dams), which leaves the region with a suite of more complex resilience projects. In particular, the region would benefit from project that address failing dams that are currently on private lands or that have multiple owners.
2. Project leaders recognize the need to engage neighbors and community stakeholders upfront in the planning and decision-making process for projects that directly affect their areas of interest. This will help ensure there is initial and ongoing support for long-term projects, which is especially important with dam removal projects that may change upstream habitat from ponds to streams, changing future recreational opportunities as a result.
3. Most of the key projects in the watershed are in the early planning stages, and resources provided to help with planning and preparing for action when resources become available could be very important in building future resilience.

Table 7. Summary of resilience-related projects identified for the Narragansett Bay and Coastal Rhode Island 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
Beach or dune restoration	1				1
Community resilience planning	1			3	4
Dam removal/aquatic connectivity	12		2		14
Living Shoreline/Shellfish reef addition	2				2
Green infrastructure	2		3		5
Marsh/wetland restoration	6		1		7
Eelgrass restoration		1			1
Totals	**24**	**1**	**6**	**3**	**34**

As can be seen in **Figure 20**, the submitted resilience projects are geographically dispersed throughout much of the watershed, with key inland projects related to dam removal/modification, and coastal projects that address a wider range of issues from sea level rise and storm surge to habitat improvement. Projects were submitted by a wide range of stakeholders—from local NGOs to town government representatives to federal and state agency representatives. Locally-based NGOs submitted five projects and local municipalities submitted 11 project ideas, demonstrating that the stakeholder engagement process was effective in attracting project ideas from local stakeholders. There were eight submissions from federal agencies and nine from state agencies and university partners. In addition, there was one project submitted from a private university. Project sizes varied greatly, ranging from large-scale planning projects that covered entire watersheds to small dam removal projects with limited project footprints but wider potential positive impacts throughout the watershed.

Fourteen submitted projects have a dam removal and/or aquatic connectivity component. This theme continued to emerge during interviews and site visits since many municipalities and local communities are considering the potential effects of a catastrophic, hazardous dam failure and/or upstream flooding caused by defunct and poorly maintained dams. Six marsh/wetland restoration projects were submitted, highlighting the need to restore and/or build resiliency of the existing tidal and freshwater marshes in the region. A full list of these submitted projects and summary information about each is in Appendix 6.

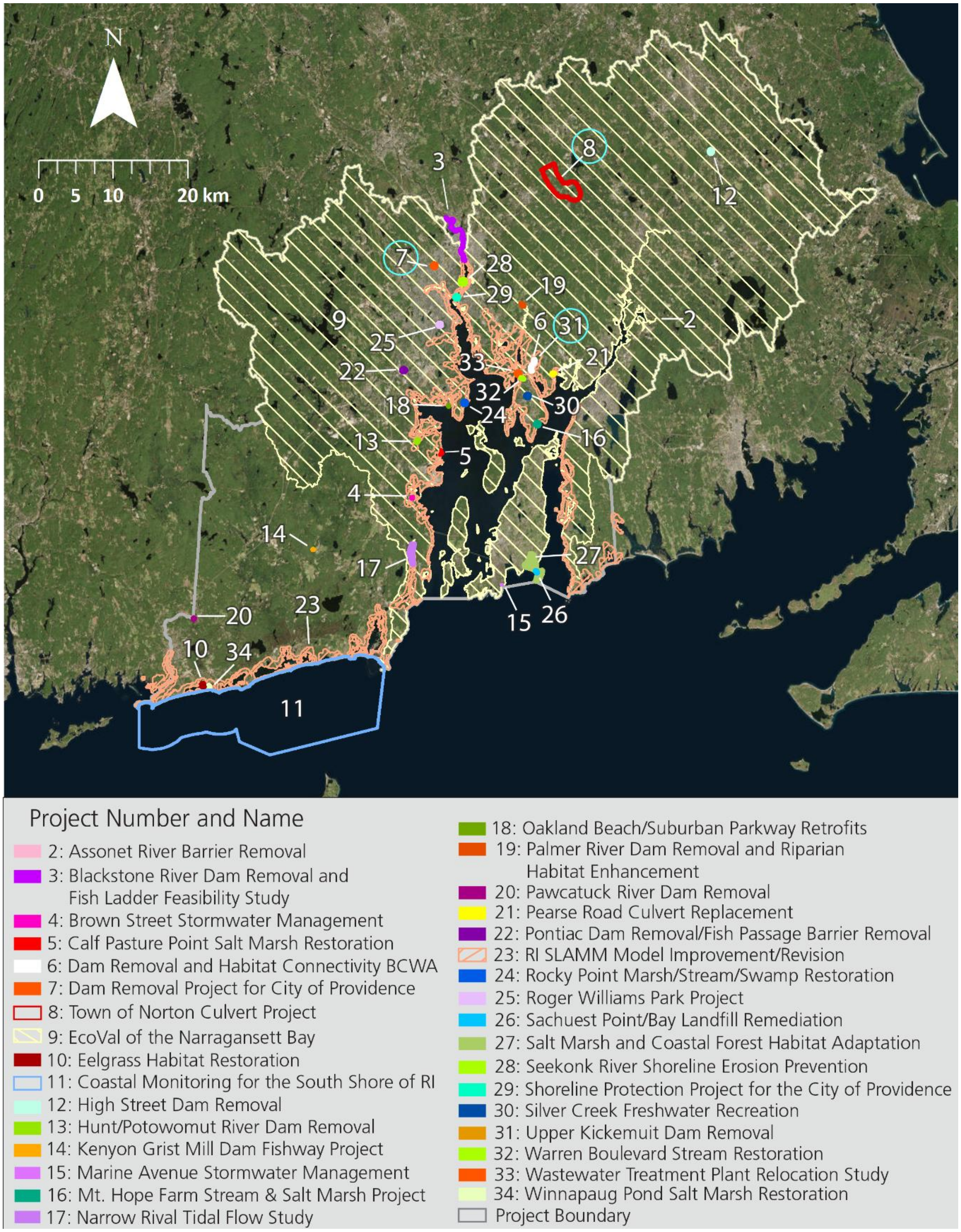


Figure 20. Map showing the boundaries of resilience projects compiled for the Narragansett Bay and Coastal Rhode Island Watersheds. *Detailed case studies were developed for projects #7, #8, and #31. Project #1 is not pictured on the map because no spatial data was submitted. See Appendix 6, Table A6-1 for a full list of projects.*

Suggested Uses

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

Case Studies

The three case studies that follow illustrate how proposed resilience projects may benefit fish and wildlife habitat and human communities faced with coastal resilience challenges such as storm surge and heavy precipitation during extreme weather events. The case studies described in the Narragansett Bay and Coastal Rhode Island Watersheds share some interesting traits with one another:

- All case studies involve building resilience along river corridors, which have been historically impacted by dams and/or culverts that have altered flow and potentially exacerbated potential flooding of key human assets.
- Each of the projects has the potential to reduce flooding and/or sea level rise affects to adjacent human assets such as homes, schools, hospitals, and places of business.
- Each project has an outreach component to involve interested individuals in the community in planning and/or implementation process, potentially leading to greater long-term success through ongoing community support and excitement about future projects.
- All projects have potential benefits to anadromous fish populations.

The three case studies are good examples of the importance of water quality and the health of rivers in the watershed and show how improvements upstream can potentially benefit both human assets and fish and wildlife populations upstream and downstream throughout the entire study area.

Case Study 1: Canada Pond Dam

Figure CS1-1. Photo of Canada Pond Dam showing cracks and other signs of age.

Project Overview

Location: Providence, RI

Date Visited: March 27, 2018

Contact: Wendy Nilsson, Providence Parks and Recreation

Canada Pond Dam has been classified by the Rhode Island Department of Environmental Management as a small-size significant hazard dam, meaning that its failure would cause major economic loss or disturbance to key facilities downstream. The City of Providence has completed a feasibility study that confirmed: 1) the dam is in fair to poor condition but is deteriorating, and 2) complete or partial removal of the dam would be a lower cost option than repairing the existing dam. Partial or complete removal of the dam is the preferred option, and would potentially improve fish passage, restore wetland habitat, improve water quality, and help filter pollutants. Project leaders will evaluate partial versus full dam removal scenarios before completing engineering studies and commence implementation if/when funding for the project can be secured.

More specifically, the project will:

- Continue to meet with neighbors and stakeholders to build public support for the project and address concerns.
- Develop engineering design plans for either a partial or complete dam removal.
- Conduct physical removal of a portion or all of dam and restoration of upland and wetland habitat in impacted areas.

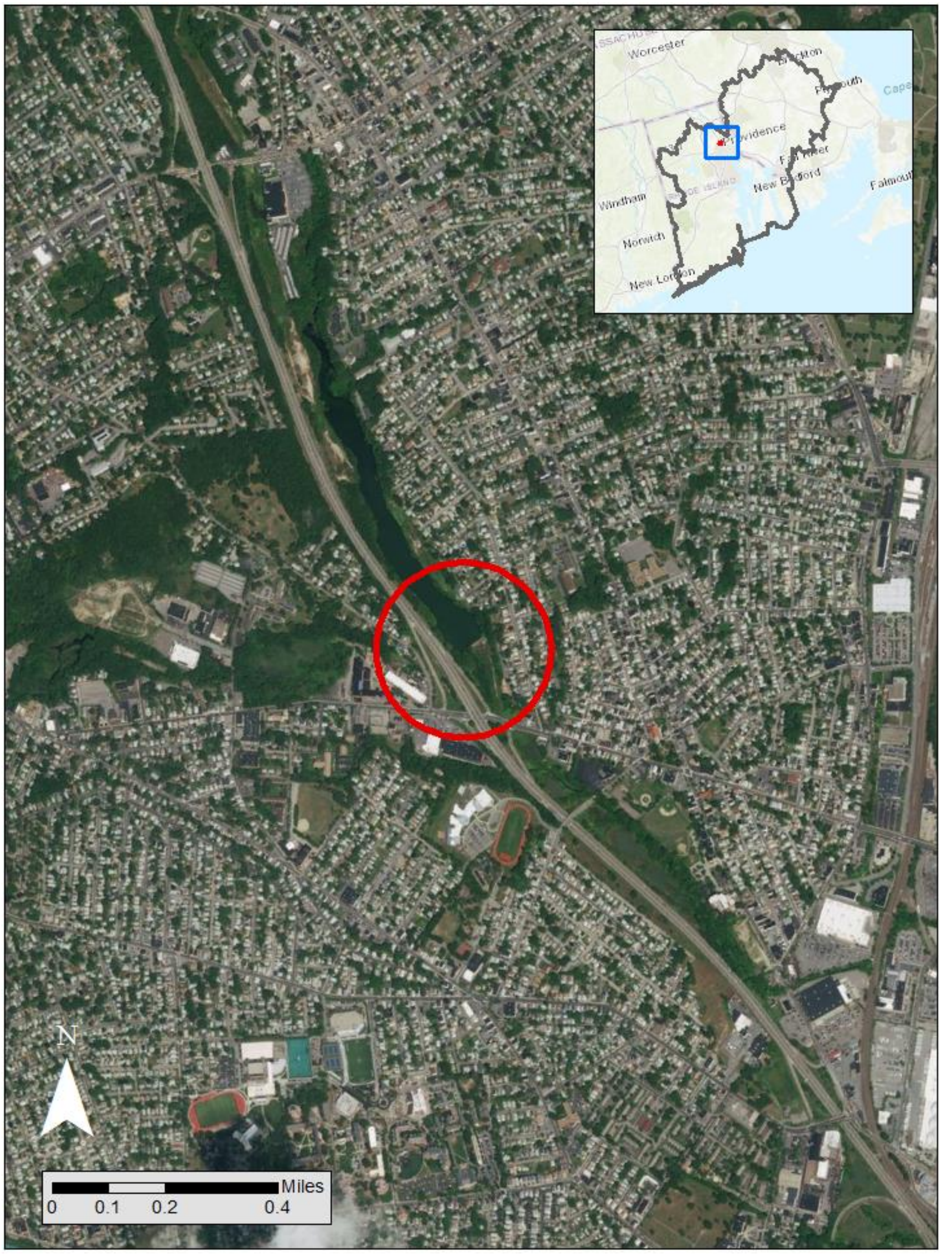


Figure CS1-2. Approximate project area (red boundary). *The north and south sections of the area are bisected by a road that is not considered part of the project area. Adjacent areas of human development are evident in the imagery.*

Estimated Cost of the Project

The estimated cost of the project is $3.0 million for complete removal of the dam, or $2.3 million for partial removal. For more detailed numbers, please contact the project sponsor, Providence Parks and Recreation.

Stressors and Threats

This site contains a high concentration of existing and future threats to human communities and fish and wildlife habitat condition. Existing stressors to fish and wildlife habitats include roads that bisect important habitat and developed areas such as high/medium density housing (see Table CS1-1). In addition, both human communities and fish and wildlife habitat downstream from the dam itself are vulnerable to future threats related to potential floods combined with the potential for dam failure due to its current age and condition (see Figure CS1-3).

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

Existing Stressors
Local neighborhood and connecting roads, bridges/culverts
Secondary roads
Water quality - low
Developed Open Spaces
High/Medium Density Housing
Low Density Housing
Dams & Reservoirs
Flooding Threats
Floodway

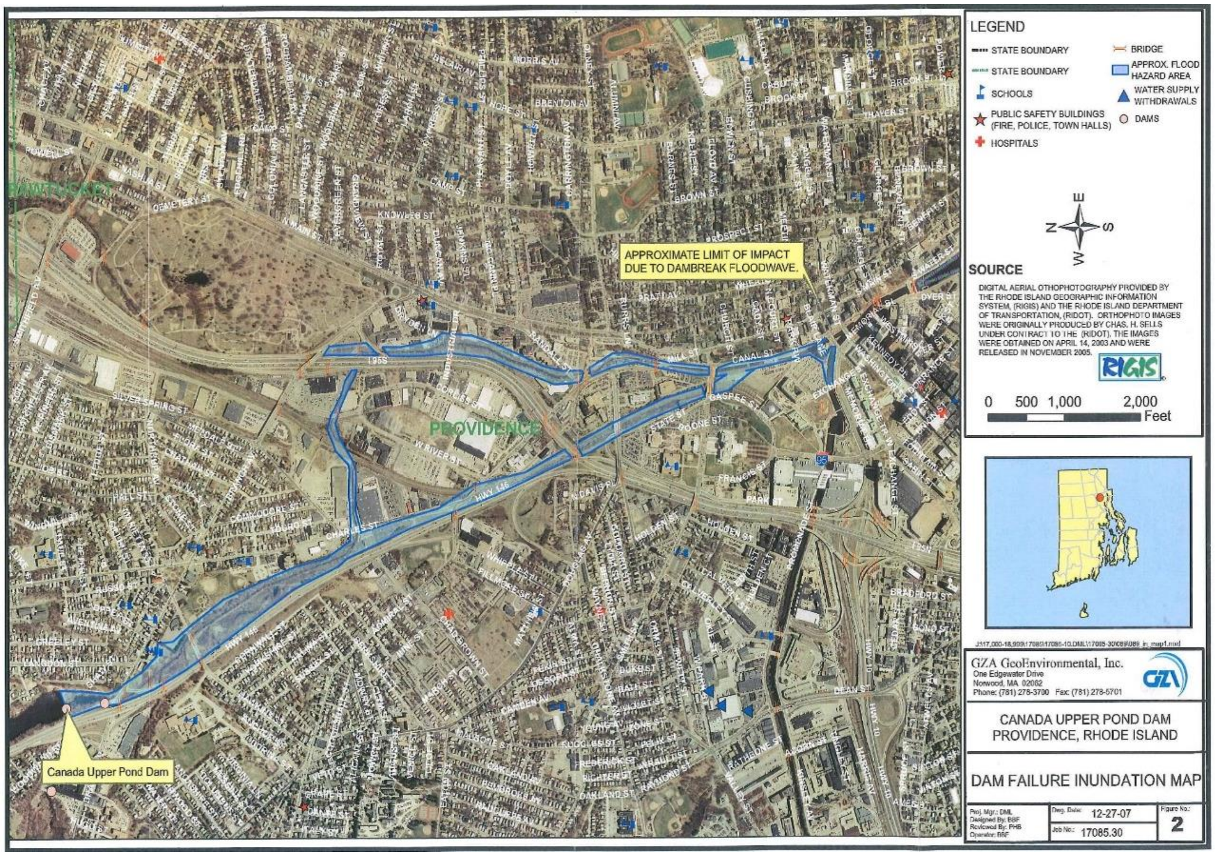


Figure CS1-3. Map of area where flooding would occur should the dam fail. *Map produced by GZA GeoEnvironmental, Inc. for the City of Providence, RI as part of the Canada Pond Dam removal feasibility study.*

Human Community Assets

This site and surrounding areas contain a high concentration of important human *assets, including high population density and critical infrastructure and facilities such as key roads (e.g., the highway interchange just downstream of the dam, Table CS1-2).* ***Error! Reference source not found.*** *below s hows (in pink) areas where there are high concentrations of HCAs.*

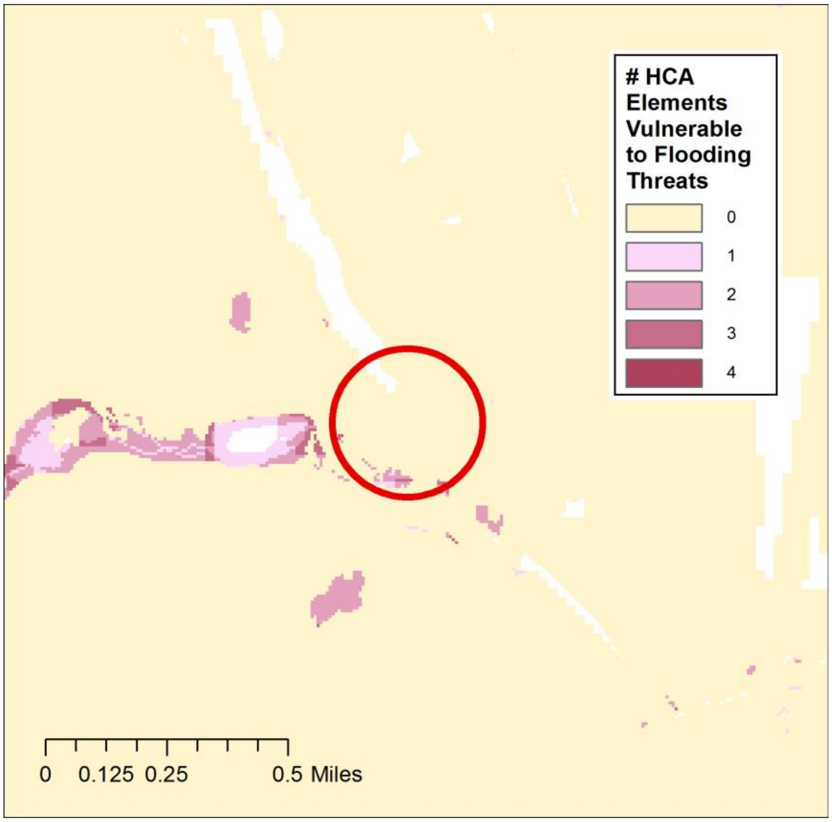


Figure CS1-4. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements) within and around the Canada Pond Dam project. Tan color indicates areas with HCAs that are not categorized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

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

Categories of Human Assets Identified within Project Boundary
Densely populated areas Critical infrastructure
Mapped Community/Human Assets within Project Boundary
Critical facilities Wanskuck Early Years Learning Center Dams (3)

Fish and Wildlife

This site contains important habitat (and/or potential habitat) for priority fish and wildlife species, including many species highly valued by regional stakeholders (**Table CS1-3**). The identified elements support (or could potentially support) a variety of fish and wildlife species and important ecosystems including freshwater meadows and marshes and vernal pools/fens. In addition, improvements in water quality from wetland restoration could benefit additional species within the bay (such as migratory fish species).

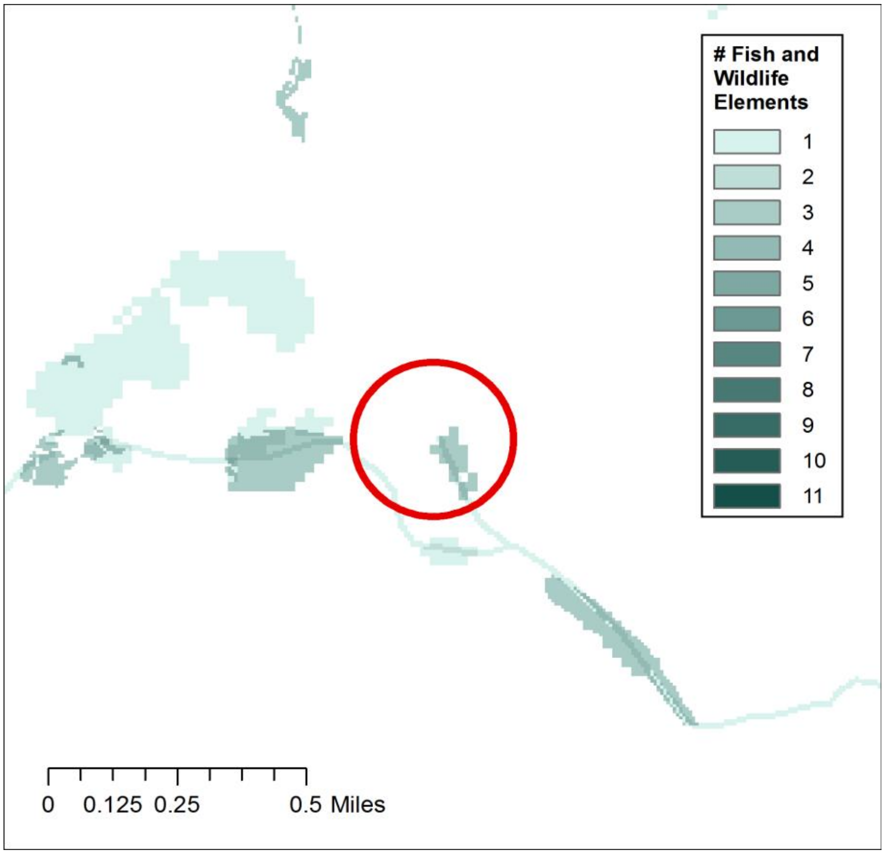


Figure CS1-5. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements richness (darker green signifies a higher number of elements co-occurring in the same place). Red outline is the project boundary.*

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 **
Freshwater meadow marsh	Mink, muskrat, seaside sparrow
General fens vernal pools	Spotted salamander, wood frog (not likely in this urban habitat, but in theory could be restored if appropriate adjacent habitat existed)
Species greatest conservation need	Various species from the Rhode Island State Wildlife Action Plan

**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.*

Expected Project Impact

If implemented, the removal or modification of the dam and subsequent restoration of adjacent habitat and hydrology will have immediate positive impacts to both human communities and fish/wildlife habitat. Based on the proponent's analysis, the project could reduce potential for catastrophic flooding downstream due to the potential for large-scale failures of existing dam structure, increase water quality of aquatic areas, thereby potentially increasing opportunities for recreation and fishing, improve habitat for commercially important species downstream, and potentially encourage passive recreation use (such as hiking and walking). In addition to these human benefits, the fish/wildlife benefits include potential future river herring access to spawning and rearing habitats, improved marsh/wet meadow habitat along stream, and improvements in water quality downstream for fisheries.

Case Study 2: Upper Kickemuit River Restoration Project (Warren, RI)

Figure CS2-1. Earthen dam and impoundment of the Kickemuit River.

Project Overview

Location: Warren, RI

Date Visited: March 26, 2018

Contact: Ken Booth, Bristol County Water Authority and Wenley Ferguson, Save the Bay

Two Kickemuit River impoundments currently serve as an emergency back-up source of drinking water for the Bristol County Water Authority's customers. However, these back-up water supplies are threatened by saltwater intrusion due to a combination of their low elevation and future sea level rise scenarios. To address this, the Bristol County Water Authority (BCWA) is working on securing other back-up water supplies that are more secure in the face of these coastal threats. At the same time, BCWA and other local partners recognize the potential benefit of restoring the free flow of the river once the back-up supply is secured and online. This restoration effort, including the partial or full removal of key dams/berms, will: 1) enhance habitat and access for key diadromous fish species, and 2) provide potential areas for future marsh migration in currently impounded areas. At the same time, restoring the river will reduce flood risk to a key emergency evacuation route in the Upper Kickemuit area. Project leaders plan to improve hydraulic function of the system by removing impoundments and restoring riparian habitat to allow for a dual human and fish and wildlife benefits.

More specifically, the project will:

- Finalize engineering designs for the removal of the Upper Kickemuit River dam and complete engineering assessment and plans to address undersized culverts under Schoolhouse Road located directly downstream of the Upper Kickemuit dam.
- Continue to build on high level of public support for project by keeping the community up to date on the project and educating them about the positive impact.
- Remove an Upper Kickemuit River dam, elevate Schoolhouse Road with properly designed culvert to effectively pass both flood flows and migratory fishes, and restore habitat in former impoundment area.

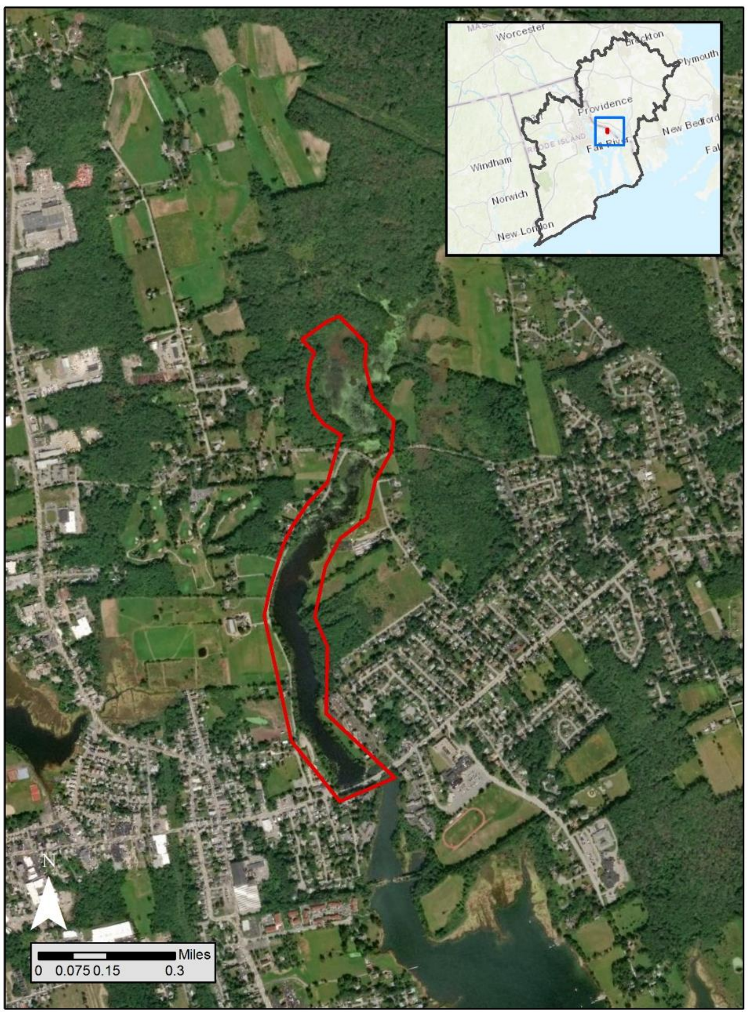


Figure CS2-2. Approximate project area (red boundary). *Area includes the Kickemuit River dam removal and road improvement project site.*

Estimated Cost of the Project

The project is estimated to cost approximately $750,000 to remove the dam/earthen berm and restore impacted areas. For more detailed numbers, please contact the project sponsor, BCWA.

Stressors and Threats

This site contains a high concentration of existing and future threats to human communities and fish and wildlife habitat condition. Existing stressors to fish and wildlife habitats include roads that bisect important habitat and developed areas such as high/medium density housing (see **Table 1**). The road just below the dam (Schoolhouse Road) has flooded repeatedly in the recent times. In addition, both human communities and fish and wildlife habitat are vulnerable to future threats related to potential floods that could increase in frequency due to more severe storm events.

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

Existing Threats
Local Neighborhood and Connective Roads, bridges/culverts
Secondary Roads
Water Quality - Low
Developed Open Spaces
High/Medium Density Housing
Low Density Housing (Rural Residential)
Ruderal (maintained pasture, old field)
Flooding Threats
500-Year Floodplain

Human Community Assets

This site and surrounding areas contain a high concentration of important human assets, including high population density and critical infrastructure and facilities such as key roads. **Figure CS2-3** below shows (in pink) areas where there are high concentrations of human community assets that are also highly threatened by the stressors listed above. Highly important human community assets that exist within the project area include a key storm evacuation route, schools, fire and police departments, and BCWA administrative and operations centers (see **Table CS2-2**). These assets may potentially benefit from a resilience project that reduces flooding risk.

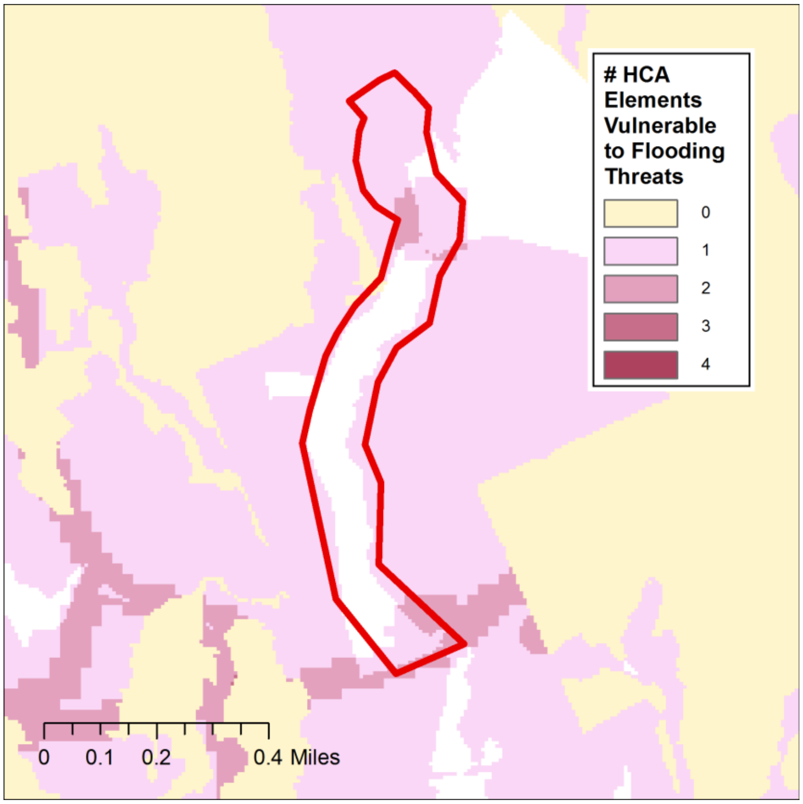


Figure CS2-3. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements) within and around the Kickemuit River project. Tan color indicates areas with HCAs that are not categorized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

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

Categories of Human Assets Identified within Project Boundary
Densely populated areas
Critical infrastructure
Critical Facilities
Evacuation Routes/Highways
Hazardous Sites
Primary Roads
Dams
Mapped Community/Human Assets within Project Boundary
Kickemuit Middle School
Hugh Cole School
Warren Fire Department
Swansea Police Department
Swansea Fire Department Station 4
Bristol County Water Authority Facilities

Fish and Wildlife

This site contains important habitat (and/or potential habitat) for priority fish and wildlife species, including many species highly valued by regional stakeholders. The identified habitats support a wide variety of fish and wildlife species including river herring and American eel. There is future potential habitat for eastern brook trout since it would have occurred historically in this watershed. In addition, benefits of restoration could include better water quality in the tidal estuary and bay downstream, benefiting species like bay scallop and striped bass. Restoration work on the site itself has the potential to positively benefit species beyond the specific boundary of the project by restoring stream flows and improving the water quality.

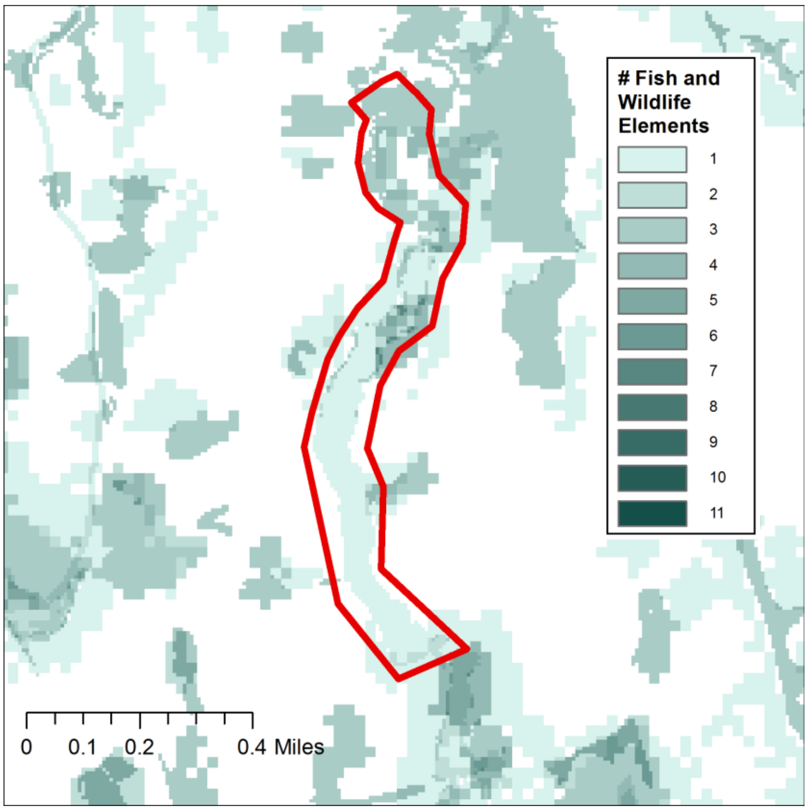


Figure CS2-4.Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements combined (darker green signifies more elements/value). Red outline is the project boundary.*

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 **
Atlantic herring habitat	Alewife, blueback herring, American eel, striped bass, white perch
Brook trout habitat	Brook trout
Coastal forest	Red fox, Eastern cottontail rabbit
Diadromous fish habitat	Alewife, blueback herring
Diamondback terrapin habitat	Diamondback terrapin
Freshwater meadow marsh	Mink, muskrat, seaside sparrow
General fens and vernal pools	Spotted salamander (historic), wood frog (historic)
Nesting birds shrubland habitat	snowy egret
Oyster reefs	Oyster
Recreational fishing (fresh and saltwater)	Brook trout (historic range but doesn't currently exist in this watershed), assorted species in bay downstream of dams including Atlantic menhaden, striped killifish, grass shrimp, sand shrimp, mud shrimp, Atlantic silverside, stickleback, blue crab, striped bass.
Salt marsh tidal habitat	Salt marsh sparrow, seaside sparrow
Sandbar and sand tiger shark essential fish habitat	Dogfish
Shellfish collection areas	Oyster, hard and softshell blue crab
Species greatest conservation need	Numerous species identified from State Wildlife Action Plan process
Winter flounder habitat	Winter flounder

** 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.*

Expected Project Impact

The removal of the berm and subsequent restoration of aquatic habitat and hydrology along the Kickemuit River will have immediate positive impacts to human communities and fish and wildlife habitat. The project could reduce potential flooding to a key emergency evacuation route between population centers, increase water quality of aquatic areas, thereby potentially increasing opportunities for recreation and fishing, and improve habitat for commercially important species downstream. In addition, specific fish/wildlife benefits include increased access to spawning habitat for anadromous fish, improved health of aquatic species downstream by improving water quality, and improved existing marsh and tidal habitat in addition to providing new marsh migration areas as sea level rise occurs.

Case Study 3: Wading River Culvert Replacement Project

Figure CS3-1. Photo showing under-sized culvert on the Wading River, Norton, MA.

Project Overview

Location: Norris, MA

Date Visited: March 26, 2018

Contact: Bill Napolitano (Southeastern Regional Planning and Economic Development District) and Jennifer Carlino (Town of Norton, MA)

Culverts are common structures used to divert the flow of a stream or river beneath roadways or stretches of land. Culverts can disrupt the natural movement of water by creating bank erosion, inlet and outlet scour, restricted wildlife passage, and increased flooding risk upstream and on the roads they pass under.

The Town of Norton has two culverts on Walker Street that have been designated as a “significant barrier” in the Stream Continuity Assessment in the Taunton Watershed, prepared by Mass Audubon (2017). The first culvert is a stream crossing of the Wading River that consists of dual corrugated metal pipes that are undersized and perched, leading to the creation of a plunge pool on the downstream side of the road which impairs fish passage. During heavy rain events, these undersized pipes can cause flooding upstream. A second culvert on Walker Street is on a tributary to the Wading River and is further identified as one of the "Top Ten Priorities for Restoration" in the same report.

This project proponent's goal is to design and install appropriately sized structures and/or bridges at these two locations to restore hydrology that has been disrupted by under-sized and degraded culverts under Walker Street. The project will potentially address degradation of habitat as well as increased flooding risk caused by these culverts. Project leaders plan to implement the project in a way that allows for dual human and fish/wildlife benefits by reducing flooding risk over the roads and the adjacent neighborhood, while also restoring aquatic connectivity and habitat quality for key species, including a state-listed fish species (bridal shiner) that is in the project area.

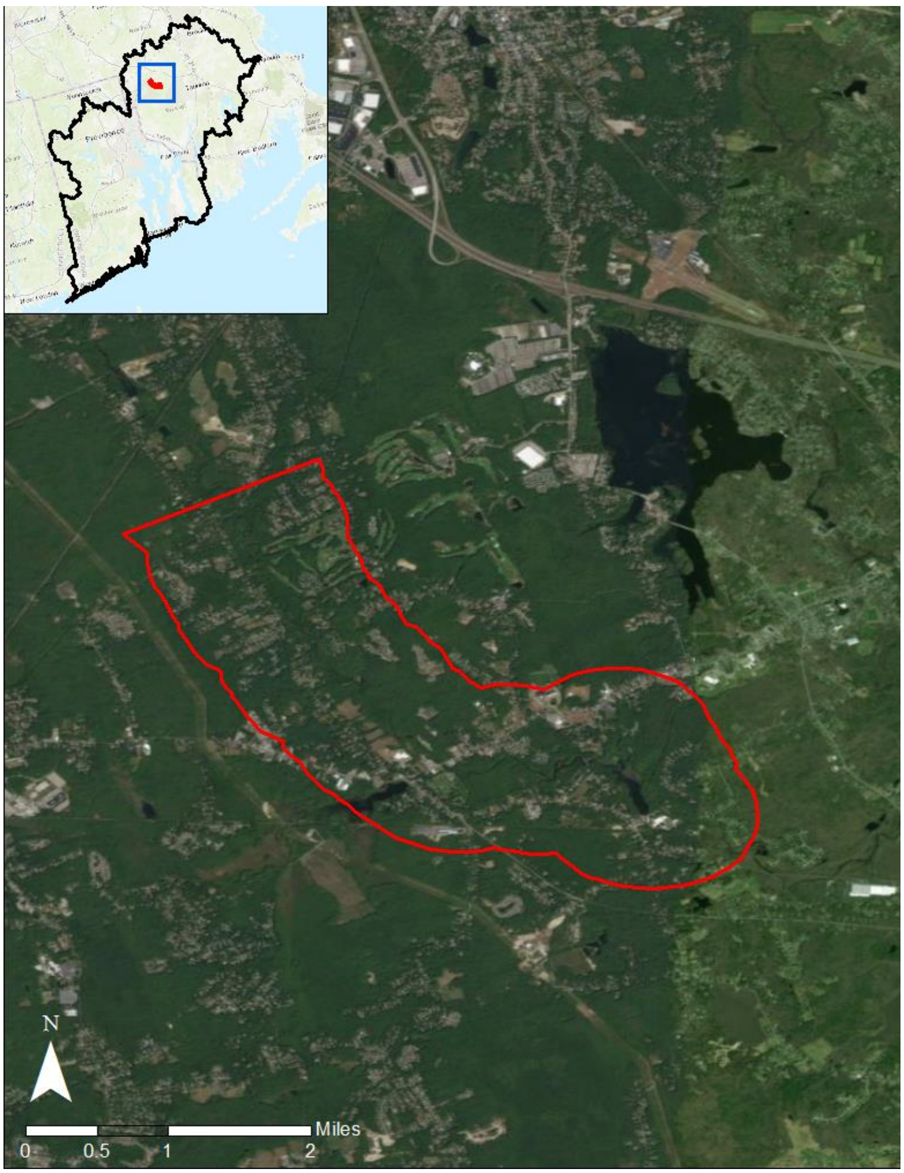


Figure CS3-2. Approximate project area (red boundary). *Aerial view includes the project area and adjacent neighborhoods.*

Estimated Cost of the Project

The project is estimated to cost between $182,000-$264,000 depending upon whether one or both culverts are replaced. For more detailed numbers, please contact the project sponsors.

Stressors and Threats

This site contains a high concentration of existing and future threats to human communities and fish and wildlife habitat conditions (see table 1). Existing threats to human communities include flooding of homes, increased flood insurance rates, flooding of roads, road closures, and detours. Existing threats to fish and wildlife habitats include fragmented habitat, inability to migrate upstream and reduced genetic diversity, inability to reach cooler temperature waters upstream, sedimentation of interstitial streambeds, turbidity and impaired water quality, and risk to fish and wildlife from road crossings and vehicular traffic. Replacing the undersized and inefficient culverts to meet Massachusetts Stream Crossing Standards would provide the capacity to pass the 100-year storm event, preventing flooding of adjacent residential homes, restoring more natural conditions to the stream bottom to allow for better fish and wildlife passage, and potentially creating more opportunities for wildlife to pass under rather than across the road.

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

Existing Stressors
Local Neighborhood and Connecting Roads
Secondary Roads
Water Quality - Low
Developed Open Spaces
High/Medium Density Housing
Low Density Housing (Rural Residential)
Ruderal (maintained pasture, old field)
Railroads, Bridges Culverts
Dams & Reservoirs
Flooding threats
Floodway
500-year floodplain

Human Community Assets

Currently flooding overtops the road, shutting down traffic passage and access by the highway department and local fire department. If flooding risk increases, this could hamper the ability of emergency vehicles to access residents during storms. In addition, flooding caused by culvert backup has led to negative impacts on adjacent homeowners. Addressing the culvert issues will lessen the chance of future flooding on these properties. The map below shows areas (in pink) where there are high concentrations of human community assets that are also highly threatened by the threats listed above.The primary human community assets in the area include densely populated areas near the site, State Route 123, and railroads and bridges that pass through the area. These assets would potentially benefit from any project that reduces flooding intensity and extent.

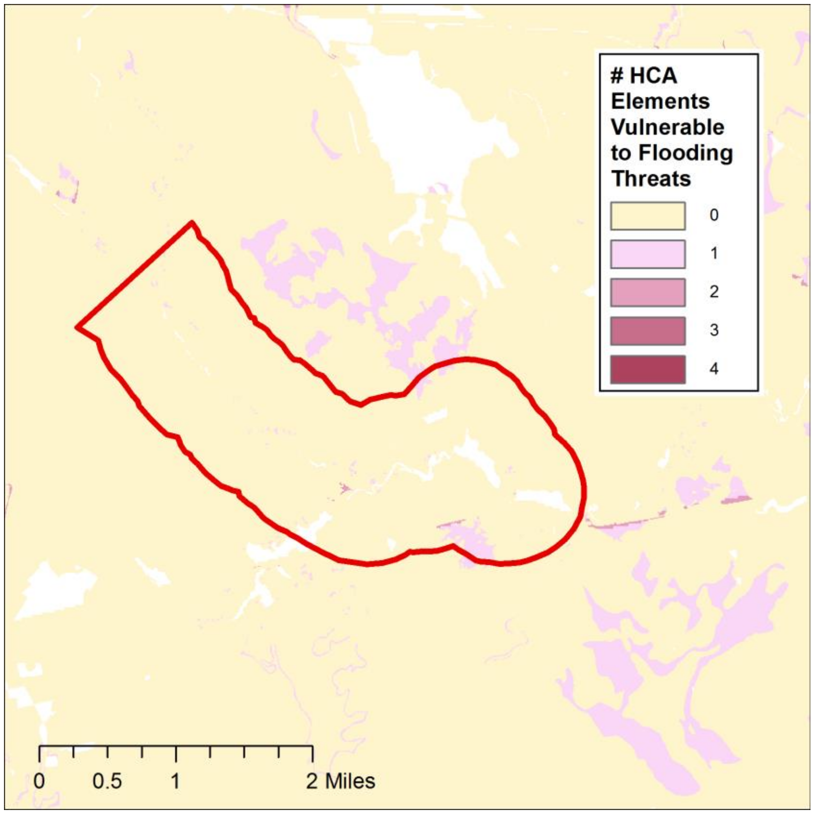


Figure CS3-3. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements) within and around the Wading River project. Tan color indicates areas with HCAs that are not categorized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

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

Categories of Human Assets Identified within Project Boundary
Densely populated areas Critical Infrastructure Social Vulnerability
Mapped Community/Human Assets within Project Boundary
Norton Middle School Solmonese School Norton Fire Department Rainbow Kids Learning Center Route 123 Railroad Power St bridge by Barrowsville Pond Richardson Ave bridge over Wading River Route 123 bridge over Wading River Barrow St bridge over Wading River

Fish and Wildlife

This site contains important habitat (and/or potential habitat) for priority fish and wildlife species, including many species highly valued by the stakeholders of the region. In particular, the state-listed bridal shiner has been documented in the area near existing culverts. Culvert replacement may improve connectivity between populations on either side of the road, thereby increasing potential population viability. The fish and wildlife habitats mapped in this area also support a wide variety of important species including wetland/shrubland birds, eastern brook trout, vernal pools and fens, etc. Despite high population density surrounding this stretch of the river, it provides very high quality cold habitat.

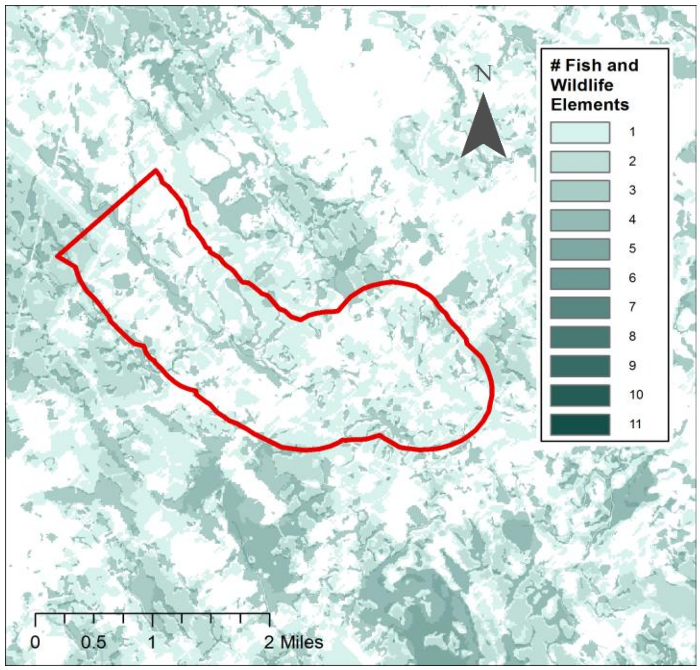


Figure CS3-4. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements combined (darker green signifies more elements/value). Red outline is the project boundary.*

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 ****
Brook trout habitat	Brook trout
Freshwater meadow marsh	Mink, birds dependent on freshwater meadows
General fens/vernal pools	Spotted salamander, wood frog
Nesting shrubland bird habitat	Warblers, American woodcock, flycatchers
Species of Greatest Conservation Need	Various species as identified in the state wildlife action plan

**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.*

Expected Project Impact

The project team concluded that an open-bottom arch culvert is likely the best option for culvert placement, but engineering analysis will be required to confirm.

A properly-sized arch structure has the capacity to handle flows up to 1,500 cubic feet per second (cfs), the equivalent of the 500-year flood, while maintaining minimal contact with the natural streambed. This new design will span the entire width of the existing Wading River channel which minimizes the amount of riverbank and in-stream constriction impact. In addition, the project will improve and promote stream continuity and safe wildlife passage and improve environmental and public health and safety through reduction in flood events causing damage to public and private property as well as public transportation infrastructure.

Based on the analysis, the project could reduce extent and period of flooding of homes and overtopping of road due to storm events and reduce cost to emergency and highway services, who will not need to deploy sandbags along road during high water events. In addition, fish and wildlife could benefit through improved passage of terrestrial species such as fishers without needing to cross a dangerous road and improved habitat and connectivity for aquatic species. Project will likely allow access to an additional 4,000-9,000 linear feet of stream for populations that currently exist on other side of the culvert.

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 Narragansett 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 Narragansett Bay and Coastal Rhode Island 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 results of this assessment are consistent with those from the NBEP (2017) study--that community vulnerability in key locations in the watershed is very high owing to exposure to all forms of flooding threats. This watershed is generally less vulnerable to flooding than other areas along the Eastern Seaboard owing to its higher topography, although many communities and human assets are exposed to flooding threats along the immediate outer coast and areas around the bay and tidally-influenced rivers. Some inland assets are vulnerable in areas prone to precipitation-based flooding, especially where historic obstructions such as dams and under-sized culverts impede flow. The extent of vulnerable areas will increase with sea level rise and more intense storms and protective features like the Fox Point Hurricane Barrier (that protects downtown Providence) may not provide complete protection in the future.

The urbanized areas such as Providence's densely developed center and hardened shoreline areas offer few nature-based resilience opportunities, but such opportunities are found more commonly in other small and scattered resilience hubs throughout the region. High scoring resilience hubs occur, for example, along the outer coastal areas of Charlestown, Green Hill, Narragansett, and Westerly; and along the northern portion of the bay. Inland areas such as the large area around Raynham (MA) stand out because of relatively intact forest and wetlands around flood-vulnerable towns and roads.

Nature-based resilience opportunities are 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:

- Dam and culvert modification/removal can benefit fish/wildlife while also improving resilience both upstream and downstream from the restoration sites, thereby providing outsized impacts for a relatively small project area;
- Some dams and culverts at lower elevations near the coast (such as the Kickemuit dam) are already being impacted by the effects of sea level rise, so planning for future ocean levels will be important in building coastal resilience and protecting key evacuation corridors that might otherwise be inundated without action; and
- Even though not featured among the current case studies, highly impactful near-coastal restoration opportunities within the region exist as well, and should be considered for future implementation.

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 2 for details on this method). This approach has some limitations such as extrapolating impacts in all directions instead of only downslope, only affecting water bodies within the distance effect (e.g., no mixing), and not accounting for downstream accumulation or mixing.
5. The selection of fish and wildlife elements was geared to the specific objectives of this assessment and, therefore, does not represent biodiversity generally or necessarily all fish and wildlife of conservation interest. Not all nominated elements could be represented at the preferred level of precision. A list of elements for which data was not available or was deemed insufficient for appropriately representing the element is provided in Appendix 5. That said, no elements can be assumed to have complete and accurate distributions. The Vista DSS project can be amended with additional elements of interest.

Putting this Assessment to Work

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

Regional Resources:

- *Resilient Rhody,* the state of Rhode Island's climate adaptation strategy. http://climatechange.ri.gov/resiliency/. A robust clearinghouse of resources for state and local government agencies, residents, and business.
- *Massachusetts Municipal Vulnerability Preparedness Program*. https://www.mass.gov/municipal-vulnerability-preparedness-mvp-program. Provides support to communities to conduct vulnerability assessments and develop resiliency plans. It also certifies communities which makes them eligible for funding.

Other Resources:

- 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 Narragansett and Coastal Rhode Island Bay 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.

References

Advameg Inc. 2007. Providence Economy. *City-Data.com.* Retrieved Dec. 25, 2018. *http://www.city-data.com/us-cities/The-Northeast/Providence-Economy.html*

Bender M. A., Knutson T.R., Tuleya R.E., Sirutis J.J., Vecchi G.A., Garner S.T., and I.M. Held. 2010. Modeled impact of anthropogenic warming on the frequency of intense Atlantic hurricanes. Science 327:454–458.

Dobson, J.G., I. Johnson, and K. Rhodes. 2019. Coastal Resilience Assessment for the United States: Final Report for the National Fish and Wildlife Foundation. Asheville, NC: UNC Asheville's National Environmental Modeling and Analysis Center.

Environmental Protection Agency (EPA). 2016. Extent of Coastal Watersheds in the Conterminous U.S. Map. EPA. https://www.epa.gov/wetlands/coastal-wetlands

Faber-Langendoen, D., J. Nichols, L. Master, K. Snow, A. Tomaino, R. Bittman, G. Hammerson, B. Heidel, L. Ramsay, A. Teucher, and B. Young. 2012. NatureServe Conservation Status Assessments: Methodology for Assigning Ranks. NatureServe, Arlington, VA.

Gornitz, V.M., R.C. Daniels, T.W. White, and K.R. Birdwell. 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. 327-338.

Hak, J.C. and P.J. Comer. 2017. Modeling landscape condition for biodiversity assessment—Application in temperate North America. Ecological Indicators 82 (2017) 206-216.

Harrison, D. M. and P. Kooistra. 2017. Sea Level Rise and Society. Unpublished manuscript.

Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K. 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5 (2011) 345-354.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, R.K, Pachauri and A. Reisinger (eds). Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Mass Audubon. 2017. Stream Continuity Assessment in the Taunton Watershed. Accessed at http://nbep.org/publications/NBEP-17-191.pdf.

MarineCadaster.gov. 2012. 2010 United States Automatic Identification System Database., URL: https://marinecadastre.gov/ais/, NOAA's Ocean Service, Office for Coastal Management (OCM), Charleston, SC.

Massachusetts Division of Fisheries and Wildlife. 2015. Massachusetts State Wildlife Action Plan 2015. Westborough, MA.

Narragansett Bay Estuary Program. 2017. The State of Narragansett Bay and Its Watershed Technical Report. Technical Report. Providence, RI.

Narayan, S., M.W. Beck, P. Wilson, C.J. Thomas, A. Guerrero, C.C. Shepard, B.G. Reguero, G. Franco, J. Carter Ingram, and D. Trespalacios. 2017. The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA. Scientific Reports 7, Article Number: 9463 (2017), doi: 10.1038/s41598-017-09269-z.

National Oceanic and Atmospheric Administration, Office for Coastal Management. 2018. "Marsh Migration Data" NOAA Sea Level Rise Viewer. Charleston, SC: NOAA Office for Coastal Management. Accessed April 2018 at www.coast.noaa.gov/slr.

National Oceanic and Atmospheric Administration. 2015. Guidance for Considering the Use of Living Shorelines. Accessed May 2018 at https://www.habitatblueprint.noaa.gov/wp-content/uploads/2018/01/NOAA-Guidance-for-Considering-the-Use-of-Living-Shorelines_2015.pdf

NatureServe. 2011. Terrestrial Ecological Systems and Current Land Cover version 3.5. Arlington VA. Version 3.5 2018.

Newton, A. and M. Elliott. 2016. A Typology of Stakeholders and Guidelines for Engagement in Transdisciplinary, Participatory Processes. Frontiers in Marine Science, 3, 230.

Powell E.J., M.C. Tyrrell, A. Milliken, J.M. Tirpak, and M.D. Staudinger. 2017. A synthesis of threshold for focal species along the U.S. Atlantic and Gulf coasts: a review of research and applications. Ocean & Coastal Management 148 (2017) 75-88.

Reed, M. S. 2008. Stakeholder participation for environmental management: A literature review. Biological Conservation, 141(10), 2417–2431.

Rhode Island Coastal Resources Management Council. 2010. Rhode Island Ocean Special Areas Management Plan. University of Rhode Island Coastal Resources Center.

RIGIS, 2012. Rhode Island Forest Health Works Project: Points. Rhode Island Geographic Information System (RIGIS) Data Distribution System, URL: http://www.rigis.org, Environmental Data Center, University of Rhode Island, Kingston, Rhode Island (date acquired: 5 September 2017).

Soulard, C.E. and W. Acevedo. 2016. Improving urban change maps for the conterminous United States from 1992 to 2011 by disaggregating roads from the National Land Cover Dataset. American Geophysical Union, Fall General Assembly 2016, abstract id. B33H-0703.

Spaulding, M.L., A. Grilli, C. Damon, R. Hashemi, S. K. Anbaran, and G. Fugate. 2018. STORMTOOLS Design Elevation (SDE) Maps. Ocean Engineering, University of RI, Narragansett, RI, USA.

Department of Environmental Management. 2014. Annual report to the Governor on the activities of the Dam Safety Program. State of Rhode Island. Accessed at http://www.dem.ri.gov/programs/benviron/compinsp/pdf/damrpt14.pdf.

Department of Environmental Management. 2016. Annual report to the Governor on the activities of the Dam Safety Program. State of Rhode Island. Accessed at http://www.dem.ri.gov/programs/benviron/compinsp/pdf/damrpt16.pdf.

U.S. Army Corps of Engineers. 2015. Use of Natural and Nature-Based Features for Coastal Resilience. ERDC SR-15-1. Found at http://www.dtic.mil/dtic/tr/fulltext/u2/a613224.pdf.

U.S. Census Bureau. 2016. TIGER/Line® Shapefiles. U.S. Census Bureau. Found at https://www.census.gov/geo/maps-data/data/tiger-line.html.

U.S. Geological Survey, Gap Analysis Program (GAP). 2016. Protected Areas Database of the United States (PAD-US), version 1.4 Combined Feature Class.

U.S. Geological Survey. 2017. National Hydrography Dataset (NHD) - USGS National Map Downloadable Data Collection. Retrieved from https://catalog.data.gov/dataset/usgs-national-hydrography-dataset-nhd-downloadable-data-collection-national-geospatial-data-as on 25 June 2018.

U.S. Geological Survey, & U.S. Department of Agriculture Natural Resources Conservation Service. 2013. Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD). U.S. Geological Survey Techniques and Methods 11–A3.

United States Government. 1988. Endangered Species Act of 1973, as amended through the 100th Congress. U.S. Department of the Interior.

Acknowledgements

Funders

This assessment and publication were commissioned by the National Fish and Wildlife Foundation and funded by the National Oceanic and Atmospheric Administration. It was conducted in consultation with the National Oceanic and Atmospheric Administration and the U.S. Army Corps of Engineers.

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 Fall River State Heritage Park and the University of Rhode Island.

Project Team and Partners

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

Steering Committee

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

Technical Committee

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

Watershed Committee

National Oceanic and Atmospheric Administration	Alison Verkade Jim Turek
Rhode Island Coastal Resources Management Council	Cailtlin Chaffee Grover Fugate
Rhode Island Sea Grant, University of Rhode Island	Jen Critcher

Additional Stakeholders

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

Aquidneck Island Planning Council
American Planning Association
Atlantic Coast Joint Venture
Audubon Society of RI
Blue Sky Planning Solutions
City of Newport
City of Providence
City of South Kingstown
City of Warwick
Clean Ocean Access
Clean Water Action
Coastal Management Resources Council
Coastal Resources Center
Cox
Drexel University
Enduring Conservation Outcomes
Grow Smart Rhode Island
Kennebec Estuary Land Trust
MA Energy and Environmental Affairs
MA Department of Environmental Protection
MA Division of Ecological Restoration
MA Natural Heritage & Endangered Species Program
ME Natural Areas Program
Narragansett Bay Commission
Narragansett Bay National Estuarine Research Reserve
Narragansett Indian Tribe
Narrow River Preservation Authority
National Environmental Modeling Analysis Center
National Fish and Wildlife Foundation
National Sea Grant Office
National Wildlife Foundation
Natural Resources Conservation Service
NatureServe

NE Interstate Water Pollution Control Commission
NOAA
North Atlantic Landscape Conservation Cooperative
Northeastern Regional Association of Coastal Ocean Observing Systems
Office of Senator Sheldon Whitehouse
Pawtuxet River Authority
RI Coastal Resources Management Council
RI Department of Administration
RI Department of Environmental Management
RI Emergency Management Agency
RI Land Trust Council
RI Natural History Survey
RI Wildlife Action Plan
River Watershed Alliance
Save the Bay
South Atlantic Landscape Conservation Cooperative
Southeastern Regional Planning and Economic Development District
The Nature Conservancy RI
Town of Narragansett
Town of Warwick
University of Rhode Island
US Army Corps of Engineers
US Environmental Protection Agency
US Fish and Wildlife Service
Wood-Pawcatuck Watershed Association
Woonasquetuckett River Watershed Council

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 129 invited participants, 26 participated in the in-person stakeholder workshops, but many others followed up with additional information and input after the workshops, providing critical data leads and resilience project ideas. (See Acknowledgments section for a list of the agencies represented in the stakeholder process.)

Project Outreach and Coordination Resources

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

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

Watershed Webinars and Stakeholder Workshops

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

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

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

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

Name of Engagement Activity	Participation	Date
First Watershed Committee meeting (by webinar)	Watershed Committee	April 7, 2017
Pre-stakeholder webinar	Stakeholders, Watershed Committee	May 11, 2017
In-person stakeholder workshops	Stakeholders, Watershed Committee	May 18-19, 2017
Post workshop follow-up to summarize workshop results	Watershed Committee	June 24, 2017
Review of fish and wildlife and vulnerability assets	Watershed Committee	June 26, 2017
Draft results webinar to discuss GIS analysis and obtain final input from all stakeholders that wish to participate	Stakeholders, Watershed Committee	November 9, 2018

Post-workshop Activities

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

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

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

Gathering Candidate Projects

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

Appendix 2. Condition and Vulnerability Technical Approach and Modeling Methods

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

GIS Tools

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

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

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

Modeling Approach

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

The process steps used are listed and described below.

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

Definition of Scenarios

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

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

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

Stressor and Threat Data

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

<u>Soil Erodibility</u>

To assess the erodibility of soils throughout the coastal watersheds, the USDA-NRCS Soil Survey Geographic Database (SSURGO) classification kffact was used. The kffact score represents the susceptibility of soil particles to detachment by water. Soil erosion resulting from flooding can drastically alter the landscape and impact wildlife habitat. Erosion can be devastating in extreme flood events. In this assessment, soil erodibility varies tremendously across regions and is dependent on soil type. Also highlighted in this input are beaches and dunes that are migratory by nature. Although these landforms can help buffer a community from flooding, the risk of erosivity is fairly high.[12]

[12]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.[13] 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.[14] 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

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

[14]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		
	Intensive Agriculture	NatureServe Systems Map (Comer 2009)	Baseline, Combined
	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		

Stressor/Threat Primary & Secondary Categories		Data Sources	Scenarios
	Railroads, bridges, culverts	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later); Federal Highway Administration, NBI v.7, NTAD (2015 or later)	
	Utility & Service Lines (overhead transmission, cell towers, etc.)	No data	n/a
Dredge Material Placement Areas		No data	n/a
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	<= 1'	STORMTOOLS Design Elevation (SDE) Maps, TOTALDEPTH surge model for 100year storm at SLR 0 (Spaulding et al 2018)	Flooding Threats, Combined
	1' – 3'		
	3' – 9'		
	> 9'		
Water Quality	Moderate	EPA Impaired Waters AIS Commercial Vessel Traffic Density (See References section for citation)	Baseline, Combined
	Low		
Invasive Species	Terrestrial	RI Forest Health Works Project (See References section for citation)	Baseline, Combined
	Aquatic	No data	n/a
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 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 Narragansett Bay and Coastal Rhode Island Watersheds Committee and other stakeholders. Model inputs and assumptions are described in Appendices 2 and 3.

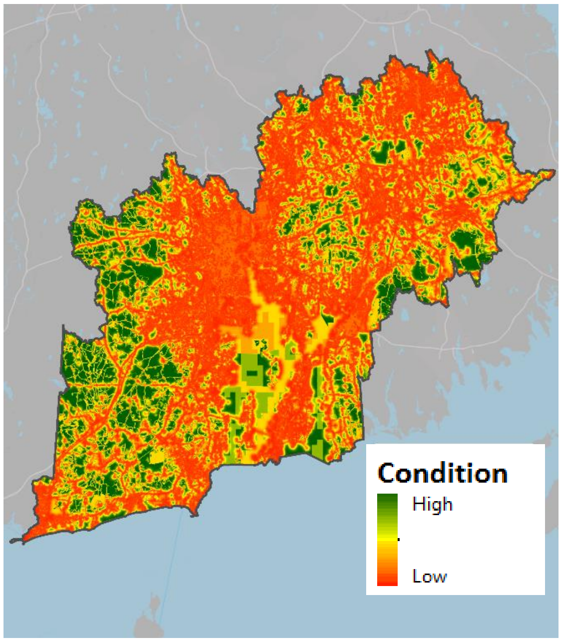
Model Element Condition

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.

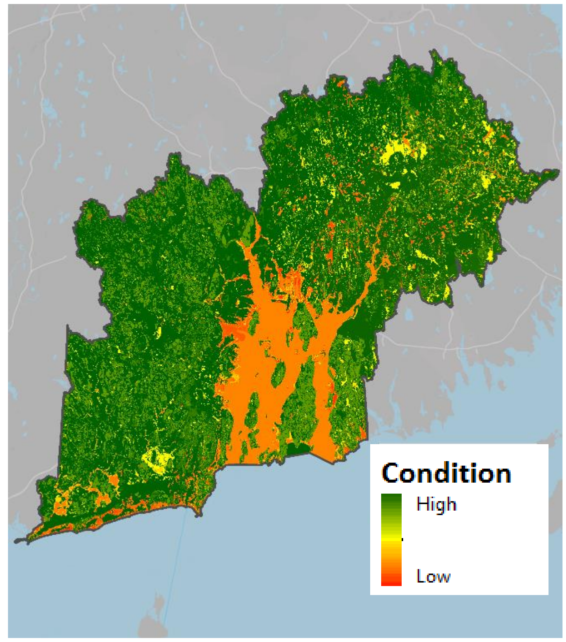
The LCM calculates the condition score of every pixel in the watershed as depicted in the four maps below (Figure A2- 1) using the relevant response models per above without regard to locations of elements to which the scores will be applied. The LCM first calculates the response scores on each individual 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.

Model Element Vulnerability

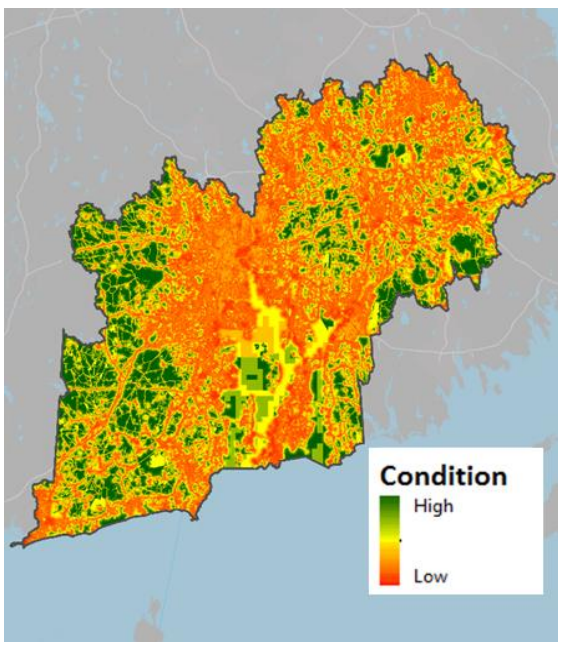
To assess vulnerability, the individual element results from the condition modeling above were subjected to the condition threshold for the same element groups described above in Building Element Response Models (see Appendix 3 for thresholds). All pixels below the threshold were attributed as non-viable (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.



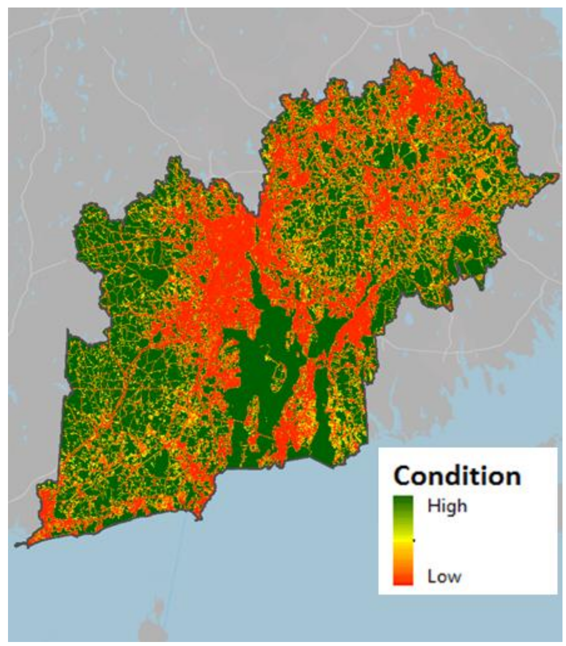
Terrestrial Elements Condition



Freshwater Elements Condition



Estuarine Elements Condition



HCA Elements Condition

Figure A2-1. Landscape condition model outputs for the Narragansett Bay and Coastal Rhode Island Watersheds. *These maps depict the watershed-wide results of each of the four landscape condition models used in the assessments.*

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

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

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

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

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

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

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

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

responses by narrowing whether they should be above or below the condition threshold; second to support use of the Vista project for planning purposes where it allows rapid testing of proposed actions at the site scale (in the Vista DSS see the Site Explorer function).

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

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

Storm surge effects modeling

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

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

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

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

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

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Transportation and Service Corridors	Primary roads, e.g., Interstates, high traffic/volume, wide roads, bridges	Categorical Response	Negative	Complete clearing, pavement, vehicular visual and noise disturbance, wildlife mortality, fragmentation, loss of connectivity.
		LCM Site Intensity	0.05	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Secondary roads, e.g., moderate traffic/volume state highways, bridges	Categorical Response	Negative	Somewhat reduced footprint and traffic impacts than a primary road but still highly significant.
		LCM Site Intensity	0.2	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a habitat type change.
	Local, neighborhood and connecting roads, bridges/culverts	Categorical Response	Negative	Similar effects as secondary road.
		LCM Site Intensity	0.2	
		LCM Distance	50	Smaller distance effect due to narrower footprint and reduced traffic volume.
	Dirt/Private roads/culverts	Categorical Response	Negative	Very narrow footprint, very low traffic volume, and can have continuous forest canopy over road, higher potential for restorability than wider/public roads.
		LCM Site Intensity	0.4	
		LCM Distance	30	Narrow footprint, low traffic volume, and potential for continuous forest canopy means smaller distance effect.
	Railroads, bridges, culverts	Categorical Response	Negative	Similar effects as secondary road.
		LCM Site Intensity	0.2	
		LCM Distance	100	Edge effects can have long-term effects on microclimate, exotic species invasion, species diversity, and dominance (among other impacts) resulting in a change to the existing habitat type.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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.
	Invasive Species - Terrestrial	Categorical Response	Negative	
		LCM Site Intensity	0.6	Effects can change biotic composition and sometimes habitat structure, which may lead to increased erosion, occasionally change an entire habitat type (to invasives dominated). Score is at threshold, so viability will be retained, but will benefit from control of invasives.
		LCM Distance	100	Indicates potential for spread over relatively short time without control depending on species.
	High Subsidence (Rank 4)	Categorical Response		
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response		
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response		Assume slightly less impact than for Very High Erodibility below.
		LCM Site Intensity	0.95	
		LCM Distance		

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Very High Erodibility	Categorical Response		Assume exposure to Category 3 storm surge in combination with very erodible soils would result in reduction of condition to just below threshold necessitating restoration for near term recovery. See assumptions for storm surge categories.
		LCM Site Intensity	0.9	
		LCM Distance		Assume no offsite effect.
Flood Prone Areas	500 Year Floodplain	Categorical Response	Negative	Assume enough damage to habitat through soil erosion or deposition to require some restoration to bring back habitat and species viability or several years for natural recovery.
		LCM Site Intensity	0.5	
		LCM Distance	n/a	Assume no offsite effect.
	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.

<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="12">Resilience Project Protection/ Restoration Actions</td><td rowspan="3">Living shoreline implementation</td><td>Categorical Response</td><td>Positive</td><td rowspan="2">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.</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">Beach or dune restoration</td><td>Categorical Response</td><td>Positive</td><td rowspan="2">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.</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">Marsh restorations.</td><td>Categorical Response</td><td>Positive</td><td rowspan="2">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.</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">Restoration of aquatic connectivity</td><td>Categorical Response</td><td>Positive</td><td rowspan="2">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.</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>

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Upland restoration	Categorical Response	Positive	Projects with on-the-ground actions that improve upland conditions and/or expand natural upland area by means that are designed to enhance ecological assets may reduce flooding effects from precipitation-caused flooding upstream.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Riparian and floodplain restoration	Categorical Response	Positive	Projects with on-the-ground actions to improve conditions and/or expand floodplain or riparian area by means that are designed to enhance ecological assets will reduce/prevent erosion and may reduce flooding effects.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Storm Surge	Category 1	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.5	
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect.
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.7	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.

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

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

<table>
<tr><th colspan="4">Key Assumptions of this Model</th></tr>
<tr><td colspan="2">Applies to any consistently wet habitats or species adapted to freshwater environments.</td><td colspan="2">Responses to stressors focused on water quality impacts, increased salinization, physical impacts on submerged aquatic vegetation, and the potential for other biotic impacts.</td></tr>
<tr><td>Importance Weighting (Optional, used only for the CVS)</td><td>Values range from: 0.0 (Low) to 1.0 (High). There may be as many weighting systems as desired based on rarity, cultural or economic value, etc. Value based on G-rank can be automatically populated if G-rank attribute is provided.</td><td>n/a</td><td>Importance weighting is not set for fish and wildlife elements. Assumption is that all fish and wildlife elements are equally important.</td></tr>
<tr><td>Element Condition Threshold</td><td>Values range from: 0.0 (Low) to 1.0 (High). This value will determine the LCM result threshold under which a species is no longer viable in a pixel. Nearing 0.0 indicates increasing resilience and nearing 1.0 indicates increasing sensitivity.</td><td>0.7</td><td>Assumption is that freshwater elements have less adaptive capacity to the stressors and threats in this assessment (flooding scour, erosion, salinization) than terrestrial elements. Therefore, they require better condition to maintain function.</td></tr>
<tr><td colspan="4">Land Use Intents (term used in Vista 3.x for all land uses, infrastructure, other stressors and threats, and conservation management and practices anticipated under any scenario). The IUCN/CMP classification list (v3.1, 2011) of direct threats and conservation practices was modified to meet the needs of this project.</td></tr>
</table>

<table>
<tr><th>Primary Category</th><th>Secondary Category</th><th>Response Types</th><th>Responses</th><th>Response Assumptions</th></tr>
<tr><td rowspan="6">Residential & Commercial Development</td><td rowspan="3">High/Medium Density Housing (high imperviousness >50%)</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">Developed/armored shorelines, heavy runoff volume and pollutants, lack of shading with temperature increases. Low restorability.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.2</td></tr>
<tr><td>LCM Distance</td><td>1000</td><td>Long distance effect to compensate for lack of water quality data.</td></tr>
<tr><td rowspan="3">Low Density Housing (moderate imperviousness 20-49%)</td><td>Categorical Response</td><td>Neutral</td><td rowspan="2">Septic tank pollutants, effects of clearing such as loss of tree cover and temperature increases, and increased runoff volume and landscape chemicals. Low restorability in general although there is potential to restore hydrologic connectivity and vegetation along streams.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.3</td></tr>
<tr><td>LCM Distance</td><td>300</td><td>Long distance effect to compensate for lack of water quality data.</td></tr>
</table>

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Ruderal (maintained pasture, old field)	Categorical Response	Negative	NOAA indicated some agriculture chemicals used on pastures. Runoff is anticipated to be low but sediment may runoff depending on uses, and shoreline erosion may stress these elements up to their viability threshold.
		LCM Site Intensity	0.7	
		LCM Distance	300	Long distance effect to compensate for lack of water quality data.
	Aquaculture	Categorical Response	Negative	Habitat alteration, infrastructure, ongoing impacts of waste, nitrogen, and pathogens but high restorability.
		LCM Site Intensity	0.5	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Mining	Categorical Response	Negative	Assumption for pit type mining. Effects can include complete removal of habitat, deep excavation, noise, dust, runoff of sediment, vehicle traffic. Difficult restorability and typically to different ecosystem type.
		LCM Site Intensity	0.1	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
Transportation and Service Corridors	Primary roads, e.g., Interstates, high traffic/volume, wide roads, bridges	Categorical Response	Negative	Complete clearing, pavement, vehicular visual and noise disturbance, wildlife mortality, fragmentation, loss of connectivity, and pollutant runoff.
		LCM Site Intensity	0.05	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Railroads, bridges, culverts	Categorical Response	Negative	Over water assume bridge with in-water and shoreline structures, and clearing, altered hydrology, shading, and noise impacts. Assume these impacts will drop immediate area to just below viability threshold and low restorability.
		LCM Site Intensity	0.6	
		LCM Distance	50	Smaller distance effect with assumed smaller size, volume, and runoff.
	Utility & Service Lines (overhead transmission, cell towers, etc.)	Categorical Response	Neutral	Assume over water feature with in-water support structures, infrequent maintenance, and noise impacts. High restorability.
		LCM Site Intensity	0.9	
		LCM Distance	20	Very small distance effect.
Dredge Material Placement Areas		Categorical Response	Negative	Assumption is not for dredge materials to be placed within aquatic systems but that offsite effects would include chemical and sediment runoff. Moderate restorability to vegetative cover that would reduce impacts to adjacent aquatic systems.
		LCM Site Intensity	0.3	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.85	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Other threats	Water Quality - Moderate	Categorical Response	Neutral	Assume moderate water quality will just maintain viability.
		LCM Site Intensity	0.7	
		LCM Distance	100	For partial water quality data, distance effect can extrapolate further, optional distance effect depending on the nature of data.
	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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Subsidence	Moderate Subsidence (Rank 3)	Categorical Response	Neutral	Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have a small multiplicative effect.
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.
	High Subsidence (Rank 4)	Categorical Response	Neutral	Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have a small multiplicative effect.
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	Neutral	Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response	Neutral	Freshwater wetland systems would be less exposed to erosion events, so in combination with Storm Surge Category 4 would drop below viability threshold.
		LCM Site Intensity	0.85	
		LCM Distance		Assume no offsite effect.
	Very High Erodibility	Categorical Response	Neutral	Freshwater wetland systems would be less exposed to erosion events, so in combination with Storm Surge Category 4 would drop below viability threshold.
		LCM Site Intensity	0.85	
		LCM Distance		Assume no offsite effect.
Flood Prone Areas	500 Year Floodplain	Categorical Response	Negative	Impact at just below viability threshold to indicate that some restoration action and/or years may be needed to restore viability from erosion, sedimentation, deposition of pollutants and anthropogenic debris, dispersal of invasives, and other severe impacts on species life histories/populations.
		LCM Site Intensity	0.6	
		LCM Distance	n/a	No offsite effect.
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.

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

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

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

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

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)	Categorical Response	Negative	Assume developed/armored shorelines and heavy runoff of freshwater and pollutants may cause effects, such as waterfowl hazing and noise that would greatly reduce condition below viability. Substantial restoration required to bring back viability, and in some cases successful restoration might not be possible.
		LCM Site Intensity	0.2	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
Agriculture and Aquaculture	Silviculture - Intensive	Categorical Response	Neutral	Assume periodic clearing with high impacts on habitat, some on hydrology, sedimentation, and from chemical application. Some in-wetland harvesting occurs in the Narragansett 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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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.
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.

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	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.
	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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
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.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	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	
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.

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

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

<table>
<tr><th colspan="4">Key Assumptions of this Model</th></tr>
<tr><td colspan="2">Applies to all human community assets</td><td colspan="2">Responses to stressors focused on physical damage/loss from flooding</td></tr>
<tr><td colspan="4">Note: elevated roads/bridges were not separated from surface roads is the source data, so they are treated equally.</td></tr>
<tr><td rowspan="10">Importance Weighting (Optional, used only for the CVS)</td><td rowspan="10">Values range from: 0.0 (Low) to 1.0 (High). These ratings were approximated from those used in the regional coastal resilience assessment.</td><td>.2</td><td>Critical Infrastructure (Rank 1)</td></tr>
<tr><td>.2</td><td>Environmental Justice Rank 1</td></tr>
<tr><td>.2</td><td>Population Density (Rank 1)</td></tr>
<tr><td>.4</td><td>Critical Infrastructure (Rank 2)</td></tr>
<tr><td>.4</td><td>Population Density (Rank 2)</td></tr>
<tr><td>.6</td><td>Critical Infrastructure (Rank 3)</td></tr>
<tr><td>.6</td><td>Population Density (Rank 3)</td></tr>
<tr><td>.8</td><td>Population Density (Rank 4)</td></tr>
<tr><td>1.0</td><td>Critical Facilities</td></tr>
<tr><td>1.0</td><td>Population Density (Rank 5)</td></tr>
<tr><td>Element Condition Threshold</td><td>Values range from: 0.0 (Low) to 1.0 (High). This value will determine the LCM result threshold under which a species is no longer viable in a pixel. Nearing 0.0 indicates increasing resilience and nearing 1.0 indicates increasing sensitivity.</td><td>0.5</td><td>Assume human assets have moderate sensitivity owing to their ability to repair/rebuild vs. ecological features that can rarely be restored to original type/health or take a very long time to recover naturally.</td></tr>
<tr><td colspan="4">Land Use Intents (term used in Vista 3.x for all land uses, infrastructure, other stressors and threats, and conservation management and practices anticipated under any scenario). The IUCN/CMP classification list (v3.1, 2011) of direct threats and conservation practices was modified to meet the needs of this project.</td></tr>
</table>

<table>
<tr><th>Primary Category</th><th>Secondary Category</th><th>Response Types</th><th>Responses</th><th>Response Assumptions
(Restorability is not included because assets are not natural features to be restored.)</th></tr>
<tr><td rowspan="3">Sea Level Rise</td><td rowspan="3">Use 1-foot SLR in targeted watersheds to represent 2050 timeframe for planning purposes.</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">Assume severe impact but not complete loss if there is built protection for key assets. This may include raising structures, converting key roads to causeways, etc.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.2</td></tr>
<tr><td>LCM Distance</td><td>50</td><td>Distance indicating impacts from backup of groundwater can flood/destabilize foundations of structures and increase susceptibility to wave action.</td></tr>
<tr><td rowspan="3">Storm Surge</td><td rowspan="3">Category 1</td><td>Categorical Response</td><td>Negative</td><td rowspan="2">See assumptions in Appendix introduction.</td></tr>
<tr><td>LCM Site Intensity</td><td>0.65</td></tr>
<tr><td>LCM Distance</td><td>0</td><td>Assume no offsite effect.</td></tr>
</table>

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		
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.
	High Subsidence (Rank 4)	Categorical Response		
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response		
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Flat (Slope <=0.75%) & Poor Drainage	Flat & Somewhat poorly drained	Categorical Response		Assume areas of flattest slope and somewhat poorly draining soils under extreme precipitation events will lead to flooding. It could approach the 100-year floodplain in level of impact.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions *(Restorability is not included because assets are not natural features to be restored.)*
	Flat & Poor or Very poorly drained	Categorical Response		Assume areas of flattest slope and poorest draining soils under extreme precipitation events may lead to flooding approaching that of a 100-year floodplain.
		LCM Site Intensity	0.5	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response		Assume only a minor impact on human community assets that may require some remediation.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Very High Erodibility	Categorical Response		Assume that in combination with Storm Surge Category 3, expect condition to drop below the viability threshold.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions *(Restorability is not included because assets are not natural features to be restored.)*
	Floodway	Categorical Response	Negative	Assume it is highly unlikely to have human community assets directly within the floodway. A score of .9 was applied to assets in the floodway. They are vulnerable, however, likely to remain viable because they were designed with the anticipation of flooding in the area.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
Conservation Areas	Areas designated for conservation use	Categorical Response	Positive	Assume no stressors inherent in this use other than those overlapping from other categories. Conservation areas will support condition and allow for natural restoration.
		LCM Site Intensity	1.0	
		LCM Distance	0	Assume no offsite effect.
Resilience Project Protection/ Restoration Actions *(categories needed for Scenario breakouts)*	Living shoreline implementation	Categorical Response		Assume project enacts a shoreline management strategy for controlling erosion and enhancing water quality by providing long-term protection, restoration, or enhancement of vegetated or non-vegetated shoreline habitats.
		LCM Site Intensity	1	Restoration practices uniformly indicating positive response for human assets, understanding that in some cases individual structures might be removed in the future to promote and maintain resilience of the human or natural communities. For example, marsh expansion that would help mitigate flooding.
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Projects with on-the-ground actions focused on improving beach or dune conditions. May reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect

Primary Category	Secondary Category	Response Types	Responses	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
	Marsh restorations	Categorical Response	Positive	Assume projects with on-the-ground actions that improve marsh conditions and/or expand marsh area by means of hydrology and thin layer dredge activities are designed to enhance ecological assets. They may reduce flooding by slowing and lowering the height of storm surge, as well as reducing coastal erosion, and the effects of sea level rise.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Restoration of aquatic connectivity	Categorical Response	Positive	Assume projects with on-the-ground actions in riverine settings that remove or replace man-made barriers to water flow and fish movement (e.g., dams and culverts) may reduce flooding threats and culvert/road failures.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Upland restoration	Categorical Response	Positive	Assume projects with on-the-ground actions that improve upland conditions and/or expand natural upland area by means designed to enhance ecological assets may reduce flooding effects from precipitation-caused flooding upstream
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Riparian and floodplain restoration	Categorical Response	Positive	Assume projects with on-the-ground actions to improve conditions and/or expand floodplain or riparian area by means designed to enhance ecological assets may reduce/prevent erosion and may reduce flooding effects.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

Appendix 4. Fish and Wildlife Vulnerability Index

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

Methods

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

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

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

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

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

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

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

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

Steps to model element vulnerability under each scenario:

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

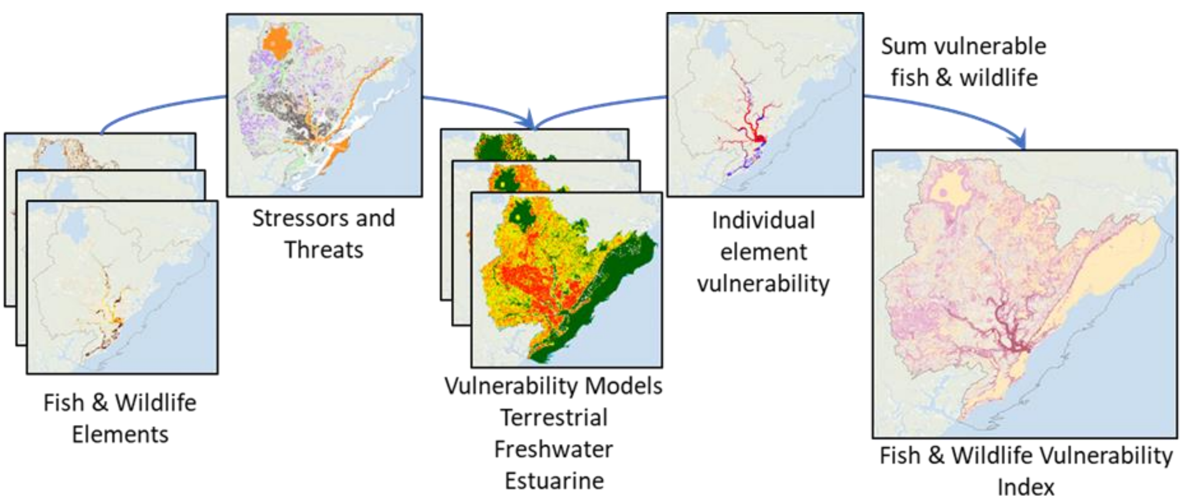


Figure A4-1. Method for calculating fish and wildlife vulnerability indices. *Elements are intersected with stressors and/or threats, the vulnerability model is applied, and individual element vulnerability results are summed to create each index. Diagram represents the Charleston, SC region as an example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

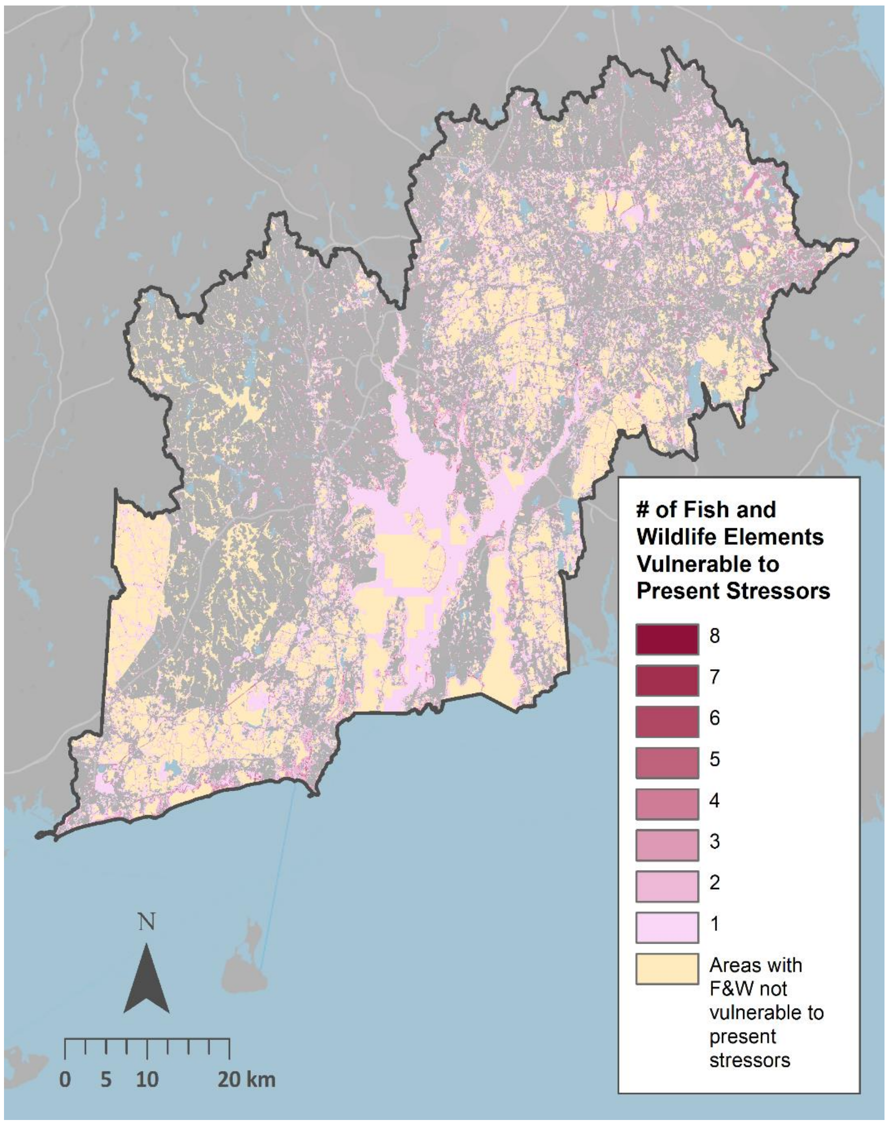


Figure A4-2. Fish and Wildlife Baseline Vulnerability for the Narragansett Bay and Coastal Rhode Island Watersheds*. This map is an overlay or index of all fish and wildlife elements that are vulnerable to the existing mapped stressors. Gray areas within the project boundary represent areas with no mapped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

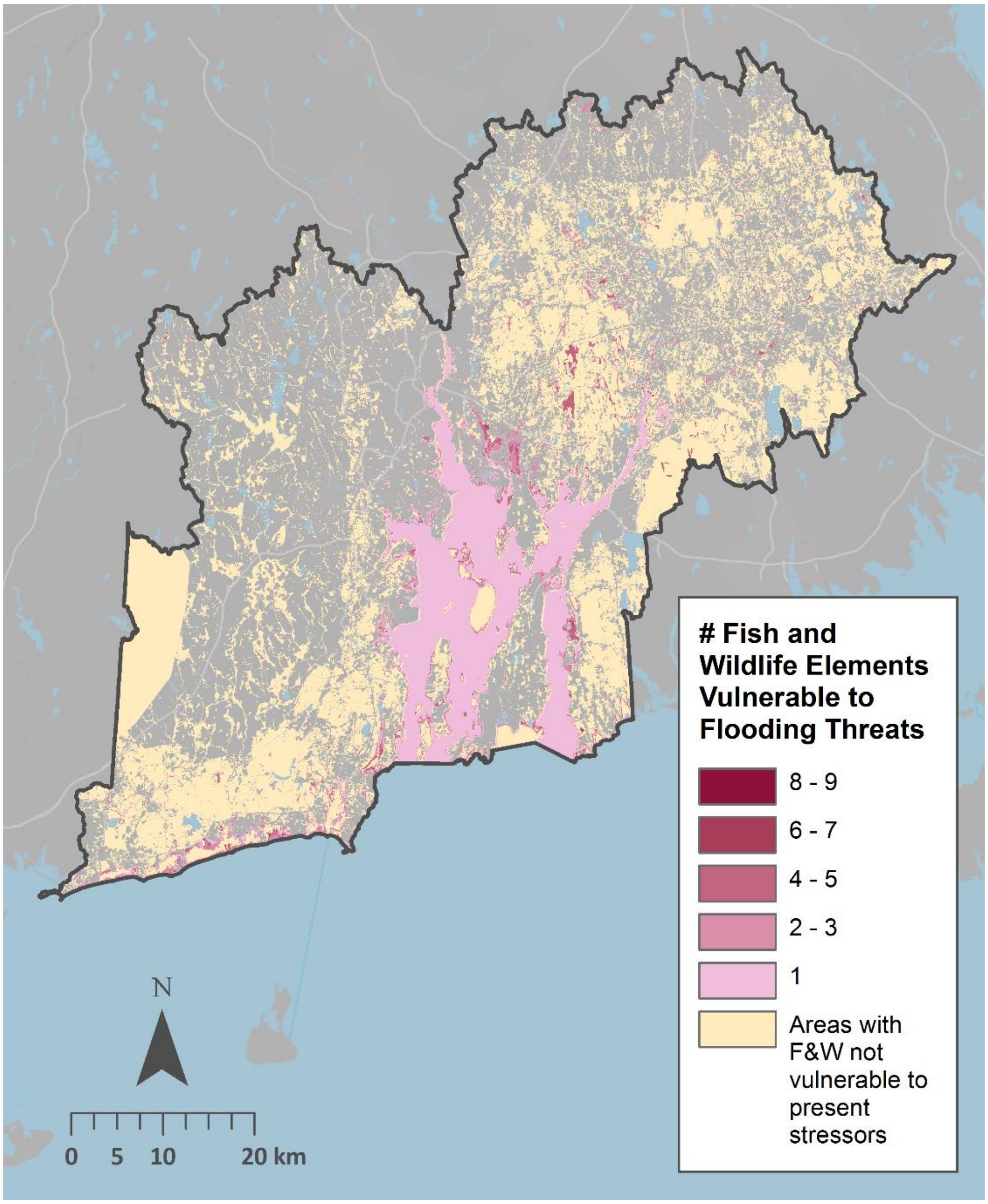


Figure A4-3. Fish and wildlife vulnerability to flooding threats in the *Narragansett* ***Bay and Coastal Rhode Island Watersheds.*** *Pink to red shades indicate the number of elements vulnerable to flooding threats. Tan areas indicate areas of low to no impact. Gray areas within the project boundary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

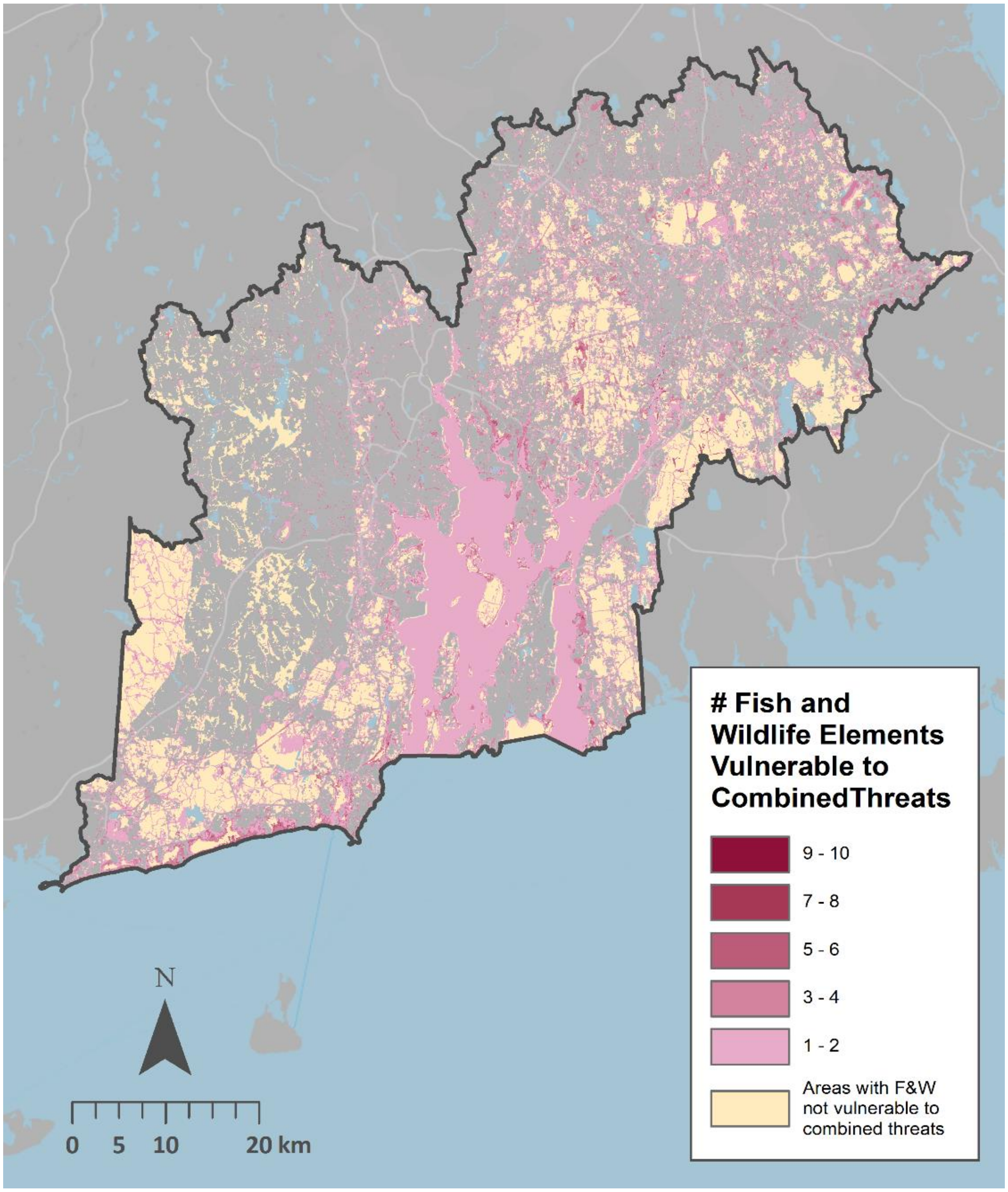


Figure A4-4. Fish and wildlife elements vulnerability to combined stressors and flooding threats for the *Narragansett* ***Bay and Coastal Rhode Island Watersheds.*** *Pink to red shades indicate the number of elements vulnerable to threats. Tan areas indicate areas of low to no impact from the baseline 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 this assessment as well as those considered but not ultimately used in this assessment.

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

Fish/Wildlife Element	***Data Source(s) Used***	***Data Sources Not Used and Why***
NOAA Trust Resources		
Atlantic beach and dune habitat	Marine Beaches (MassGIS); NatureServe Terrestrial Ecological Systems v35 [gridcode = 7436]	State Designated Barrier Beaches (MassGIS) --> Doesn't add additional information to the proposed data sources.
Diadromous fish habitat	Important Anadromous Fish Habitat (Nature's Network) [FTYPE <> "Artificial Path"]; National Wetland Inventory (USFWS) [WETLAND_TYPE="Estuarine and Marine Deepwater"]; Aquatic Core Networks (UMass) lentic layer; TNC Headwaters and Creeks [DESC_23 IN('High Gradient, Cold, Headwaters and Creeks' , 'Low Gradient, Cool, Headwaters and Creeks' , 'Low Gradient, Cool, Small River' , 'Low Gradient, Warm, Headwaters and Creeks' , 'Missing, uninitialized in NHDPlusV1' , 'Moderate Gradient, Cold, Headwaters and Creeks' , 'Moderate Gradient, Cool, Headwaters and Creeks' , 'Moderate Gradient, Cool, Small River' , 'Tidal Headwaters and Creeks' , 'Tidal Small and Medium River' , 'Warm, Medium River'). TNC Headwaters and Creeks were included only if within 100m of other three layers mentioned or Anadromous Fish (MassGIS).	DFW Coldwater Fisheries Resources (MassGIS)

Fish/Wildlife Element	***Data Source(s) Used***	***Data Sources Not Used and Why***
NOAA Trust Resources		
Salt marsh and tidal creek (including open water)	Combination of Salt Marsh and Tidal Creek (RIGIS) ["AttrCode" IN(3,9,10,11,12,13)], Ecological Terrestrial Systems v35 (NatureServe) ["gridcode" =9197], MassDEP Wetlands (MassGIS) ["WETCODE" = 11]	Salt Marsh Restoration Sites (MassGIS) --> Does not intersect project area; Marsh Migration Zones, Northeast U.S. (MassGIS) --> Not a current distribution (shows potential change due to climate change); Landscape Capability for Salt Marsh Sparrow, Version 3.0, Northeast (UMASS) --> Raster Model, with predicted areas outside study area; Tidal Marshes Zone 3 - With DEM (SHARP (Tidal Marsh Zone 3 datasets)) → Doesn't add additional information to the proposed data source; SHARP salt marsh sparrow data (SHARP) --> Data is sensitive so not used as element distribution is covered by other elements.
Harbor seal haulout sites	Ecological Terrestrial Systems v35 (NatureServe) [system_nam in ('Northern Atlantic Coastal Plain Dune and Swale', 'Acadian-North Atlantic Rocky Coast')] within 2km of Harbor Seal Haulout Site point data (Save the Bay)	N/A
Oyster reefs	For MA: Shellfish Suitability Areas (MassGIS) ["HABITAT" = 'AO']; For RI: Commercial Shellfishing Areas of Narragansett Bay (URI) that are not bay or island [FID <> 0 AND ISLAND <> “Y”] and that intersect with Oyster Diseases Sampling Sites (URI). We do not expect the sampling sites to be exhaustive of oyster sites, but only way found to tease out RI oysters and Shellfish Collection Areas will capture any areas missed.	Shellfish Habitat (TNC) --> Doesn't add additional information to the proposed data source, only covers MA portion of study area, and doesn't break into species. Benthic Habitat (TNC) --> Didn't add additional information to proposed data sources.
Recreational fishing areas	Recreational fishing area data (NBEP)	N/A
Atlantic cod habitat	Eelgrass locations 2000 (RIGIS) ["GRP_2_DESC" IN('Estuarine Aquatic Beds (Eelgrass)', 'Estuarine Rocky Shores', 'Marine Aquatic Bed, Eelgrass', 'Marine Rocky Shore')] and Submerged Aquatic Vegetation (SAV) in RI Coastal Waters 2016 (RIGIS)	Atlantic Cod Essential Fish Habitat (NOAA) --> At NOAA’s direction used alternate data that better represents element.

Fish/Wildlife Element	*Data Source(s) Used*	*Data Sources Not Used and Why*
NOAA Trust Resources		
Summer flounder essential fish habitat	Eelgrass locations 2000 (RIGIS) ["GRP_2_DESC" IN('Estuarine Aquatic Beds (Eelgrass)', 'Estuarine Rocky Shores', 'Marine Aquatic Bed, Eelgrass', 'Marine Rocky Shore')] and Submerged Aquatic Vegetation (SAV) in RI Coastal Waters 2016 (RIGIS); Above merged and clipped to Mid-Atlantic EFH ["sitename_l" = "Summer flounder" and "lifestage" IN ('Adult', 'Juvenile')]	N/A
Winter flounder essential fish habitat	Combination of Salt Marsh and Tidal Creek (RIGIS) ["AttrCode" IN(3,9,10,11,12,13)], Ecological Terrestrial Systems v35 (NatureServe) ["gridcode" =9197], MassDEP Wetlands (MassGIS) ["WETCODE" = 11]; Submerged Aquatic Vegetation (SAV) in RI Coastal Waters 2016 (RIGIS)	N/A
Sandbar and sand tiger shark essential fish habitat	Sandbar and Sand Tiger Shark EFH/HAPC (NOAA)	N/A
At-Risk Species and Multi-species Aggregations		
Northern diamondback terrapin	Represented by a probability of occurrence model developed by Rutgers University/NALCC.	Landscape Capability for Diamondback Terrapin, Version 3.1, Northeast (UMASS) --> This model isn't as detailed as the probability occurrence model that is currently being used.
Brook trout	Represented by TNC Headwaters and Creeks [DESC_23 in ("Low Gradient, Cool, Headwaters and Creeks", "Moderate Gradient, Cold, Headwaters and Creeks", "Moderate Gradient, Cool, Headwaters and Creeks", "High Gradient, Cold, Headwaters and Creeks")]	Trout Unlimited maps (Trout Unlimited) --> No available data; Brook trout probability (Nature's Network) --> Too coarse to use for distribution (at catchment scale), but this dataset was used to verify the used dataset.
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species		
Submerged aquatic vegetation (sav)	Eelgrass Locations (RIGIS) [10m buffer] and Submerged Aquatic Vegetation (SAV) in RI Coastal Waters 2016 (RIGIS)	Eelgrass Locations (Polygons) (RIGIS) --> Too coarse; MassDEP Eelgrass Mapping Project (MassGIS) --> not in study area; Eelgrass Bed Updates (MassGIS) --> No response from contacts.
Coastal salt ponds	Subaqueous Soils (State of RI/URI) selected based on RI Coastal Resources Management Council PDF of coastal salt ponds	

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 herbaceous and shrubby wetlands	Ecological Terrestrial Systems v35 (NatureServe) [gridcode in (9048, 9118, 9120, 9177)], National Wetland Inventory (USFWS) [WETLAND_TYPE IN('Freshwater Emergent Wetland', 'Freshwater Forested/Shrub Wetland')]	N/A
Grassland bird habitat	Grassland Bird Core Areas NE US (Nature's Network (UMass Amherst))	N/A
Shrubland-nesting bird habitat	Ecological Terrestrial Systems v35 (NatureServe) [gridcode IN (9120, 9183)] (for Mass), Forest Habitat (RIGIS) [Habitat_Cl in ('Wetland Shrubland', 'Upland Shrubland')] (for RI)	N/A
Coastal forest (maritime forest)	Ecological Terrestrial Systems v35 (NatureServe) [gridcode IN (7324, 7355, 7379, 7456, 9187, 9188)]	RI Forest Health Works Project: Points All Invasives (RINHS & RIDEM) --> Not a coastal forest map, but could be used for Landscape Condition Model; Prime Forest Land (MassGIS) --> Too coarse to use as distribution, but this dataset was used to verify accuracy other sources. Forest Habitat (RIGIS), Priority Natural Vegetation Communities (MassGIS)
Wading bird and ally colonies	Colonial Bird Nesting Area points (RIDEM Division of Fish and Wildlife) buffered by 10 meters	N/A
Fish or Wildlife-related Areas of Key Economic, Cultural, Recreational Significance		
Shellfish collection areas (e.g. quahogs)	Shellfish collection areas are near-shore areas that are traditional areas for both commercial and recreational collection of shellfish (especially digging of quahogs and other shellfish).	

Fish/Wildlife Element	*Data Source(s) Used*	*Data Sources Not Used and Why*
Cross-cutting Elements		
Continental and global Important Bird Areas	IBAs (Audubon Society) ["PRIORITY" IN ('Continental' , 'Global')]	N/A
Species of Greatest Conservation Need	Core Habitat for Imperiled Species (Nature's Network). Since this layer was derived from data on NatureServe element occurrences for multiple imperiled species, we feel this is the most appropriate layer to use to integrate disparate data across state boundaries.	Habitat Condition for Imperiled Species, Northeast U.S. (Western Pennsylvania Conservancy (Nature's Network)) --> This dataset was derived from the Nature's Network "Habitat Importance" dataset and were screened for habitat condition using the Index of Ecological Integrity. Since the Index of Ecological Integrity was developed using a condition model, weights could be "double-counted" since Vista will also be applying a condition model. It was therefore determined to not use a dataset developed using the Index of Ecological Integrity; Core Habitat for Imperiled Species, Northeast U.S. (Nature's Network/NALCC) --> This dataset was derived from Nature's Network "Habitat Condition" dataset, which used the Index of Ecological Integrity and therefore not appropriate to use in our Vista analysis (see reasoning above); MassGIS Data - NHESP Priority Habitats of Rare Species (MassGIS (NHESP)) --> Does not cover the whole study area (only the state of Mass).

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 Element Not Included in Assessment
River mussel habitat	No datasets found to represent this.
Atlantic herring essential fish habitat	Not deemed of significant conservation priority
Osprey/bald eagle nesting sites	No datasets found to represent this candidate element. The Massachusetts and Rhode Island Audubon Societies were both contacted about possible osprey/bald eagle nests. The Mass Audubon Society does not have any of this data, and we received no response from the RI Audubon Society.
Spadefoot toad occurrence areas	Lack of appropriate/sufficient data.
Spotted turtle occurrence areas	Lack of appropriate/sufficient data.
Vernal pools	Lack of appropriate/sufficient data for RI
Wood turtle distribution	Lack of appropriate/sufficient data.
River mussel habitat	No datasets found to represent this.

Table A5-3. Examples of species that rely on fish and wildlife elements explicitly included in this assessment. *ESA Status refers to species status under the U.S. Endangered Species Act.*

Included Element	Species Represented		ESA Status	G-rank	MA S-rank	RI S-rank
	Common Name	**Scientific Name**				
Atlantic beach and dune	American oystercatcher	*Haematopus palliatus*		G5	S2B	S2B, S2N
	Atlantic horseshoe crab	*Limulus polyphemus*		G5		SNR
	Green sea turtle	*Chelonia mydas*		G3	S1N	SNR
	Horned lark	*Eremophila alpestris*	FT (SE)	G5	S3B, S4N	S1B
	Kemp's ridley sea turtle	*Lepidochelys kempii*		G1	S1N	SNR
	Least tern	*Sternula antillarum*		G4	S2B	S2B, S2N
	Leatherback sea turtle	*Dermochelys coriacea*	FE	G2	S1S2N	SNR
	Loggerhead sea turtle	*Caretta*	FT (ST)	G3	S1N	SNR
	Northeastern beach tiger beetle	*Cicindela dorsalis*	FT	G3G4T2	S1	SX
	Piping plover	*Charadrius melodus*	FT	G3	S2B	S1B, S1N
	Roseate tern	*Sterna dougallii*	FE	G4	S2B, S3N	SHB, S1N
Brook trout streams/habitats	Brook trout	*Salvelinus fontanalis*		G5	S4	S5

Included Element	Species Represented		ESA Status	G-rank	MA S-rank	RI S-rank
	Common Name	Scientific Name				
Diadromous fish	Alewife	*Alosa pseudoharengus*		G5	S3S4	S3
	American eel	*Anguilla rostrata*		G4	S3S4	S5
	American shad	*Alosa sapidissima*		G5	S3S4	S1
	Atlantic sturgeon	*Acipenser oxyrinchus*	FE	G3	S1	SH
	Atlantic tomcod	*Microgadus tomcod*		G5	S4	SNR
	Blueback herring	*Alosa aestivalis*		G3G4	S3S4	S1
	Rainbow smelt	*Osmerus mordax*		G5	S3	S1
Freshwater meadows/sedge marshes	King rail	*Rallus elegans*		G4	S1B, S1N	S1B, S1N
	Least bittern	*Ixobrychus exilis*		G5	S1S2B	S2B, S2N
	Marsh wren	*Cistothorus palustris*		G5	S2S3B,S3N	S2B, S3N
	Pied-billed grebe	*Podilymbus podiceps*		G5	S1B, S4N	S1B
	Sora	*Porzana carolina*		G5	S2S3B, S4N	S1B, S1N
	Virginia rail	*Rallus limicola*		G5	S4B,S4N	S2B, S2N
	Wilson's snipe	*Gallinago delicata*		G5	S1S2B, S4N	SNA
Grassland birds	Barn owl	*Tyto alba*		G5	S2B, S2N	S1B, S1N
	Bobolink	*Dolichonyx oryzivorus*		G5	S3S4B	S3B
	Eastern meadowlark	*Sturnella magna*		G5	S3S4B	S3B
	Grasshopper sparrow	*Ammodramus savannarum*		G5	S3B	S1B, S1N
	Northern harrier	*Circus cyaneus*		G5	S2B, S4N	S1B, S3N
	Northern flicker	*Colaptes auratus*	FT (ST)	G5	S5	S5B, S5N
	Savannah sparrow	*Passerculus sandwichensis*		G5	S4B, S5M	S2S3B
	Short-eared owl	*Asio flammeus*		G5	S1B, S3N	S1N
	Upland sandpiper	*Bartramia longicauda*		G5	S1B, S1N	S1B, S1N
Harbor seal haulout sites	Harbor seal	*Phoca vitulina concolor*		G5T5	SNR	SNR
Salt marsh and tidal creek	American black duck	*Anas rubripes*		G5	S4	S4
	Clapper rail	*Rallus crepitans*		G5	S2B, S2N	S1B,S2N
	Nelson's sparrow	*Ammodramus nelsoni*		G5	S2N	SNA
	Northern diamond-backed terrapin	*Malaclemys terrapin*		G4	S2	S1
	Saltmarsh sparrow	*Ammodramus caudacutus*		G4	S3B	S3B
	Sand tiger shark	*Carcharias taurus*		G3G4		SNR
	Seaside sparrow	*Ammodramus maritimus*		G4	S2B	S2B

Included Element	Species Represented		ESA Status	G-rank	MA S-rank	RI S-rank
	Common Name	Scientific Name				
	Willet	*Tringa semipalmata*		G5	S3B, S3N	S1B,S3N
	Winter Flounder	*Pseudopleuronectes americanus*		G5		SNR
SAV/eelgrass beds and bay scallop habitat	Bay Scallop	*Argopecten irradians*		G5		SNR
Salt ponds	Canvasback	*Aythya valisineria*		G5	S3N	SNA
	Greater scaup	*Aythya marila*		G5	S5N	SNA
	Lesser scaup	*Aythya affinis*		G5	S5N	SNA
Shellfish collection area	Bay quahog	*Mercenaria*		G5		
	Sea scallop	*Placopecten magellanicus*				
	Soft-shell clam	*Mya arenaria*				
Shrubland habitats	New England cottontail	*Sylvilagus transitionalis*		G3	S2	S2
Shrubland nesting bird habitat	American woodcock	*Scolopax minor*		G5	S4B	S4B
	Blue-winged warbler	*Vermivora cyanoptera*		G5	S3S4B	S5B
	Brown thrasher	*Toxostoma rufum*		G5	S4	S4B
	Chestnut-sided warbler	*Setophaga pensylvanica*		G5	S5B	S5B
	Cuckoo		FE (SE)	G5	S4B, S4N	S5B, S5N
	Eastern kingbird	*Tyrannus*		G5	S5B	S5B,S5N
	Eastern towhee	*Pipilo erythrophthalmus*		G5	S4B	S5B
	Eastern whip-poor-will	*Antrostomus vociferus*		G5	S2S3B,S3N	S4B
	Field sparrow	*Spizella pusilla*		G5	S3S4	S4B
	Gray catbird	*Dumetella carolinensis*		G5	S5B,S2N	S5B
	Indigo bunting	*Passerina cyanea*		G5	S4B	S4B
	Nashville warbler	*Oreothlypis ruficapilla*		G5	S4B	S3B
	Prairie warbler	*Setophaga discolor*		G5	S3S4B	S5B
	Ruffed grouse	*Bonasa umbellus*		G5	S4	S5
	Willow flycatcher	*Empidonax traillii*		G5	S4B	S3B,S3N
	Yellow-breasted chat	*Icteria virens*		G5	S1B,S1N	S1B,S1N
Wading birds and ally colonies	Black-crowned night-heron	*Nycticorax*		G5	S2B	S2B
	Glossy ibis	*Plegadis falcinellus*		G5	S2B	S1B
	Great egret	*Ardea alba*		G5	S2B, S4N	S1B
	Great blue heron	*Ardea herodias*		G5	S4B,S5N	S2B

Included Element	Species Represented		ESA Status	G-rank	MA S-rank	RI S-rank
	Common Name	**Scientific Name**				
	Green heron	*Butorides virescens*		G5	S4B,S5M	S5B,S5N
	Snowy egret	*Egretta thula*		G5	S2B, S4N	S1B
	Yellow-crowned night-heron	*Nyctanassa violacea*		G5	S1B, S2N	S1B,S1N
Wetlands in general	Four-toed salamander	*Hemidactylium scutatum*		G5	S3S4	S3
	Jefferson salamander	*Ambystoma jeffersonianum*		G4	S2S3	
	Marbled salamander	*Ambystoma opacum*		G5	S2S3	S2
	Smoothlip fairy shrimp	*Eubranchipus intricatus*		G4	S1	
	Spring salamander	*Gyrinophilus porphyriticus*		G5	S3S4	S1
Wood turtle habitat/EOs	Sedge wren	*Cistothorus platensis*		G5	S1B,S1N	SNA
	Wood turtle	*Glyptemys insculpta*		G3	S3	S2

Appendix 6. Resilience Project Information

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

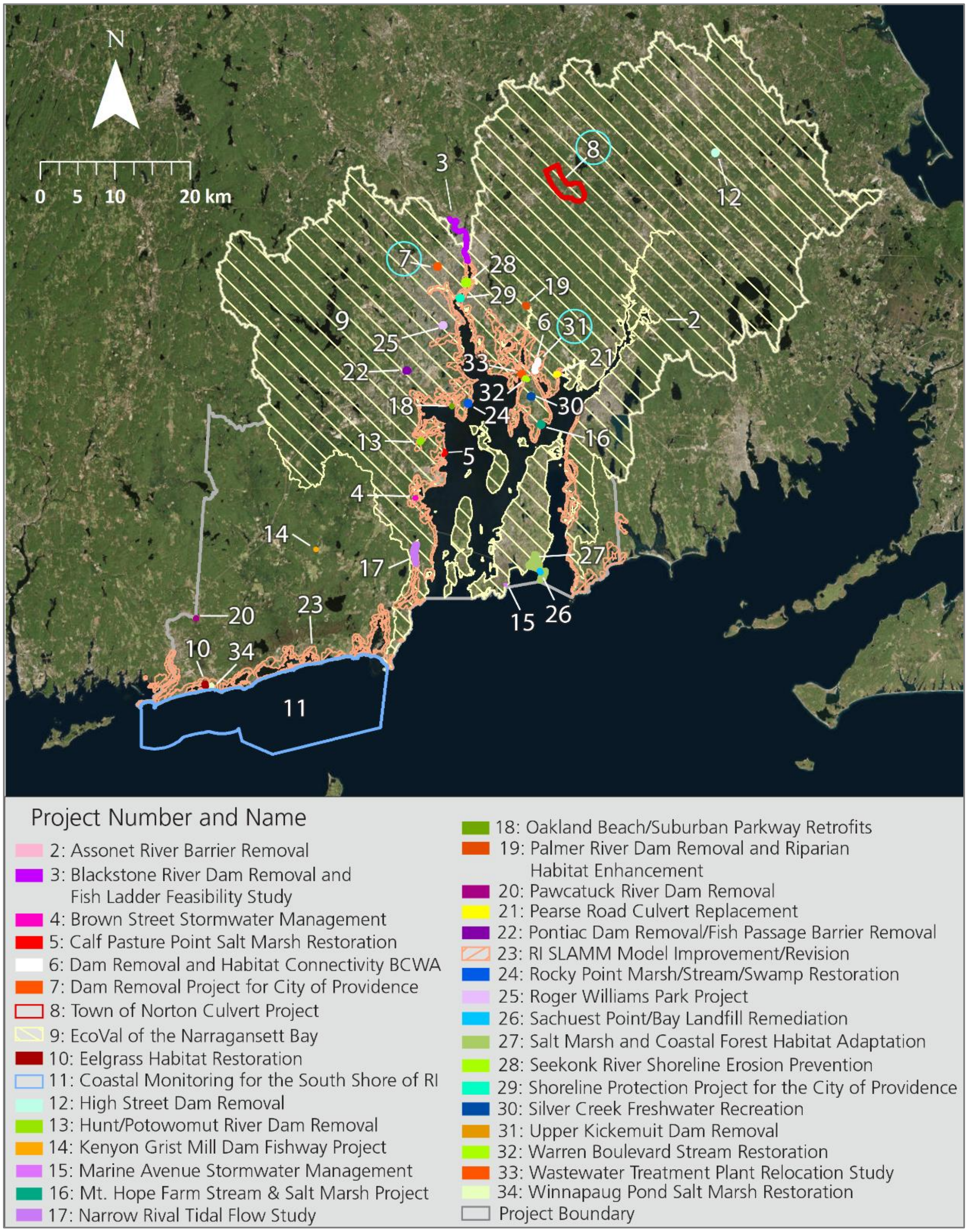


Figure A6-1. Map showing the boundaries of resilience projects compiled for the Narragansett Bay and Coastal Rhode Island Watersheds. *Detailed case studies were developed for projects #7, #8, and #31. Project #1 is not pictured on the map because no spatial data was submitted for it. See Table A6-1 for a full list of projects submitted.*

Resilience Projects Information as Submitted by Stakeholders

A summary of all resilience project submitted for the Narragansett Bay and Coastal Rhode Island 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 Narragansett Bay and Coastal Rhode Island Watersheds and the number of assets/elements mapped within each project boundary. *Sorted in order of Community Exposure Index, from greatest to least.*

Project Name	Community Exposure Index	Number of Human Assets Mapped	Fish/Wildlife Elements within Project Boundary	Map ID Number
Pontiac Dam removal/fish passage barrier removal	9	3	3	22
Assonet River barrier removal	6.66	4	7	2
Mt. Hope Farm stream and salt marsh project	6.21	1	13	16
High Street Dam removal	6	4	3	12
Brown Street Parking Lot, North Kingstown, RI stormwater management	5.57	2	4	4
Wastewater Treatment Plant Relocation Study	5.47	7	7	33
Kenyon Grist Mill dam fishway project	5.2	2	2	14
Oakland Beach/Suburban Parkway Retrofits, Warwick, RI	5	1	6	18
Pawcatuck River dam removal (Potter Hill dam)	4.69	4	3	20
Upper Kickemuit Dam Removal	4.37	6	8	31
Dam removal and habitat connectivity project for Briston County Water Authority	4.26	6	8	6
Dam Removal Project for City of Providence	4.19	10	4	7
Silver Creek freshwater recreation	4.14	1	6	30
Rocky Point Marsh/Stream/Swamp restoration	3.59	3	13	24
Narrow River tidal flow study	3.25	4	9	17
RI SLAMM model improvement/revision	3.17	11	23	23
Hunt/Potowomut River dam removal (Forge Road dam)	3.11	2	5	13
Blackstone River dam removal/fish ladder feasibility study	3.04	7	8	3

Project Name	Community Exposure Index	Number of Human Assets Mapped	Fish/Wildlife Elements within Project Boundary	Map ID Number
Winnapaug Pond salt marsh restoration implementation	3	1	6	34
Expand and maintain coastal monitoring network for the south shore of Rhode Island	2.99 (Off the coast and only overlaps a small amount with most of the Community Exposure Index outside of the target watershed)	4	8	11
Calf Pasture Point Salt Marsh Restoration project	2.95	(none)	8	5
Shoreline Protection Project for the City of Providence	2.76	3	8	29
Palmer River dam removal and riparian habitat enhancement	2.65	3	4	19
Marine Avenue Stormwater Management (Newport, RI)	2.62	2	3	15
EcoVal: Economic Value of the Narragansett Bay and its Neighboring Estuaries	2.61	11	23	9
Seekonk River shoreline erosion prevention	2.59	4	7	28
Sachuest Point/Sachuest Bay landfill remediation project	2.22	(none)	7	26
Salt Marsh and Coastal Forest habitat adaptation project	2.12	2	17	27
Roger Williams Park project	1.33	2	3	25
Eelgrass habitat restoration (dredging shoaling)	0 (Located in water, which Community Exposure Index does not cover)	(none)	1	10
Artificial shellfish reef installation	Unknown (no spatial data submitted)	Unknown (no spatial data submitted)	Unknown (no spatial data submitted)	1
Warren Boulevard Stream Restoration	Unknown (no spatial data submitted)	Unknown (no spatial data submitted)	Unknown (no spatial data submitted)	32
Pearse Road culvert replacement in the Town of Swansea	Unknown	Unknown	Unknown	21

Project Name	Community Exposure Index	Number of Human Assets Mapped	Fish/Wildlife Elements within Project Boundary	Map ID Number
	(no spatial data submitted)	(no spatial data submitted)	(no spatial data submitted)	
Designing improved culvert conditions by assessing flow capacities for the Town of Norton, MA	Currently Unknown (Still needs to be calculated)	1	5	8

Project ID# 1
Name: Artificial shellfish reef installation
Submitted by: Scheri Fultineer
Organization: Rhode Island School of Design
Project Type: Beach or dune restoration, Community resilience planning, Living shoreline implementation
Description: https://www.ecori.org/aquaculture/2016/7/23/artificial-shellfish-reefs-installed-along-providence-waterfront

Project ID# 2
Name: Assonet River barrier removal
Submitted by: Rachel Calabro
Organization: Save The Bay
Project Type: Dam removal/fish passage, Restoration of aquatic connectivity
Description: Removal of the first barrier on the Assonet River in Freetown Massachusetts will restore the Assonet River for migratory fish and will prevent flooding of downtown and protect low lying bridges.

Project ID# 3
Name: Blackstone River dam removal/fish ladder feasibility study
Submitted by: TBD (Larry Oliver)
Organization: US Army Corps of Engineers
Project Type: Dam removal/fish passage
Description: Examining the feasibility of fish ladders and dam removal on the lower three dams on the Blackstone River

Project ID# 4
Name: Brown Street Parking Lot, North Kingstown, RI stormwater management
Submitted by: Pam Rubinoff
Organization: URI Coastal Resources Center
Project Type: Green infrastructure implementations
Description: The Place: Wickford, North Kingstown: The Brown Street waterfront parking lot is in the heart of downtown Wickford Historic Village. It is a key element to support this historical, recreational, and economic hub in North Kingstown, Rhode Island. The Problem: Flooding and Water Quality: This low-lying area is vulnerable to flooding from extreme high tides, rain events and coastal storms. Aging subsurface infrastructure drains untreated stormwater from the parking lot to the harbor; the substrate is likely not suitable for infiltration; tides come up through outfalls. The parking lot serves multiple uses for business and waterfront access, and has multiple owners, both public and private. These issues will be more prominent in the future with

sea level rise and increased storm intensity. Goals and objectives: i. Consider short and medium-term options to enhance resilience while long- term options for Wickford are explored. Minimize nuisance flooding and reduce pollutants to the harbor. Elevate areas and install green infrastructure where feasible. Enhance access to the water, civic space and visibility for local businesses and maintain number of parking spots. Expand walkways, reconfigure parking spaces and flow, and install landscape features. Build on relationships with businesses and the public to promote dialog, collaborate on design, and implement actions. Raise awareness of sea level rise and water quality issues related to sediments and untreated stormwater. Incorporate good practices in municipal design guidance and standards. Evaluate long-term strategies to sea level rise including options to protect, retreat and accommodate. Incorporate these in the Comprehensive Plan and Hazard Mitigation Plan. The Solution: Green Infrastructure. Management practices use a 20-year design life to reduce impacts while long-term solutions identified. Green Infrastructure is a nature-based adaptation tool for: Stormwater filtration and infiltration; addressing shoreline erosion and failure of existing grey infrastructure; Restoration and enhancement of natural habitats. Green infrastructure practices: Use designed or engineered systems that use soil and vegetation to capture water; aim to preserve natural hydrology of watershed; reduce stress on and need for traditional "grey" or "hard" design; are applied and adaptable at different scales. Opportunities and Benefits for the Community and the Municipality. Cost-effective and practical solutions for reducing stormwater and water quality issues provides multiple benefits: Reduced contamination to coastal waters & shellfish habitats, improving public health and safety; less pressure on aging grey infrastructure; restoration of natural areas for native pollinators; enhanced public shore access and aesthetics of civic space; opportunities for public education and buy-in; promotes economic vitality, local business hubs and support for jobs.

Project ID# 5
Name: Calf Pasture Point Salt Marsh Restoration project
Submitted by: TBD (Larry Oliver)
Organization: US Army Corps of Engineers
Project Type: Marsh restoration
Description: Remove fill to restore salt marsh at Calf Pasture Point.

Project ID# 6
Name: Dam removal and habitat connectivity project for Bristol County Water Authority
Submitted by: Ken Booth
Organization: Bristol County Water Authority
Project Type: Restoration of aquatic connectivity, Riparian and floodplain restoration
Description: This project seeks to remove two dams to restore habitat connectivity and increase flood plain area for salt marsh expansion.

Project ID# 7
Name: Dam Removal Project for City of Providence
Submitted by: Wendy Nilsson
Organization: City of Providence,
Rhode Island
Project Type: Restoration of aquatic connectivity
Description: This dam removal will allow the passage of fish and will prevent flooding from this dam which is in poor condition.

Project ID# 8
Name: Designing improved culvert conditions by assessing flow capacities for the Town of Norton, MA
Submitted by: Bill Napolitano
Organization: Southeastern Regional Planning and Economic Development District (SRPEDD)
Project Type: Community resilience planning, Restoration of aquatic connectivity
Description: The overall approach to this 2016-2017 project was to determine and compare the flow capacities of several types of hydraulic structures in order to find one that improved the existing culvert conditions while remaining a practical financial option for the Town.

Project ID# 9
Name: EcoVal: Economic Value of the Narragansett Bay and its Neighboring Estuaries
Submitted by: Emi Uchida
Organization: University of Rhode Island
Project Type: Valuation of ecosystem services
Description: This proposed project will quantify the economic value of key ecosystem services from the Narragansett Bay watershed, spanning both Rhode Island and Massachusetts. The project will identify major uses and economic sectors and characterize the size of the economy. It will model the watershed's key ecosystem services—water quality, recreational benefits, coastal resiliency, and energy—to quantify these benefits and values to society. An economic valuation model will allow us to simulate the impact on these benefits and measure possible tradeoffs created by future policy scenarios involving urban development, green infrastructure, and climate change.

Project ID# 10
Name: Eelgrass habitat restoration (dredging shoaling)
Submitted by: TBD (Larry Oliver)
Organization: US Army Corps of Engineers
Project Type: Eelgrass restoration
Description: Dredging shoaling at the entrance to the Winnapaug salt pond to restore eelgrass habitat (10-12 acres).

Project ID# 11
Name: Expand and maintain coastal monitoring network for the south shore of Rhode Island
Submitted by: John W. King
Organization: University of Rhode Island Graduate School of Oceanography
Project Type: Maintain and expand a sea level rise and coastal erosion monitoring system
Description: With prior NFWF funding, we have done an initial detailed baseline characterization of the south shore of RI. We have constructed and deployed a coastal observing/monitoring network for the area that is providing detailed and accurate data inputs/boundary conditions for a suite of coastal modeling/engineering tools developed in parallel and intended to provide outputs that will underpin management policies/practices aimed at enhancement of coastal resiliency in RI. This network includes tide gauges, bottom mounted current and wave meters, and a terrestrial LiDAR system for monitoring coastal erosion. The proposed project will help maintain the existing monitoring network and allow expansion of the network and will represent the next step in developing a statewide program for enhancing coastal resiliency that will be a national model. Furthermore, this project will be the next step in creating a clearing-house for best practices in coastal adaptation to enhance resiliency that will be available to cities/municipalities and the general public. We propose a three-year project with an annual budget of $200,000 per year.

Project ID# 12
Name: High Street Dam removal
Submitted by: Sara Turner
Organization: MA Division of Marine Fisheries
Project Type: Dam removal/fish passage
Description: The High St dam in located on the Town River, one of two tributaries that join to form the Taunton River. This dam is listed by the MA Office of Dam Safety as a significant hazard in poor condition. A dam removal feasibility study in underway, and will be completed before the end of the year. This dam is a public safety risk, and also has negative impacts on ecological processes.

Project ID# 13
Name: Hunt/Potowomut River dam removal (Forge Road dam)
Submitted by: Rachel Calabro
Organization: Save The Bay
Project Type: Dam removal/fish passage, Restoration of aquatic connectivity, Riparian and floodplain restoration
Description: Removal of the Forge Road dam on the Hunt/Potowomut River would allow fish passage and restore a degraded wetland. It would allow sea level rise to push brackish marsh up past Forge Road and would prevent flooding due to the poor condition of the dam.

Project ID# 14
Name: Kenyon Grist Mill dam fishway project
Submitted by: Jim Turek
Organization: NOAA Restoration Center
Project Type: Dam removal/fish passage
Description: Kenyon Grist Mill (Glenn Rock Reservoir) dam is an historic structure on the Queens River, a tributary to the Pawcatuck River in Usquepaugh, RI. The 5-ft high structure is associated with the well-known Kenyon Grist Mill. Removal of this dam is unlikely, although a nature-like fishway may be possible, along with modifications to the dam.

Project ID# 15
Name: Marine Avenue Stormwater Management (Newport, RI)
Submitted by: Pam Rubinoff
Organization: URI Coastal Resources Center
Project Type: Green infrastructure implementations
Description: a. The Problem: Water Quality and Erosion. During rain storms, runoff from the land and impervious surfaces carries nutrients, bacteria, and sediment down Wetmore and Marine Avenue, causing erosion of the path to the Cliff Walk and sending harmful pollutants into the cove. The untreated stormwater impacts safe public access to the Cliff Walk, and the area's many recreational uses including walking, swimming, surfing, and fishing. Design: Incorporate both stormwater conveyance and coastal wave energy Reduce runoff from adjacent properties; design for today and future - define base conditions and scenarios for future (return period may be different for precipitation and storm surge); slow down stormwater to decrease bank erosion; improve water quality - address first flush to mitigate pollutants; work with abutters to adopt management strategies for turf, landscapes (longer term); infiltration on adjacent private property to reduce volume; preserve public access at Cliff Walk through shoreline management and minimizing hazards from erosion. Techniques: optimize site to determine solution and trade-offs; provide "better alternatives" that illustrate cost avoidance measures. Management: commit to maintenance and monitoring—videos, photos, data.

Project ID# 16
Name: Mt. Hope Farm stream and salt marsh project
Submitted by: Unknown
Organization: No organization listed, but the partners listed are: Bristol Landing Condo Association and Mt. Hope Farm
Project Type: Community resilience planning, Dam removal/fish passage, Marsh restoration, Restoration of aquatic connectivity, Riparian and floodplain restoration, Wetlands restored/enhanced
Description: Salt Marsh & Stream) Your property appears to include a small salt marsh. These are scarce enough now and very precious as habitat for birds, fish, and shellfish as well as for cleaning polluted groundwater and surface water runoff before it hits the bay and moderating storm surges as they come from the bay onto land. Over the next 30-80 years, present day salt marshes will be overwhelmed by sea level rise. The only places that will still be salt marshes in the future are those salt marshes that have low lying freshwater marshes or low lying wet grassland just inland of them today. Yours is just that sort of place as shown in the attached figure taken from CRMC's sea level modeling. You can see your site is the only one on the whole of southeast Bristol that will retain a salt marsh in the future. Your property also has a stream flowing across it from north to south, draining the farm ponds around Mt. Hope Farm into the bay through the salt marsh. RINHS held one of our BioBlitz biodiversity inventories at Mt. Hope in 2005 and we know from that event that this stream supports a number of fish, turtle, and insect species that have conservation value, such as the American eel. To manage the stream properly, you need strike a balance between preventing fallen trees and bushes from clogging it while also leaving lush vegetation along the edges to shelter animals and shade the stream and keep it cool. You can open areas along it to walk up to it and view it, but should leave the immediate area around it vegetated and wild. You might want to make management of the stream a subject of discussion with the management of Mt. Hope Farm. You both have an interest in keeping the stream clean and healthy for wildlife. They should particularly be cautioned to keep animal waste and erosion out of the stream where it flows through their farm. Your management plan should take into account the likely movement of that salt marsh inland in the future by avoiding putting any infrastructure there such as paths. There is an old farm road with broken culvert that currently separates the salt marsh from the freshwater marsh that is its logical path of retreat. You should reconstruct the culvert to create a natural path for bi-directional waterflow that will allow the site to respond naturally to rising sea levels. You should also maintain and monitor stormwater structures uphill of the salt marsh and maintain the stream the flows through it.

Project ID# 17
Name: Narrow River tidal flow study
Submitted by: Mitch Hartley
Organization: Atlantic Coast Joint Venture / US Fish & Wildlife Service
Project Type: Marsh restoration, Wetlands created, Wetlands restored/enhanced
Description: This project would evaluate tidal flow in the Narrow River, which currently has tidal restrictions that are eliminating or impeding 500-700 acres of tidal marsh in the watershed. Restoring tidal flow would require a combination of hydrological models, assessment of land ownership, possibly additional land protection, and restoration/improvement of transportation infrastructure (e.g., roads and bridges) to allow more natural tidal flow.

Project ID# 18
Name: Oakland Beach/Suburban Parkway Retrofits, Warwick, RI
Submitted by: Pam Rubinoff
Organization: URI Coastal Resources Center
Project Type: Green infrastructure implementations
Description: a. Design: Minimize beach closures; minimize first flush, reduce volume and rate of runoff; optimize parking (don't want to lose any spaces); manage solid waste—trash feeds gulls; reduce standing water (during precipitation events, not tides??); determine impact of long term sea level rise. Techniques: maintain view at beach and from within neighborhood; engage public through outreach campaign—local and visitors (feeding birds, trash), locals (land use and fertilizer); package with aesthetic of RI—local appearance and feel; understand permitting and regulations (allowable uses, restrictions, etc.); understand permitting and regulations (allowable uses, restrictions, etc.). Maintenance: reduce invasive species and ensure maintenance planning is part of design process.

Project ID# 19
Name: Palmer River dam removal and riparian habitat enhancement
Submitted by: Ken Booth
Organization: Bristol County Water Authority
Project Type: Restoration of aquatic connectivity, Riparian and floodplain restoration
Description: This project seeks to remove a dam and enhance riparian areas and flood plains. It will improve water quality and habitat for herring and shad in the Palmer River.

Project ID# 20
Name: Pawcatuck River dam removal (Potter Hill dam)
Submitted by: Jim Turek
Organization: NOAA Restoration Center
Project Type: Dam removal/fish passage, Restoration of aquatic connectivity, Wetlands restored/enhanced
Description: Potter Hill dam is the last remaining dam on the lower Pawcatuck River in Westerly, RI. The dam, last reconstructed in 1903 is a 9-ft high structure that prevents upstream passage by river herring, American shad, American eel and other fish species. While a technical fishway exists on the dam, it is limited by passage problems. Full dam removal or removal of the dam with replacement by a river-wide nature-like fishway are potential design alternatives.

Project ID# 21
Name: Pearse Road culvert replacement in the Town of Swansea
Submitted by: Bill Napolitano
Organization: Southeastern Regional Planning and Economic Development District (SRPEDD)
Project Type: Community resilience planning
Description: The Pearse Road culvert is an ancient dry stone masonry culvert which crosses under the road and connects a significant upland drainage area to Mount Hope Bay. Located along the waterfront of the upper Mount Hope Bay, Pearse Road is also the primary access route for emergency vehicles serving the adjacent neighborhoods. When Pearse Road is overtopped to a significant depth, conventional fire and rescue vehicles cannot travel it and emergency vehicles must make a lengthy detour, traveling three times the distance to Long Lane and Barton Ave in Warren, RI, adding significantly to response time. In the Fall of 2015, the Town commissioned Tighe & Bond Consulting Engineers to undertake a study of the culvert's capacity and viability in light of anticipated sea level rise. As a result of this study, the Town is moving forward with plans to replace the

culvert with a modern precast concrete structure which will not only meet the standards required for stream crossings, but will also be 18 inches higher in order to reduce the incidence of roadway flooding.

Project ID# 22
Name: Pontiac Dam removal/fish passage barrier removal
Submitted by: Jim Turek
Organization: NOAA Restoration Center
Project Type: Dam removal/fish passage, Restoration of aquatic connectivity, Riparian and floodplain restoration, Wetlands restored/enhanced
Description: Pontiac Dam is a defunct structure that is a total barrier to diadromous fish passage on the Pawtuxet River in Cranston, RI. Feasibility study was previously initiated. The project needs a strong lead to advance this fish passage barrier removal.

Project ID# 23
Name: RI SLAMM model improvement/revision
Submitted by: Peter August
Organization: University of Rhode Island
Project Type: Community resilience planning
Description: We will re-run the RI SLAMM model with more current parameter data where available (e.g., incorporation of Superstorm Sandy Lidar DEM and updated marsh accretion rates) and incorporate NOAA's current 2100 sea level rise estimate of 3.0 m for our region. Using the most recent science on marsh migration in RI from NBNERR and RINHS, as well as other collateral GIS data (e.g., imagery, landcover, roads, shoreline protection structures), we will identify individual land parcels that can serve as marsh migration corridors. We will rank individual parcels based on ownership, geomorphology, and the potential for removal of any barriers to migration (e.g., sea walls, rip-rap). Our prioritization of parcels will serve as the basis for future land protection and restoration activities. The final step of the project will be intensive outreach to communicate our results to state, federal, and NGO conservation organizations (e.g., land trusts, The Nature Conservancy) who comprise the land conservation community in Rhode Island.

Project ID# 24
Name: Rocky Point Marsh/Stream/Swamp restoration
Submitted by: Unknown
Organization: No organization listed, but the partners listed are:
Rocky Point Foundation; City of Warwick
Rhode Island Department of Environmental Management
Rhode Island School of Design
Rhode Island Natural History Survey
Project Type: Community resilience planning, Dam removal/fish passage, Marsh restoration, Restoration of aquatic connectivity
Description: Rocky Point has a swamp/stream/marsh system that flows south west of the ridge and enters Narragansett Bay through a small pond and salt marsh located west of the old swimming pool area. The near-shore biodiversity in this location was observed to be good, possibly indicating above average productivity as a result of diverse micro-habitats and the influx of freshwater and nutrients. As interesting as this freshwater stream appears to be, it has several impairments that could be investigated and mitigated. The stream drains southward through the woods west of Palmer Ave., which means it is somewhat buffered from overly-enriched run-off and warming. Then it flows through a culvert under Rocky Point Ave., somewhere joins water from east of Palmer Ave., and then flows along the back of the parking lot. There it is canalized into a straight strip lined

with trap-rock and choked with invasive plants and receiving trash, sediment, and run-off from the back of the parking area. The culvert location and connections should be investigated and opportunities for daylighting the stream explored. The trap-rock section along the parking lot should be re-engineered to create changes in direction and slope, shade, and other beneficial habitat features and to capture and mitigate parking lot run-off. Finally, the stream runs into the small pond behind the old swimming pool and from there into a culvert that used to go under the beach into the sea. This culvert is clogged and broken and the stream flows up and out of it through the beach sand. This culvert should be eliminated and direct, surface flow from the pond to the beach reestablished. All this would support healthy natural biodiversity in the stream and make the wetlands and near-shore waters even more productive. Another area of ecological opportunity is the low-lying south-facing cove/shoreline just north of the old Shore Dining Hall and inshore (West) of the eponymous Rocky Point promontory. This area is composed of fill, covered with poor quality grass, and protected from the sea by rip-rap. It has notably low ecological value as it is but in a scenario of rising sea-level it could be an area for future salt marsh development/shoreline retreat.

Project ID# 25
Name: Roger Williams Park project
Submitted by: Unknown
Organization: Roger Williams Park Conservancy
Project Type: Green infrastructure implementations, Living shoreline implementation, Restoration of aquatic connectivity, Riparian and floodplain restoration, Wetlands restored/enhanced, Community Engagement
Description: Roger Williams Park is the largest area of open space in Providence, with more than a million visitors each year. Its centerpiece is a hundred acres of freshwater ponds. The RWP Ponds are an important recreational resource for boating, fishing and visual enjoyment—but they are in trouble. Urban run-off and overpopulated waterfowl are polluting the ponds, destroying the aesthetic quality of the water, creating noxious odors, leading to the growth of toxic algae, and harming fish and wildlife habitat in the Pawtuxet River watershed and Narragansett Bay.

Project ID# 26
Name: Sachuest Point/Sachuest Bay landfill remediation project
Submitted by: Karrie Schwaab
Organization: USFWS
Project Type: Beach or dune restoration, Community resilience planning, Marsh restoration, Upland restoration
Description: A portion of the salt marsh at Sachuest Point National Wildlife Refuge was once used as the municipal waste site for the Town of Middletown. In 2004 the trash was removed from the salt marsh and placed on higher land adjacent to the marsh. This new landfill was capped and planted with grassland species. A liner was placed above the landfill but not below the landfill. The landfill is within 150 feet of Sachuest Bay and is vulnerable to sea-level rise, storm surge, and future storm events (hurricanes and Nor'easters). We have contracted EA Engineering, Science, and Technology, Inc., PBC to assess the resiliency of the Sachuest Point Remediated Landfill Cap. They will develop conceptual designs that will be suitable for short term protection (0-50 years) and concurrently designs for the removal of the landfill and restoration plan for the site. The contractor will also provide opinion costs for the alternate designs.

Project ID# 27
Name: Salt Marsh and Coastal Forest habitat adaptation project
Submitted by: David Gregg
Organization: Rhode Island Natural History Survey
Project Type: Community resilience planning, Marsh restoration, Upland restoration
Description: This project adapts regionally rare salt marsh and adjacent coastal forest habitats important to migratory birds to enhance their function in likely climate change scenarios. Neighbors join the work and tour the results to increase their understanding of climate adaptation and to see models applicable elsewhere.

Project ID# 28
Name: Seekonk River shoreline erosion prevention
Submitted by: Wendy Nilsson
Organization: City of Providence,
Rhode Island
Project Type: Community resilience planning, Living shoreline implementation, Green infrastructure implementations
Description: This project seeks to treat stormwater and prevent erosion along a stretch of the Seekonk River Shoreline in Providence, RI. The project will include public access to the shoreline with pedestrian, bicycle and canoe access.

Project ID# 29
Name: Shoreline Protection Project for the City of Providence
Submitted by: Wendy Nilsson
Organization: City of Providence,
Rhode Island
Project Type: Living shoreline implementation
Description: Shoreline protection project to prevent erosion and increase resiliency with living shoreline and wall enhancement.

Project ID# 30
Name: Silver Creek freshwater recreation
Submitted by: Wenley Ferguson
Organization: Save The Bay
Town of Bristol
Project Type: Wetlands created
Description: Potential project to recreate a freshwater wetland in the Silver Creek watershed to restore habitat and flood storage capacity.

Project ID# 31
Name: Upper Kickemuit Dam Removal
Submitted by: Pam Marchand
Organization: Bristol County Water Authority
Project Type: Dam removal/fish passage, Restoration of aquatic connectivity, Wetlands restored/enhanced
Description: This project would remove the upper dam of the Kickemuit Reservoir, restoring connectivity of the waterway and enhancing water quality. As part of this project, nearby Schoolhouse Road (already programmed by RIDOT for resurfacing) should be elevated to accommodate sea level rise and climate change and the culverts under the road should be upsized.

Project ID# 32
Name: Warren Boulevard Stream Restoration
Submitted by: Kate Michaud
Organization: Town of Warren
Project Type: Green infrastructure implementations, Riparian and floodplain restoration, Wetlands restored/enhanced
Description: The Town of Warren, Rhode Island (the Town) proposes to replace approximately 600 linear feet of an undersized and deteriorated dry stacked masonry drainage channel with a vegetated open swale between Main Street and Warren Boulevard. Additionally, a 24-inch culvert located beneath Warren Boulevard at the upstream end of the channel will be upsized. Together these improvements will 1) mitigate ponding and flooding of adjacent residential properties and Warren Boulevard 2) Improve native habitat by restoring a more natural floodplain and 3) Store and infiltrate stormwater. The project will also serve as a demonstration to the public to show how green infrastructure and bioengineering can be used to address local flooding, create native stream habitat, and improve stormwater quality.

Project ID# 33
Name: Wastewater Treatment Plant Relocation Study
Submitted by: Kate Michaud
Organization: Town of Warren, RI
Project Type: Community resilience planning
Description: The Town of Warren has extensively studied the location of its existing wastewater treatment facility using the best available information as provided by URI, NACCS and CRMC. As a result, it has become apparent that more than 3-feet of sea level rise will render the site virtually unusable for its intended purpose. Further elevation and flood proofing would be cost prohibitive and would, in essence, create an island with no access. Warren is not unique in this problem and serious study is needed to determine if wastewater treatment should be regional or if it should be decentralized, with smaller package plants located outside of the floodplain. Resources should be pooled across state lines where appropriate to effectively tackle this issue. Current projections are that Warren's plant is in trouble by 2065. In the world of government, time is short.

Project ID# 34
Name: Winnapaug Pond salt marsh restoration implementation
Submitted by: Caitlin Chaffee
Organization: Coastal Resources Management Council
Project Type: Marsh restoration
Description: Winnapaug Pond is one of South County's important salt ponds, located in Westerly, RI. Salt marshes in this pond, as in the other salt ponds, are rapidly degrading due to sea level rise and the loss of normal tidal wetting and drying. Waterlogged peat is resulting in the loss of the salt marsh plant community, and rapidly expanding peat flats and open water. One solution is thin-layer placement (TLP) of soils or dredged sediments, similar to the CRMC-led Ninigret and Quonnachontaug Pond TLP projects. CRMC has the project targeted with design, but funds are needed for implementation.

Appendix 7. Summary of Additional Studies and Plans

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

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

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
The State of Narragansett Bay and Its Watershed Technical Report Narragansett Bay Estuary Program. September 9, 2017. *State of Narragansett Bay and Its Watershed*. Technical Report. Providence, RI. http://nbep.org/the-state-of-our-watershed/technicalreport/ [2017_State-of-Narragansett-Bay-and-Its-Watershed]	Narragansett Bay and its Watershed	Bay scallops, flounder, striped bass, tautog, and seahorses; common mummichog, sticklebacks, and silversides; pollution-tolerant and pollution-sensitive benthic species (crustaceans called *Ampelisca* amphipod species); estuarine fish communities: opportunistic seasonal migrant species (scup, butterfish) displacing demersal resident species (winter flounder, red hake); American lobster; stream benthic macro-invertebrates (insects, worms, snails, mussels, and crayfish); freshwater fish: brook trout, longnose dace, blacknose dace, pumpkinseed, chain pickerel, yellow perch; shellfish (oyster).	Infrastructure such as wastewater treatment facilities, buildings, dams, and roads; septic systems and cesspools; engineered retention systems; green infrastructure; tunnels that store combined sewer overflow discharges; marine beaches; shellfishing areas.	Increasing air and water temperatures (freshwater and marine); more extreme precipitation events with changes in precipitation patterns (less snow, more rain); more intense tropical storms; dramatic increase in relative sea level rise; alteration in the species composition, structure, and function of Narragansett Bay Watershed ecosystems; more intense coastal and inland flooding; coastal acidification; increased flooding and erosion of coastal properties; loss of salt marshes; potentially more beach closures due to pathogens.
Massachusetts State Wildlife Action Plan 2015	Commonwealth of	287 animals Species of Greatest Conservation Need (SGCN).	Conservation easements; national wildlife refuges;	Predicted higher precipitation rates and increased groundwater tables;

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Massachusetts Division of Fisheries and Wildlife. November 8, 2016. *Massachusetts State Wildlife Action Plan 2015*. Westborough, MA. http://www.mass.gov/eea/agencies/dfg/dfw/wildlife-habitat-conservation/state-wildlife-conservation-strategy.html [Ma-swap]	Massachusetts		federal lands; military bases; state, municipal, private, and tribal lands; transportation infrastructure (contains 11,918 miles of highways and major roads and 24,471 miles of local roads).	warmer temperatures; longer and more severe summer droughts; shorter but more intense winter/spring floods; reduced extent and duration of winter snow cover causing contraction, fragmentation, or alteration of the hydrological regime of habitats; increase in severe weather events and sea-level rise; increase in invasive species.
Rhode Island Wildlife Action Plan The Rhode Island Department of Environmental Management Division of Fish and Wildlife. 2015. *Rhode Island Wildlife Action Plan*. Providence, RI. http://www.dem.ri.gov/programs/fish-wildlife/wildlifehuntered/swap15.php [2015_RIWAP]	State of Rhode Island	874 vertebrate species: birds (more than 430), fish (306), mammals (92), reptiles (26), and amphibians (19); more than 3,500 invertebrate species (beetles, butterflies, moths, and other insects; freshwater mollusks, annelids, crustaceans, and other marine invertebrates). 454 Species of Greatest Conservation Need (SGCN).	Fishery; birdwatching sites; fishing and hunting areas; conservation easements; private lands; development areas; transportation infrastructure; working farms and prime farmland; forests; drinking water sources; lands used for recreation.	Predicted higher air and water temperatures; reduced extent and duration of snow cover; more frequent and severe summer droughts; earlier and more prolonged low-flow periods in rivers and streams; winter and spring floods of shorter duration but higher intensity; delayed ice formation and earlier spring melt; increasing overall precipitation and shifts in winter precipitation type; sea-level rise; increasing invasive species and population vulnerabilities; species shifting habitat ranges; threats to wildlife exacerbated.
Massachusetts Climate Change Adaptation Report Executive Office of Energy and Environmental Affairs and the	Commonwealth of Massachusetts	Fish (commercially important seafood species such as lobster, cod, Atlantic salmon; finfish, shellfish; diadromous fishes;	Key infrastructure sectors: water, energy, transportation, dam safety & flood control, solid & hazardous waste, built infrastructure & buildings,	Accelerating sea level rise and increasing storm surges; potential increased frequency and intensity of storms; shifts in ocean temperature, currents and chemistry; higher

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Adaptation Advisory Committee. September 2011. *Massachusetts Climate Change Adaptation Report*. Boston, MA. http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf [eea-climate-adaptation-report-mass]		coldwater species; pelagic fish, forage fish). Wildlife (avifauna, marine mammals, macro- and micro-invertebrates; endangered sea turtles, seabirds, bats, benthic fauna).	telecommunications; public health infrastructure; public beaches; homes & businesses; waterways; weather-dependent industries: agriculture, forestry, fisheries, manufacturing, service industries; coastal structures: bulkheads, seawalls, revetments, groins, jetties, breakwaters, hurricane barriers, and flood and tide gates.	ambient temperature and more extreme heat days; warmer winters; precipitation shifts; more extreme rain events and frequent flooding; more droughts; decreasing winter snowpack; increasing pests and diseases causing reduced or degraded habitats; more threats to public health due to greater exposure to disease vectors and pesticide application; worse ambient air quality; affected quality and quantity of water supplies; more vulnerable agriculture and food systems.
State of the Birds 2017: Massachusetts Birds and Our Changing Climate Walsh, Joan M., and Margo S.V. Servison (Eds.), September 2017. *State of the Birds 2017: Massachusetts Birds and Our Changing Climate*. Massachusetts Audubon Society. Lincoln, Massachusetts. https://www.massaudubon.org/content/download/21633/304821/file/mass-audubon_state-of-the-birds-2017-report.pdf [mass-audubon_state-of-the-birds-2017-report]	Commonwealth of Massachusetts	One hundred forty-three (143) breeding bird species of Massachusetts.	Sandy beaches; islands; coastal banks with built jetties, groins, and seawalls; green infrastructure; human development on salt marshes; living shorelines; private forested lands.	Increased average air temperature year-round; longer warm seasons and shorter cold seasons; more precipitation falling as rain rather than snow; increased frequency of large precipitation events; increasing frequency and intensity of storms; sea level rise; increasing ocean acidification; more frequent coastal flooding; rising ocean surface temperatures; fundamental processes being disrupted such as altered marine food webs and shifts in phenology; additional stress to already stressed environments.

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Assessment and Identification of Implementable Climate Change Adaptation Strategies on the Lower Pawtuxet River Narragansett Bay Estuary Program, February 2013. Assessment and Identification of Implementable Climate Change Adaptation Strategies on the Lower Pawtuxet River. Narragansett, RI [CRE-report-no-figs-27feb13]	Lower Pawtuxet River Watershed of Narragansett Bay, RI	Native migratory fish, such as river herring and American shad; Canada geese.	Reservoirs; transportation infrastructure; urban areas; municipalities; commercial development; water supply and treatment infrastructure; flood control infrastructure; homes; businesses; sewer utilities; rain gardens; biological retention basins; fish and wildlife migration corridors; low impact infrastructure; floodplain lands; tree canopies and vegetated pavements; riparian zones; dams; historic mills; public fishing access; river-walkway; greenway; bicycle and pedestrian facilities.	Changes in precipitation and temperature; sea-level rise; flooding; more extreme precipitation events (intense rainstorms and snowstorms); temperature change effects on natural systems and potential damage from aging infrastructure like dams and undersized culverts.
Regional Reports for northeast U.S.				
Ch. 16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz, October 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 Research Program, 16-1-nn.	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 pest pressure; agriculture,

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
http://nca2014.globalchange.gov/report/regions/northeast [NCA3_Full_Report_16_Northeast]				fisheries, and ecosystems increasingly compromised by climate change impacts.
Wildlands and Woodlands, Farmlands and Communities: Broadening the Vision for New England Foster, D., K. F. Lambert, D. Kittredge, et al. September 19, 2017. *Wildlands and Woodlands, Farmlands and Communities: Broadening the Vision for New England*. Harvard Forest, Harvard University. Petersham, Massachusetts. http://www.wildlandsandwoodlands.org/vision/ww-vision-reports [Wildlands and Woodlands 2017 Report]	New England states: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island	N/A (habitats and communities; watersheds)	Rural villages and towns, suburbs, and cities; wildlands, managed woodlands, farmlands, and communities of all types and sizes supporting people and nature across New England; urban gardens, forested parks, greenways; natural and cultural infrastructure; trail network; coastal development.	Climate change gradually altering forest composition and function; rising temperatures and sea levels; the increased frequency of flooding and severe storms.
Integrating Climate Change into Northeast and Midwest State Wildlife Action Plans Staudinger, M. D., T. L. Morelli, and A. M. Bryan. May 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 ranging from Maine to Virginia, and Minnesota	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

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
[Staudinger et al. 2015 Integrating Climate Change into NE and MW SWAPs]	and Missouri in the eastern United States			gusts; intensifying streamflows; increasing water temperature; more 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.
The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA Narayan, S. *et al*. The value of coastal wetlands for flood damage reduction in the northeastern USA. *Nature Scientific Reports* **7**, 9463 (August 31, 2017). https://www.nature.com/articles/s41598-017-09269-z [Narayan et al. 2017]	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.
Through a Fish's Eye: The Status of Fish Habitats in the United States 2015 Crawford, S., G. Whelan, D.M. Infante, *et al*. 2016. *Through a Fish's Eye: The Status of Fish Habitats in the United States 2015*. National Fish Habitat	Maine, Vermont, New Hampshire, Massachusetts, Connecticut	American shad, river herring, American eel (*Anguilla rostrata*), rainbow smelt, Atlantic salmon (*Salmo salar*), brook trout, bridle shiner (*Notropis bifrenatus*), Shortnose Sturgeon (*Acipenser brevirostrum*), oysters, river	Transportation infrastructure.	N/A

Title, Citation, and Link (if available)	**Geography Covered**	**Fish and Wildlife Relevance**	**Human Asset Relevance**	**Flooding Threats Relevance**
Partnership. Accessed on September 19, 2017, at http://assessment.fishhabitat.org/#578a9a00e4b0c1aacab896c1/578a9a9ae4b0c1aacab8984f. [National Fish Habitat Partnership_Northeastern Region]	, Rhode Island, New York	herring, Atlantic tomcod, winter flounder, striped bass.		
Resilient Sites for Species Conservation in the Northeast and Mid-Atlantic Region Anderson, M.G., M. Clark, and A. Olivero Sheldon. 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 [Anderson et al. 2011]	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.

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)[15]
- A species with a NatureServe global imperilment rank of G1, G2, or G3[16]
- 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 [17]

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

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

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

CVS: See Conservation Value Summary.

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

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

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

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

EO: See Element Occurrence.

EPA: Environmental Protection Agency

ESA: Endangered Species Act

---

[15] 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)

[16] 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)

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

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

GIS: Geographic information system

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

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

HCA: See Human Community Asset.

HUC: See Hydrologic unit code.

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

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

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

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

LCC: See Landscape conservation cooperative.

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

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

LCM: See Landscape condition model.

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

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

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

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

NEMAC: National Environmental Modeling and Analysis Center

NFWF: National Fish and Wildlife Foundation

NHD: see National Hydrography Dataset.

NOAA: National Oceanic and Atmospheric Administration

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

NWI: National Wetlands Inventory (USFWS product)

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

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

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

SGCN: See Species of Greatest Conservation Need.

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

SLR: Sea level rise

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

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

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

SCDNR: South Carolina Department of Natural Resources

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.