Coastal Resilience Assessment of the Portland and Midcoast Maine Watersheds

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

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

Cover Image: A tidal marsh meets the ocean at Southport Island, Lincoln County, Maine. Photo: Pete Cutter.

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Abstract

The Portland and Midcoast Maine 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. Communities in this area, ranging from Maine's largest city to small towns that rely on fishing, tourism, or agriculture, are experiencing flooding during storm events and king tides (exceptionally high tides) that impacts coastal properties and makes roads unsafe or impassable.

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 Portland and Midcoast Maine Watersheds.

As part of the assessment process, 18 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

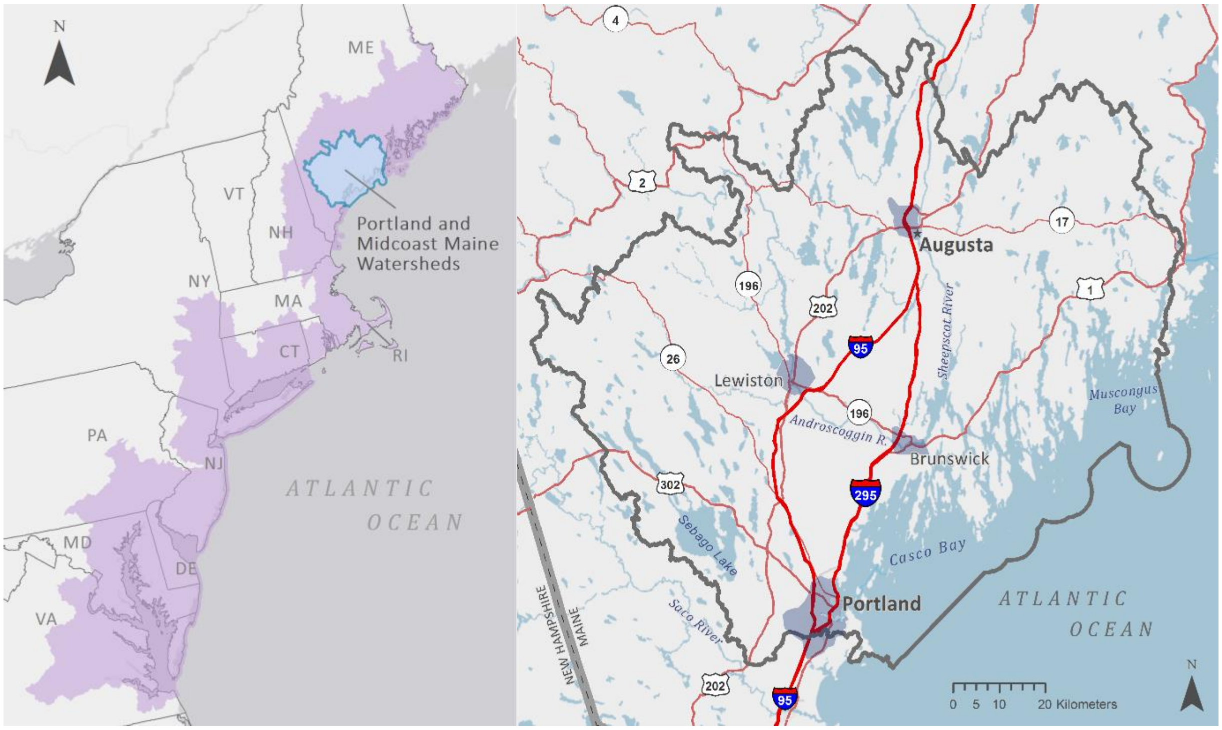
In response to increasing frequency and intensity of coastal storm events, the National Fish and Wildlife Foundation (NFWF) is committed to supporting programs and projects that improve community resilience by reducing communities' vulnerability to these coastal storms, sea-level rise, and flooding through 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 watersheds flowing into the coastal waters of the Portland and Midcoast Maine region. 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.

Portland and Midcoast Maine Watersheds

The Portland and Midcoast Maine Watersheds region stretches from Cape Elizabeth at the southern end of Casco Bay north through Port Clyde. River systems of varying sizes drain into the coastal region, which is characterized by extensive intertidal flats that grade to saltmarsh or rocky shorelines. The steep coastal topography that is common to this region helps to restrict the extent of coastal flooding; however, flooding impacts are still felt in the low-lying coastal communities. As flooding on coastal roads becomes more common, some residents have begun to plan departure times for school or work so that they can avoid high tide during storm surge and monthly high spring tide events.



***Location and boundary of Portland and Midcoast Maine study area**. The map on the left shows the watershed in the context of the North Atlantic Coast Regional Assessment area (purple). In the map on the right, the study area is indicated by the dark gray outline, which consists of coastal watersheds and the lower portions of major river watersheds for Casco Bay and Midcoast Maine estuaries.*

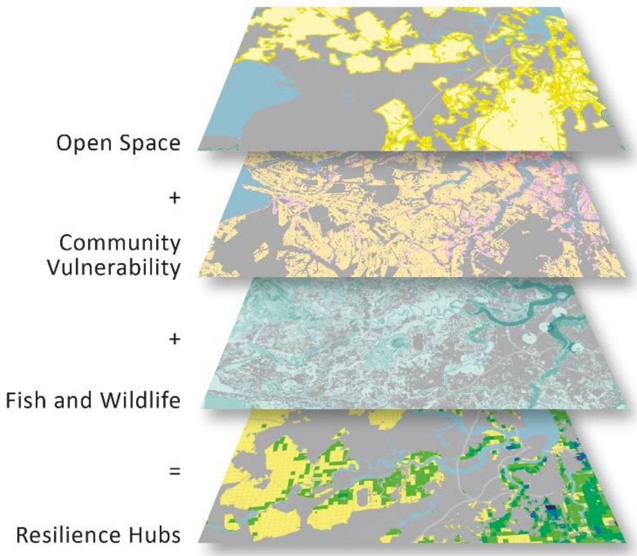
Assessment Objectives

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.



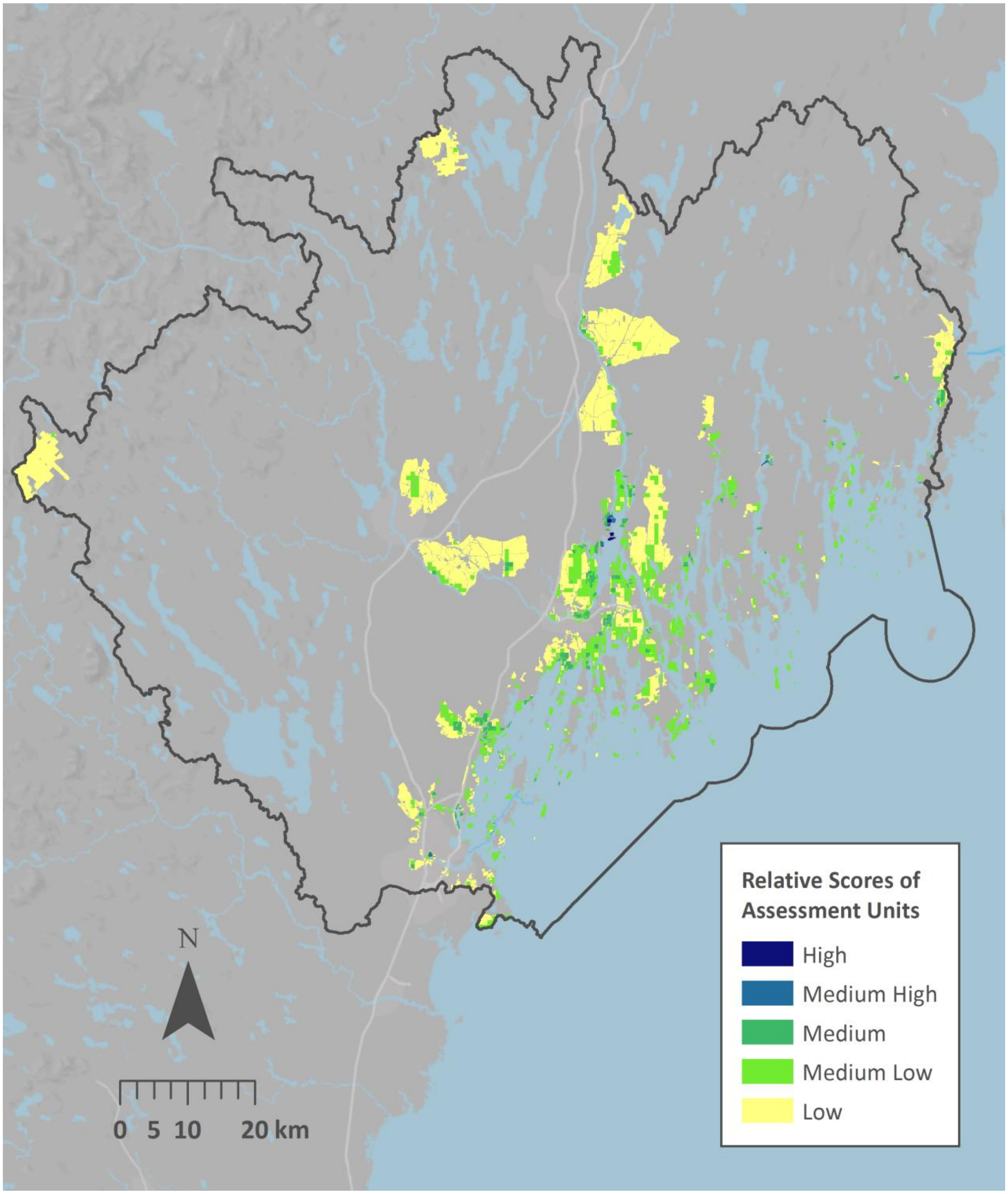
Left: Diagram of the overall approach of this assessment. *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas in proximity to HCAs with high vulnerability **and** high fish and wildlife richness are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



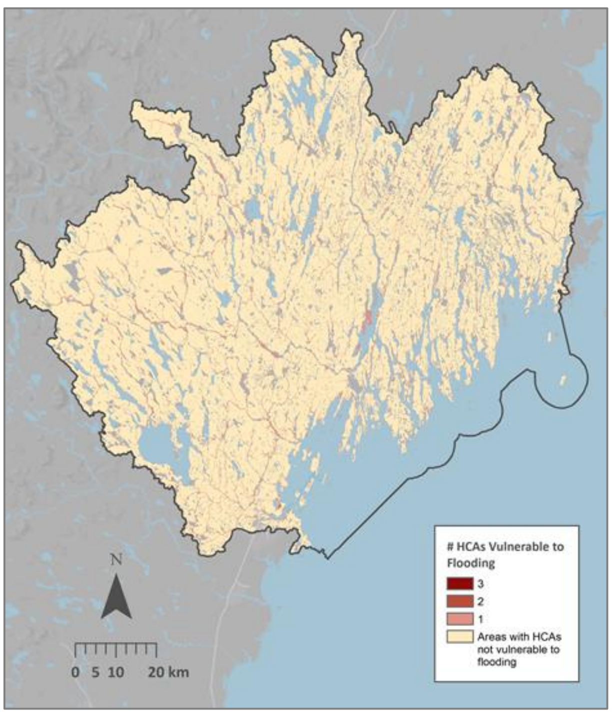
Resilience Hubs assessment unit relative scores for the Portland and Midcoast Maine Watersheds*. Assessment units are 100-acres grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieve both community resilience and fish and wildlife benefits. Gray areas are outside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

Community Vulnerability

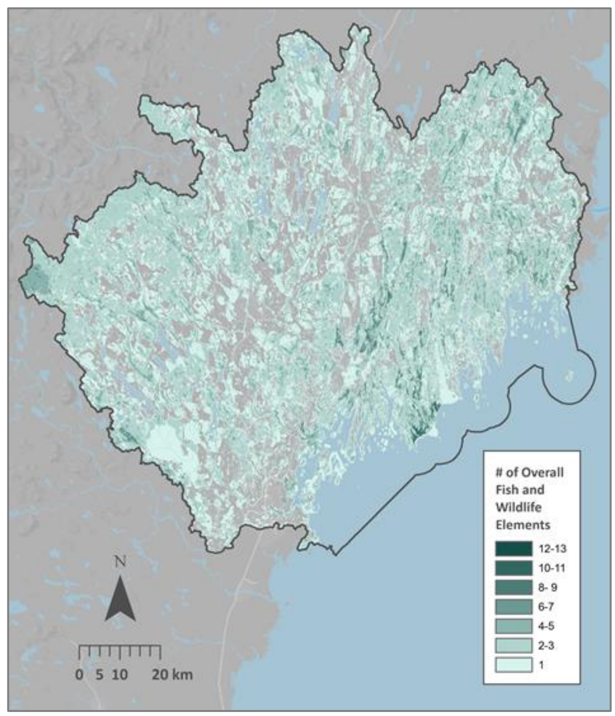
The Community Vulnerability Index (see map below) accounts for approximately half of the scoring of the Resilience Hubs. This index communicates threats to human community assets wherever they occur as well as concentrated areas of threat. Vulnerability is generally low throughout the region; however, there are many, scattered pockets where concentrations of HCAs are exposed to the largest number of overlapping threats creating areas of vulnerability—such as around Back Cove in Portland. Low density rural areas exposed to flooding are visible around Merrymeeting Bay and along many rivers throughout the region. Because of the relatively high topography, areas of vulnerability are distributed both along the coast and inland due to precipitation-caused flooding threats (flood zones and flat areas with poorly draining soils).

Fish and Wildlife

A total of 25 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 Portland and Midcoast Maine 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 Portland and Midcoast Maine 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: Small Point Culvert Replacement
- Case Study 2: Back River Creek Coastal Infrastructure Resilience and Salt Marsh Restoration
- Case Study 3: Basin Point Road and Tidal Exchange Improvement

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

Products may be used to:

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

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

Introduction

Background

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

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

Regional Assessment

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

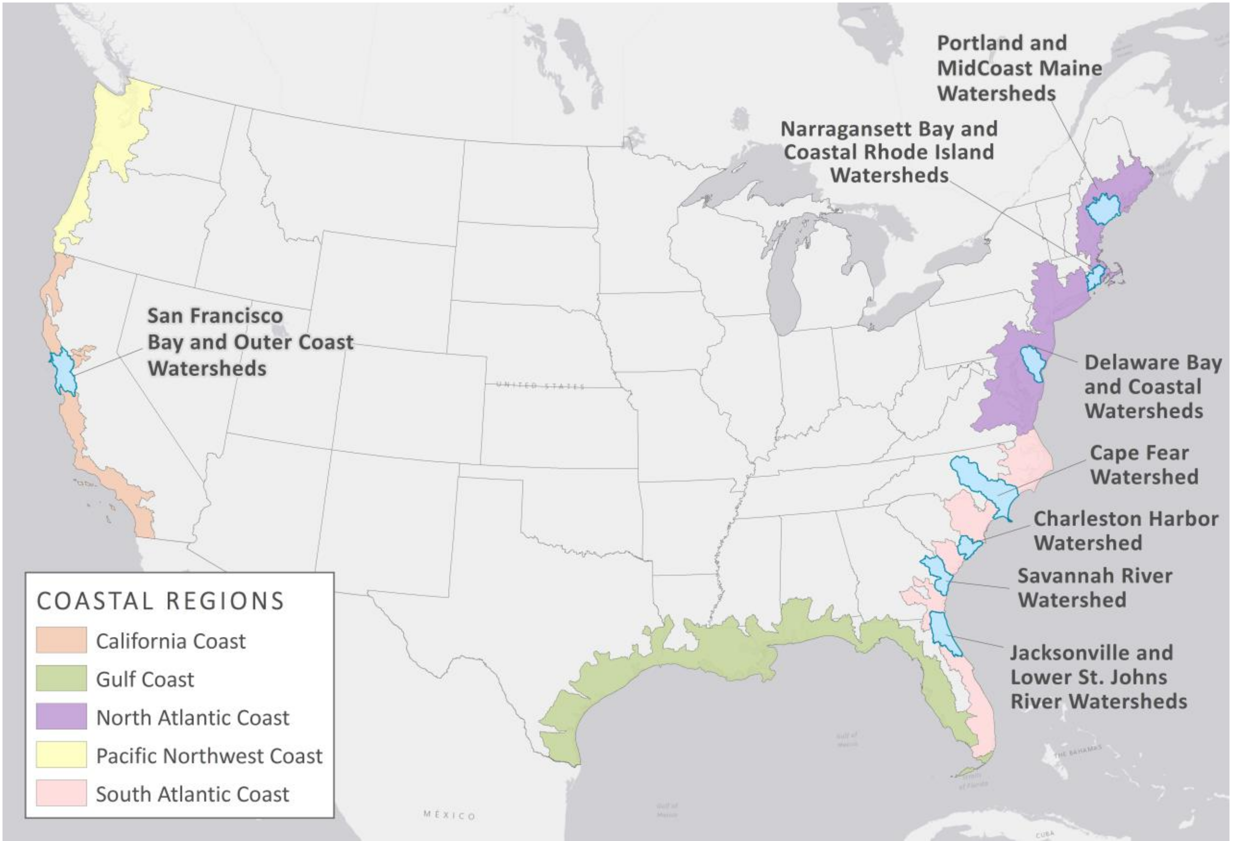


Figure 1. Map showing study areas for the Regional and Targeted Watershed Assessments. The broad Regional Assessment included five coastal regions. *High resolution resilience assessments were carried out in eight coastal Targeted Watershed Assessment study areas (in blue); the Cape Fear Watershed was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

Targeted Watershed Assessments

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

Resilience Hubs

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

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

Targeted Watershed Assessment Objectives

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

Assessment Products

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

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

Application of the Assessment

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

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

Portland and Midcoast Maine Watersheds

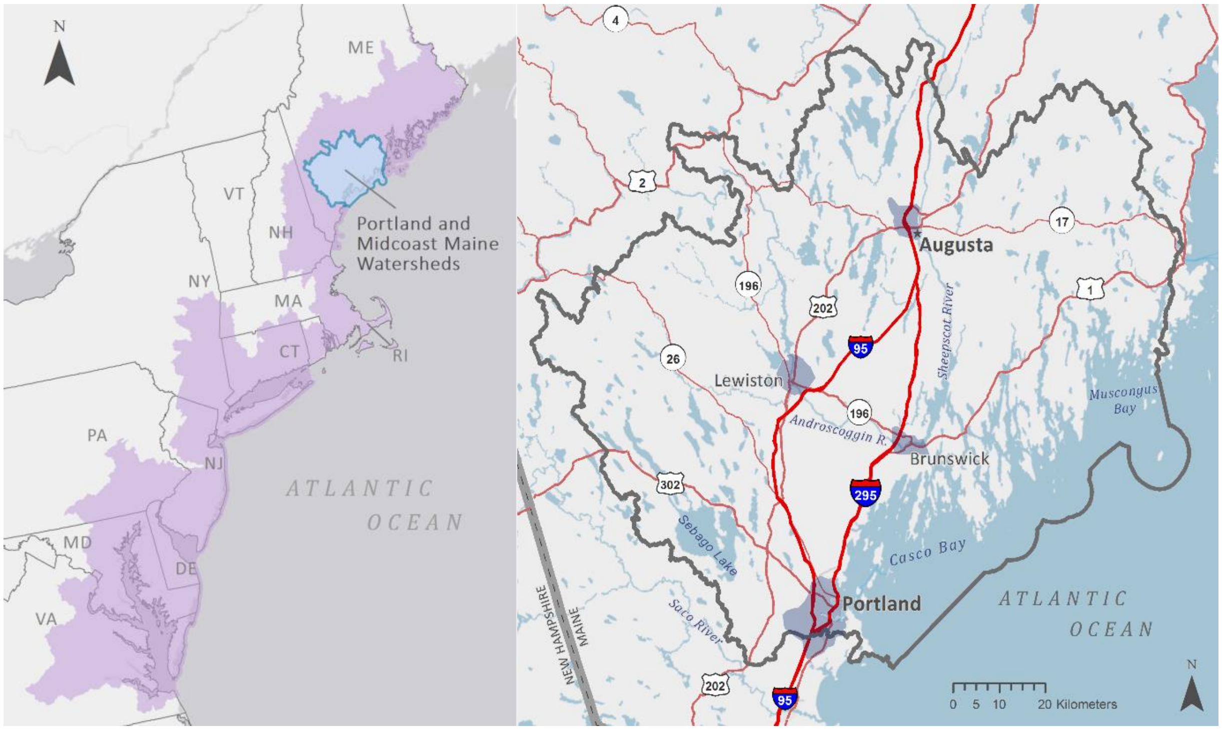


Figure 2. Location and boundary of the Portland and Midcoast Maine Watersheds study area. *The map on the left shows the watershed in the context of the North Atlantic Coast Regional Assessment area (purple). In the map on the right, the study area is indicated by the dark gray outline. Note that it represents a combination of several Midcoast Maine watersheds.*

The Portland and Midcoast Maine Watersheds study area is situated in central coastal Maine, stretching from Casco Bay northeast through Muscongus Bay (**Figure 2**). The boundary of the study area extends north through Waterville, capturing many streams and rivers that drain to the coastal region, which is dominated by intertidal flats, saltmarshes, and rocky shorelines.

The coastal areas have a diverse range of habitats and communities. Portland—Maine's largest city and port—sits in Casco Bay, a nationally significant estuary known for its rich abundance of diverse marine life. The Casco Bay embayment borders the southern coast of the study area. Further north in the Midcoast area, the coast is dominated by narrow peninsulas with towns that are heavily reliant on commercial fishing and tourism. The state has the highest median age in the country, and for residents of many of the small communities in the region, access to hospitals and other emergency services often requires travelling significant distances.

The region has a combination of large and small watersheds that primarily contain a mix of forest and agricultural lands. The largest watershed drains to the Kennebec Estuary, channeling water from about one-third of the state through Merrymeeting Bay—the state's largest freshwater tidal wetland and one of the most important waterfowl areas in New England.

The coastal waters support commercial fisheries for lobster and shellfish and a growing number of oyster, mussel, scallop, and kelp aquaculture farms. Rocky shorelines, tidal mudflats, eelgrass beds, small to mid-sized salt marshes, and a small number of sandy beaches can be found throughout the study area. The coastal habitats are home to numerous bird species like the piping plover and salt marsh sparrow, and they provide spawning and rearing habitat for a variety of fishes, including mummichogs, American eel, sticklebacks, and silversides. Threatened and endangered species such as Atlantic salmon, shortnose sturgeon, and Atlantic sturgeon can also be found in the Midcoast Maine watersheds.

Historic Impacts from Flooding

Flooding within this region predominantly affects low-lying coastal communities and roads. However, nuisance flooding during king tides at new and full moons is becoming more common, and with higher high tides, storm surge from tropical storms or nor'easters has the potential to contribute to more severe and widespread impacts along the coast. Historic and recent flood events highlight the flooding risk in the Portland and Midcoast Maine Watersheds:

- The waters around Portland have reached flood stage (12 feet) more frequently in recent years. On average, between 1912 and 2006 water levels reached the 12-foot flood stage for just three hours per year; however, between 2006 and 2016, that average increased to 10 hours per year, indicating that 1.3% of all high tides in a given year reached flood stage. The most flood stage readings occurred in 2010, with 25 hours at flood stage. When water reaches flood stage, flooding can occur on coastal roads, leading to unsafe travel conditions and restricting access for emergency services. Some flooding of low-lying properties also occurs[1].
- If water levels increase by one foot (the assumption used in this assessment), which is predicted to occur before 2100[2], models predict the tidal levels experienced in 2010 would have led to more than 200 hours of flooding. Under this scenario, the average flooding between 2006 and 2016 would have resulted in 98 hours of flooding per year, or 13.5% of high tide events.
- Storm surges measured at the Portland tide gauge have added as much as 4.61 feet to the predicted tide level. Because of Maine's large tidal range, storm surge would cause the most damage if it occurred near high tide. As water levels rise and tidal heights shift higher, smaller storms in the future will have the same impact as large storms in the past.
- These same weather events that affect human communities also affect fish and wildlife habitat, with strong waves and flooding on beaches, submerged marshes, and saltwater inundating freshwater habitats.

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[1] Slovinsky, P (Maine Geological Survey). Latest Trends in Sea Level Rise and Storm Surge in Maine, presented at Island Institute's Sea Level Rise Symposium (Staying Above High Water:
Helping Prepare Maine's Coastal Communities for Coastal Flooding and Sea Level Rise), 28 November 2017.

[2] Sweet WV, Kopp RE, Weaver CP, Obeysekera J, Horton RM, Thieler ER, Zervas C. 2017. *Global and Regional Sea Level Rise Scenarios for the United States* (NOAA Technical Report NOS CO-OPS 083). Silver Spring, MD: National Ocean Service Center for Operational Oceanographic Products and Services.

Sea level rise and storm surge mapping by the Maine Geological Survey has helped communities to start thinking about flooding threats. Some communities in the Portland and Midcoast Maine region, including Portland, have completed vulnerability assessments that identify flooding threats. These have been completed as stand-alone documents or incorporated into towns' comprehensive plans (e.g., the town of Bowdoinham). Other communities, like Georgetown, have developed climate change adaptation reports. Studies of regional vulnerability to sea level rise and flooding have been carried out by non-profits, regional planning organizations, and a National Estuary Program. The state has also developed a "Maine Flood Resiliency Checklist" to help communities evaluate their flooding hazards and resiliency (https://digitalmaine.com/mgs_publications/521/).

Methods Overview

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

Overall Approach

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

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

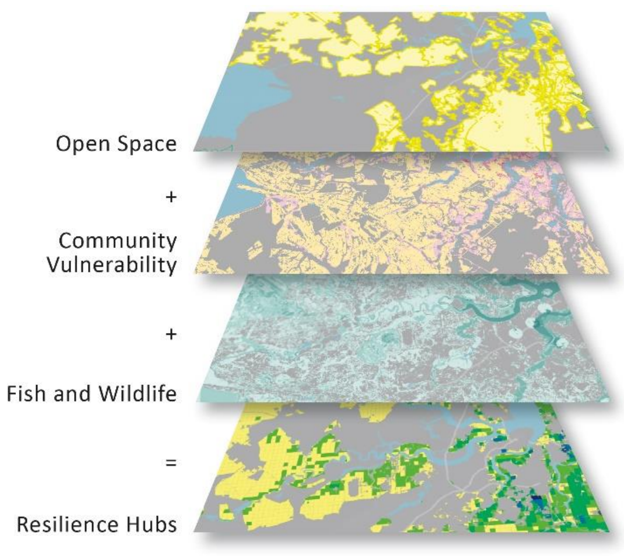


Figure 3. Diagram of the overall approach of this assessment. *Human community asset (HCA) vulnerability and fish and wildlife richness are assessed within all areas of public and private open space. Open space areas with high HCA vulnerability and high fish and wildlife richness are mapped as Resilience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

Stakeholder Participation

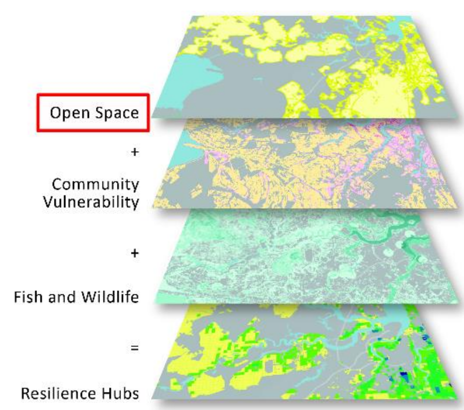
A fundamental part of this Targeted Watershed Assessment was to engage and work with individual and organizational stakeholders and partners within the Portland and Midcoast Maine Watersheds. Stakeholder involvement can improve the quality of decisions and policy—especially in the context of complex environmental and social challenges (Elliott 2016, Reed 2008). The stakeholder engagement process for the Portland and Midcoast Maine 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 Portland and Midcoast Maine Watersheds Committee was formed consisting of local experts from the National Oceanic and Atmospheric Administration (NOAA), the North Atlantic Landscape Conservation Cooperative (LLC), Blue Sky Planning Solutions, Casco Bay Estuary Partnership, Kennebec Estuary Land Trust, Maine Dept. of Agriculture, Conservation and Forestry, Maine Department of Inland Fisheries & Wildlife, Maine Sea Grant, 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 150 stakeholders including federal and state agency representatives, NGO staff, local elected officials and municipal staff, and citizens representing their communities were invited to engage in the assessment process. through. Of these, over 50 participated in various ways including attending web meetings and in-person workshops, participating in site visits to proposed resilience project sites, contributing and reviewing data, etc. Additional details on key stakeholder inputs, details about the stakeholder process, and the committee structure that guided the assessment can be found in Appendix 1.

Components of the Assessment

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



Open Space

Large contiguous areas of habitat may provide mutual resilience benefits to HCAs and fish and wildlife elements, especially with the implementation of resilience projects.

Identifying these areas of open space serves as a first step in identifying high value Resilience Hubs where prospective conservation and restoration projects could contribute to resilience and benefit fish and wildlife. The method for scoring the value of the Hubs using results from the watershed assessments is further described below.

Mapping Open Space

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

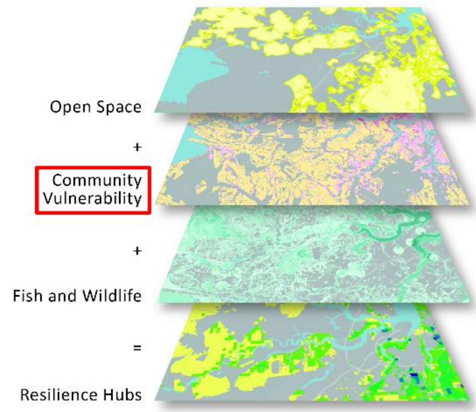
1. Protected areas, which are defined as lands that are part of the USGS Protected Areas Database of the United States (PAD-US).
2. Unprotected privately owned lands with contiguous habitat, as identified from the USGS National Land Cover Database (NLCD). The open space areas were further processed to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

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

1. Protected areas were augmented with Maine Conserved Lands data on protected properties. All protected area polygons were intersected with the Resilience Hubs as identified in the Regional Assessment to distinguish protected from unprotected areas.
2. Hubs with shorelines (rivers or coastal) were supplemented with the National Hydrography Dataset (NHD) to include waters within a 50-meter buffer to add nearshore habitat areas that could provide locations for aquatic resilience projects such as marsh protection/restoration.
3. Impervious surfaces were deleted from the Hubs using the Maine Land Cover Database (MELCD 2004) and Topologically Integrated Geographic Encoding and Referencing (TIGER) roads data (U.S. Census 2016). The removed areas might be protected but have pavement or structures in place that would limit restoration actions.
4. Tracts that were less than five acres (mostly slivers resulting after deleting impervious surfaces and splitting polygons) were removed from consideration. For the purposes of this assessment, areas under this threshold were assumed to have significantly less potential for improving community resilience or supporting fish and wildlife in meaningful, measurable terms.

Community Vulnerability

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



Human Community Asset Weighted Richness Index

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

Human Community Asset categories are defined as follows:

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

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

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

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

Table 2. Critical infrastructure categories and sources of data.

Critical Infrastructure Category	Data Source
Ports	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later)
Power plants	EIA-860, Annual Electric Generator Report, EIA-860M, Monthly Update to the Annual Electric Generator Report and EIA-923, Power Plant Operations Report (2016 or later)
Wastewater treatment facilities	USGS National Structures Dataset File GDB 10.1 or later
Railroads	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later)
Airport runways	National Transportation Atlas Database (2015 or later)
National Highway Planning Network	National Transportation Atlas Database v11.09 (2015) or later; on behalf of the Federal Highway Administration
Evacuation routes	Maine Emergency Management Agency Evacuation Network (2017)
Major dams	USDOT/Bureau of Statistics NTAD (2015 or later)
Petroleum terminals and refineries	EIA-815, "Monthly Bulk Terminal and Blender" Report; *Refineries*: EIA-820 Refinery Capacity Report (2015 or later)
Natural gas terminals and processing plants	EIA, Federal Energy Regulatory Commission, and U.S. Dept. of Transportation; *Processing Plants*: EIA-757, Natural Gas Processing Plant Survey (2015 or later)
National Bridge Inventory	Federal Highway Administration, NBI v.7, NTAD (2015 or later)
Hazardous facilities & sites	EPA Facility Registry Service (2016 or later)

The HCA weighted richness index expresses values based on the number of HCAs present in a location and their importance weights. The HCAs were combined in the Vista DSS using its Conservation Value Summary function[3] by first assigning a weighting factor that approximated the ranked weights used in the Regional Assessment (see **Table 1**). For the purposes of the Targeted Watershed Assessment, the weights used in the Regional Assessments (1=lowest importance, 5= highest) were adjusted to a 0-1 scale (1=0.2, 2=0.4, 3=0.6, 4=0.8, 5=1). Next, the HCAs were overlaid, and their adjusted weights summed for each pixel.

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

Flooding Threats

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

- Storm surge (with values of 1-5, which are based on hurricane categories 1-5)
- Flood zones (100 and 500-year floodplains and flood-ways)
- Sea level rise (one foot was used to correspond with an approximate 20-30-year planning time frame)
- Flood prone areas (flat topography with poorly draining soils)
- Moderate to high erosion potential
- Subsidence

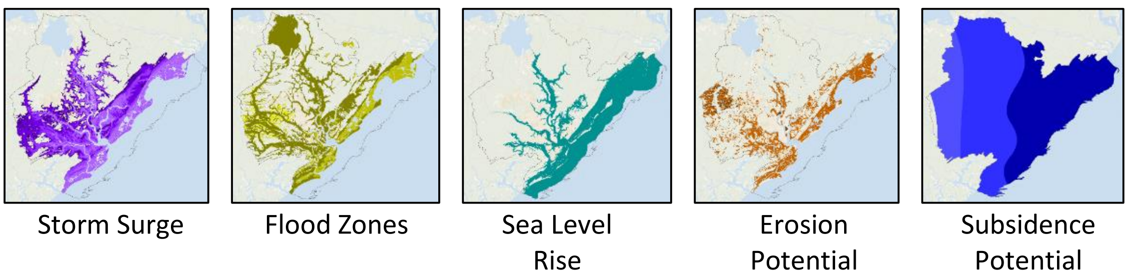


Figure 4. Flooding threats used to assess community vulnerability. *Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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

Community Vulnerability Assessment

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

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

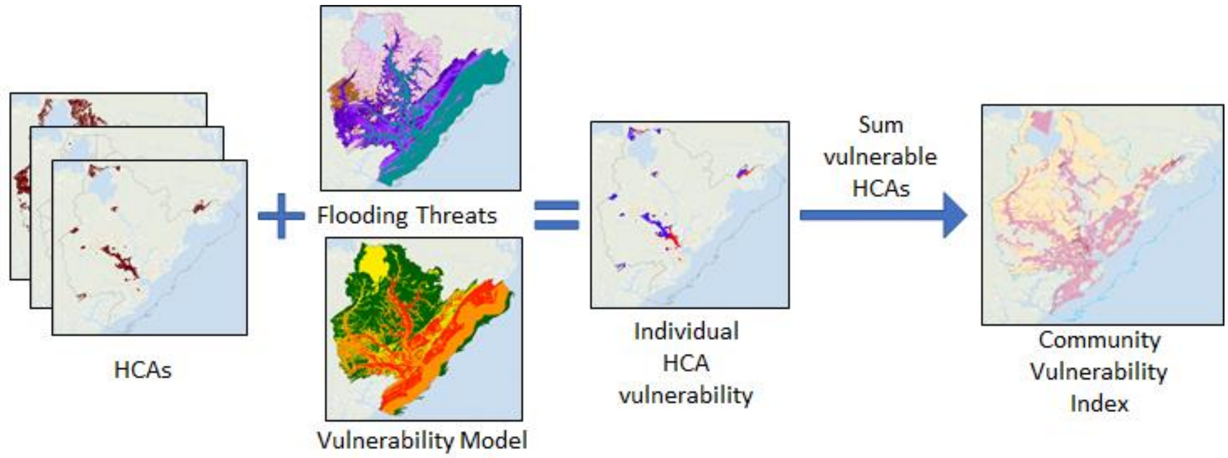
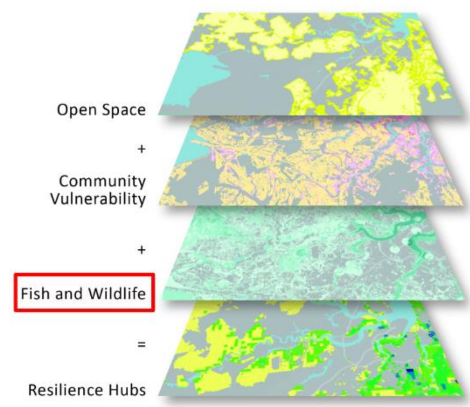


Figure 5. Community vulnerability assessment process. *Human Community Assets (HCAs) are intersected with the flooding threats, a vulnerability model is applied, and individual HCA results are summed to create the Community Vulnerability Index. Diagram represents the Charleston, SC region as an example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

Fish and Wildlife

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



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

Selection of Fish and Wildlife Elements

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

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

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

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

- A NOAA Trust Resource[4]
- A formally recognized at-risk species based on its inclusion in one of the following categories at the time of this assessment including:
    - A species listed as ‘endangered’, ‘threatened’, or ‘candidate’ under the provisions of Endangered Species Act (ESA)[5]

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

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

    - A species with a NatureServe global imperilment rank of G1, G2, or G3[6]
    - A species with a NatureServe state imperilment rank of S1, S2, or S3
    - A State Species of Greatest Conservation Need (SGCN) as recorded in current State Wildlife Action Plans
- A distinctive ecological system or species congregation area that represents habitat important to at-risk species and/or species of significance to stakeholders in the region. Examples might include heron rookeries that represent important wading bird habitat or tidal marsh representing shrimp nursery areas and diamondback terrapin habitat; or
- A species or population of commercial, recreational, or iconic importance in the watershed. This includes:
    - Fish or wildlife species or populations of significant commercial value,
    - Fish or wildlife-related features that confer resilience to biodiversity or human assets (such as oyster beds which have high economic significance as a fishery component and/or play a valuable role in coastal resilience by virtue of their physical structure which in many cases mitigates destructive wave action and storm surge impacts),
    - Fish or wildlife populations or wildlife habitat-related features that provide unique recreational opportunities (such as Atlantic Beach and Dune habitat that provides key habitat while also providing recreational opportunities for visitors), and/or
    - Iconic species that define the watershed and/or distinguish it from other geographies and represent species that have conservation support.

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

Stressors

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

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

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

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.

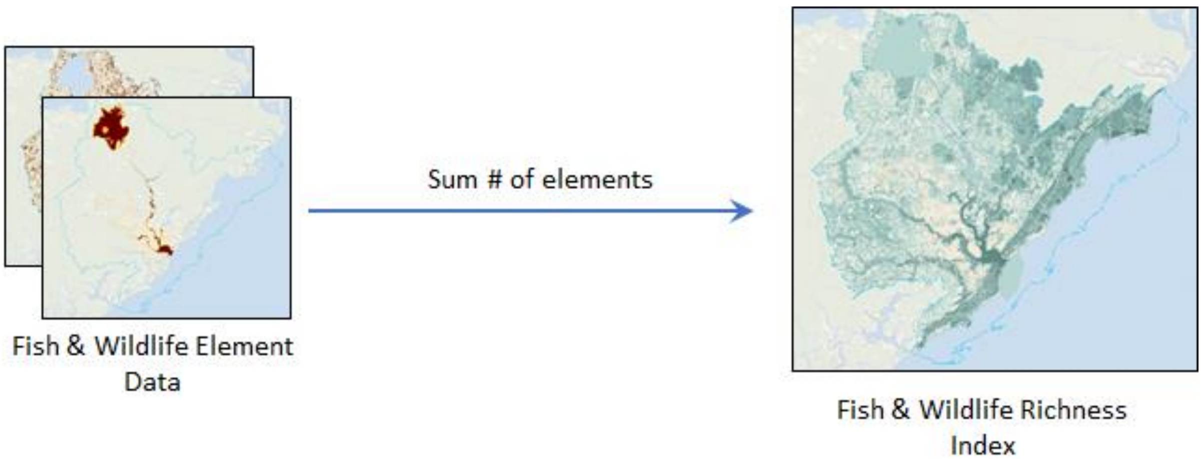


Figure 7. Method for generating the Fish and Wildlife Richness Index. *All elements are overlaid and the sum of elements occurring in a location is calculated. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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.

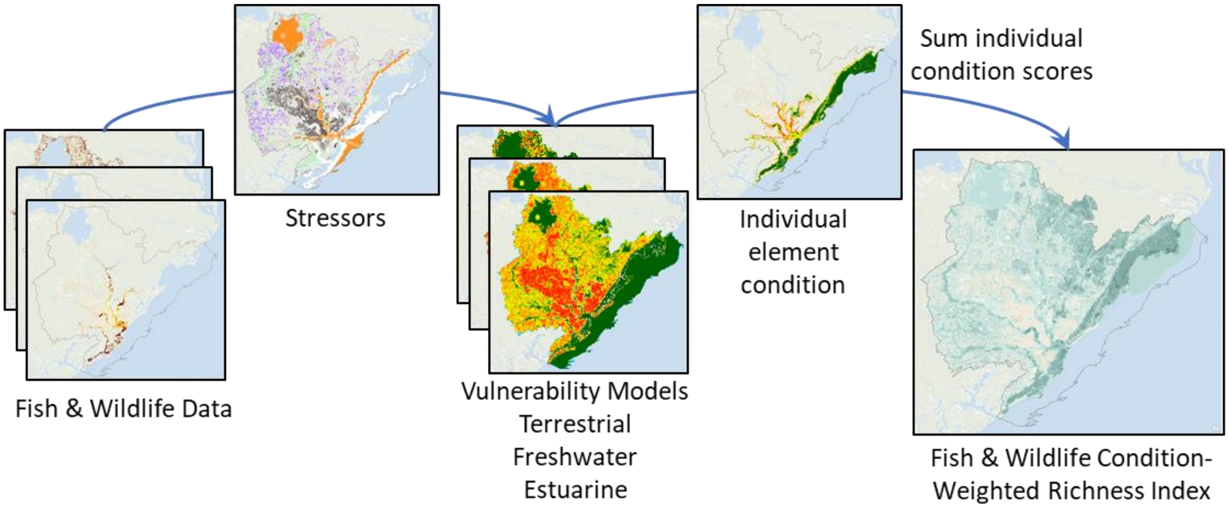
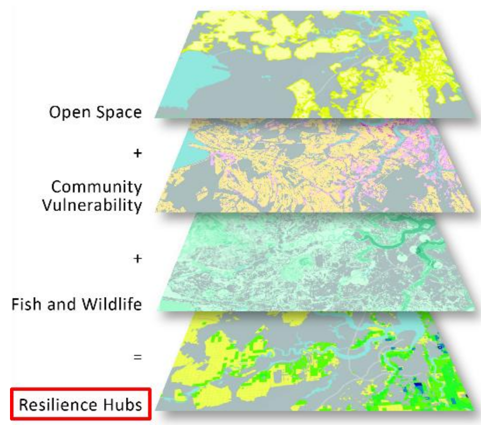


Figure 8. Method for generating the Fish and Wildlife Condition-Weighted Richness Index. *Fish and wildlife elements are intersected with stressors, the vulnerability model is applied, and individual element condition results are summed. Diagram represents the Charleston, SC region as an example and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

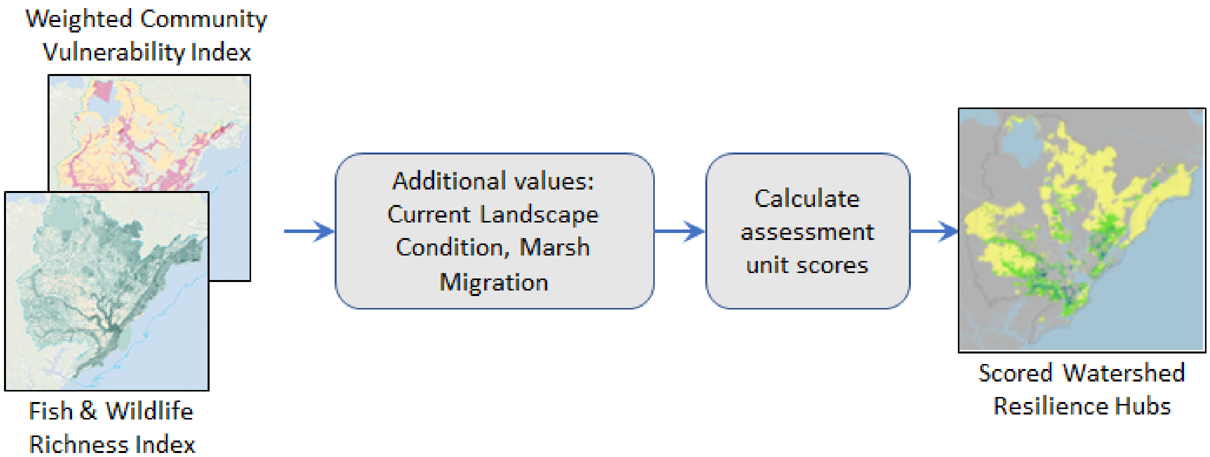


Figure 9. Method for scoring watershed Resilience Hubs. *Resilience Hub assessment units were scored based on their community resilience and fish and wildlife. Diagram represents the Charleston, SC region as an example and is only intended to illustrate methods.*

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 1 km (0.62 miles) of any resilience hub
- Community Vulnerability Index: The average value of the regional Community Vulnerability Index for the project polygon
- Number of HCAs found within the project polygon
- List of the HCAs mapped within the project polygon
- Number and percentage of the HCAs within the project polygon that are designated non-viable in the Coastal Threats scenario evaluation
- Number of fish and wildlife elements found within the project polygon
- List of the fish and wildlife elements mapped within the project polygon
- Number and percentage of the fish and wildlife elements vulnerable to flooding threats

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

Site Visits

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

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

Results

This section portrays the key set of products primarily focused on the resulting Resilience Hubs and key indices. Many map and tabular products were generated for this Targeted Watershed Assessment. In addition to this report, key results may be viewed in the Coastal Resilience Evaluation and Siting Tool (CREST), which is an interactive online mapping tool that includes results for the Regional Assessment and each of the eight Targeted Watersheds (available at resilientcoasts.org). CREST can also be used to download data including the Portland and Midcoast Maine 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 Portland and Midcoast Maine 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).

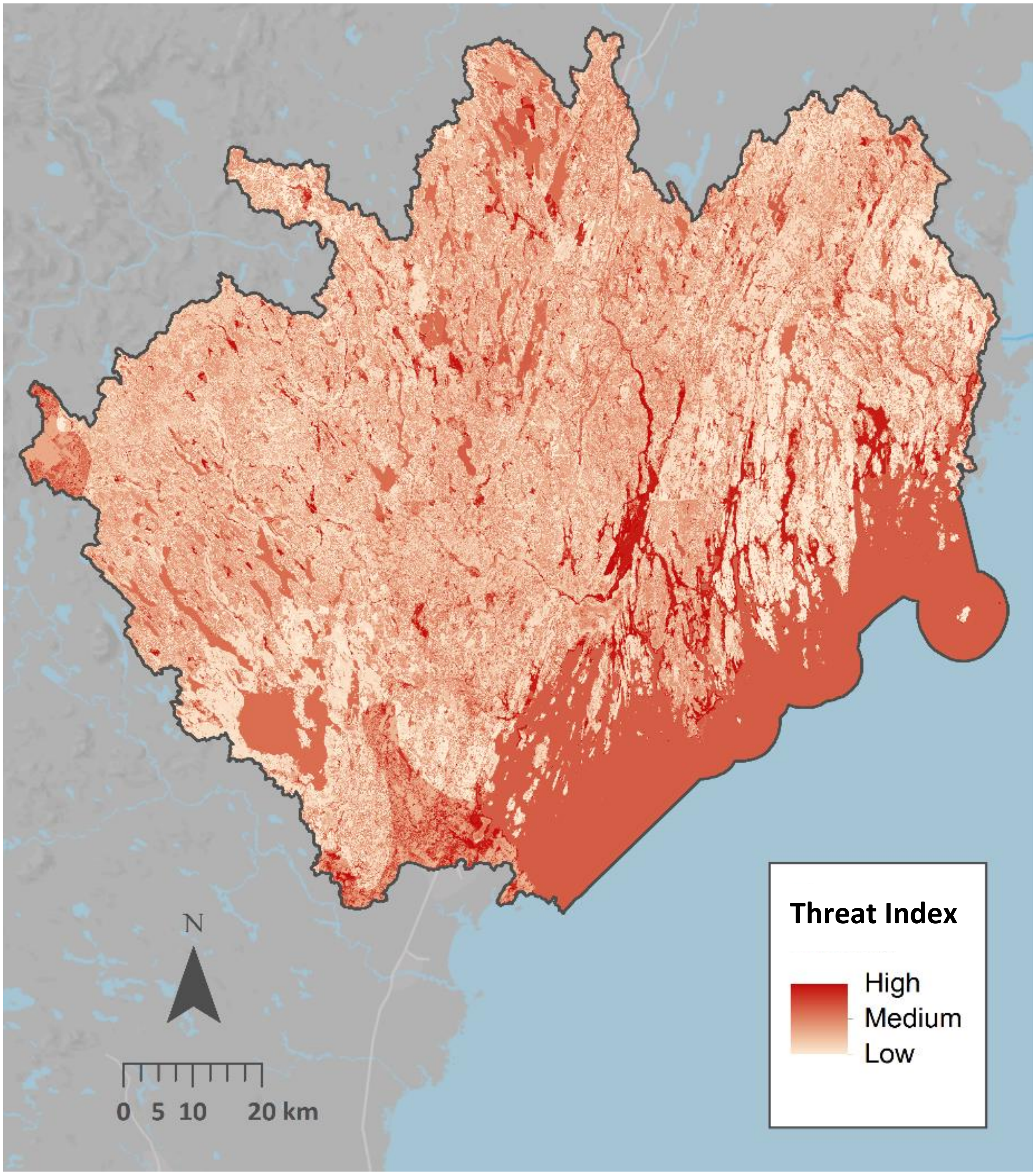


Figure 10. Weighted Threat Index for the Portland and Midcoast Maine Watersheds. *Map shows the number of overlapping threats modified by a weighting based on their probability of occurrence.*

Suggested Uses

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

Human Community Assets

HCA Weighted Richness Index

This index indicates areas of HCA concentrations (**Figure 11**). Darker shades can be an indication of overlapping HCAs, higher or lower importance weightings, or both. The Portland and Midcoast Maine Watersheds have a low HCA richness over most of the area because the region is dominated by rural communities. The areas of higher richness are near the region's urban areas or along important road infrastructure.

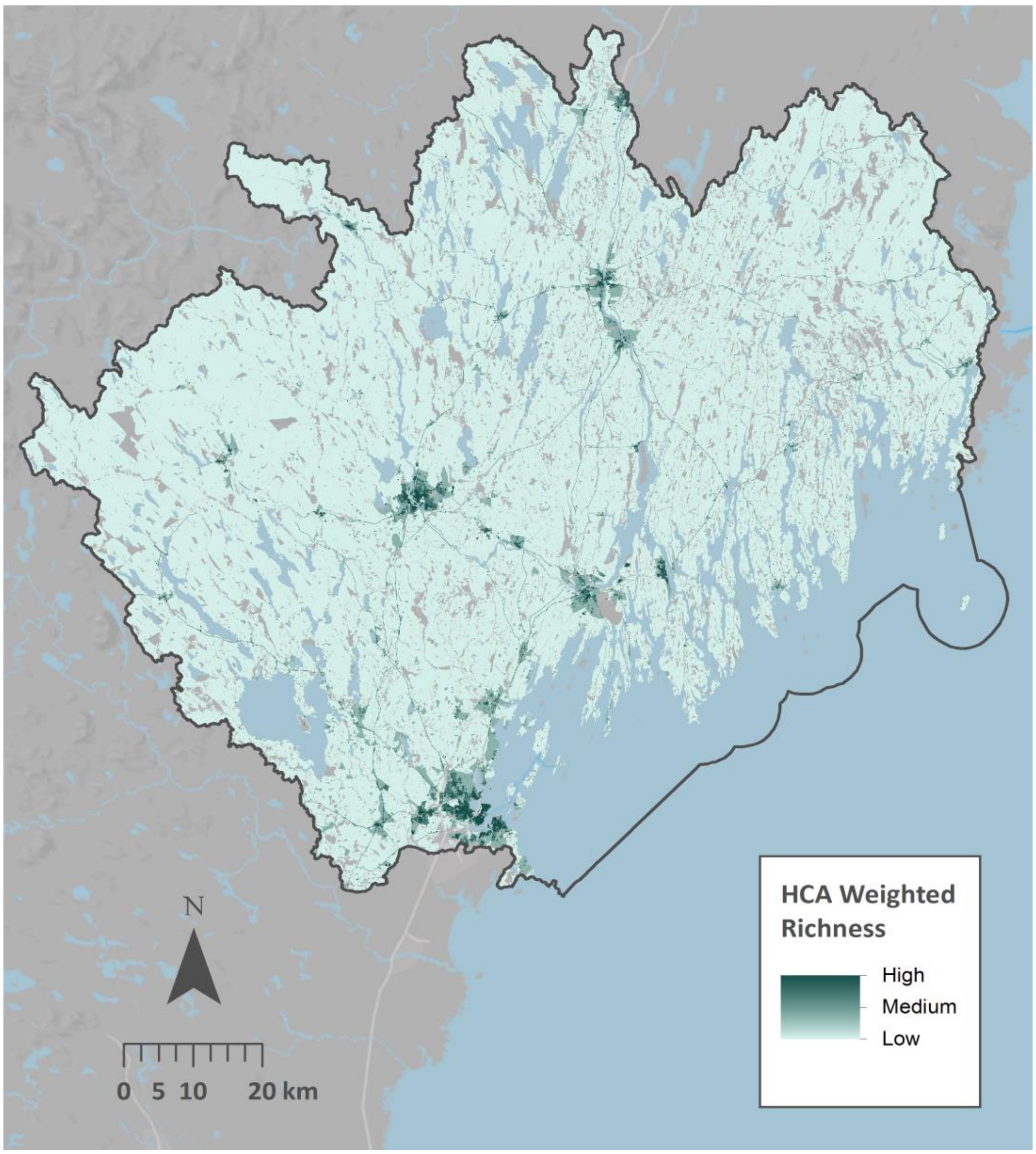


Figure 11. Human Community Asset (HCA) Weighted Richness Index for the Portland and Midcoast Maine Watersheds. *Darker shades indicate higher value based on the number and importance weightings of HCAs in each location. Gray areas within the project boundary represent areas with no mapped HCAs.*

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**).

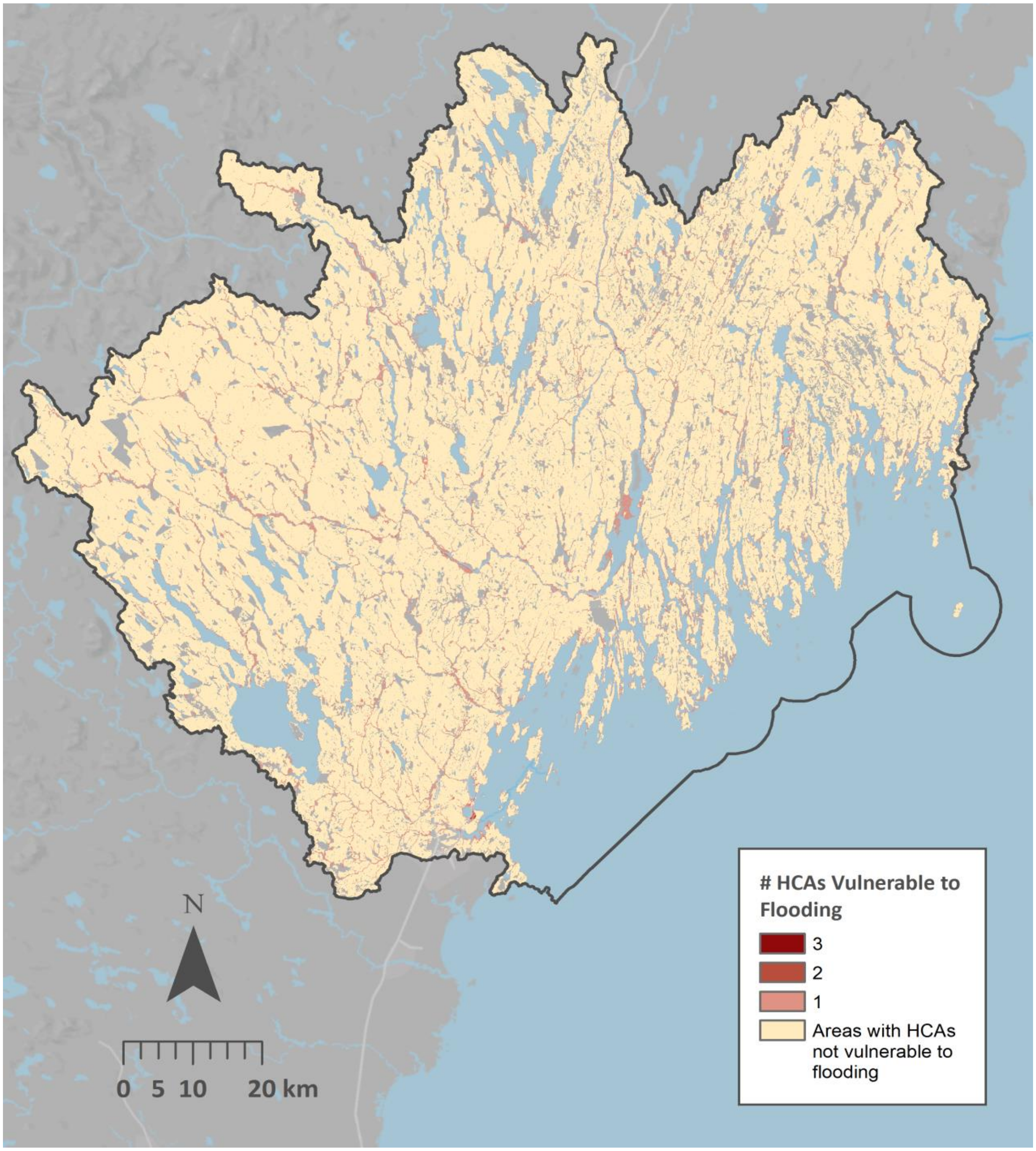


Figure 12. Community Vulnerability Index for the Portland and Midcoast Maine Watersheds. *Pink to red shades indicate the number of Human Community Assets (HCAs) exposed to flooding related threats. Tan areas indicate areas of low to no impact from the flooding threats. Gray within the project boundary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

Vulnerability is generally low across the watershed but with many, scattered pockets of vulnerability where there are concentrations of HCAs exposed to the largest number of overlapping threats, such as the areas around Back Cove in Portland. Low density rural areas exposed to flooding are visible at Merrymeeting Bay and generally along the rivers. Because of the relatively high topography in the region, there are few very large areas of flooding. Areas of vulnerability are distributed both along the coast and inland due to precipitation-caused flooding threats (i.e., flood zones and flat areas with poorly draining soils).

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).

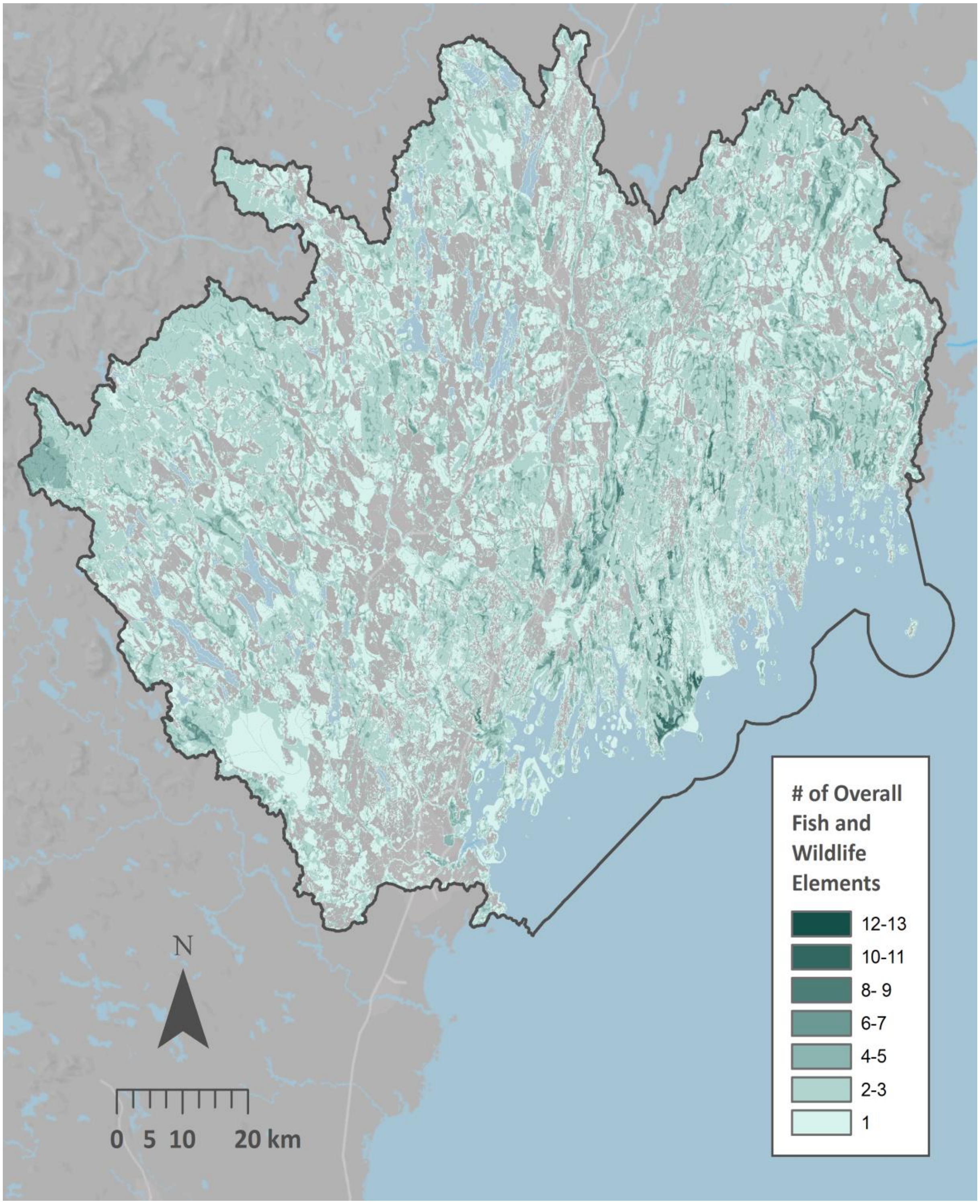


Figure 13. Richness of fish and wildlife elements in the Portland and Midcoast Maine Watersheds. *Green shades indicate the number of elements found in a location. Gray areas within the project boundary have no mapped fish and wildlife elements considered in this assessment.*

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 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.

Richness and condition are currently highest in the coastal areas, such as those along the Kennebec Estuary and Merrymeeting Bay. Other areas with high richness and conditions scores can be found farther inland, including intact forest and wetland areas between Liberty and Appleton. When viewed at the full extent of the watershed, the differences between the two indices appear subtle, but some differences can be seen in the condition-weighted richness (**Figure 14**), for example, the agricultural land around Merrymeeting Bay or the urban around Portland.

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.

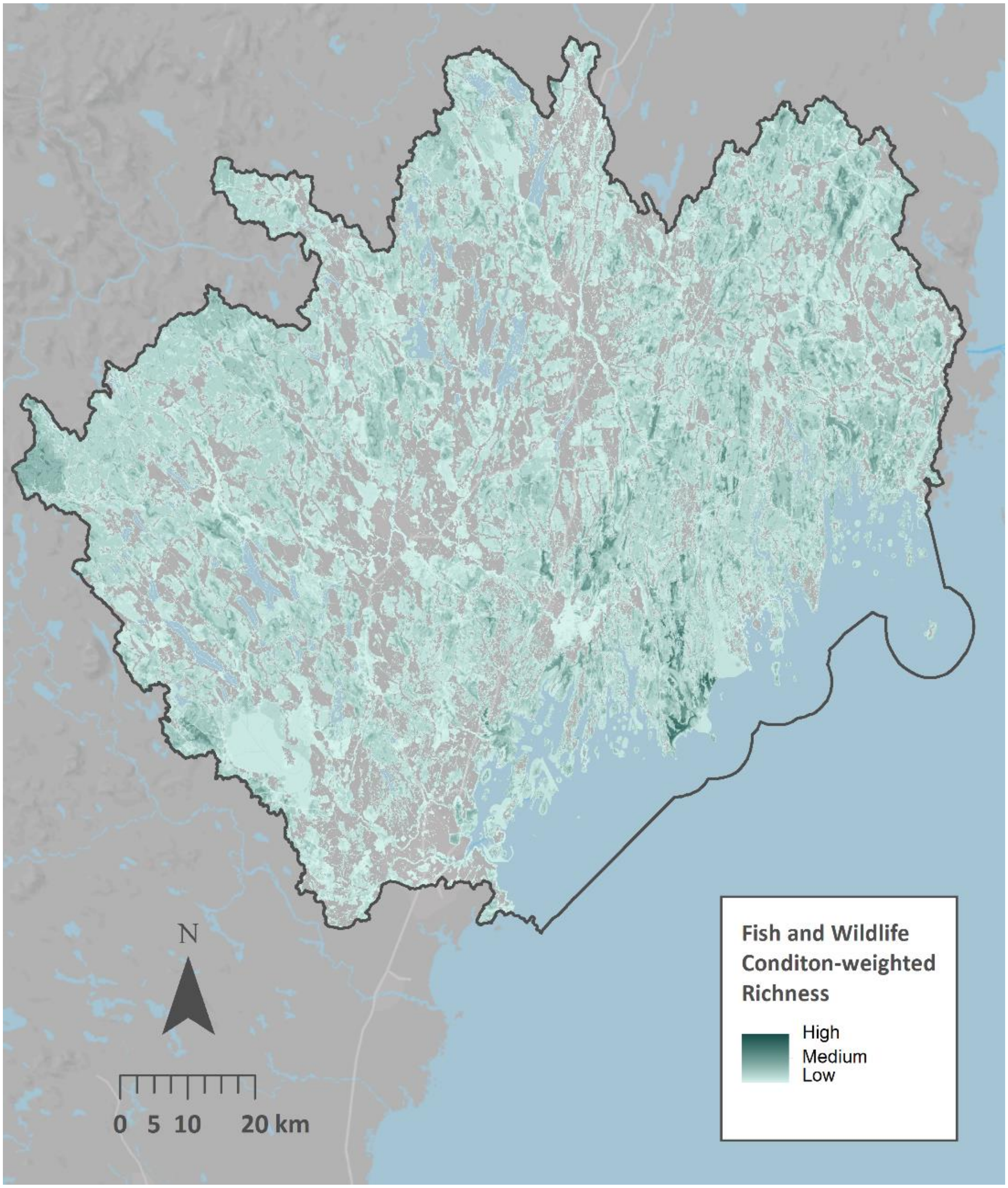


***Figure 14. Fish and Wildlife Condition-weighted Richness Index results for the Portland and Midcoast Maine Watersheds**. Green shades indicate the added condition scores of the elements found in a location, with a maximum value of one per element. Grey areas within the project boundary signify areas 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 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.

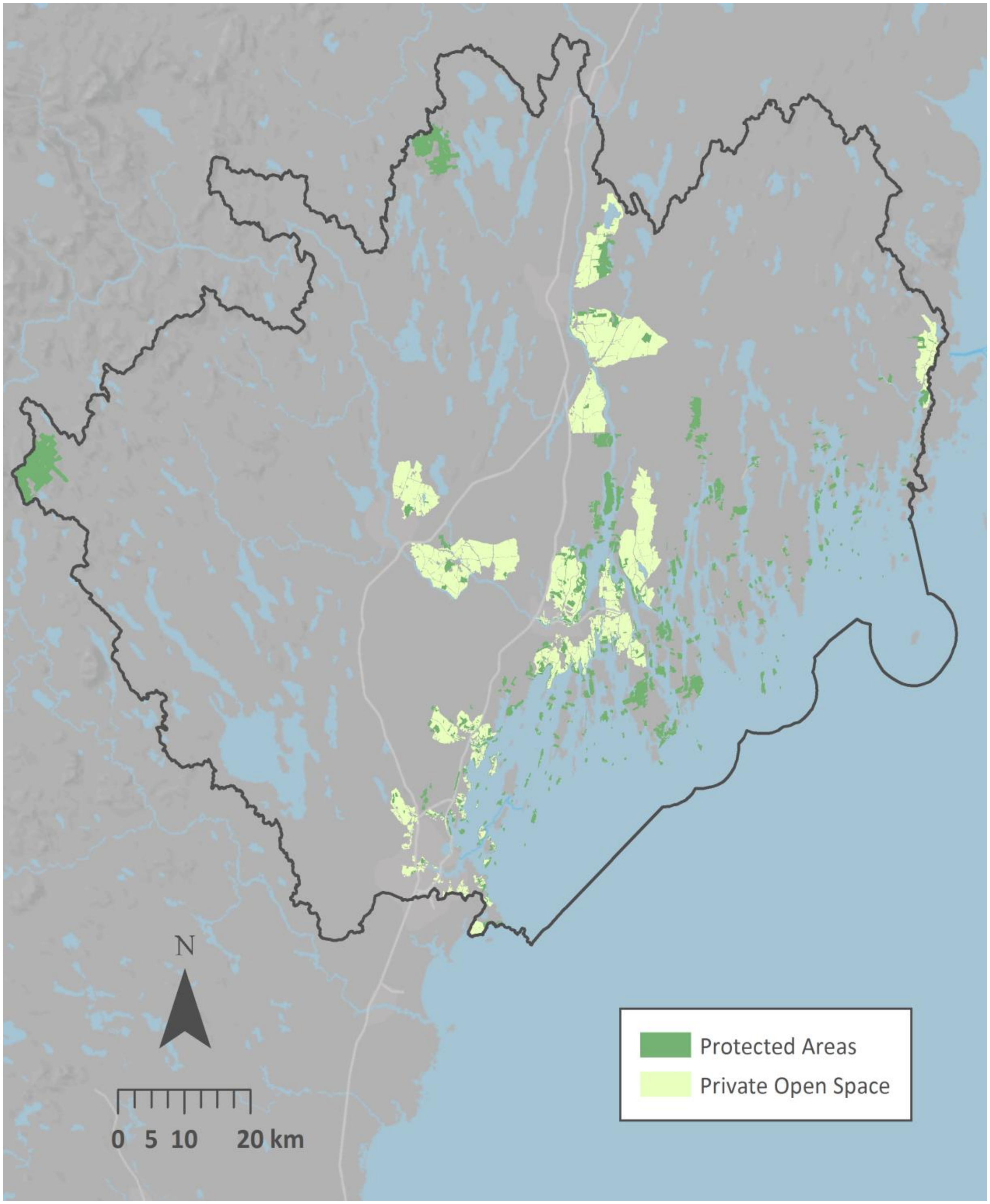


***Figure 15. Undeveloped protected areas and unprotecccted privately owned areas of open space in the Portland and Midcoast Maine Watershed**. Map displays the distribution of these areas within Resilience Hubs identified in the study area and therefore does not include all such areas within the study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

By design, 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.

Hubs in this watershed are primarily concentrated along the major rivers and along the coast, often in very small pockets. There are some exceptions, such as the area in the northwest near North Lovell, which borders the White Mountain National Forest. Identifying which portions of the hubs are already in protected status determines which resilience project actions may be most suitable. Protected areas may offer opportunities for restoration projects to increase their resilience capabilities; adding protection to adjacent lands or connections between protected lands can increase the effectiveness of those conservation areas. Other unprotected locations may only need added protection (if in good condition) to ensure long-term investments in resilience projects but may also benefit from restoration actions.

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, 3,575 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**).

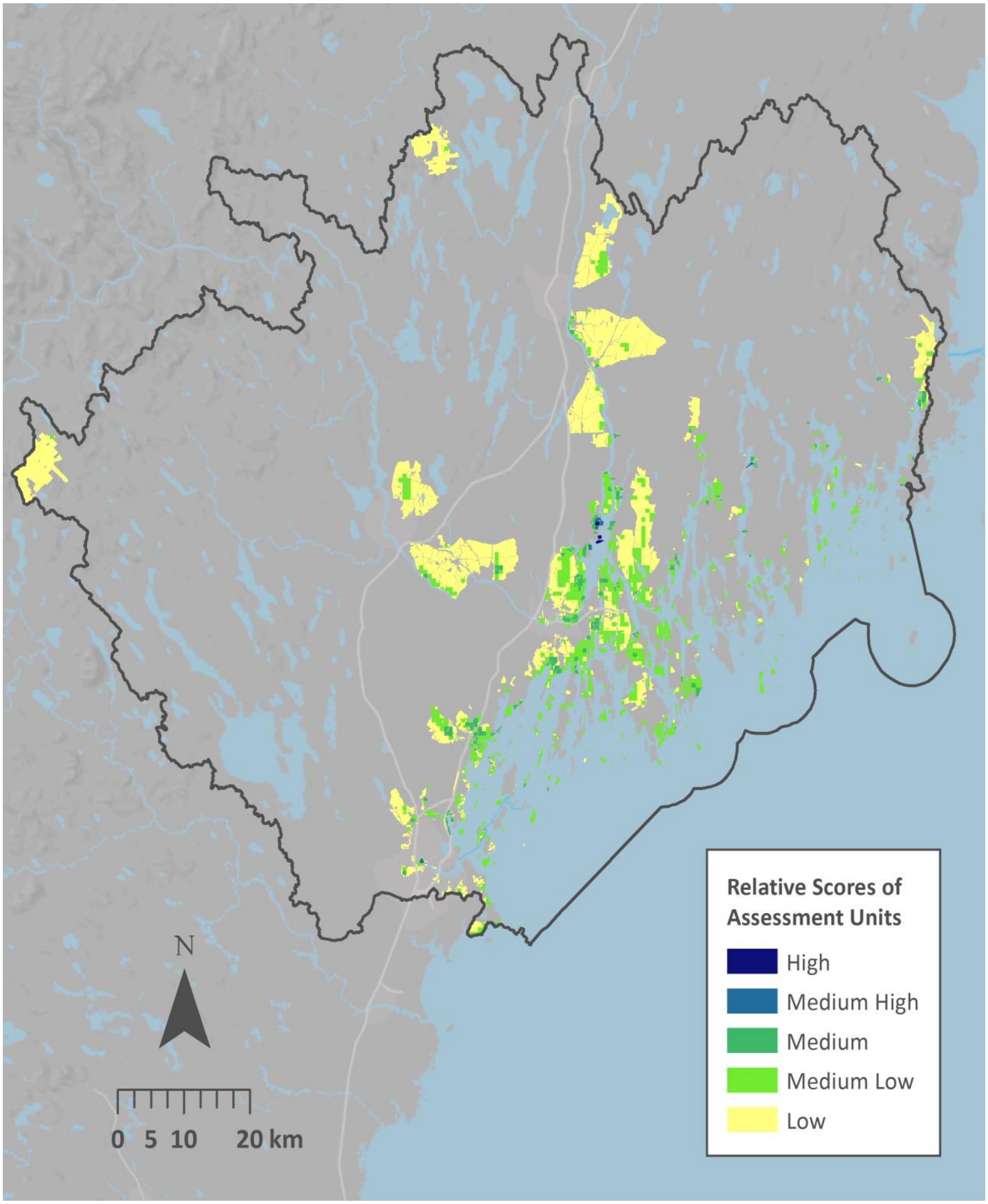


Figure 16. Resilience Hubs assessment unit relative scores for the Portland and Midcoast Maine Watersheds. *Assessment units are 100-acre grids or smaller parcels. Darker shades have higher scores and thus greater potential to achieve both community resilience and fish and wildlife benefits. Gray areas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

Hub scores are generally low in this region because of the lack of vulnerable human asset concentrations (**Figure 12**), which emphasizes the low-density population areas that also have high threat, such as the dark blue areas around Merrymeeting Bay. Small, but important hub areas can be found at the mouth of the Presumpscot River by East Deering, near the Brunswick Executive Airport, and at the head of Maquoit Bay. Other areas with high relative assessment unit scores are at the head of coastal rivers, including Great Salt Bay in Damariscotta, or are farther inland near large rivers such as along the Kennebec at Augusta.

Suggested Uses

The Resilience Hubs map for the Portland and Midcoast Maine 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.

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.

Merrymeeting Bay Resilience Hub Area Example

The area outlined in pink on the map below is located near the shore of Merrymeeting Bay (**Figure 17**) and was the highest scoring area for resilience potential within the entire Portland and Midcoast Maine Watersheds region. The low-lying forests and productive agricultural fields along the bay are threatened by flooding from a combination of sea level rise, storm surge, and high river flows, and have one of highest concentrations of flooding threats within the Portland and Midcoast Maine region (**Figure 10**). Even though the population density in this area is low, the area's high flooding potential contributes to a large impact. Another component of the high resilience score for this area is the large number of fish and wildlife elements within its boundaries and the good condition of the habitat for these elements. Merrymeeting Bay contains the largest area of freshwater tidal marsh in the state and is the drainage point for six rivers, which together, drain roughly one-third of the land area of Maine (and part of New Hampshire). With its good condition and unprotected status, the area is well suited for conservation through conservation easements or land acquisitions, so it scored high for restorability. The final component that contributes to the resilience score is marsh migration potential.

This area is modeled to be a site for marsh migration under a three-foot sea level rise scenario, indicating that it has the potential to provide important habitat into the future.

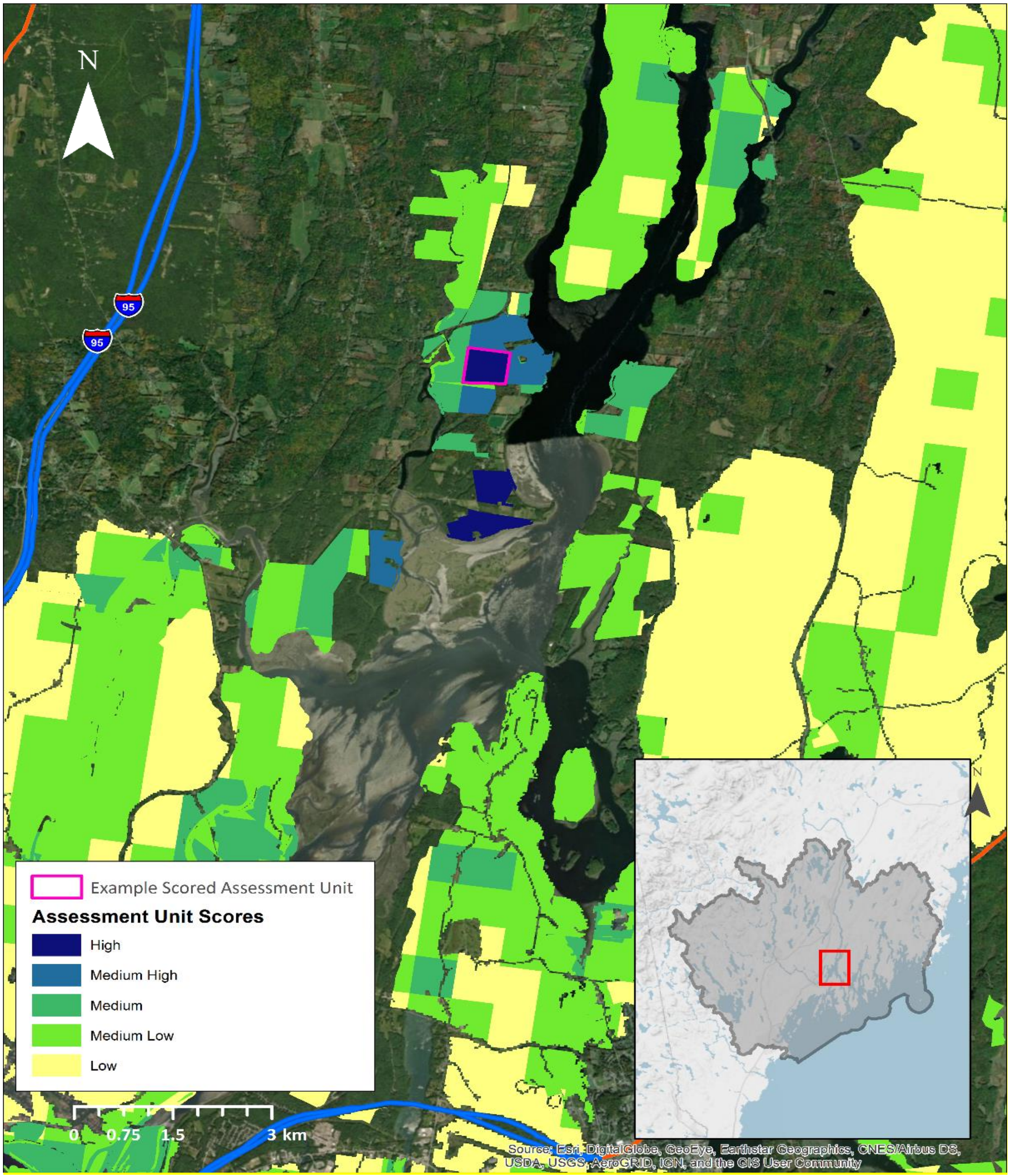


Figure 17. Merrymeeting Bay Resilience Hub area example. *The yellow-blue shaded areas are the scored Resilience Hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Habitats for Marsh Migration
- Undeveloped Habitat Blocks
- Focal Species Cores
- Terrestrial Resilient Landscape Sites
- Rare and Exemplary Natural Communities – Terrestrial
- Riparian Zone and Water Resources
- Tidal Freshwater Wetlands
- Atlantic Salmon Critical Habitat

HCA elements in or near assessment unit:

- Population Density Rank 1

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

Description of Scoring Attributes	Score
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	8
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1, mean 0.05 and standard deviation of 0.06)	1.0 (very high)
Restorability index	0.5 (already protected and in good condition)
Average Condition (1= current very high condition)	0.98 (high)
Final score	**5.22 (rank #1 out of 3,575 units)**

Cousins River Resilience Hub Area Example

The area highlighted in pink below (**Figure 18**) is situated along the Cousins River and scored moderately as a resilience hub. It sits a short distance downstream from one of Maine's major highways, Interstate 295. For the Portland and Midcoast Maine Watersheds region, it has a high level of HCA vulnerability. The area also has many fish and wildlife elements, ranging from shorebirds to diadromous fishes and horseshoe crabs. It is suited for marsh migration, so it can continue to serve as an important habitat as sea levels rise. Portions of the area are conserved by the town and local land trusts. With its moderate environmental condition (e.g., ditching, poor culverts, invasive plants, run-off, poor buffer), it has significant potential for restoration.

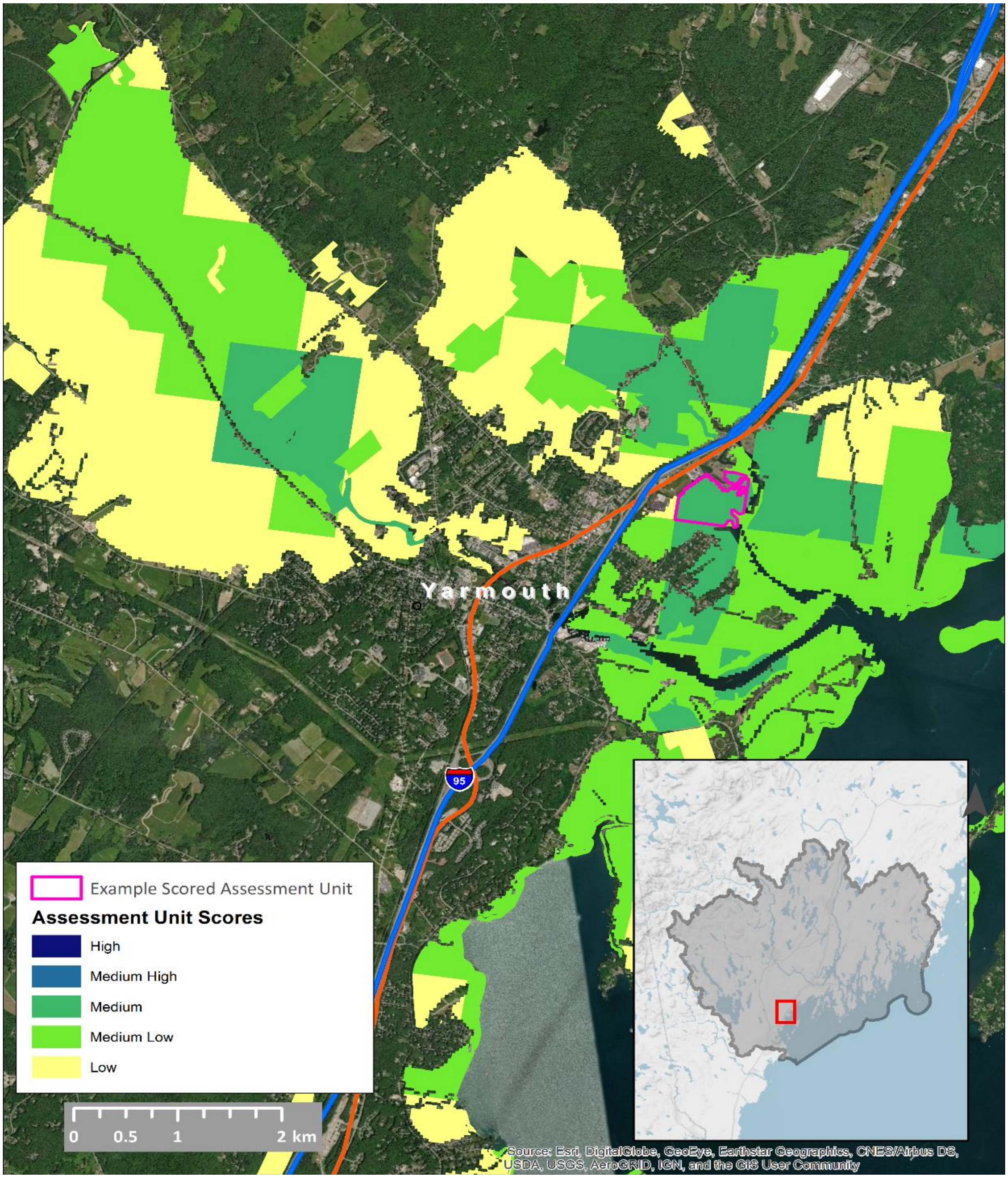


Figure 18. Cousins River Resilience Hub area example. *The yellow-blue shaded areas are the scored Resilience Hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Habitats for Marsh Migration
- Obligate Saltmarsh Birds
- Shorebird and Seabird Habitat
- Wading Bird and Waterfowl Habitat
- Focal Species Cores
- Terrestrial Resilient Landscape Sites
- Rare and Exemplary Natural Communities – Terrestrial
- Diadromous Fish Habitat
- Riparian Zone and Water Resources
- Tidal Brackish and Saltwater Marshes
- Horseshoe Crabs
- Maine State Wildlife Action Plan Priority 1 and 2 Estuarine

HCA elements in or near assessment unit:

- Critical Infrastructure Ranks 1, 2, and 3
- Population Density Ranks 1, 2, 3, 4, and 5 (Yarmouth)

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

Description of Scoring Attributes	**Score**
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	12
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1, mean 0.05 and standard deviation of 0.06)	0.20 (high)
Restorability index	1 (restorable and unprotected)
Average Condition	0.63 (moderately high)
Final score	**2.46 (rank #41 out of 3,575 units)**

Popham Beach Resilience Hub Area Example

The area highlighted in pink below (**Figure 19**), on the southern coast of Phippsburg, is near the popular Popham Beach State Park. Most of this area is low-lying salt marsh. The one road to the state park and the homes, businesses, and historic sites on the peninsula beyond it crosses through this hub area. Flooding has occurred on the road in this area during high storm tides, cutting off access at high tide. Erosion along the beach near roads and park infrastructure has been a strong concern. The area is a moderately scored resilience hub. The healthy salt marsh and neighboring upland of this area allow it to host a very high number of fish and wildlife species, with the low-lying adjacent wetlands providing space for the marshes to migrate. The impervious surface of the road helps contribute to an average ranking of environmental condition for the area. It is located near conserved property at Popham Beach and Morse Mountain. It has a moderate score as a resilience hub because it is already protected and in good environmental condition.

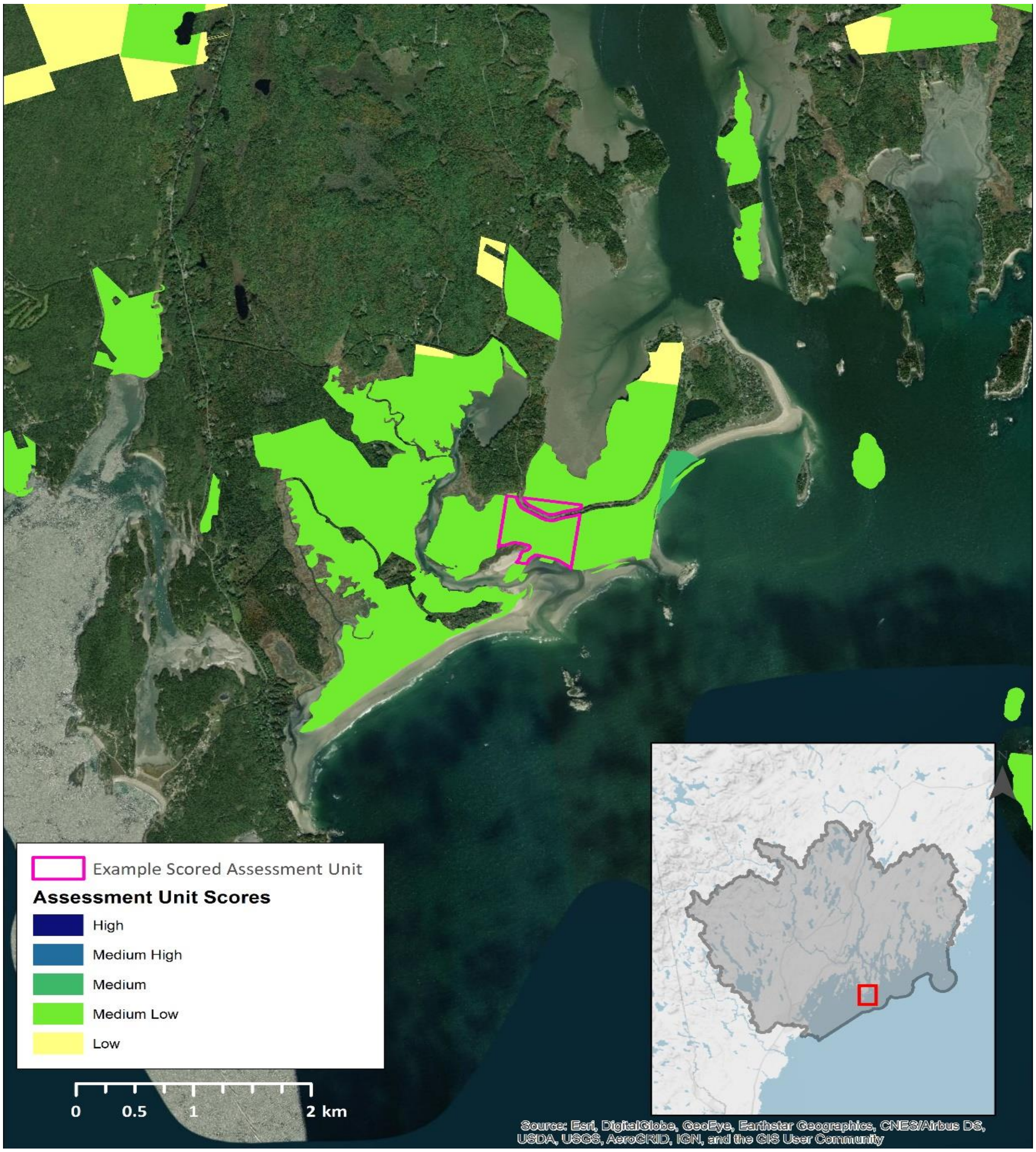


Figure 19. Assessment units in and around the Popham Beach. *The yellow-blue shaded areas are the scored Resilience Hub assessment units. The hub assessment unit outlined in pink is the one used to characterize the values in this example.*

Elements in this assessment unit:

- Habitats for Marsh Migration
- Obligate Saltmarsh Birds
- Sand Dune Habitat
- Shorebird and Seabird Habitat
- Wading Bird and Waterfowl Habitat
- Focal Species Cores
- Maine State Wildlife Action Plan Priority 1 and 2 Terrestrial
- Terrestrial Resilient Landscape Sites
- Rare and Exemplary Natural Communities – Terrestrial
- Riparian Zone and Water Resources
- Atlantic Salmon Critical Habitat
- Marine Shellfish
- Tidal Brackish and Saltwater Marshes
- Horseshoe Crabs
- Maine State Wildlife Action Plan Priority 1 and 2 Estuarine

HCA elements in or near assessment unit:

- Population Density Rank 1

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

Description of Scoring Attributes	Score
Fish and wildlife richness (# of fish/wildlife elements out of 16 possible)	15
Presence of modeled marsh migration	1 (yes)
Weighted Human asset vulnerability (normalized to 0-1, mean 0.05 and standard deviation of 0.06)	0.14 (moderate)
Restorability index	0.5 (already protected and in good condition)
Average Condition	0.84 (high)
Final score	**1.96 (rank # 275 out of 3,575 units)**

Fish and Wildlife Elements

The final list of elements explicitly represented in the Portland and Midcoast Maine 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 Portland and Midcoast Maine Watersheds assessment.

Fish/Wildlife Element	*Description/Significance*
NOAA Trust Resources	
Atlantic salmon critical habitat	This layer includes the area designated by NOAA as Atlantic salmon Gulf of Maine DPS critical habitat
Atlantic sturgeon critical habitat	This layer includes the area designated by NOAA as critical habitat for Atlantic sturgeon.
Diadromous fish habitat	This layer includes distribution information of most of the diadromous fish species found in the Gulf of Maine: alewife, American eel, American shad, Atlantic Salmon, Atlantic sturgeon, Atlantic tomcod, blueback herring, rainbow smelt, sea lamprey, sea run brook trout, shortnose sturgeon, and striped bass.
Horseshoe crabs	This layer represents areas utilized as important habitat by juvenile horseshoe crabs.
Marine shellfish	This layer identifies distribution information for the following molluscan shellfish species, which are important ecologically and for their economic commercial harvest value: sea scallop, American oysters, Atlantic surf clams, blue mussels, European oysters, hard clams, razor clams, and softshell clams.
At-Risk Species and Multi-species Aggregations	
Maine State Wildlife Action Plan priority 1 and 2 freshwater aquatic species	This layer maps habitat for species that are listed as Endangered, Threatened, or Special Concern in Maine's freshwater aquatic habitats.
Maine State Wildlife Action Plan priority 1 and 2 terrestrial species (freshwater wetland and upland)	This layer maps habitat for species that are listed as Endangered, Threatened, or Special Concern in Maine's terrestrial habitats.
Maine State Wildlife Action Plan priority 1 and 2 estuarine species (saltwater wetland and aquatic estuarine)	This layer maps habitat for species that are listed as Endangered, Threatened, or Special Concern in Maine's estuarine habitats.

Fish/Wildlife Element	*Description/Significance*
At-Risk Species and Multi-species Aggregations	
Focal species core areas	This identifies the suitable habitat for 31 species that were selected as representative species for the Northeast. They represent the landscape's capability of supporting a much larger suite of conservation priority species. It highlights habitats where multiple species have high landscape capability while also ensuring the core areas are large enough to provide ecologically meaningful habitat. The focal species are: American black duck (breeding), American black duck (nonbreeding), American oystercatcher, American woodcock, Bicknell's thrush, black bear, Blackburnian warbler, blackpoll warbler, box turtle, brown headed nuthatch, cerulean warbler, common loon, diamondback terrapin, eastern meadowlark, Louisiana waterthrush, marsh wren, moose, northern waterthrush, ovenbird, piping plover, prairie warbler, red-shouldered hawk, ruffed grouse, saltmarsh sparrow, sanderling, snowshoe hare, snowy egret, Virginia rail, wood duck, wood thrush, and wood turtle.
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Wading bird and waterfowl habitat	This layer represents inland waterfowl and wading bird habitat, a Significant Wildlife Habitat defined under Maine's Natural Resources Protection Act (NRPA).
Obligate saltmarsh birds	This identifies habitat for saltmarsh sparrow and yellow rail, the two bird species in Maine that depend upon salt marsh habitat for a portion of their life cycle.
Significant vernal pools (with 500 ft buffer)	Vernal pools provide critical breeding habitat for key amphibian and frog species. *Note: this layer includes only pools that were mapped and surveyed in the field for indicator species and subsequently identified as 'Significant Vernal Pools' or 'Potentially Significant Vernal Pools'.*
Tidal freshwater wetlands	These wetlands provide key habitat and nursery areas for a wide array of fish species and important habitat for migratory birds. This is one of the rarest wetland types along the Northeast coast.
Tidal brackish and saltwater marshes	These wetlands provide key habitat and nursery areas for a wide array of commercially important fish species and increase resiliency to coastal flooding.
Heritage brook trout waters/EBTJV data	This includes stream and pond habitats in Maine known to be actively used, or very likely to be actively used, by wild brook trout.
SAV/eelgrass beds	Eelgrass stabilizes sediment and provides vital nursery habitat for a variety of species in shallow subtidal areas. This layer includes eelgrass distribution mapped in 1997, 2010, and 2013in order to represent viable habitat for eelgrass.
Significant aquifers	This layer is included to aid in characterizing cold water input for streams, which provide refuges for fish when water temperatures rise in the summer. It also identifies areas that are important for drinking water resources.
Riparian zones and water resources	Tidal waters, ponds, rivers, and streams provide connectivity and a range of habitats. This layer also includes the land that buffers their shorelines, which serves to help protect water quality.

Fish/Wildlife Element	*Description/Significance*
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species	
Shorebird habitat / seabird nesting islands	This includes shorebird areas and seabird nesting islands that are defined as Significant Wildlife Habitat under the Natural Resources Protection Act. It also includes Essential Habitat for three shorebird species of concern: piping plovers, least terns, and roseate terns.
Sand dune habitat	Dunes provide protection from waves during storm events and provide habitat for a variety of priority species.
Rare and exemplary natural communities	Natural communities are assemblages of vegetation and landforms that support specific fish and wildlife species. The rare and exemplary natural communities are most at risk, putting the fish and wildlife they support at risk as well.
Cross-cutting Elements	
Continental and global important bird areas	Areas of key importance for bird species.
Terrestrial resilience landscape sites	This layer identifies terrestrial areas that have an above average ability to be able to continue to support healthy assemblages of fish, wildlife, and vegetation as temperature and precipitation regimes change.
Habitats for marsh migration	These are areas that are modeled to be important shoreline habitat as sea levels rise. It includes undeveloped land that is suitable for marsh migration with 1 m (3.28 ft) of sea level rise, and it also includes undeveloped land that will be the new shoreline buffer when water has risen to this level.
Undeveloped habitat blocks	This layer identifies blocks of habitat greater than 1,200 acres that are not currently developed or directly adjacent to current development or roads. These large habitat blocks support species that require larger home ranges and provide corridors for species to move.

Resilience Projects Portfolio

A portfolio of resilience projects within the Portland and Midcoast Maine Watersheds was compiled from plans and other project documents submitted by stakeholders (**Table 7**). A total of 18 projects were submitted for these watersheds. Beyond a review of project documents, projects were further evaluated using several data layers created in the GIS assessments.

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

1. Agency, NGO, and extension staff in this region have capacity to implement coastal resilience projects where funding is available.
2. Project leaders recognize the need to engage neighbors and community stakeholders upfront in planning and decision-making for projects that directly affect their areas of interest to ensure there is initial and ongoing support for long-term projects.

3. Citizens in the region are experiencing more frequent flooding and communities are concerned about how the flooding on coastal roads will impact travel, safety, and access to emergency services.

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

Project Type	Project Phase				
	Unknown	Conceptual	Planning Complete	Ready to Implement	Total
Studies & Modeling					0
Living Shorelines					0
Aquatic Connectivity	1	6	1	1	9
Beach or Dune Restoration					0
Monitoring & Mitigation					0
Riparian Restoration		1			1
Wetland and/or Marsh Restoration	1	2	1		4
Green infrastructure			1		1
Community Resilience Planning		3			3
Eelgrass Restoration					0
Totals	**2**	**12**	**3**	**1**	**18**

As can be seen in **Figure 20**, the projects relate to either tidal sites or inland river systems. Most of the submitted resilience projects are in the conceptual stage. Eight projects were submitted by non-profits, seven projects were submitted by a national estuary program, and one project each was submitted by a town, regional planning commission, and soil and water conservation district.

Connectivity was an important part of many of the submitted projects. Nine are focused on aquatic connectivity, and an additional four are focused on marsh restoration through the restoration of tidal connectivity. The two other coastal projects were for community resilience planning and green infrastructure, and an additional inland project addressed riparian restoration. A full list of submitted projects and summary information about each is in Appendix 6.

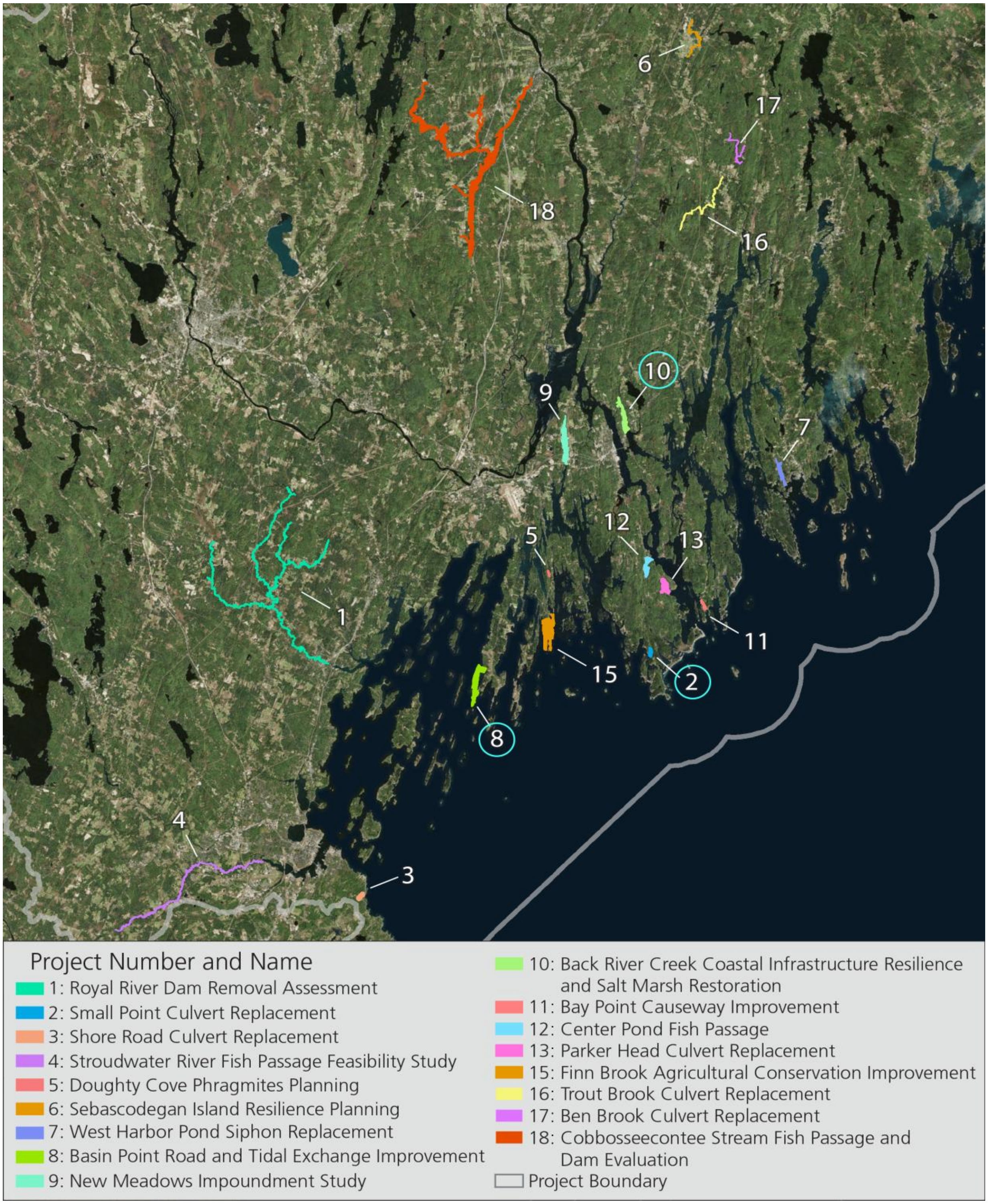


Figure 20. Map showing the boundaries of resilience projects compiled for the Portland and Midcoast Maine Watersheds. *Projects #2, #8, and #10 for which detailed case studies were written are indicated by blue circles around the project number. Project #14 is not pictured due to its distributed nature. See Appendix 6, Table A6-1 for a full list of projects.*

Suggested Uses

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

Case Studies

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

- All projects will have high visibility during and after implementation due to their proximity to roads, neighborhoods, and/or areas used frequently by fishermen and boaters.
- All the projects are near lands that are conserved by state agencies or local non-profits, supporting fish and wildlife habitat in perpetuity.
- Each of the projects has the potential to reduce flooding and/or storm surge affects to roads and adjacent human assets such as homes and places of business.
- Each project depends on partnerships between federal, state, town, and non-profit organizations, allowing projects to build broad support by considering the needs of each partner.
- All projects have potential benefits for fish nursery areas for key species that support recreational and commercial endeavors in the region.

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

Case Study 1: Small Point Culvert Replacement

Project Overview

Location: Phippsburg, ME

Date Visited: May 8, 2018

Contact: Matt Craig, Casco Bay Estuary Partnership (CBEP)

Figure CS1-1. Stone structure under Route 216. *Structure has logs at the top level supporting the stone under the roadbed and what appears to be a collapsed rock in the center that only leaves a small gap for water to flow. It severely limits tidal flow to over 13 acres of wetland upstream.*

An undersized and deteriorating culvert-like stone structure conveys a limited volume of tidewater beneath Small Point Road/Route 216 in Phippsburg, Maine, where it crosses the over 13-acre Small Point Marsh and wetland system. Erosion is visible along the bank on the downstream side of this road. This structure restricts tidal exchange, causing a muted tidal range so that the upstream marsh experiences smaller high tides and impounded water at low tide. During an extreme storm event, water can rise to the edge of the road, signaling the potential for severe flooding effects under future scenarios.

Route 216 is the only road that provides access to the Small Point region of the Town of Phippsburg. This peninsula, framed by Sprague marsh to the west and Casco Bay to the east, has a combination of year-round and seasonal residents. The road is well used in the summer, as people travel down the point to seasonal homes, summer rental cottages, large popular campgrounds, and a beach frequented by both tourists and residents. If the road were cut off due to flooding or storm damage, fire department and ambulance services would be unavailable to Small Point residents and visitors.

A restoration project at this site would evaluate and design a new bridge or culvert (pending further assessment) that would increase the stability and elevation of the road and allow for tidal exchange with the upstream wetland. In addition, low lying adjacent freshwater wetland and upland habitat are suitable for marsh migration as sea level rise occurs. The upstream property is owned by the Phippsburg Land Trust, and they have expressed support for restoration work at the site. The Casco Bay Estuary Partnership has carried out a preliminary site evaluation, measuring the elevation of the road and adjacent channel, as well as monitoring surface water elevation for a month both upstream and downstream from the site. The surface water elevation monitoring indicated that the structure under the road is severely limiting the flow of water to the upstream marsh, muting the tidal range and influence of salt water.

Route 216 is a state road, so it is managed by Maine Department of Transportation (Maine DOT). There are many crossings that rank higher than this one on the Maine DOT prioritization work list, and without external support it would be difficult for Maine DOT to replace the culvert with anything more than a five- to six-foot round metal pipe. Although this would certainly be an improvement over the less than one square foot of passage currently present, it would not account for the tidal dynamics at the site, sea level rise, marsh migration, threats to adjacent property, or the low road elevation that makes it susceptible to flooding. It would be a missed opportunity to design a structure that benefits both fish and wildlife and human communities. A considerably larger structure would be needed at the site to provide full tidal exchange to the upstream wetland. If project partners were to raise funding to aid in the costs of engineering or construction, the project may be able to move up the prioritization list and meet the design specifications for wetland restoration. The Casco Bay Estuary Partnership, Phippsburg Land Trust, Kennebec Estuary Land Trust, Town of Phippsburg, and Maine DOT have been in communication about this crossing.

This project could significantly increase key fish and wildlife habitat while reducing flooding. Fish and wildlife that could benefit include horseshoe crabs, obligate salt marsh birds, wading birds, waterfowl, and NOAA trust fish species like mummichogs and American eels. Important habitats and landscapes that would benefit include tidal brackish and saltwater marsh, riparian zones, marsh migration corridors, and resilient landscapes.

More specifically, the project will:

- Reduce the extent of damaging inundation from future major storm events.
- Preserve access for emergency services (fire, police, ambulance).
- Increase resilience/restoration of tidal marshes.
- Improve path for future marsh migration in the face of sea level rise.
- Improve integrity for over 13-acres of existing tidal marsh.
- Improve water quality through flushing of tidal marsh.
- Reduce maintenance costs (culvert and road repairs, debris removal).

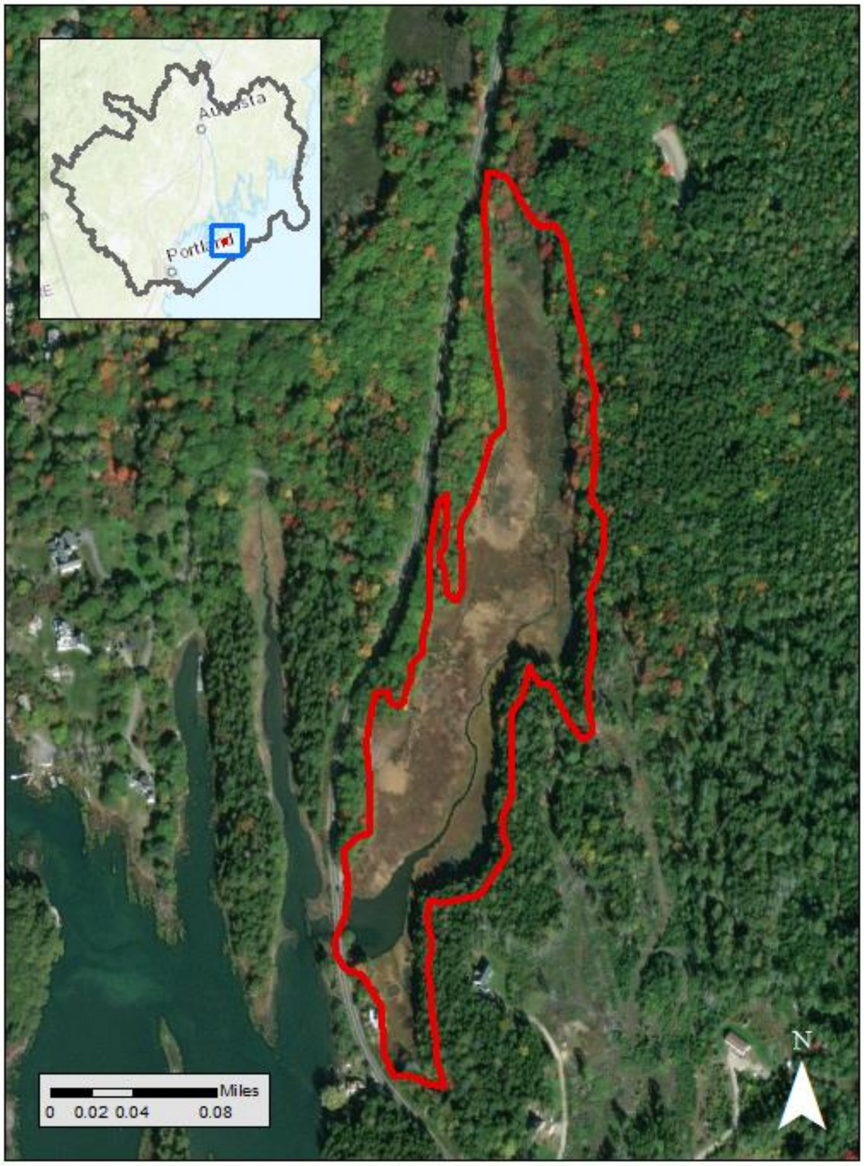


Figure CS1-2. Approximate project area (red boundary). *Boundary represents the area upstream of the culvert on Route 216. This area has an elevation that falls below the current highest annual tide. A project that enchances tidal exchange to this area could increase salt marsh size and health.*

Estimated Cost of the Project

Project partners estimate that a feasibility study and engineering designs at the site will cost approximately $75,000. For more detailed numbers, please contact the project sponsor, Matt Craig at Casco Bay Estuary Partnership.

Stressors and Threats

Storm surge, sea level rise, and flooding are the primary stressors at this site. See **Table CS1-1** for a list of stressors and flooding threats. The road and the small capacity of the current culvert under it create additional stressors for fish and wildlife at the site by limiting the influx of tidal waters and decreasing the tidal range. These conditions stress wetland health, limiting sedimentation rates and potentially causing degradation and erosion of the saltmarsh. The limited flow also prevents the wetland from serving as prime habitat for juvenile fish. The area around this site is forested, and forest management operations that change the canopy cover or don't make efforts to minimize erosion and sedimentation can be stressors on fish and wildlife.

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

Existing Stressors
Secondary Roads
Silviculture
Flooding Threats
Sea Level Rise
Storm Surge (Category 1)
Storm Surge (Category 2)
100-year Floodplain

Human Community Assets

The road crossing at the project site is the only access route to Small Point, and therefore, the human and community assets (HCAs) related to the site include all of those located south of this point on Route 216. Small Point has more than 100-year-round residents, and during the summer the number of residents increases significantly. Summer daily traffic counts reach 800 to 1,000 cars as people travel down the point to seasonal homes, summer rental cottages, campgrounds, a restaurant, and beaches. The seasonal rentals and businesses provide important income for the community. The sale of recreational clam licenses at the beach also brings in revenue for the town, and at certain times of year, the clam flats serve as a resource for commercial harvest as well. Small Point does not have its own critical services, like medical facilities, a school, fire department, or ambulance, so it depends on vehicles being able to travel across the road at the project site. **Figure CS1-3** shows the human and community assets in the immediate vicinity of the project site, and **Table CS1-2** outlines some of the resources that lie within and depend upon access to the project site.

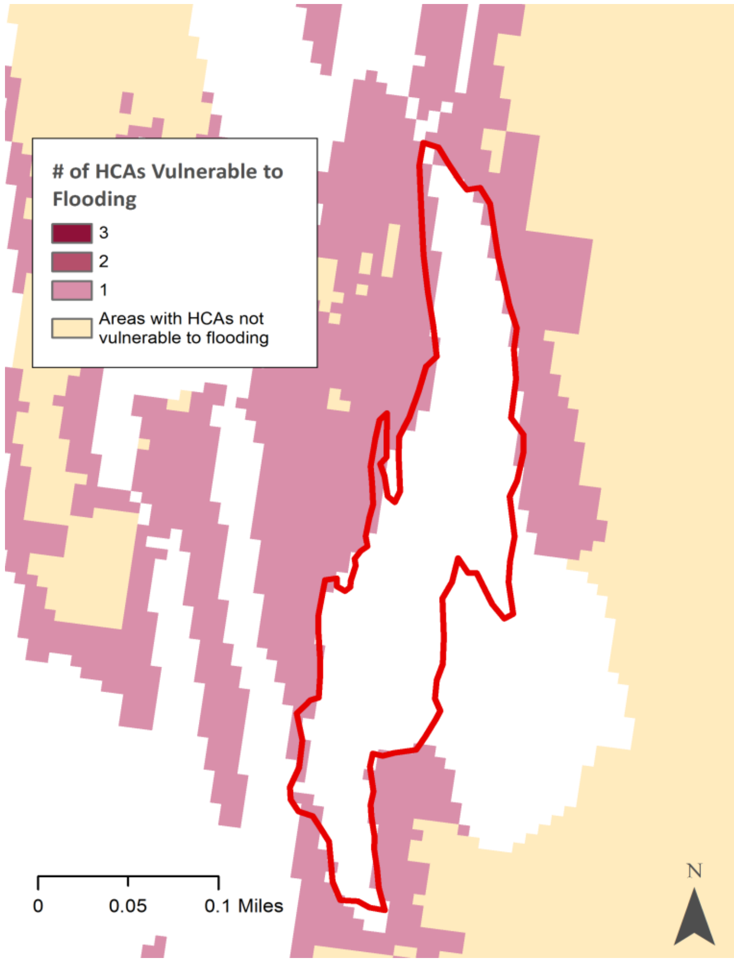


Figure CS1-3.Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (pink signifies vulnerable HCA elements) within and around the Small Point Culvert Replacement project. Tan color indicates areas with HCAs that are not categorized as vulnerable to flooding-related threats for the purposes of this assessment.*

Table CS1-2. Human Community Assets identified within the project boundary. *Also includes those HCAs that are reliant upon access to the road at the project site.*

Categories of Human Assets Identified within Project Boundary
Densely populated areas
Mapped Community/Human Assets within Project Boundary
Hermit Island Campground Head Beach Campground The Lobster House Restaurant Rental Cottages Head Beach

Fish and Wildlife

The project area impacted by this proposed restoration project contains saltmarsh and brackish marsh habitat that supports fish and wildlife species highly valued by regional stakeholders. **Table CS1-3** outlines the habitats within the project area and **Figure CS1-4** identifies where these habitats are concentrated. The more than 13 acres of salt marsh support species like the saltmarsh sparrow, identified as a species of greatest conservation need by the State Wildlife Action Plan. They also support habitat for juvenile fishes and wading birds and waterfowl. Because many of the fish and bird species that use the site only spend some of their lifespan within the project area boundary, the benefits of the restoration project could be realized at other locations distant from the project site. Upstream from the current marsh habitat, there is acreage available for marsh migration, and this location has some of the greatest potential for marsh migration in the town of Phippsburg.

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 **
Horseshoe crab habitat	Horseshoe crab, red knot, mussels
Marsh migration	Mink, muskrat, saltmarsh sparrow, mummichog, American eel
Obligate salt marsh birds	Saltmarsh sparrow, yellow rail
Resilient landscape	Layer showing areas that are particularly important to maintain resilient landscapes in the face of future changes.
Riparian zones – water resources	Cattail, brook trout
Tidal brackish saltwater marshes	Saltmarsh sparrow, glossy ibis, Atlantic silverside
Wading bird waterfowl habitat	Great blue heron, snowy egret, greater yellowlegs

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

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

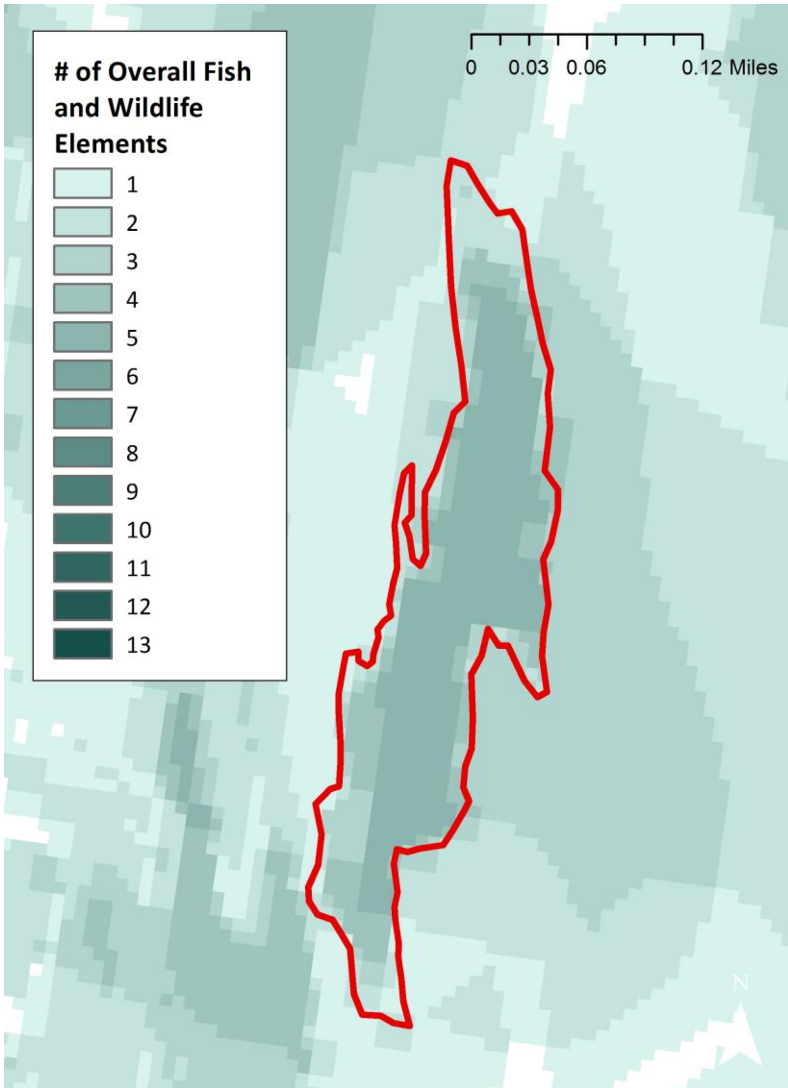


Figure CS1-4. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements richness (darker green signifies a higher number of elements co-occurring in the same place). Red outline is the project boundary.*

Expected Project Impact

Replacing the culvert at Small Point marsh on Route 216 has the potential to improve the health of more than 13 acres of salt marsh, which will support and provide access to habitat for fish and wildlife species. The improved connectivity that results from the project will also allow the site to provide opportunities for marsh migration, so the area surrounding the site will be able to support healthy marshes in the future. Replacing the culvert has additional benefits for human community assets. A new structure would fix a location where erosion on the downstream bank is approaching the edge of the pavement. It would also raise the road elevation above the level threatened by storm surge and predicted sea level rise. These changes would make the road more resilient to these events and ensure that it is accessible by residents, visitors, and emergency vehicles.

Case Study 2: Back River Creek Coastal Infrastructure Resilience and Salt Marsh Restoration

Figure CS2-1. Downstream view of the under-sized culvert under George Wright Road. *Built in the 1930s, the culvert is completely submerged at high tides. Photo shows water forcefully exiting the culvert as tide recedes.*

Project Overview

Location: Woolwich, ME

Date Visited: May 8, 2018

Contact: Ruth Indrick, Kennebec Estuary Land Trust

At this site, U.S. Route 1—the major coastal road in Maine—and the town owned George Wright Road serve as tidal restrictions that limit upstream tidal exchange from Pleasant Cove to the large marsh upstream along Back River Creek. Flooding also occurs in the low-lying sections of these roads during extreme tide and storm events. For tidal waters to reach the marsh, they currently flow through a nine-foot culvert under the town road that was constructed in the 1930s. The water then pools between the town road and US Route 1 before flowing through three culverts under U.S. Route 1 to the marsh upstream. The City of Bath, to the west of this site, receives its drinking water from Woolwich's Nequasset Lake, to the east, via a 16-inch transmission main pipe that sits under the town road on top of the 80+ year old culvert. Another important structure that ties into the road infrastructure at this site is a boat launch adjacent to the culvert that provides public access to tidewater. A rail line crosses the marsh about 100 acres upstream from U.S. Route 1. The site is also influenced by a dike built across the marsh surface that served as a road more than 100 years ago. This grassy gravel path acts as an unmaintained levee just downstream from U.S. Route 1.

The culvert under the town road is completely underwater during high tides, and it has high flows and remnant structures from a dismantled tide gate that restrict fish passage. Downstream from the crossing, the habitat is mainly intertidal *Spartina* salt marsh, a natural ecological community that occurs in salty and brackish water. As a result of the restriction, the 158 acres of marsh habitat upstream from the town road and U.S. Route 1 that is below the current highest annual tide is dominated by cattail marsh, which indicates a high-level of freshwater. The tidal range on the upstream side of the culvert is much lower than the natural tidal range due to the restricted flow from the culvert. The U.S. Fish and Wildlife Service (USFWS) installed dataloggers to measure flow in this area in 2017 and found that both U.S. Route 1 and the town road act as barriers, and the tidal range in the wetlands upstream from the roads is an average of 4.8 ft. smaller than the natural tidal range due to the restricted flow from the culverts.

This project will develop a plan for increasing tidal flow to the upstream wetland while reducing flooding risks to the roads. The structures that will be considered in the feasibility planning and design include: 1) the low-lying area of U.S. Route 1 that regularly floods, 2) U.S. Route 1 on the eastern side of the wetland that currently has three culverts in the tidal channel, 3) the culvert under George Wright Road, 4) the abandoned portion of old road, 5) the water main pipe, and 6) the boat launch. The adjacent upstream property and most of the upstream wetlands are owned by the Maine Department of Inland Fisheries and Wildlife. They have expressed support for restoring tidal flow. Different owners manage different pieces of infrastructure –U.S. Route 1 is managed by the Maine Department of Transportation, George Wright Road is managed by the Town of Woolwich, and the drinking water pipe is managed by the quasi-municipal Bath Water District.

Due to concern about the poor condition of their culvert under George Wright Road, the Town of Woolwich funded the pre-engineering and design for a structure to replace it that was completed in summer 2018. This initial assessment identified that increasing the size of the structure under the town road or removal of the road would not alone restore the upstream wetland because the culverts under U.S. Route 1 also act as barriers. The tidal range may increase by one to two feet by changing the town road, but it would still be about three feet smaller than the downstream tidal range. The surveying and modeling also found that alterations to the George Wright Road culvert would not change the flooding on Route 1 during current extreme high tides. Due to concerns about the stability of the town road's culvert, the Bath Water District is considering replacing the pipe at that site by doing a directional boring to put a new pipe underground.

Because the current structures on and around George Wright Road and U.S. Route 1 all combine to cause the flooding and restricted tidal flow, the feasibility and design study of this site will include a consideration of the combined hydrologic impacts of all of these structures and their alternatives. Project partners include the Kennebec Estuary Land Trust, town of Woolwich, Maine Department of Transportation, Bath Water District, Maine Department of Inland Fisheries and Wildlife, USFWS, and NOAA.

This project has the potential to restore about 158 acres of saltmarsh, improve fish passage, increase the resilience of U.S. Route 1 to flooding and sea level rise, and protect the structures that supply drinking water to the nearby city of Bath.

More specifically, the project will:

- Restore more than 150 acres of tidal salt marsh
- Reduce inundation from major storm and flood events and reduced hazard flooding.
- Protect the public drinking supply.
- Restore diadromous fish passage.
- Decrease potential for the flooding of a major road.
- Maintain public access for outdoor recreational activities such as boating, fishing, waterfowl hunting and birdwatching.

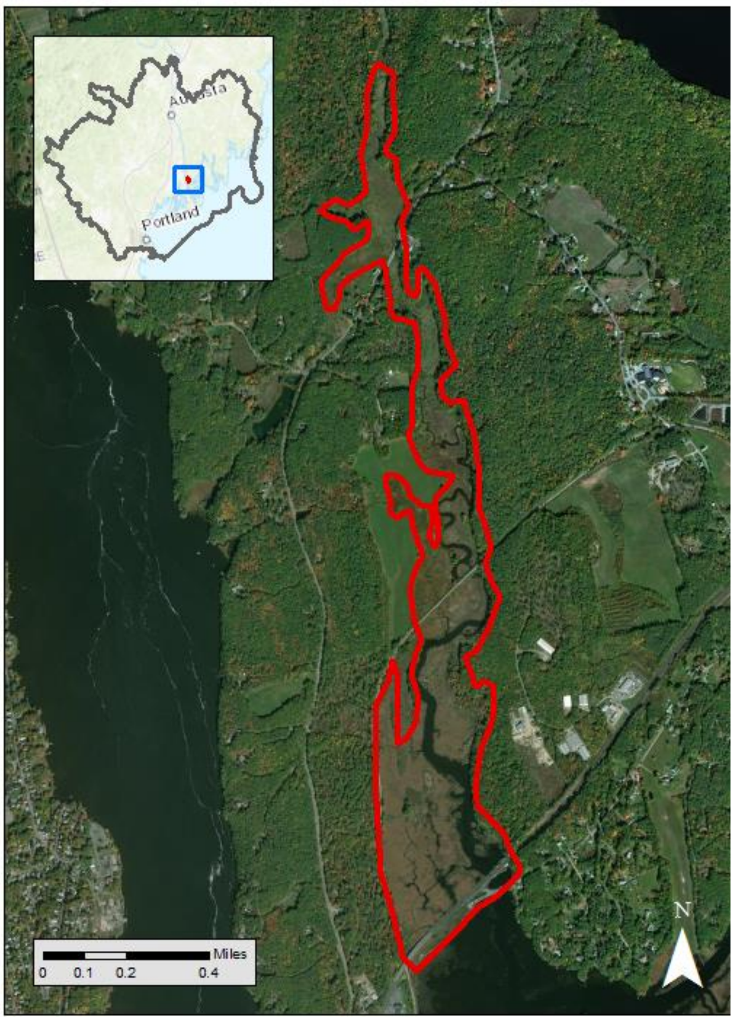


Figure CS2-2. Approximate project area (red boundary). *Boundary includes the upstream of the infrastructure along George Wright Road and Route 1. This is the area that is most likely to benefit from the proposed project.*

Estimated Cost of the Project

The town of Woolwich has invested about $19,000 in preliminary designs for the George Wright crossing. Maine DOT provided rough estimates that feasibility studies and designs for the restoration work on and around U.S. Route 1 will be $500,000, with total project costs of about $5 million. For more detailed numbers, please contact the project sponsor, Ruth Indrick, Kennebec Estuary Land Trust.

Stressors and Threats

This site has a high concentration of existing stressors and flooding threats for human community assets (HCAs) and fish and wildlife. It is prone to threats from storm surge, sea level rise, high erosion, and 100-year floods. These threats will not only affect the road infrastructure through the site (an emergency route), but will also continue to degrade habitat and lead to habitat loss for key fish and wildlife species.

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

Existing Stressors
Developed Open Spaces (low imperviousness <20%)
Local, neighborhood and connecting roads, bridges/culverts
Low Density Housing (moderate imperviousness 20-49%)
Railroads, bridges, culverts
Ruderal (maintained pasture, old field)
Primary Roads
Silviculture - Sustainable
Flooding Threats
Very High Erosion (Rank 5)
Sea Level Rise
Poor or Very Poorly Drained
High Erosion (Rank 4)
Storm Surge (Category 1)
Storm Surge (Category 2)
Storm Surge (Category 3)
Storm Surge (Category 4)
100-year Floodplain

Human Community Assets

This site and the surrounding area contain important HCAs including U.S. Route 1, Rockland Branch railroad line, and the water main pipe for the Bath Water District (**Table CS2-1**). **Figure CS2-3** shows areas where there are high concentrations of human community assets that are vulnerable to the threats listed above. For this area, flooding risk is highest for U.S. Route 1, as it already experiences flooding during extreme tides. The map below shows the extent of human community assets that are threatened (in pink and red coloring), especially near U.S. Route 1 and the culvert at George Wright Road (far southern end of figure). (**Figure CS2-4**).

Figure CS2-3. High river flows, an offshore storm, and spring tides in March 2018 combined to cause an extreme high tide that flooded U.S. Route 1 and George Wright Road. *The top image shows the area from the west, as cars avoid the water that covers half of U.S. Route 1. The bottom image shows the area from the east, highlighting the flooding on U.S. Route 1 and showing water completely covering George Wright Road to the south.*

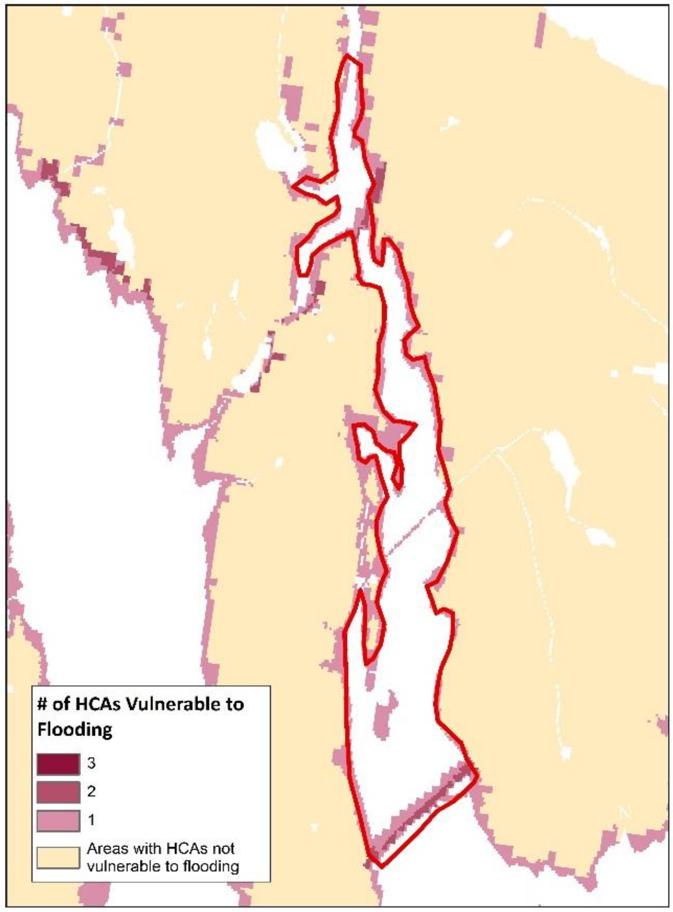


Figure CS2-4. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCA elements). Tan color indicates areas with HCAs that are not categorized as vulnerable to flooding-related threats 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 (mapped but not observed)
Critical facilities
Bridges
Primary roads
Railroads
Drinking water
Mapped Community/Human Assets within Project Boundary
U.S. Route 1
Rockland Branch Railroad Line
Water main pipe for the Bath Water District

Fish and Wildlife

This site contains current and/or potential habitat for priority fish and wildlife species, including many species highly valued by regional stakeholders (**Table CS2-3**). In addition, restoration work on the site has the potential to positively impact species beyond the project boundary since many species (like the horseshoe crab, yellow rail, and shortnose sturgeon) only spend some of their lifespan within the site boundary, and many restoration benefits may be realized downstream and upstream of the project site.

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 Salmon Habitat	Atlantic salmon
Diadromous Fish Habitat	Atlantic sturgeon, blueback herring, American shad
Focal Species Cores	General layer showing big habitat blocks near key species habitat.
Horseshoe Crabs	Horseshoe crab, red knot, mussels
Marsh Migration	Mink, muskrat, saltmarsh sparrow, mummichog, stickleback, striped bass
Obligate Salt Marsh Birds (and associates)	Saltmarsh sparrow, yellow rail
Rare/Exemplary Natural Communities Terrestrial	Combined layer of all imperiled species in the state
Resilient Landscapes	Layer showing areas that are particularly important to maintain resilient landscapes in the face of future changes
Riparian Zones – Water Resources	Cattail, freshwater fishes
Shorebird Seabird Habitat	Saltmarsh sparrow, spotted sandpiper, greater yellowlegs
Tidal Freshwater Wetlands	Saltmarsh sparrow, northern pintail, American eel
Wading Bird Waterfowl Habitat	Great blue heron, least bittern, bufflehead, American oystercatcher

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

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

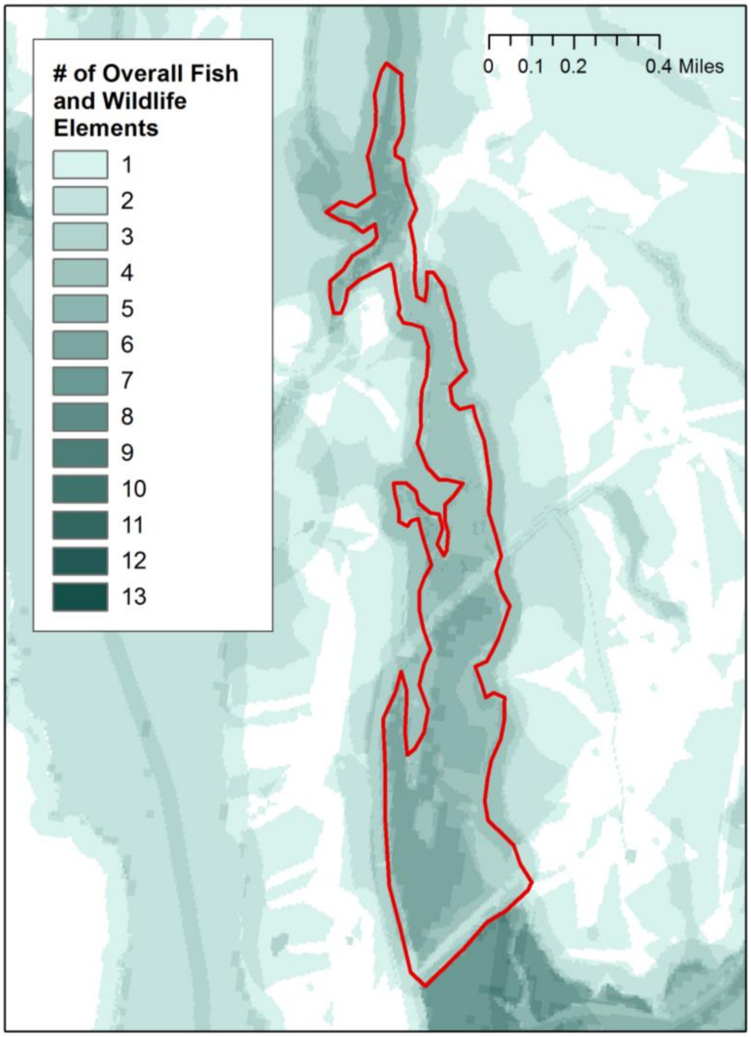


Figure CS2-5. Density of fish and wildlife elements in project area. *Map of fish and wildlife element richness (darker green signifies more elements).*

Expected Project Impact

This will be a high-profile project to increase resilience of a major road and restore a significant amount of saltmarsh habitat, which is important for species currently experiencing declines such as saltmarsh sparrow and America eels. By addressing the road elevation and undersized culverts, this project will increase accessibility, durability, and safety of coastal U.S. Route 1, the main road connecting Maine's coastal communities. It will also help to ensure that the City of Bath has reliable access to potable water by replacing the water main pipe that supplies the City's drinking water.

This project has the potential to restore 158 acres of salt marsh. The current tidal restriction severely inhibits freshwater from draining and saltwater from entering wetlands upstream from the George Wright Road culvert. As a result, the marshes downstream of the culvert are *Spartina*-dominated brackish salt marsh, and the upstream marshes are freshwater cattail marshes. By improving tidal flow through US Route 1 and George Wright Road, salt water will return to the upper marshes, allowing them to transition to healthy *Spartina* saltmarsh. The current flow out of the George Wright Road culvert is such high velocity that it is difficult and possibly impassable for fish. The flow also poses a safety hazard for swimmers or people in small boats who may be swept into the culvert. This resilience project will increase safety for people and fish. By making it possible for fish to travel under George Wright Road and access the large expanse of marshes upstream from the road, it will allow the marsh to once again serve its function as nursery habitat for juvenile fishes and support a number of migratory fish species.

Case Study 3: Basin Point Road and Tidal Exchange Improvement

Figure CS3-1. This small culvert under Basin Point Road sits about four feet above the tidal flat surface. *During extreme tides, water has been observed as high as the edge of the pavement.*

Project Overview

Location: Harpswell, ME

Date Visited: May 7, 2018

Contact: MaryAnn Nahf - Harpswell Conservation Commission; Mark Eyerman - Town of Harpswell

Basin Point Road in the Town of Harpswell, ME is threatened by flooding from storm events and sea level rise. In 2015, the town identified 14 public roads that would be threatened by one to three feet of sea level rise. Of these roads, Basin Point has the largest community impact and the largest interest in addressing future issues that could occur. The road curves around Basin Cove and is the only road that provides access to Basin Point. The road is threatened at the head of the cove, where it is bordered by fringing marsh that connects to extensive tidal mudflats to the south and a small brackish pond and forested wetland to the north. The only tidal exchange currently available at the site is through a small culvert, perched about four feet above the surface of the tidal flat. The perched culvert, combined with additional rock and fill placed upstream of the culvert inlet, impound water upstream, creating a pond above the culvert. The property north of the road extends for approximately 1,000 feet before ending at a barrier beach in Curtis Cove. The beach is exposed to waves that have about three miles of fetch length. The land between the road and Curtis Cove beach is low elevation, and sea level rise and storm surge models indicate that this road could be inundated by tidal waters coming from both the north and the south, effectively turning Basin Point into an island.

The property to the north is owned by the Harpswell Heritage Land Trust (HHLT), a land conservation nonprofit that is a supportive partner on the project. Modeling suggests that the property, due to its relatively low topography, could provide new salt marsh habitat and opportunities for expansion of salt marsh habitat as sea level rises if tidal flow was restored.

Basin Point has several human assets that rely on Basin Point Road for access. There are more than 100 residents that live on the point, a number of small home businesses, two restaurants, and a large marina that services both commercial fishing and recreational boats. The site is currently publicly accessible with parking and walking trails.

The town carried out a feasibility study at the site in 2018, evaluating alternatives that included raising the road and increasing the size of the culvert in order to address road flooding and habitat degradation. Town staff worked with an engineer and the Casco Bay Estuary Partnership to carry out this study and included input from local stakeholders. This is the first site where the town is considering actions to address sea level rise, so this project can serve as a model for the community and region as they address the other roads that are also threatened by rising waters.

This project would help mitigate the effects of sea level rise and saltwater intrusion on low-lying areas that are currently freshwater. In addition, this project would help develop alternative plans to increase resilience of road infrastructure in the face of sea level rise. The project could possibly benefit horseshoe crabs, marine shellfish, wading birds, waterfowl, resilient landscapes, riparian zones, eelgrass, and submerged aquatic vegetation, and allow for marsh migration. It could provide spawning and rearing habitat for fish species, including mummichogs, American eel, sticklebacks, and silversides.

More specifically, the project will:

- Improve marsh migration options as sea level rise occurs.
- Provide a great opportunity to study how restoration might mitigate impacts to low-lying freshwater ponds as sea level rise occurs.
- Reduce flooding based on implementation of plan recommendations.
- Reduce maintenance costs due to road damage and debris removal.
- Potentially serve as model for other restoration projects in the community, especially proactive solutions from residents and municipalities to prepare for future changes.

Figure CS3-2. Approximate project area (red boundary). *Boundary includes the area beyond the crossing at the head of Basin Cove. During storm events that flood the road, this entire area would be cut off from the rest of the town.*

Estimated Cost of the Project

The town has invested $29,000 in the initial feasibility assessment for the site. The assessment developed cost estimates for raising the road 4.3 feet ($691,00) and 6 feet ($1,378,000), and the town is now in the process of reviewing the assessment and determining the next steps. For more detailed information, please contact the project sponsors, MaryAnn Nahf - Harpswell Conservation Commission or Mark Eyerman - Town of Harpswell.

Stressors and Threats

This site has several existing stressors and flooding threats that impact them and the human community assets (HCAs) on Basin Point. Stressors and flooding threats in the proximity of the project site are shown in **Table CS3-1**. Storm surge, high erosion potential, the presence of floodplain, poor drainage, and sea level rise all combine to create conditions at the site that put fish and wildlife and HCAs at risk.

Figure CS3-3. Photos of the project site. *The low lying land between Basin Cove and Curtis Cove (top) is bordered by tidal mud flats to the south (left photo) and sandy beach to the north (right photo), both of which are susceptible to erosion and conducive to flooding.*

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

Existing Stressors
Aquaculture
Developed Open Spaces (low imperviousness <20%)
Dirt/Private Roads/Culverts
Ruderal (maintained pasture, old field)
Local neighborhoods and connecting roads, bridges/culverts
Low Density Housing (moderate imperviousness 20%-49%)
Negligible Impact LUI
Silviculture - Sustainable
Flooding Threats
Poor or Very Poorly Drained
Storm Surge (Category 1)
Storm Surge (Category 2)
Storm Surge (Category 3)
Storm Surge (Category 4)
100-year Floodplain

Human Community Assets

There are approximately 115 seasonal and year-round homes along Basin Point Road that include several home businesses such as coastal fishing operations, an artist's teaching studio and gallery, a music school, and a seafood takeout. One of Harpswell's major marine businesses, a full-service marina and restaurant, is located at the end of Basin Point. This business employs over 90 people, and the restaurant serves thousands of visitors each year (over 85,000 in 2016). The marina has 40 slips, 80 moorings, and 740 feet of face dock that provide space for both commercial and recreational boats. Private charters to tourist destinations that leave from the tip of the point are another source of jobs and revenue for the community.

Flooding on Basin Point Road would disrupt and threaten business operations, tourism, commercial fishing, aquaculture, critical services, and transportation networks, and could displace residents and damage property. With no emergency service providers (fire or ambulance) on Basin Point, flooding could leave the homes and businesses on the point without access to these services. **Figure CS3-4** shows areas where these human community assets are concentrated; assets are described in **Table CS3-2**.

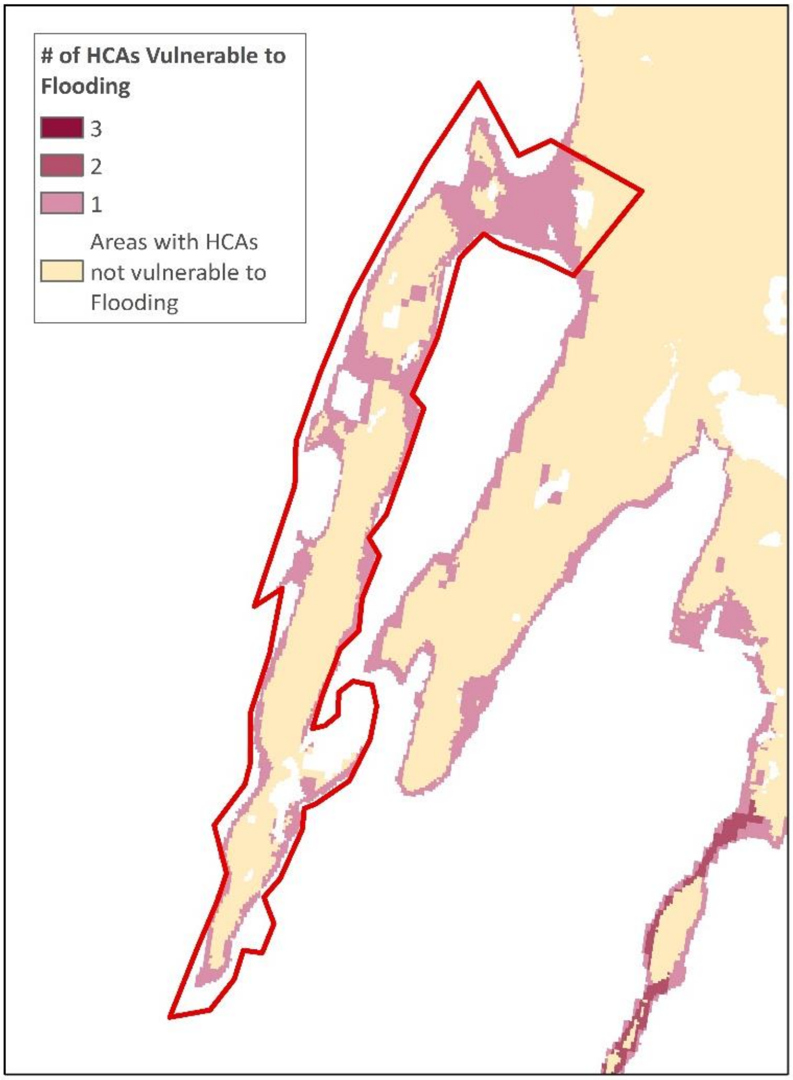


Figure CS3-4. Human Community Asset (HCA) elements vulnerable to flooding threats. *Map of areas where there are vulnerable HCAs (darker pink/red signifies concentrations of vulnerable HCAs). Tan color indicates areas with HCAs that are not categorized as vulnerable to flooding-related threats for the 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
Mapped Community/Human Assets within Project Boundary
Dolphin Marina Local Businesses

Figure CS3-5. The marina at Basin Point. *The equipment and offices (left photo) and slips and moorings (right photo) represent a significant community asset that could be cut off from the town of Harpswell if Basin Point Road floods.*

Fish and Wildlife

This site contains habitat for priority fish and wildlife species, including many species highly valued by the stakeholders of the region such as horseshoe crabs, eelgrass, and marine shellfish (**Table CS3-3**). The low-lying area between the tidal flats to the south and the barrier beach to the north is an area where tidal marshes could migrate as sea level rises if tidal barriers were removed. In addition, restoration work at the site has the potential to positively impact species richness and diversity beyond the project boundary since many species (like great blue herons, egrets, American eels, and horseshoe crabs) only spend some of their lifespan within the site area.

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 ****
Horseshoe crabs	Horseshoe crab, red knot, clams
Marine shellfish	Blue mussel, softshell clams
Marsh migration	Mink, muskrat, saltmarsh sparrow, mummichogs, American eel
Resilient landscape	Layer showing areas that are particularly important to maintain resilient landscapes in the face of future changes
Riparian zones – water resources	Cattail
SAV eelgrass beds	Razor clams, American lobster, cod, hake
Wading bird waterfowl habitat	Great blue heron, snowy egret, common eider

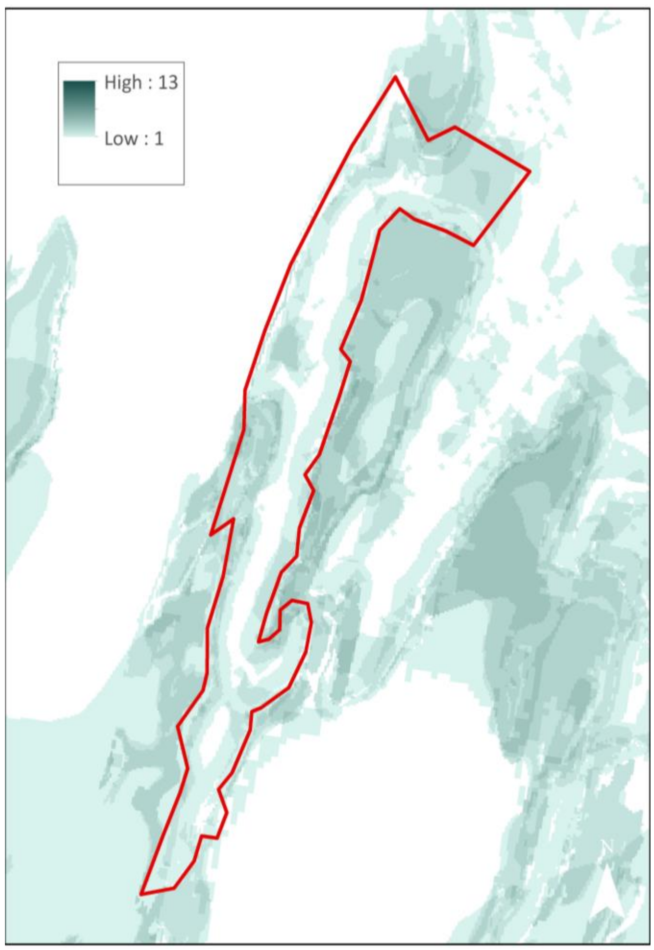


Figure CS3-6. Density of fish and wildlife elements in project area. *Map of all fish and wildlife elements combined (darker green signifies more elements).*

Expected Project Impact

A project on Basin Point Road that raises the road and increases tidal exchange would increase safety and resilience of HCAs by keeping the road accessible during extreme storm events and rising sea levels. An increase in tidal exchange at the site could also increase habitat for species like horseshoe crabs and provide opportunities for saltmarsh migration. With the current pond created by the restricted tidal flow, an opportunity exists to study and provide recommendations about how to mitigate the ecological impacts to a freshwater pond and wetland as it transitions to a marine environment.

This project will serve as a demonstration project for the community of Harpswell, combining the ecological and stakeholder considerations that are important to increase resilience. By showing the value of a restoration project, work at this site could increase community buy-in for resilience project implementation, paving the way for the community to address the 13 other public road sites and significant number of private road sites that are threatened by flooding from sea level rise and storm surge.

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 Portland and Midcoast Maine 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 Portland and Midcoast Maine 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

Human community vulnerability in this watershed is concentrated within coastal areas and in small towns and rural communities primarily along the rivers. Resilience project opportunities coincide with the higher scoring Resilience Hub areas.

While the urbanized Portland area's dense development has areas of vulnerability, the lack of open space offers few nature-based resilience opportunities, but there are exceptions such as the mouth of the Presumpscot River by East Deering. Nature-based resilience opportunities are best illustrated via the three case studies featured in this report above, which highlight several important opportunities for improving resilience while benefiting fish and wildlife, such as:

- tidal crossing improvements that replace undersized and/or perched culverts under coastal roads with larger culverts or bridges to improve salt marsh health and extent, providing opportunities for marsh migration, opening fish passage, and increasing public safety by reconstructing roads to prevent flooding during extreme tides and storm events;
- relocating critical infrastructure (such as water supply lines) to a site less threated by flooding thereby allowing restoration of hydrologic flow and habitat improvement; and

- raising roads and redesigning culverts to support public and emergency access to homes and businesses when coastal waters are high, also increasing tidal exchange that will improve salt marsh and salt pond habitat and provide opportunities for marsh migration.

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

Summary of Limitations

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

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

preferred level of precision. A list of elements for which data was not available or was deemed insufficient for appropriately representing the element is provided in Appendix 5. That said, no elements can be assumed to have complete and accurate distributions. The Vista DSS project can be amended with additional elements of interest.

Putting this Assessment to Work

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

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

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

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

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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 give us the best and most useful product possible. This high level of stakeholder engagement would not have been possible without venue space for workshops provided by the Casco Bay Estuary Partnership at the University of Southern Maine and the Maine Maritime Museum.

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Additional Stakeholders

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

Androscoggin Land Trust
Androscoggin Valley Council of Governments
Androscoggin Valley Soil and Water Conservation District
Arrowsic
Atlantic Salmon Federation
Belgrade Regional Conservation Alliance
Biological Conservation

Blue Sky Planning Solutions
Boothbay Region Land Trust
Bowdoin College
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Cape Elizabeth
Cape Elizabeth Land Trust
Casco Bay Estuary Partnership
Chebeague and Cumberland Land Trust
Chewonki Foundation
City of Portland
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Damariscotta
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Friends of Merrymeeting Bay
Friends of Scarborough Marsh
Georges River Land Trust
Georgetown
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Gulf of Maine Research Institute
Harpswell
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Harpswell Heritage Land Trust
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Kennebec Estuary Land Trust
Kennebec Land Trust
Kennebec Valley Council of Governments (KVCOG)
Knox-Lincoln Soil and Water Conservation District
Lakes Environmental Association
Lincoln County Regional Planning Commission
Loon Echo Land Trust
Maine Audubon
Maine Coast Heritage Trust
Maine Department of Marine Resources - Maine Coastal Program
Maine Department of Environmental Protection
Maine Department of Agriculture, Conservation and Forestry - Bureau of Parks and Lands
Maine Department of Agriculture, Conservation and Forestry - Maine Geological Survey
Maine Department of Agriculture, Conservation, and Forestry – Maine Natural Areas Program
Maine Department of Inland Fisheries & Wildlife - Beginning with Habitat
Maine Department of Inland Fisheries & Wildlife
Maine Department of Marine Resources
Maine Department of Transportation
Maine Emergency Management Agency
Maine Farmland Trust
Maine Historic Preservation Commission
Maine Island Trail Association
Maine Rivers
Maine Sea Grant
Maine Woodland Owners
Manomet
Maine Department of Energy
Medomak Valley Land Trust
Midcoast Conservancy
Midcoast Council of Governments
Mid-Coast Regional Planning Commission
Maine Department of Agriculture Conservation and Forestry - Municipal Planning Assistance Program
National Sea Grant Foundation
NatureServe
National Environmental Modeling and Analysis Center
National Fish and Wildlife Foundaion

National Oceanic and Atmospheric Administration
National Oceanic and Atmospheric Administration – National Marine Fishery Service
National Oceanic and Atmospheric Administration - Restoration Center
North Atlantic Landscape Conservation Cooperative
Northeast Wilderness Trust
Oxford County Soil and Water Conservation District
Peaks Island Land Preserve
Pemaquid Watershed Association
Phippsburg
Phippsburg Land Trust
Portland Trails
Portland Water District
Portland, Planning Department
Presumpscot Regional Land Trust
Royal River Conservation Trust
Scarborough Land Trust
Southern Maine Community College
South Portland
South Portland Land Trust
Southern Maine Conservation Collaborative
The Nature Conservancy
The Trust for Public Land
Trout Unlimited
University of Maine - School of Marine Sciences
University of Maine - Holt Research Forest
Upstream
U.S. Fish and Wildlife Service
U.S. Fish and Wildlife Service - Gulf of Maine Coastal Program
University of Southern Maine
Wells National Estuarine Research Reserve
Western Foothills Land Trust
Woolwich
Yarmouth

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 153 invited participants, 35 participated in the in-person stakeholder workshops, but many others followed up with additional information and input after the workshops, providing critical data leads and resilience project ideas. (See Acknowledgments section for a list of the agencies represented in the stakeholder process.)

Project Outreach and Coordination Resources

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

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

Watershed Webinars and Stakeholder Workshops

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

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

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

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

Name of Engagement Activity	Participation	Date
First Watershed Committee meeting (by webinar)	Watershed Committee	June 19, 2017
Pre-Workshop Stakeholder Introductory Webinar	Stakeholders, Watershed Committee	July 20, 2017
In-person stakeholder workshops	Stakeholders, Watershed Committee	July 25 & 26, 2017
Post workshop follow-up to summarize workshop results	Watershed Committee	December 20, 2017
Review of fish and wildlife and vulnerability assets	Watershed Committee	May 1, 2018
Draft results webinar to discuss GIS analysis and obtain final input from all stakeholders that wish to participate	Stakeholders, Watershed Committee	July 23, 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, and utility & service lines	X		X
Mining	X		X
Aquatic invasive species	X		X
Water quality or stressors that can affect water quality (e.g. nitrogen load and vessel traffic)	X		X
Flooding Threats	**Baseline**	**Threats**	**Combined**
Sea level Rise		X	X
Storm surge potential		X	X
Erosion potential		X	X
Flat and poorly drained soils		X	X
Flood prone areas		X	X

Stressor and Threat Data

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

Soil Erodibility

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

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

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

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

Sea Level Rise

Sea level rise is occurring at different rates across the U.S. Coasts, for example relative sea level rise along the western portion of the Gulf Coast and a large portion of the North Atlantic Coast will be greater than the Pacific Northwest Coast as a result of groundwater and fossil fuel withdrawals.[8] The sea level rise scenarios modeled by NOAA can inform coastal decision-makers and wildlife managers. Gornitz et al. (1994) cited many studies as early as 1989 that demonstrated the potential vulnerability of the barrier islands and wetlands within the South Atlantic region to changing environmental conditions and other episodic flood events.[9] Scenarios for a 1-5 foot rise in sea level were used in the Regional Assessment but a lower level was used in this Targeted Watershed Assessment (see Methods Overview).

Storm Surge

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

Areas of Low Slope

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

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

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

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

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%)	MELCD (2004)	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	MELCD (2004)	Baseline, Combined
	Intensive Agriculture		
	Ruderal (maintained pasture, old field)		
	Aquaculture	No data	N/A
Energy Production and Mining	Solar Arrays	No data	N/A
	Wind		
	Oil and Gas Fields		
	Mining	ME DEP (2017)	
Transportation and Service Corridors	Primary Roads	ME DOT (2017)	Baseline, Combined
	Secondary Roads		
	Local, neighborhood and connecting roads, bridges/culverts		
	Dirt/Private roads/culverts		
	Railroads, bridges, culverts	USDOT/Bureau of Transportation Statistics' National Transportation Atlas Database (2015 or later); Federal Highway Administration, NBI v.7, NTAD (2015 or later)	

Stressor/Threat Primary & Secondary Categories		Data Sources	Scenarios
	Utility & Service Lines (overhead transmission, cell towers, etc.)	ME DOT (2017)	N/A
Dredge Material Placement Areas		No data	N/A
Dams & Reservoirs		USDOT/Bureau of Statistics' NTAD (2015 or later)	Baseline, Combined
Sea Level Rise – 1 ft		NOAA Sea-level Rise Scenarios	Flooding Threats, Combined
Storm Surge	Category 1	FEMA National Flood Hazard Layer	Flooding Threats, Combined
	Category 2		
	Category 3		
	Category 4		
	Category 5		
Water Quality	Moderate	EPA Impaired Waters	Baseline, Combined
	Low	2010 AIS Commercial Vessel Traffic Density (obtained from Rua Mordecai pers. comm.)	
Invasive Species	Terrestrial	No data	N/A
	Aquatic	ME DEP (2017) Aquatic Invasive Plants	Baseline, Combined
	Aquatic Invasives Likely	Stream Habitat Viewer (2017) Non-native Fish	Baseline, Combined
Landslide Susceptibility	High Susceptibility, Moderate Incidence	USGS Landslide Susceptibility Data	Flooding Threats, Combined
	High Incidence		
Subsidence	Moderate	UNAVCO Subsidence Data	Flooding Threats, Combined
	High		
	Very High		
Poorly drained areas	Flat & Somewhat Poorly Drained	NRCS SSURGO	Flooding Threats, Combined
	Flat & Poorly or Very Poorly Drained		
Erosion	High Erodability	NRCS SSURGO Soil Erodibility Data	Flooding Threats, Combined
	Very High Erodability		
Flood Prone Areas	Occasional Flooded Soils	FEMA National Flood Hazard Layer	Flooding Threats, Combined
	Frequent Flooded Soils		
	500 Year Floodplain		
	100-year Floodplain		
	Floodway*		

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

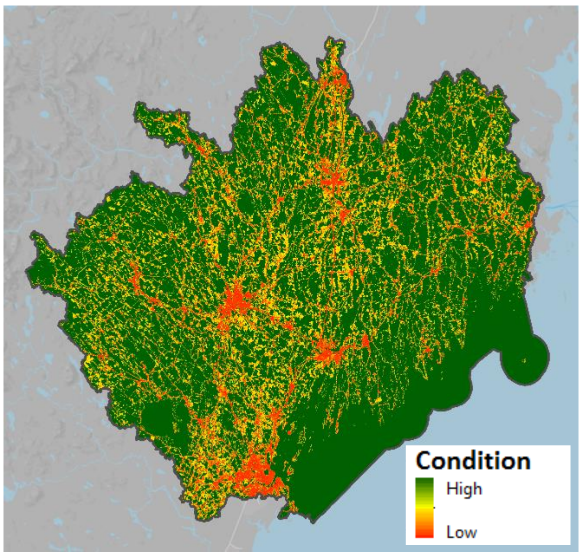
Building Element Response Models

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

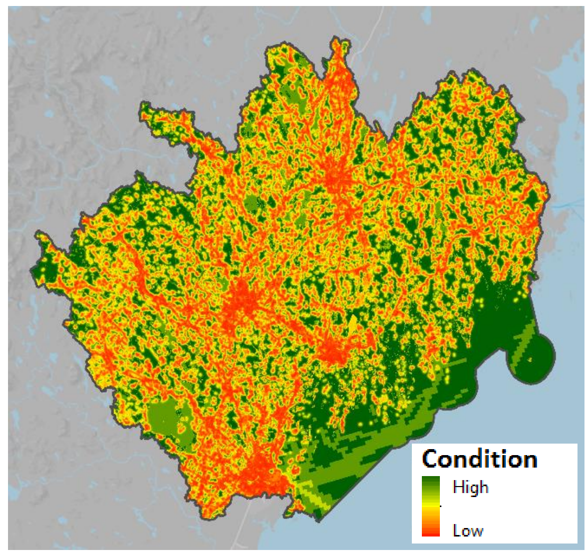
Model Element Condition

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

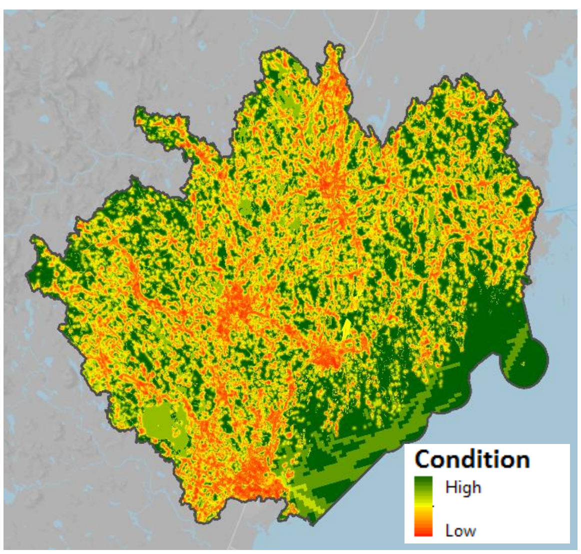
The LCM calculates the condition score of every pixel in the watershed as depicted in the four maps below (**Figure A2- 1**) using the relevant response models per above without regard to locations of elements to which the scores will be applied. The LCM first calculates the response scores on each individual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



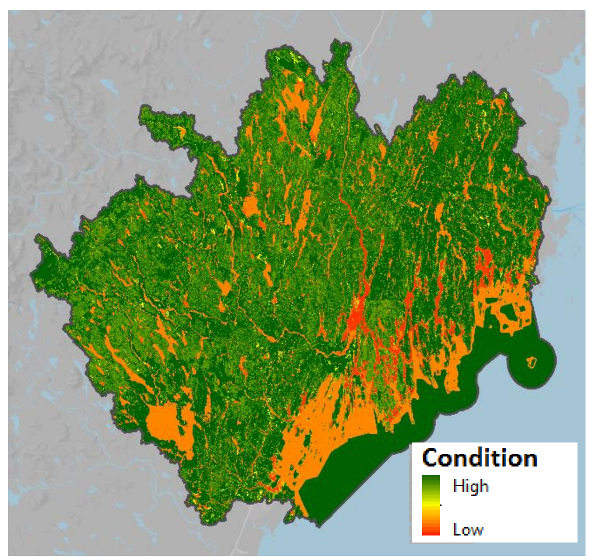
Terrestrial Elements Condition



Freshwater Elements Condition



Estuarine Elements Condition



Human Community Assets Condition

Figure A2-1. Landscape condition model outputs for the Portland and Midcoast Maine Watersheds. *These maps depict the watershed-wide results of each of the four landscape condition models used in the assessments.*

Model Element Vulnerability

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

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

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

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

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

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

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

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

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

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

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

Storm surge effects modeling

Because only a single threats scenario was assessed in this rapid assessment, all 5 categories of storm surge had to be combined and treated simultaneously. The scores for the site intensity (impact) for each category of storm surge were, therefore, set with this combination in mind versus scoring each independently. The scores are described in the tables below, but the general logic of the combination is that where category 1 surge overlaps with all other categories and, therefore, deeper flooding and higher energy water movement, the impact is highest; where there is category 5 surge (not overlapping any other categories) and thus the shallowest, lowest energy fringe area of flooding (furthest inland), the impact is lowest. Categories 2-4 will have intermediate levels of impact from high to low respectively. While the individual impact scores are not severe, the multiplication of them, where they overlap, equates to high impact. To illustrate, the impact on human assets from a category 5 surge that overlaps with the category 1-4 surges (that area closest to the coast) would be scored as category 1 (0.65) x category 2 (0.7) x category 3 (0.75) x category 4 (0.8) x category 5 (0.85) = a cumulative impact score of 0.23 which is far below the vulnerability threshold of 0.5. If the Vista DSS user wished to create separate scenarios for each category of storm surge, the settings should be adjusted to reflect the anticipated level of each category independently.

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

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

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

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

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

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

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Vessel Traffic – High	Categorical Response	Neutral	Assume no effect on terrestrial elements.
		LCM Site Intensity	1	N/A
		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 Likely - Aquatic	Categorical Response	Neutral	Assume no effect on terrestrial elements.
		LCM Site Intensity	1	N/A
		LCM Distance	0	Assume no offsite effect.
	Invasive Species - Terrestrial	Categorical Response	Negative	N/A
		LCM Site Intensity	0.6	Effects can change biotic composition and sometimes habitat structure, which may lead to increased erosion, occasionally change an entire habitat type (to invasives dominated). Score is at threshold, so viability will be retained, but will benefit from control of invasives.
		LCM Distance	100	Indicates potential for spread over relatively short time without control depending on species.
	High Subsidence (Rank 4)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Erosion	High Erodibility	Categorical Response	N/A	Assume slightly less impact than for Very High Erodibility below.
		LCM Site Intensity	0.95	
		LCM Distance	N/A	N/A
	Very High Erodibility	Categorical Response	N/A	Assume exposure to Category 3 storm surge in combination with very erodible soils would result in reduction of condition to just below threshold necessitating restoration for near term recovery. See assumptions for storm surge categories.
		LCM Site Intensity	0.9	
		LCM Distance	0	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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Resilience Project Protection/ Restoration Actions	Living shoreline implementation	Categorical Response	Positive	Project enacts a shoreline management strategy for controlling erosion and enhancing water quality by providing long-term protection, restoration, or enhancement of vegetated or non-vegetated shoreline habitats. Restoration practices uniformly indicating positive response for human assets, understanding that in some cases some individual structures might potentially be removed for purposes such as allowing for marsh expansion, but at this time it is quite unlikely.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Projects with on-the-ground actions focused on improving beach or dune conditions. May reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect
	Marsh restorations.	Categorical Response	Positive	Projects with on-the-ground actions that improve marsh conditions and/or expand marsh area by means of hydrology and thin layer dredge activities that are designed to enhance ecological assets may reduce flooding by slowing and lowering height of storm surge, reducing coastal erosion, and reducing effects of sea level rise.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Restoration of aquatic connectivity	Categorical Response	Positive	Projects with on-the-ground actions in riverine settings that remove or replace man-made barriers to water flow and fish movement (e.g., dams and culverts) may reduce flooding threats and culvert/road failures.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Upland restoration	Categorical Response	Positive	Projects with on-the-ground actions that improve upland conditions and/or expand natural upland area by means that are designed to enhance ecological assets may reduce flooding effects from precipitation-caused flooding upstream.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

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

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

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

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

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 Portland and Midcoast Maine area and would stress habitats well below the viability threshold and require significant wetland restoration.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Silviculture - Sustainable	Categorical Response	Neutral	Small runoff effects from these practices.
		LCM Site Intensity	0.9	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
	Intensive Agriculture	Categorical Response	Negative	Agricultural chemical runoff, sediment runoff, and shoreline erosion may stress elements below the viability threshold. Where agriculture occurs directly on wetlands, significant restoration would be required to bring it back.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Ruderal (maintained pasture, old field)	Categorical Response	Negative	NOAA indicated some agriculture chemicals used on pastures. Runoff is anticipated to be low but sediment may runoff depending on uses, and shoreline erosion may stress these elements up to their viability threshold.
		LCM Site Intensity	0.7	
		LCM Distance	300	Long distance effect to compensate for lack of water quality data.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Aquaculture	Categorical Response	Negative	Habitat alteration, infrastructure, ongoing impacts of waste, nitrogen, and pathogens but high restorability.
		LCM Site Intensity	0.5	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
Energy Production and Mining: assume on land	Solar arrays	Categorical Response	Negative	Assessed for impacts from adjacent solar arrays, not within the aquatic elements. More intensive clearing and maintaining of barren ground affects temperature, sedimentation, and some herbicide runoff but with fairly high restorability to natural vegetative cover.
		LCM Site Intensity	0.4	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.
Energy Production and Mining: assume on land	Wind	Categorical Response	Negative	Assumption is for a wind field not individual wind towers. Less footprint clearing and maintaining than solar and greater restorability with more remaining natural cover, but height and visual/noise effects may lead to overall similar effect as solar.
		LCM Site Intensity	0.4	
		LCM Distance	300	Height of towers leading to larger visual and noise avoidance impacts will be highly variable.
	Oil and Gas Fields	Categorical Response	Negative	Assumptions for well field, not individual pads. Assume dispersed clearing, maintained dirt pads, roads, noise but with mostly natural habitat in between. Some pollutant runoff expected but fairly high restorability.
		LCM Site Intensity	0.4	
		LCM Distance	100	Moderate distance effect to compensate for lack of water quality data.

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 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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Storm Surge	Category 1	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.75	
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.85	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Other threats	Water Quality - Moderate	Categorical Response	Neutral	Assume moderate water quality will just maintain viability.
		LCM Site Intensity	0.7	
		LCM Distance	100	For partial water quality data, distance effect can extrapolate further, optional distance effect depending on the nature of data.
	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.
	Vessel Traffic – Moderate/Low	Categorical Response	Neutral	Assume moderate/low vessel traffic will degrade habitat but remain above viability threshold.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Vessel Traffic – High	Categorical Response	Negative	Assume high vessel traffic will reduce viability just below threshold.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect
	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.
	Invasive Species Likely – Aquatic	Categorical Response	Neutral	Assume potential for invasive species alone will not drive elements below viability threshold.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect
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	0	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	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Flood Prone Areas	500 Year Floodplain	Categorical Response	Negative	Impact at just below viability threshold to indicate that some restoration action and/or years may be needed to restore viability from erosion, sedimentation, deposition of pollutants and anthropogenic debris, dispersal of invasives, and other severe impacts on species life histories/populations.
		LCM Site Intensity	0.6	
		LCM Distance	N/A	No offsite effect.
Conservation Areas		Categorical Response	Positive	No stressors inherent in this use other than those overlapping from other categories. Supports condition and allows for natural restoration.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Resilience Project Protection/ Restoration Actions *(categories needed for Scenario breakouts)*	Living shoreline implementation	Categorical Response	Neutral	Project enacts a shoreline management strategy for controlling erosion and enhancing water quality by providing long-term protection, and restoration or enhancement of vegetated or non-vegetated shoreline habitats. Restoration practices uniformly indicate positive response for human assets, understanding that in some cases individual structures might be removed for purposes such as allowing for marsh expansion in the future.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Beach or dune restoration	Categorical Response	Positive	Projects with on-the-ground actions focused on improving beach or dune conditions may reduce impacts of storm surge and effects of sea level rise and coastal erosion.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.

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

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

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

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

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Commercial & Industrial Areas (e.g., airports, energy transfer terminals, etc.)	Categorical Response	Negative	Assume developed/armored shorelines and heavy runoff of freshwater and pollutants may cause effects, such as waterfowl hazing and noise that would greatly reduce condition below viability. Substantial restoration required to bring back viability, and in some cases successful restoration might not be possible.
		LCM Site Intensity	0.2	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
Agriculture and Aquaculture	Silviculture - Intensive	Categorical Response	Neutral	Assume periodic clearing with high impacts on habitat, some on hydrology, sedimentation, and from chemical application. Some in-wetland harvesting occurs in the Portland and Midcoast Maine 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 increased runoff, sedimentation, and toxins, potentially armored shorelines. Moderate restorability.
		LCM Site Intensity	0.4	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.
	Mining	Categorical Response	Negative	Assume land-based mining. Effects can include noise, dust, runoff of sediment, vehicle traffic, and the installation of culverts. Hydrology is Difficult restorability typically to different ecosystem type.
		LCM Site Intensity	0.3	
		LCM Distance	1000	Long distance effect to compensate for lack of water quality data.

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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Utility & Service Lines (overhead transmission, cell towers, etc.)	Categorical Response	Neutral	Assume over-water feature with some in-water support structures, but infrequent maintenance or noise. High restorability.
		LCM Site Intensity	0.9	
		LCM Distance	20	Relatively small distance effect.
Dredge Material Placement Areas		Categorical Response	Negative	Assume dredge materials will not be placed within aquatic systems. Offsite effects could include chemical and sediment runoff. Moderate restorability for vegetative cover that would reduce impacts to adjacent aquatic systems.
		LCM Site Intensity	0.4	N/A
		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.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
Storm Surge	Category 1	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.75	
		LCM Distance	0	Assume no offsite effect.
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.85	
		LCM Distance	0	Assume no offsite effect.
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Other threats	Water Quality - Moderate	Categorical Response	Neutral	Assume moderate water quality is just above element viability threshold, so viability is maintained. Restoration is possible if sources impairing water quality are addressed.
		LCM Site Intensity	0.7	
		LCM Distance	100	Extrapolates incomplete water quality data to surrounding waters.
	Water Quality - Low	Categorical Response	Negative	Assume impact relative to threshold is somewhat less than freshwater. It Assume greater dilution/flushing action. Restorability is possible if sources impairing water quality are addressed.
		LCM Site Intensity	0.5	
		LCM Distance	100	Extrapolates incomplete water quality data to surrounding waters.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	Vessel Traffic – Moderate/Low	Categorical Response	Neutral	Assume moderate/low vessel traffic will degrade habitat but remain above viability threshold.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect
	Vessel Traffic – High	Categorical Response	Negative	Assume high vessel traffic will reduce viability just to the viability threshold.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect
	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 Likely - Aquatic	Categorical Response	Neutral	Assume potential for invasive species alone will not drive elements below viability threshold.
		LCM Site Intensity	0.7	
		LCM Distance	0	Assume no offsite effect
	Invasive Species - Terrestrial	Categorical Response	Neutral	No anticipated effect.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
Subsidence	Moderate Subsidence (Rank 3)	Categorical Response	Neutral	Assume minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect. Restoration generally not feasible.
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
	High Subsidence (Rank 4)	Categorical Response	Neutral	Assumption: Minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect. Restoration generally not feasible.
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	Neutral	Assume minor effect due to high uncertainty of occurrence, but risk coupled with other threats and stressors would have small multiplicative effect. Restorability not feasible.
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Erosion	High Erodibility	Categorical Response	Neutral	Assume estuarine wetland systems are better adapted to currents from tidal action so the element would be above the viability threshold, however if erosion is combined with e Storm Surge Category 3, it would drop below the viability threshold. Restorability is high.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Very High Erodibility	Categorical Response	Neutral	Assume estuarine wetland systems are better adapted to currents from tidal action so the element would be above the viability threshold, however if erosion is combined with e Storm Surge Category 3, it would drop below the viability threshold. Restorability is high.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions
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 t are designed to enhance ecological assets. They may reduce flooding by slowing and lowering height of storm surge, reducing coastal erosion, and reducing effects of sea level rise.
		LCM Site Intensity	1	
		LCM Distance	0	Assume no offsite effect.
	Restoration of aquatic connectivity	Categorical Response	Positive	Assume projects with on-the-ground actions in riverine settings that remove or replace man-made barriers to water flow and fish movement (e.g., dams and culverts) may reduce flooding threats and culvert/road failures.
		LCM Site Intensity	1	Assume no offsite effect.
		LCM Distance	0	
	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

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

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

Primary Category	**Secondary Category**	**Response Types**	**Responses**	**Response Assumptions** *(Restorability is not included because assets are not natural features to be restored.)*
	Category 2	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.7	
		LCM Distance	0	Assume no offsite effect.
	Category 3	Categorical Response	Negative	See assumptions in Appendix introduction.
		LCM Site Intensity	0.75	
		LCM Distance	0	Assume no offsite effect.
	Category 4	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
	Category 5	Categorical Response	Neutral	See assumptions in Appendix introduction.
		LCM Site Intensity	0.85	
		LCM Distance	0	Assume no offsite effect.
Subsidence	Moderate Subsidence (Rank 3)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.99	
		LCM Distance	0	Assume no offsite effect.
	High Subsidence (Rank 4)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.97	
		LCM Distance	0	Assume no offsite effect.
	Very High Subsidence (Rank 5)	Categorical Response	N/A	N/A
		LCM Site Intensity	0.95	
		LCM Distance	0	Assume no offsite effect.
Flat (Slope <=0.75%) & Poor Drainage	Flat & Somewhat poorly drained	Categorical Response	N/A	Assume areas of flattest slope and somewhat poorly draining soils under extreme precipitation events will lead to flooding. It could approach the 100-year floodplain in level of impact.
		LCM Site Intensity	0.6	
		LCM Distance	0	Assume no offsite effect.
	Flat & Poor or Very poorly drained	Categorical Response	N/A	Assume areas of flattest slope and poorest draining soils under extreme precipitation events may lead to flooding approaching that of a 100-year floodplain.
		LCM Site Intensity	0.5	
		LCM Distance	0	Assume no offsite effect.

Primary Category	Secondary Category	Response Types	Responses	Response Assumptions *(Restorability is not included because assets are not natural features to be restored.)*
Erosion	High Erodibility	Categorical Response	N/A	Assume only a minor impact on human community assets that may require some remediation.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
	Very High Erodibility	Categorical Response	N/A	Assume that in combination with Storm Surge Category 3, expect condition to drop below the viability threshold.
		LCM Site Intensity	0.8	
		LCM Distance	0	Assume no offsite effect.
Flood Prone Areas	Occasional Flooded Soils	Categorical Response	Neutral	Assume structures may be vulnerable but will remain viable unless there are additional stressors or threats in these areas.
		LCM Site Intensity	0.5	
		LCM Distance	0	Assume no offsite effect.
	Frequent Flooded Soils	Categorical Response	Negative	Assume conditions should indicate older structures as just barely non-viable because newer structures built in floodplain areas are probably designed for them.
		LCM Site Intensity	0.4	
		LCM Distance	0	Assume no offsite effect.
	500 Year Floodplain	Categorical Response	Negative	Assume similar impacts to full cumulative storm surge.
		LCM Site Intensity	0.2	
		LCM Distance	0	Assume no offsite effect.
	100-year Floodplain	Categorical Response	Negative	Assume structures in these areas will sustain some damage bringing them to just below the viability threshold. Therefore, if flooded, the structures would require repair to remain viable.
		LCM Site Intensity	0.4	
		LCM Distance	0	Assume no offsite effect.
	Floodway	Categorical Response	Negative	Assume it is highly unlikely to have human community assets directly within the floodway. A score of .9 was applied to assets in the floodway. They are vulnerable, however, likely to remain viable because they were designed with the anticipation of flooding in the area.
		LCM Site Intensity	0.9	
		LCM Distance	0	Assume no offsite effect.
Conservation Areas	Areas designated for conservation use	Categorical Response	Positive	Assume no stressors inherent in this use other than those overlapping from other categories. Conservation areas will support condition and allow for natural restoration.
		LCM Site Intensity	1.0	
		LCM Distance	0	Assume no offsite effect.

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

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

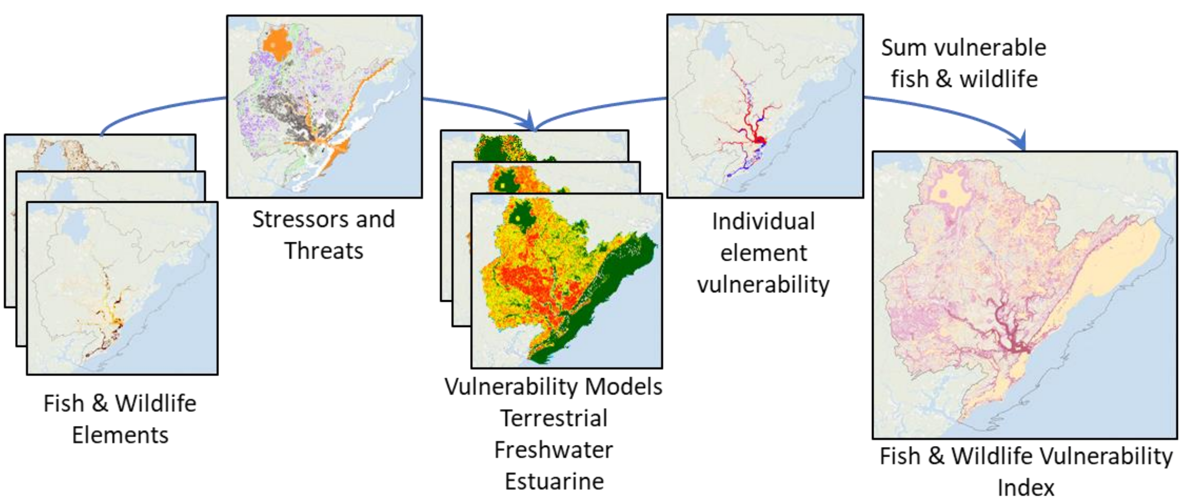


Figure A4-1. Method for calculating fish and wildlife vulnerability indices. *Elements are intersected with stressors and/or threats, the vulnerability model is applied, and individual element vulnerability results are summed to create each index. Diagram represents the Charleston, SC region as an example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

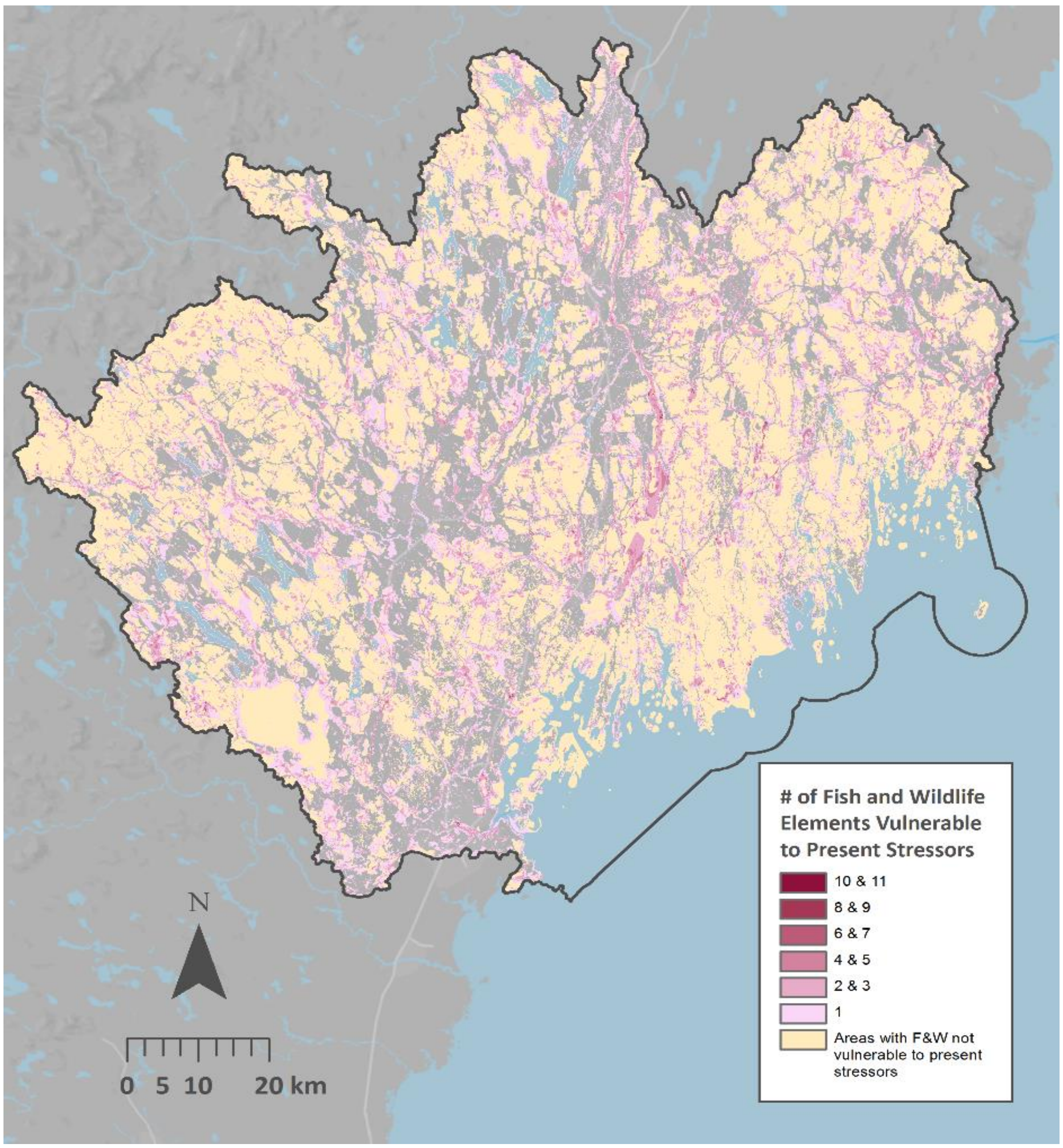


Figure A4-2. Fish and Wildlife Baseline Vulnerability for the Portland and Midcoast Maine Watersheds. *This map is an overlay or index of all fish and wildlife elements that are vulnerable to the existing mapped stressors. Gray areas within the project boundary represent areas with no mapped fish and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

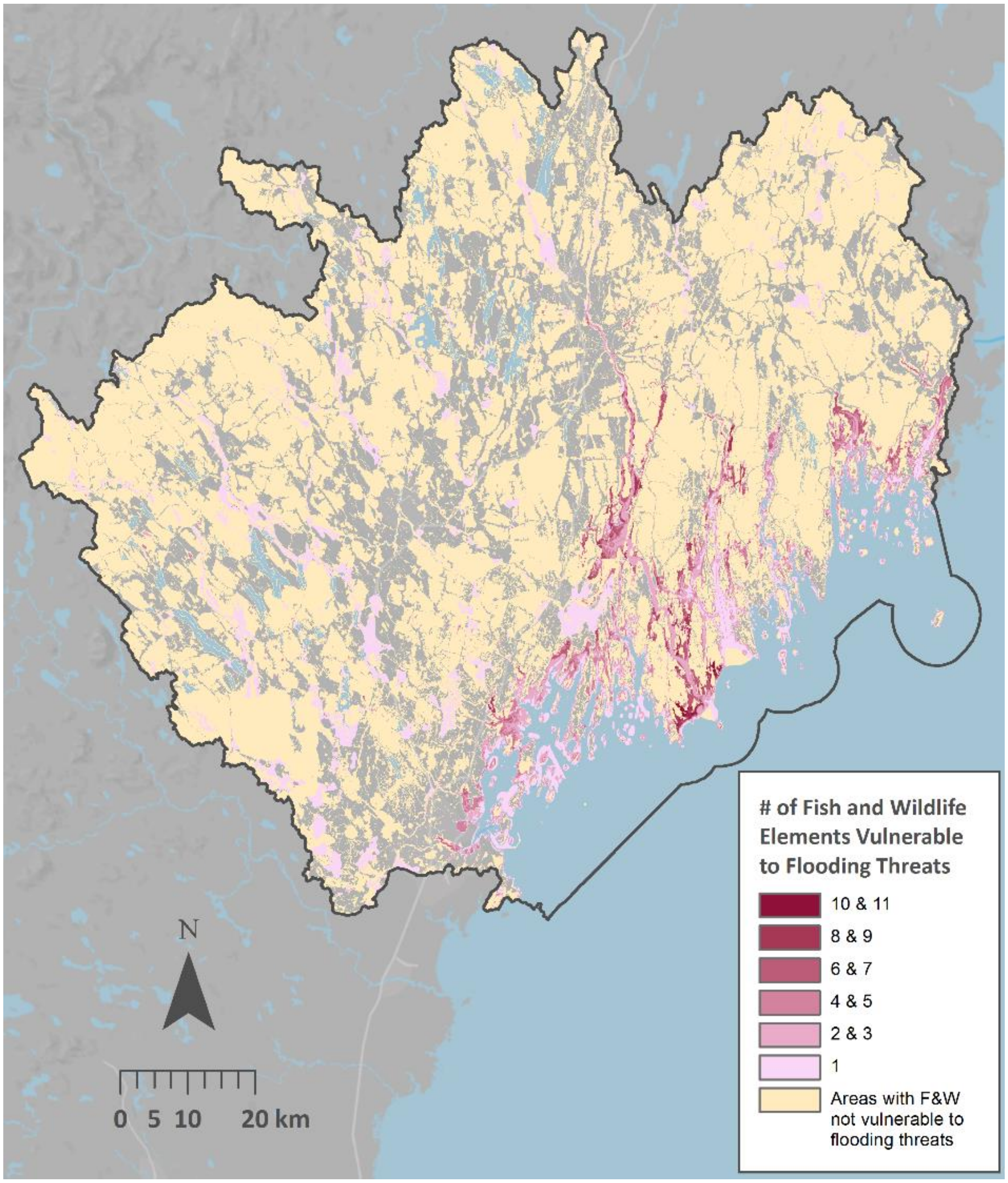


Figure A4-3. Fish and wildlife vulnerability to flooding threats in the Portland and Midcoast Maine Watersheds. *Pink to red shades indicate the number of elements vulnerable to flooding threats. Tan areas indicate areas of low to no impact. Gray areas within the project boundary represent areas with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

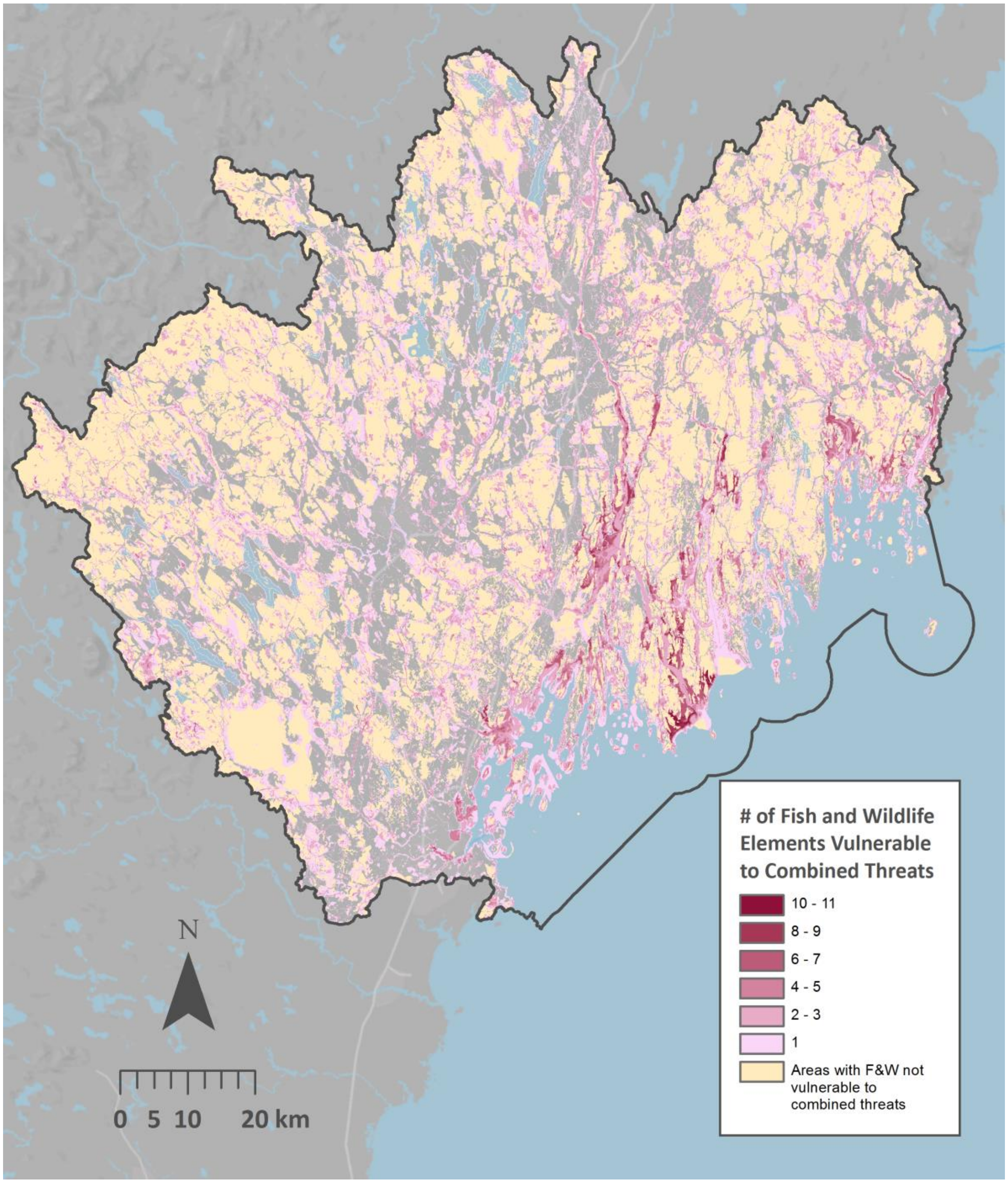


Figure A4-4. Fish and wildlife elements vulnerability to combined stressors and flooding threats for the Portland and Maine Watersheds. *Pink to red shades indicate the number of elements vulnerable to threats. Tan areas indicate areas of low to no impact from the baseline threats. Gray areas within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

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

These results may be accessed through the Vista project.

Limitations

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

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

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

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

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
NOAA Trust Resources		
Atlantic Salmon Critical Habitat	Intersected Atlantic Salmon Critical Habitat HUC10s (NOAA) with NWI [any/all categories] (USFWS) to remove terrestrial areas.	• Atlantic Salmon EFH (NOAA) → NOAA experts in Maine advised that the NOAA critical habitat was the best layer to represent salmon in the project area. • Atlantic Salmon Habitat (MEGIS) → Overlaps with USFWS lines, so doesn't provide new information.
Atlantic Sturgeon Critical Habitat	Atlantic Sturgeon Critical Habitat (NOAA) was used to select or erase appropriate waterbodies from National Hydrography Dataset (USGS) polygons.	N/A
Diadromous Fish Habitat	Diadromous Fish Species spawning/corridors (USFWS) buffered by 30m.	• Salmon (MDIFW) → Overlaps with USFWS lines, so doesn't provide new information. • Atlantic Sturgeon Critical Habitat (NOAA) → Overlaps with USFWS lines, so doesn't provide new information. • Atlantic Salmon Habitat (MEGIS) → Only contains data for Atlantic Salmon. • Diadromous Fish Species spawning/corridors (MDMR) → This dataset is outdated.
Horseshoe Crabs	Horseshoe Crab Habitat in the Gulf of Maine (USFWS) [HORSESHOE_ IN = 7, 10]	N/A
Marine Shellfish	Shellfish Beds (MDIFW).	• Shellfish Habitat (NALCC) → Shellfish habitat overlaps with MDIFW, so doesn't provide new information. → Benthic habitat/soft sediment (which could be used as proxies) are too coarse. • Mussel seed conservation areas (MEGIS) → Doesn't fall within study area.

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
At-Risk Species and Multi-species Aggregations		
Maine State Wildlife Action Plan Priority 1 and 2 Freshwater Aquatic Species	Beginning with Habitat Endangered Threatened Species (MDIFW) ["Macrogroup" IN = 'Coastal Plain Pond', 'Lakes and Ponds', 'Rivers and Streams' OR "SCOMNAME" = 'Creeper']	N/A
Maine State Wildlife Action Plan Priority 1 and 2 Terrestrial Species (Freshwater Wetland and Upland)	Beginning with Habitat Endangered Threatened Species (MDIFW) ["Macrogroup" IN = 'Central Oak-Pine', 'Cliff and Talus', 'Maintained Grasses and Mixed Cover', 'Rocky Coast', 'Ruderal Shrubland & Grassland', 'Northern Peatland & Fens', 'Coastal Plain Peat Swamp', 'Northern Swamp') OR "SCOMNAME" = 'Bald Eagle']	N/A
Maine State Wildlife Action Plan Priority 1 and 2 Estuarine Species (Saltwater wetland and Aquatic Estuarine)	Beginning with Habitat Endangered Threatened Species (MDIFW) ["Macrogroup" IN ('Subtidal Mud Bottom', 'Intertidal Tidal Marsh (peat-forming)', 'Intertidal Sandy Shore', 'Intertidal Mollusc Reefs') AND "SCOMNAME" <> 'Great Blue Heron']	N/A
Focal Species Core Areas	Designing Sustainable Landscapes (DSL) Species Core Areas Dataset (UMASS/NALCC)	• L Focal species landscape capability models (UMASS/NALCC). Utilizing each of the 31 landscape capability models contained in this data product posed at least two problems: → The model outputs are continuous rasters, and there was no clear way to develop an ecologically meaningful cut-off for each species to convert the data to binary (presence/absence) format. → There was no clear way to combine the datasets in a way that wouldn't overrepresent the landscape.

Fish/Wildlife Element	Data Source(s) Used	Data Sources Not Used and Why
Distinctive Ecological Systems and Species Congregation Areas Supporting One or More Species		
Wading Bird and Waterfowl Habitat	Inland and Tidal Waterfowl and Wading Bird Habitat (MDIFW)	N/A
Obligate Saltmarsh Birds	Beginning with Habitat Endangered Threatened Species (MDIFW) ["SCOMNAME" = 'Saltmarsh Sparrow'] combined with Gulf of Maine Watershed Habitat Analysis Additional Bird Species of R5 MBMO [YELLOW_RAIL IN (2,4,5,10)]	• Obligate Saltmarsh Birds (UMASS) Focal Species/NALCC MDIFW saltmarsh sparrow occurrences appears to be more accurate than the focal species dataset. • Tidal Marsh Zone (Saltmarsh Habitat & Avian Research Program (SHARP)) → data doesn't fall within study area. → additionally, saltmarsh sparrow distribution is sensitive information and would therefore be difficult to share the model after the project is completed.
Significant Vernal Pools	Significant Vernal Pools (with 500' buffer) (MEGIS)	N/A
Tidal Freshwater Wetlands	Current Tidal Marshes (MNAP) [habitat_si = "Freshwater Tidal Marsh"]	• Tidal Freshwater Wetlands (MDIFW) → Appears to be inaccurate (includes significant areas known to be saltwater wetlands). • Tidal Freshwater Wetlands (NALCC) → Appears to be derived from the above MDIFW dataset and contains similar apparently significant inaccuracies. • (NWI) → Doesn't contain appropriate wetland category.
Tidal Brackish and Saltwater Marshes	Current Tidal Marshes (MNAP) [habitat_si = "Salt or Brackish Marsh"]	• Tidal Brackish and Saltwater Marshes (NWI) → Covers extra areas compared to MNAP that appear to be open water. • Ecological Terrestrial Systems Map (NatureServe) → much coarser than MNAP which was deemed more suitable resolution for this assessment.
Heritage Brook Trout Waters/Eastern Brook Trout Joint Venture (EBTJV) data	Wild Brooke Trout Habitat (MDIFW)	N/A
Submerged Aquatic Vegetation/ Eelgrass Beds	SAV/Eelgrass beds – current and historic extent (MEGIS/MDMR)	• Eelgrass Beds (NALCC) → Overlaps with MEGIS dataset, so doesn't provide new information.
Significant Aquifers	Aquifers (MGS)	• Aquifers/Headwaters (USFWS) → Data too coarse for the resolution of this analysis.

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		
Riparian Zones and Water Resources	Combination of six (MDIFW) datasets: Wetland Areas, Wetland Buffers, Coast and River Riparian Buffers, Great Pond Riparian Buffers, Stream Riparian Buffers, Pond Riparian Buffers.	N/A
Shorebird Habitat / Seabird Nesting Islands	Shorebird Habitat Seabird Nesting Islands combined with Shorebird Areas (MDIFW)	N/A
Sand Dune Habitat	Sand Dunes (MGS)	• Sand Dunes (CMGE) → Comparison to recent aerial imagery indicated significant inaccuracies for the resolution of this assessment.
Rare and Exemplary Natural Communities	Element Occurrence data (MNAP)	N/A
Cross-cutting Elements		
Important Bird Areas	Important Bird Areas (Audubon Society) [PRIORITY IN (“Continental”, “Global”)]	N/A
Terrestrial Resilience Landscape Sites	Resilient and Connected Landscapes (TNC) [Above Average Resilience]	N/A
Habitats for Marsh Migration	Marsh Migration Areas (MNAP)	• Migration Zone by Feet (TNC/NALCC) → Coarser than the data provided by MNAP and MGS. • Marsh Migration (CBEP) → Casco Bay Estuary Partnership has discussed completing a more advanced mapping that went beyond a bathtub model, but this has not yet been completed. It would also only cover part of the study area. • Undeveloped Blocks (MDIFW) → Covers a lot more area than the MGS dataset and appears to overrepresent.
Undeveloped Habitat Blocks	Undeveloped Blocks (MDIFW)	N/A

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

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

Fish/Wildlife Element Proposed for Inclusion	Reason Element Not Included in Assessment
Lobsters	The Maine DMR layers for lobster and other nearshore commercial fisheries were considered. The DMR has prioritized digitizing boundaries that are used for fishing regulation. This enables fishers to see the maps in real-time when they are out on the water. Due to confidentiality rules, they are unable to share port landings information. Maps showing high concentrations or catch for certain species are not available. For the lobster data specifically, the trawl maximum limits are based on regulations that relate to whales - fewer traps/trawl mean less lines in the water. The conservation areas are not related to lobster populations - the whole coast is reasonably good for lobster. None of the lobster data available highlights particularly important commercial fishery area or particularly important lobster habitat, so this data will be excluded.
Diadromous fish potential habitat	This element would have reflected areas that aren't currently accessible to diadromous fish but could be with dam or structural removal downstream. There are very few dataset possibilities to accurate display this, but the main one considered was Aquatic Index of Ecological Integrity (Nature's Network). The Aquatic Index of Ecological Integrity was determined to not be suitable for this assessment because potential habitat is currently blocked by dams that block migration – this would make it difficult to determine how a dam removal project would improve the habitat if this "expanded" habitat is already taken into account. There is also not a clear link between ecological integrity and specifically diadromous fish. The other dataset considered, NOAA's "Fish Passage Prioritization," was too coarse (HUC 8). In addition to the lack of appropriate data sources, the element "Riparian Zone and Water Resources" included in the analysis would likely represent potential diadromous fish habitat.

Appendix 6. Resilience Project Information

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

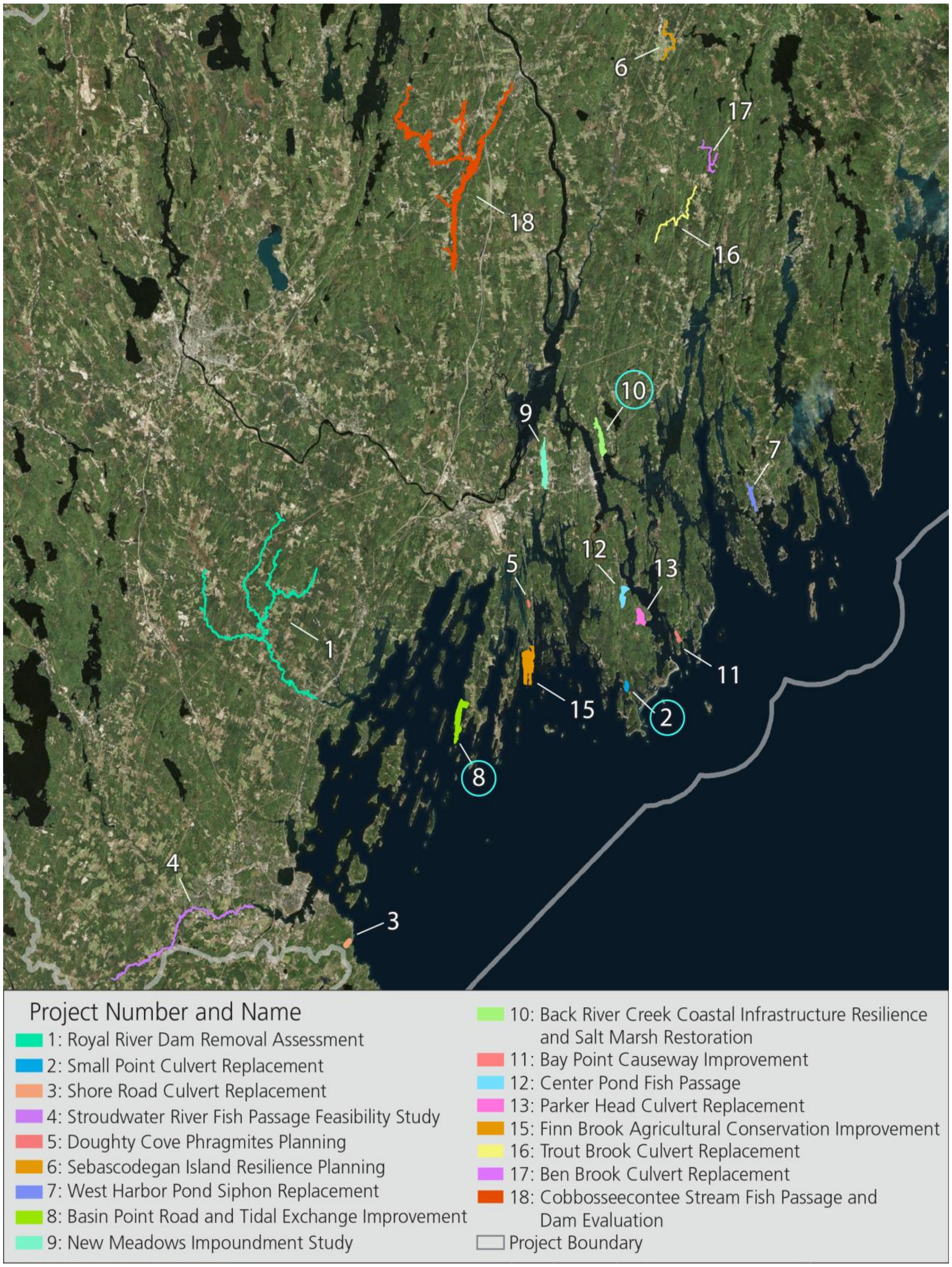


Figure A6-1. Map showing the boundaries of resilience projects compiled for the Portland and Midcoast Maine Watersheds. *Projects #2, #8, and #10 for which detailed case studies were written are indicated by blue circles around the project number. Project #14 is not pictured due to its distributed nature. 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 Portland and Midcoast Maine 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 Portland and Midcoast Maine 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
Back River Creek Coastal Infrastructure Resilience and Salt Marsh Restoration	3.19	5	12	10
Small Point Culvert Replacement	2.76	1	7	2
Stroudwater River Fish Passage Feasibility Study	2.76	5	9	4
Shore Road Culvert Replacement	2.73	1	5	3
New Meadows Impoundment Study	2.59	4	13	9
Doughty Cove Phragmites Removal	2.59	1	6	5
Parker Head Culvert Replacement	2.53	1	15	13
Center Pond Fish Passage	2.33	3	13	12
Bay Point Causeway Improvement	2.32	1	12	11
West Harbor Pond Siphon Replacement	2.10	3	6	7
Ben Brook Culvert Replacement	1.90	1	7	17
Cobbosseecontee Stream Fish Passage and Dam Evaluation	1.82	6	11	18
Basin Point Road and Tidal Exchange Improvement	1.69	2	7	8
Trout Brook Culvert Replacement	1.68	2	8	16
Royal River Dam Removal Assessment	1.56	5	11	1
Sebascodegan Island Resilience Planning	1.51	2	11	6
Finn Brook Agricultural Conservation Improvement	1.32	1	9	15
Culvert Upgrades	(No spatial data)	(No spatial data)	(No spatial data)	14

Project ID# 1

Name: Royal River Dam Removal Assessment

Submitted by: Matt Craig

Organization: Casco Bay Estuary Partnership

Project Type: Dam removal/fish passage; Restoration of aquatic connectivity

Description: Two main stem dams on the Royal River in Yarmouth, Maine block aquatic organism passage between Casco Bay and the Royal River watershed. Although Denil-style fish ladders were installed decades ago, they have not been maintained and recent analysis documents technical problems with these structures even if they were fully operational.

The Royal River watershed once supported anadromous species that are no longer present, and since 2010, local organizations have worked with the Town to assess options for restoration of fish passage. Several conceptual options have been explored through numerous studies (provided in the .zip file), but no restoration option has been agreed upon today. Concerns about sediments stored behind the two dams have slowed the pace of discussions. Additional assessment is needed to proceed.

Project ID# 2

Name: Small Point Culvert Replacement

Submitted by: Matt Craig

Organization: Casco Bay Estuary Partnership

Project Type: Marsh Restoration; Restoration of aquatic connectivity; Wetlands restored/enhanced

Description: An undersized and perched culvert-like stone structure conveys a limited volume of tidewater beneath Small Point Road/Route 123 in Phippsburg, Maine, where it crosses the 13+ ac. Small Point Marsh / wetland system. This structure restricts tidal exchange, causing a muted high tides upstream and impounding water at low tide. Low lying adjacent freshwater wetland and upland are suitable for marsh migration, and at the upper end, additional low-lying road crossings are threatened by sea level rise. Preliminary assessment work at the primary crossing has been completed by CBEP.

Project ID# 3

Name: Shore Road Culvert Replacement

Submitted by: Matt Craig

Organization: Casco Bay Estuary Partnership

Project Type: Community resilience planning; Restoration of aquatic connectivity; Wetlands restored/enhanced

Description: An undersized and perched set of three round culverts convey freshwater and tidewater beneath Shore Road in Cape Elizabeth, Maine at Pond Cove. At this location, Shore Road is prone to over-wash during storms, as well as flooding under sea level rise scenarios. The pipes set above water/wastewater infrastructure, causing impoundment of freshwater and complicating restoration/replacement options. Extensive assessment and design work would be needed. Adjacent uplands and freshwater wetland are at suitable elevations for salt marsh migration/formation. The perched crossing blocks aquatic organism movement into the stream from Casco Bay during all but the highest astronomic tides.

Project ID# 4

Name: Stroudwater River Fish Passage Feasibility Study

Submitted by: Matt Craig

Organization: Casco Bay Estuary Partnership

Project Type: Fish passage

Description: The Stroudwater River is a 15.2 mile long coastal stream with a 27.8 square mile watershed that empties into the Fore River at Stroudwater Falls in Portland. For hundreds of years, dams located at head-of-tide have blocked fish passage at this location, with historical anecdotes of local residents left to hand-carry river herring over the dam in an ultimately futile effort to maintain the runs. Currently, a 16 foot tall, 50 foot wide concrete and stone dam at head of tide blocks passage into the watershed’s 31.5 miles of upstream river and stream habitat. Conceptual feasibility studies are needed to assess upstream habitat and run potential for diadromous species, develop conceptual options for providing fish passage at the dam, and identify cost scenarios for conceptual alternatives. Below the dam, the Stroudwater currently supports a small sea-run rainbow smelt population, and the upper watershed supports wild brook trout. Historic documents indicate the river once supported river herring and other diadromous species. An unpublished map of important anadromous fish habitat in the Northeast US (https://databasin.org/datasets/f7d42872ffb34541855227765d577345) identified the river as within the top 5% for Alosids (shad and river herring) within the study area. The Stroudwater is on the Maine Department of Environmental Protection's watch list of priority watersheds related to elevated nutrient levels and other monitoring parameters. Restoration of diadromous species into the watershed has the potential to provide benefits to nutrient cycling and exchange processes that were severed by the dam.

Project ID# 5

Name: Doughty Cove Phragmites Removal

Submitted by: Matt Craig

Organization: Casco Bay Estuary Partnership

Project Type: Wetlands restored/enhanced

Description: Three or four stands of invasive *Phragmites australis* took hold in a wetland that for many years was cut off from tidal inundation due to the presence of a severe tidal restriction at Long Reach Lane over Doughty Cove, to the north. In 2014, tidal exchange was fully restored at Long Reach Lane, consistently delivering salt water to the southern portion of the wetland for the first time in decades. The Phragmites stands show clear signs of stress, consistent with monitoring data collected by CBEP that show salinity levels consistently exceeding 20 PPT. This project would take additional measures to eliminate some or all of the Phragmites through mechanical and other means, to be determined in consultation with adjacent property owners including residents and the Harpswell Heritage Land Trust, which holds a conservation easement over a substantial amount of the marsh.

Project ID# 6

Name: Sebascodegan Island Resilience Planning

Submitted by: Matthew Craig

Organization: Casco Bay Estuary Partnership

Project Type: Community resilience planning

Description: The tip of Sebascodegan Island in Harpswell, including parts of Gun Point, Long Point, and a tidal impoundment referred to as Dan's Ice Pond, are situated at low elevations relative to sea level and are therefore increasingly vulnerable to flooding, particularly under predicted sea level rise scenarios. The area is partially developed with single family residences and seasonal homes, with access provided through a combination of private and public roads. A tidal dam severely restricts the exchange of salt water into Dan's Ice Pond, forming a 44-acre impoundment upstream and submerging former tidal marsh. The local community needs facilitated resilience planning to prepare for sea level rise, address flood risks and low-lying infrastructure, and address habitat degradation.

Project ID# 7

Name: West Harbor Pond Siphon Replacement

Submitted by: Robert Faunce

Organization: Lincoln County Regional Planning Commission

Project Type: Green infrastructure implementations; Water Quality Improvement; Coastal Road Protection

Description: The West Harbor Pond Watershed Association and a number of cooperating agencies and organizations are proposing to design a replacement for the 1880 siphon that for over 120 years protected the water quality of West Harbor Pond in Boothbay Harbor. With the siphon's failure in about 2008, salt water seeping into the pond through the dam/causeway and entering the pond through the fishway at extreme high tide no longer can be removed from the pond, resulting in an effective “dead zone” below the 12’ depth with the resulting significant adverse impact on aquatic life. Replacement of the 1880 siphon will permit the evacuation of this salt water, restoring the pond’s water quality and reversing the adverse impact on the pond’s aquatic life. The broken siphon is also allowing water to enter the center of the dam/causeway on Route 27. This is causing the road to slump, the guardrails to splay out, and the riprap to become unstable. By June of next year, the project engineering design and permitting will be completed. The project will be ready for implementation.

Project ID# 8

Name: Basin Point Road and Tidal Exchange Improvement

Submitted by: Planner, Mark Eyerman/Conservation Commission, Mary Ann Nahf.

Organization: Town of Harpswell

Project Type: Community resilience planning; Restoration of aquatic connectivity; Wetlands created; Wetlands restored/enhanced

Description: The Town has begun the process of gathering data to plan for the impact of Sea Level Rise (SLR) and coastal storms on public and private roads and areas with high habitat values. Basin Cove Road is predicted to be impacted by SLR with negative consequences for economy, transportation, residents and habitat. Currently a feasibility study, with input from local stakeholders, is about to be launched to assess existing conditions where a low-lying section of road crosses a tidal creek, impounding water and impacting tidal exchange. The project will explore conceptual alternatives for addressing road flooding and habitat degradation, thereby promoting community and ecological resilience. The feasibility study will be completed in fall 2018.

Project ID# 9

Name: New Meadows Impoundment Study

Submitted by: Contact (not "lead"): Matt Craig

Organization: Casco Bay Estuary Partnership

Project Type: Community resilience planning; Marsh restoration; Restoration of aquatic connectivity; Wetlands restored/enhanced

Description: Study options for improving resilience of habitat and local economy at the New Meadows ‘lake’, situated at the head of the New Meadows River in Brunswick and West Bath, Maine. A 150-acre impoundment is formed by the State Road causeway, which severely restricts tidal exchange into upstream waters and mutes tidal range from 11-13’ downstream to 1’ upstream. A productive quahog fishery provides steady income for shellfish harvesters from around the region. The ‘Lake’ is under consideration for 303d listing as an impaired water body due to elevated nutrient levels and anoxia caused by tidal restriction. Previous studies (see Tidal Restoration Feasibility Studies at: http://www.newmeadowspartnership.org/accomplishments.htm) identified structural tidal restoration alternatives and associated benefits to tidal marsh. Additional studies are needed to evaluate options in the context of a number of emergent factors, including: 1) minimizing impact to the robust quahog fishery; 2) sea level rise and marsh migration potential, 3) water quality degradation within the impounded area, 4) property values associated with living on a tidal impoundment, 4) the effect of upstream road crossings (Route 1; Old Bath Road) on tidal exchange, 5) potential for salt water intrusion into groundwater wells and septic systems. *Vibrio* spp. was recently documented in the Lake. In late 2017, results from a SLAMM model of this region under different management alternatives will be available from Warren Pinnacle, which is under contract to CBEP.

Project ID# 10

Name: Back River Creek Coastal Infrastructure Resilience and Salt Marsh Restoration

Submitted by: Ruth Indrick

Organization: Kennebec Estuary Land Trust

Project Type: Marsh restoration; Restoration of aquatic connectivity; Wetlands restored/enhanced

Description: This project will replace a very undersized culvert that is located on George Wright Road in Woolwich, Maine. This culvert acts as a tidal restriction, preventing adequate flow of water to more than 158 acres of upstream wetland. It is more than 80 years old and supports the pipe that brings drinking water to the city of Bath. This structure currently causes degradation of salt marsh, high flows that limit fish passage, and threats to the city of Bath's drinking water supply. The tidal restriction also threatens Route 1, which is located just upstream from George Wright Road. The three culverts under Route 1 have a much larger capacity than the culvert on George Wright, but they are not able to effectively drain the upstream marsh because water backs up at the George Wright restriction. George Wright Road is a town-owned road, and the wetlands immediately adjacent to it are owned by the Maine Department of Inland Fisheries and Wildlife. The town has recently connected with the Bath Water District, the Kennebec Estuary Land Trust, and a local engineering firm to focus on replacing the culvert with a structure that does not inhibit tidal flow. The town has allocated money for pre-engineering and design, which will be completed this winter. Maine DOT and staff at NOAA have also expressed interest in providing guidance on the design of the new structure. The project will restore more than 158 acres of upstream wetland, enable fish to utilize this area of wetland, and increase the resilience of both Route 1 and Bath's drinking water supply to coastal flooding and storm events.

Project ID# 11

Name: Bay Point Causeway Improvement

Submitted by: Ruth Indrick

Organization: Kennebec Estuary Land Trust

Project Type: Community resilience planning; Restoration of aquatic connectivity

Description: The Bay Point Road causeway in Georgetown, Maine that cuts across salt marshes on Todd's Bay and Heal Eddy is important for the community that lives on Bay Point. This road serves as the only access route to Bay Point. It already floods on very high tides, cutting off access for Bay Point residents to fuel and emergency services. Improving this causeway so the road does not flood on high tides and so that hydrologic flow is restored between Todd's Bay and Sagadahoc Bay will improve the wetlands and improve the resilience of the Bay Point community in Georgetown.

Project ID# 12

Name: Center Pond Fish Passage

Submitted by: Ruth Indrick

Organization: Kennebec Estuary Land Trust

Project Type: Dam removal/fish passage; Restoration of aquatic connectivity

Description: The replacement of the Center Pond Fish ladder will improve access for alewives and American eels to 75 acres of spawning habitat in Center Pond. A ladder currently exists at the site, but it is inaccessible to fish for 52% of a tide. It causes problems for controlling water height in the pond and can create unsafe conditions for juvenile and adult fish exiting the pond. The new ladder design fixes the problems associated with the old ladder, supporting a sustainable alewife run and harvest in Center Pond. A viable alewife harvest from this site will provide income to the town and an affordable source of local lobster bait. This project has significant community support, and the town and local citizens have made some contributions toward construction. The new ladder will further connect the community with this resource by providing a safe platform for visitors to view the run and the harvest. All engineering designs and permitting are completed for this project.

Project ID# 13

Name: Parker Head Culvert Replacement

Submitted by: Ruth Indrick

Organization: Kennebec Estuary Land Trust

Project Type: Marsh restoration; Restoration of aquatic connectivity

Description: The undersized, perched culvert on Parker Head Road is a problem for wetland habitat, water quality, and road safety. This project is identified in the Sagadahoc County Hazard Mitigation Plan. The plan suggests replacement of the current 6 ft. culvert with two 7 ft. culverts. The current undersized culvert is too high on the upstream side, so water pools and is unable to drain. Habitat that was likely salt marsh before the installation of this tidal restriction is now a shallow pond. In the summer, it has high temperatures, low dissolved oxygen, and floating mats of algae. On the downstream side, water that flows out of the perched culvert has hallowed out a hole in front of the outlet, pushed boulders out of the way, and eroded the edge of fringing salt marsh. In high water events, the integrity of Parker Head Road and Sam Day Hill Road (which crosses the same body of water further upstream) is at risk. Through the installation of the new culverts which more than double the capacity, the salt marsh will be restored upstream from the restriction and the road will be more resilient to storm events.

Project ID# 14

Name: Culvert Upgrades

Submitted by: Heather True

Organization: Cumberland CSWCD

Project Type: Community resilience planning; Dam removal/fish passage; Restoration of aquatic connectivity; Riparian and floodplain restoration; Upland restoration; Wetlands restored/enhanced

Description: CCSWCD works with municipalities and private roads to design and assist with permitting and logistics for increased culvert crossings. CCSWCD maintains a list of priority sites to address on a local watershed and municipal basis.

Project ID# 15

Name: Finn Brook Agricultural Conservation Improvement

Submitted by: Garrison Beck

Organization: Midcoast Conservancy

Project Type: Riparian and floodplain restoration

Description: Restrict cattle access to Finn Brook in Whitefield, ME and establish buffer through agricultural properties.

Project ID# 16

Name: Trout Brook Culvert Replacement

Submitted by: Garrison Beck

Organization: Midcoast Conservancy

Project Type: Dam removal/fish passage

Description: Upgrade private culvert to allow improved fish passage at Trout Brook in Alna, ME

Project ID# 17

Name: Ben Brook Culvert Replacement

Submitted by: Garrison Beck

Organization: Midcoast Conservancy

Project Type: Dam removal/fish passage

Description: Upgrade of municipal culvert which is a barrier to fish passage on Ben Brook in Alna, ME, tributary to the Sheepscot River.

Project ID# 18

Name: Cobbosseecontee Stream Fish Passage and Dam Evaluation

Submitted by: Tina Wood

Organization: Upstream

Project Type: Dam removal/fish passage; Restoration of aquatic connectivity

Description: Upstream, a 501(c)3 organization dedicated to the restoration of river herring in Cobbosseecontee Stream, has the goal of restoring native sea-run fisheries and the permitted activity of installing a fish ladder on Cobbosseecontee Stream at the Gardiner Paperboard Dam site in Gardiner, Maine. In 1997, the Maine Department of Marine Resources began stocking a small number of alewives in Pleasant Pond, the impoundment behind New Mills Dam. Native alewives began returning to Cobbosseecontee Stream, only to be blocked by the Gardiner Paperboard (also called York Town Paper) dam. Although a preliminary agreement to remove the dam was reached in 2003, the death of the landowner before a formal agreement was signed left the dam in place. The current property owner, PaperRoute LLC (now owned by Carter Becker) is supportive of fish passage but not dam removal at this time. Upstream is working with Kennebec Land Trust and the city of Gardiner to install a steep pass at the dam as KLT owns the easement to the property on the west side of the stream and is also interested in fish passage at the site. Because American Tissue, the middle dam, is a hydroelectric facility, the moment sea-run fish reach the base of the dam, the federal government will require the owner, Kruger Maine, to provide fish passage. The plan for passage around American Tissue is likely to involve New Mills, the third dam, which is sited less than a quarter of a mile upstream; Kruger already provides maintenance services to the owners – the towns of Gardiner, Litchfield and Richmond. Providing passage around the first dam therefore triggers passage around the second and perhaps the third dam, allowing sea-run fish to reach their goal – Pleasant Pond and more than 15 miles of additional habitat. While Upstream is focused on fish passage at the first dam, Gardiner Paper Board, creating fish passage at all three downtown dams would build resiliency for flooding and storm events as the New Mills Dam which holds the headwaters of Pleasant Pond needs extensive repairs and is the most likely to fail in its present condition.

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
FISH AND WILDLIFE HABITATS AND RESOURCES				
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/ http://necsc.umass.edu/sites/default/files/Staudinger%20et%20al.%202015%20Integrating%20Climate%20Change%20into%20NE%20and%20MW%20SWAPs.pdf	22 Northeast Climate Science Center states ranging from Maine to Virginia, and Minnesota and Missouri in the eastern United States	Amphibians (56), birds (421), fish (freshwater 346 and marine 83), freshwater mussels (83), insects (259), marine invertebrates (22), other invertebrates (73), mammals (112), reptiles (69), wetlands, land conservation, floodplains, green infrastructure	Forest products industries, land management, development, seawalls, bridges, culverts	Warming air temperatures esp. in winter, inland, and at higher latitudes and elevations, increasing frequency and intensity of heatwaves, increased intensity and quantity of precipitation, snow shifting to rain, reduced snowpack and extent of snow cover, increased atmospheric moisture content, declining wind speeds, intensifying wind gusts, intensifying streamflows, increasing freshwater temperature, more severe thunderstorms, increasing

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
				intensity of floods and droughts, longer dry periods, more frequent blizzards and ice storms, accelerating sea level rise, increasing intensity of tropical cyclones and hurricanes, storm tracks shifting northward along the coast, warming ocean temperatures, ocean acidification, saltwater intrusion, changing natural community composition, invasive species
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. Available at: http://www.wildlandsandwoodlands.org/vision/ww-vision-reports	New England states: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island	Watersheds, natural infrastructure, forests, carbon sequestration, land conservation, streams, wetlands, lakes, large habitat blocks, riparian areas, grassland, shrubland	Rural villages, towns, suburbs, cities, wildlands, managed woodlands, forest products industries, farmlands, agriculture, urban gardens, forested parks, greenways, cultural infrastructure, trail networks, coastal development, recreation, drinking water, green infrastructure	Changes in forest composition and function, rising air temperatures, sea level rise, increased frequency of flooding, increased frequency of severe storms, low-density sprawl
Through a Fish's Eye: The Status of Fish Habitats in the United States 2015	Maine, Vermont, New Hampshire, Massachusetts, Connecticut,	American shad, river herring, American eel, rainbow smelt, Atlantic salmon, brook trout,	Transportation infrastructure	N/A

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
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 Partnership. Available at: http://assessment.fishhabitat.org/#578a9a00e4b0c1aacab896c1/578a9a9ae4b0c1aacab8984f http://assessment.fishhabitat.org/pdfReports/Northeastern%20States%20Region.pdf	Rhode Island, New York	bridle shiner, shortnose sturgeon, oysters, river 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. Available at: http://www.fwspubs.org/doi/suppl/10.3996/062016-JFWM-044/suppl_file/fwma-08-01-28_reference+s02.pdf	United States Northeast and Mid-Atlantic Region, from Maine to Virginia.	234 species of greatest conservation including high responsibility species and high concern species, conserved land, large habitat blocks	Agriculture, development	Changes in species distribution, changes in ecological processes, species movement
Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic US Anderson, M.G. and Barnett, A. 2017. Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic US. The Nature Conservancy, Eastern Conservation Science. Available at: http://easterndivision.s3.amazonaws.com/coastal/Resilient_Coastal_Sites_for_Conservation_NE_Mid_Atlantic.pdf	9 northeast states: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, Delaware, Maryland, Virginia	Coastal wetlands, salt marshes, brackish marshes, tidal flats, beaches, dunes, seagrass beds, river deltas, sounds, inlets, estuaries, marsh migration areas, resilient sites capable of maintaining species diversity and ecological function even	N/A	Sea level rise, nitrogen pollution, sediment availability, changes in groundwater, changes in precipitation

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
		as the composition and proportion of habitats change in response to climate change		
Conserving the Eastern Brook Trout: Action Strategies Conservation Strategy/Habitat Work Group - Eastern Brook Trout Joint Venture. 2011. Conserving the Eastern Brook Trout: Action Strategies. Available at: http://www.fishhabitat.org/the-partnerships/eastern-brook-trout-joint-venture	17 States: Maine, Massachusetts, Connecticut, Vermont, Rhode Island, New Hampshire, New York, Pennsylvania, Tennessee, Ohio, New Jersey, Virginia, West Virginia, Maryland, North Carolina, South Carolina, Georgia	Eastern Brook Trout	N/A	N/A
Final Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar) National Oceanic and Atmospheric Administration: National Marine Fisheries Service and U.S. Fish Wildlife Service: Northeastern Region. 2005. Final Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar) Available at: https://www.fisheries.noaa.gov/action/recovery-plan-gulf-maine-dps-atlantic-salmon	Gulf of Maine Watersheds: Connecticut, Massachusetts, Rhode Island, Vermont New Hampshire, Maine	Atlantic Salmon	N/A	N/A

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Species in the Spotlight Priority Actions: 2016-2020 Atlantic Salmon Salmo salar National Oceanic and Atmospheric Administration. 2016. Species in the Spotlight Priority Actions: 2016-2020 Atlantic Salmon Salmo salar. Available at: https://www.fisheries.noaa.gov/species/atlantic-salmon-protected/spotlight	Gulf of Maine Watersheds: Connecticut, Massachusetts, Rhode Island, Vermont New Hampshire, Maine	Atlantic Salmon	N/A	N/A
Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar): Public Review Draft National Oceanic and Atmospheric Administration: National Marine Fisheries Service and U.S. Fish Wildlife Service: Ecological Services and Fisheries. 2016. Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar): Public Review Draft.	Gulf of Maine Watersheds: Connecticut, Massachusetts, Rhode Island, Vermont New Hampshire, Maine	Atlantic Salmon	N/A	N/A
Maine Department of Transportation Coastal Wetland Tidal Restriction Study 2004. Maine Department of Transportation Coastal Wetland Tidal Restriction Study. Department of the Army Corps of Engineers, New England District: Planning Assistance to States Program.	Midcoast Maine and Casco Bay – Scarborough to Boothbay Harbor	Coastal Wetlands	Road infrastructure, culverts	Sea level rise, storm surge
Range-wide Assessment of Brook Trout at the Catchment Scale: A Summary of Findings	17 States: Maine, Massachusetts, Connecticut, Vermont, Rhode Island, New	Eastern wild Brook Trout, wild brown trout, wild rainbow trout	N/A	N/A

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Eastern Brook Trout Joint Venture. 2016. Range-wide Assessment of Brook Trout at the Catchment Scale: A Summary of Findings. Available at: http://easternbrooktrout.org/resources/catchment-assessment-summary-report-appendix-tables	Hampshire, New York, Pennsylvania, Tennessee, Ohio, New Jersey, Virginia, West Virginia, Maryland, North Carolina, South Carolina, Georgia			
The Kennebec Estuary: Restoration Challenges and Opportunities Moore, S., and J. Reblin. 2010. The Kennebec Estuary: Restoration Challenges and Opportunities. Biological Conservation, Bowdoinham, Maine. Available at: https://www.kennebecestuary.org/publications/	Kennebec Estuary, Maine (Sagadahoc County, Maine)	Sand beach, dune, saltmarsh, mudflat, brackish tidal marsh, freshwater tidal marsh, submerged aquatic vegetation, eelgrass, diadromous fish (blueback herring, Atlantic sturgeon, alewife, American shad, rainbow smelt, striped bass, shortnose sturgeon, Atlantic salmon, American eel, sea lamprey, Atlantic tomcod, sea-run brook trout), redfin pickerel, tidewater mucket, waterfowl, shorebirds, wading birds, saltmarsh sharp-tailed sparrow, piping plover, least tern, roseate tern, Arctic tern, groundfish, American	Shellfish harvesting, dams, commercial fisheries, recreational fisheries, waterfowl hunting, coastal infrastructure	Urbanization, erosion, water pollution, invasive species, nitrogen pollution, phosphorous pollution, fish passage barriers, rising water temperatures, rising air temperatures, changing precipitation regimes, sea level rise, increased storm events, flooding, harmful algal blooms, acidification

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
		lobster, marsh migration, land conservation		
State of the Bay 2015 Report Casco Bay Estuary Partnership. 2015. State of the Bay 2015 Report. Portland, Maine. Available at: https://www.cascobayestuary.org/wp-content/uploads/2014/06/2015-SOTB-Report-final-3-16-16.pdf	Casco Bay Watershed, Maine	Conserved lands, fish passage for native freshwater and migratory fish (eg. eastern brook trout, shad, blueback herring, alewife, sturgeon, and striped bass), water birds (such as seabirds, wading birds, waterfowl and shorebirds), eelgrass beds, river, stream, lake, bay, soft-shell clams, mussels, oysters, quahogs	Road crossings designed for fish passage, urbanization, declines in forest and farmland, stormwater systems, wastewater treatment plants,	Increasing development, barriers to fish passage, water pollution, invasive species, increasing population, increased impervious surface and runoff, road salt pollution, acidification, water temperature increases, bacterial water pollution, harmful algal blooms, air temperature increases, sea level rise, more frequent and intense precipitation
State of Maine's Beaches in 2017 P.A. Slovinsky, S.M. Dickson, D.B. Cavagnaro. 2017. State of Maine's Beaches in 2017. Maine Geological Survey: Open-File 17-14. Available at: https://digitalmaine.com/mgs_publications/518/	Maine Southern and Midcoast Maine - Kittery, York, Ogunquit, Wells, Kennebunk, Kennebunkport, Biddeford, Saco, Old Orchard Beach, Scarborough, Cape Elizabeth, South Portland, Phippsburg, Georgetown	Sand beaches, dunes	NA	Sea level rise, winter storm severity, storm surge, beach erosion

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Resilient and Connected Landscapes for Terrestrial Conservation Anderson, M.G., Barnett, A., Clark, M., Prince, J., Olivero Sheldon, A. and Vickery B. 2016. Resilient and Connected Landscapes for Terrestrial Conservation. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA. Available at: http://nwblcc.org/wp-content/uploads/2016/08/Anderson-et-al.-2016-Resilient_and_Connected_Landscapes_For_Terrestial_Conservation.pdf	Maine, Massachusetts, Connecticut, Vermont, Rhode Island, New Hampshire, New York, Pennsylvania, Tennessee, New Jersey, Virginia, West Virginia, Maryland, Delaware, Kentucky, Florida, Alabama, Mississippi Portions of: Ohio, Indiana, Illinois, Louisiana Canadian Provinces of Nova Scotia, New Brunswick, Prince Edward Island Portions of: Quebec	Resilient landscapes, connected habitat, land conservation, restoration, plants, herptiles, mammals, invertebrates, and fish, riparian corridors, wetlands, landscape permeability, natural heritage program priority species	Water supply/drinking water, energy infrastructure, forest management, roads, future development	Increasing intense storms, droughts, floods, fires, roads as barriers to aquatic and terrestrial species, fragmented natural landscapes, increasing development, temperature changes, habitat range shifts, changing precipitation
Report on The Health of the Damariscotta River Estuary	Damariscotta River Estuary, Maine	River, salt marsh, vernal pools, bird nesting, fish migration, sea urchin, lobster, clams, eelgrass, alewives, American eels,	Commercial fishing, tourism	Water pollution, invasive species

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Damariscotta River Association. 2012. Report on the Health of the Damariscotta River Estuary. Available at: https://www.damariscottariver.org/wp-content/uploads/2014/07/Report-CardFinal12.pdf		rainbow smelt, horseshoe crab, short-nosed sturgeon, land conservation		
Incorporating Climate Change into Maine's State Wildlife Action Plan 2016. Incorporating Climate Change into Maine's State Wildlife Action Plan. Maine Department of Inland Fisheries and Wildlife and Maine Natural Areas Program. Available at: http://climatechange.lta.org/wp-content/uploads/cct/2015/03/OSI-MtA2C-Case-Study-Fact-Sheet_ME_Statewide_Jan2016.pdf	Maine	State wildlife action plan species of greatest conservation need, resilient landscapes	N/A	Sea level rise, temperature changes, precipitation changes
Life in Maine's Lakes and Rivers: Our Diverse Aquatic Heritage The Nature Conservancy. 2008. Life in Maine's Lakes and Rivers: Our Diverse Aquatic Heritage. Brunswick, ME: The Nature Conservancy. 32p. Available at: https://mainerivers.org/wp-content/uploads/2009/05/2008-TNC-Maine-Aquatic-BioDivReport.pdf	Maine	Rivers, lakes, shoreland buffers, land conservation, wetlands, brook trout, rainbow smelt, lake chub, black dace, finescale dace, amphibians, reptiles, fish, macroinvertebrates, biodiversity, pickerel, white perch, Atlantic salmon, vernal pools, spotted turtles, American eel, alewife, sea lamprey, shortnose sturgeon, lake	Shoreland zoning, dams, hydroelectric dams, culverts, tourism, recreation, drinking water	Invasive species, fish passage barriers, habitat degradation, nonpoint source pollution, increased air and water temperatures, drought, water pollution, stormwater runoff, changing seasonal hydrology, increased development

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
		whiefish, lake trout, wood turtles		
Maine's Most Pristine Wetlands: Implementing a Long-Term Monitoring Plan Stone, E.M., Cutko, A. 2011. Maine's Most Pristine Wetlands: Implementing a Long-Term Monitoring Plan. Maine Natural Areas Program- Maine Department of Conservation. Available at: https://www.maine.gov/dacf/mnap/about/publications/mohf_092-02-12_jan2011_wetlandmonit.pdf	Maine	Wetlands, salt marsh	N/A	Invasive species, sea level rise
New Evidence of Tree Species on the Move Hushaw, J. 2017. New Evidence of Tree Species on the Move. Manomet Center for Conservation Sciences. Available at: http://climatesmartnetwork.org/wp-content/uploads/2017/05/TreeMigrationUpdate_Bulletin-revised.pdf	United States	Forests, tree species migration, ecosystem shifts	N/A	Changing temperatures, changing precipitation, invasive species, changing drought patterns, storm events, change in forest species distribution
Salt Marshes in the Gulf of Maine: Human Impacts, Habitat Restoration, and Long-term Change Analysis Taylor, Peter H. 2008. Salt Marshes in the Gulf of Maine: Human Impacts, Habitat Restoration, and Long-term Change Analysis. Gulf of Maine Council on the Marine Environment. Available at: http://www.gulfofmaine.org/2/wp-	Gulf of Maine: Massachusetts, New Hampshire, Maine, New Brunswick, Nova Scotia	Salt marshes, fish nursery, shellfish, winter flounder, striped bass, ellegrass, wading birds, migratory waterfowl, raptors, seabirds, otters, mummichogs, Atlantic silversides, Atlantic cod, silver hake, Atlantic mackerel, clams, seals,	Roads, culverts, railroads, dikes, dams	Tidal barriers, water pollution, fish passage barriers, invasive plants, impervious surfaces, runoff, coastal flooding

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
content/uploads/2014/06/Salt_Marshes-2008.pdf		rockweed, vegetative buffers		
2013 Casco Bay Clam Flat pH Study Friends of Casco Bay. 2014. 2013 Casco Bay Clam Flat pH Study. Friends of Casco Bay. Available at: https://www.cascobayestuary.org/wp-content/uploads/2018/01/Casco-Bay-Clamflat-pH-Study-FOCB-2013.pdf	Freeport, Maine	Soft-shell clams, tidal mud flats	N/A	Ocean acidification, coastal acidification, algal blooms, nutrient pollution
Maine State Forest Assessment and Strategies Maine Forest Service, Department of Conservation. 2010. Maine State Forest Assessment and Strategies. Maine Forest Service, Department of Conservation, Augusta. 225 pp. Available at: https://www.maine.gov/dacf/mfs/about/state_assessment/index.html	Maine	Forests, sustainable forests, carbon storage, lakes, rivers, streams, wetlands, wild turkey, whitetail deer, standing snags, raptors, songbirds, woodpeckers, bats, owls, flying squirrels, late successional forests, land conservation, salamanders, frogs, carbon sequestration, vernal pools, rare, threatened, or endangered species, brook trout, Canada lynx, Beginning with Habitat Focus Areas, Maine State Wildlife Action Plan	Working forests, forestry related jobs, forest products, recreation, roads, best management practices for water quality, drinking water, biofuels, impervious surface	Wildfire, catastrophic storms, increasing storm intensity, invasive species, fragmentation, wind, ice storms, fish passage barriers, sea level rise, earlier ice out and snow melt, warmer temperatures, wetter conditions, increasing periods of drought, development
Maine Forest Action Plan: National Priorities Section- Updated Report, State of Maine 2015	Maine	Forest landscapes, land conservation, streams, wetlands, brook trout	Working forests, recreation, forestry best management practices for water quality, roads	Invasive species, wildfire, fish passage barriers, water pollution

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Maine Forest Service. 2015. Maine Forest Action Plan: National Priorities Section-Updated Report, State of Maine 2015. Available at: https://stateforesters.org/sites/default/files/publication-documents/Maine%20National%20Priorities.pdf				
Harpswell Intertidal Wetlands, Watersheds, Eelgrass and Erosion Richard Joyce, Claire Ellwanger, Tim Farley. 2011. Harpswell Intertidal Wetlands, Watersheds, Eelgrass and Erosion. Bowdoin College, Environmental Studies Department. Available at: http://www.harpswell.maine.gov/vertical/Sites/%7B3F690C92-5208-4D62-BAFB-2559293F6CAE%7D/uploads/2011_Harpswell_Intertidal__local_infrast_Nov11_Bowdoin_Students.pdf	Harpswell, Maine	Eelgrass, tidal marsh, marsh migration	N/A	Sea level rise, erosion, tidal restrictions
Geomorphology and the effects of sea level rise on tidal marshes in Casco Bay Curtis Bohlen, Marla Stelk, Matthew Craig, Lauren Redmond, Caitlin Gerber. 2012. Geomorphology and the effects of sea level rise on tidal marshes in Casco Bay. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/geomorphology-effects-sea-level-rise-tidal-marshes-casco-bay/	Casco Bay, Maine	Salt marshes, tidal wetlands, marsh migration	Dams, roads	Sea level rise, tidal restrictions, coastal erosion, impervious surface

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Update on a Continuing Saga: Eelgrass and Green Crabs in Casco Bay, Maine Hilary A. Neckles, Angela D. Brewer, John W. Sowles, Seth Barker, Curtis C. Bohlen, Matthew Craig, Michael Doan, Sandra Lary. 2015. Update on a Continuing Saga: Eelgrass and Green Crabs in Casco Bay, Maine. USGS. Available at: https://www.cascobayestuary.org/publication/update-continuing-saga-eelgrass-green-crabs-casco-bay-maine-poster/	Casco Bay, Maine - South Portland, Portland, Falmouth, Yarmouth, Freeport, Brunswick, Harpswell, Chebeague Island, Long Island, Peaks Island	Eelgrass	N/A	Invasive species
Maine Eelgrass Mapping Protocol Barker, S. 2015. Maine Eelgrass Mapping Protocol. Casco Bay Estuary Partnership and Maine Dept. of Environmental Protection. Available at: https://www.cascobayestuary.org/publication/maine-eelgrass-mapping-protocol/	Maine	Eelgrass	N/A	N/A
Project Report: Mapping and Restoration Inventory of Fringing Marsh Habitat in the Casco Bay Estuary Peter Hayes, Rachel Carr, Michele Dionne. 2008. Project Report: Mapping and Restoration Inventory of Fringing Marsh Habitat in the Casco Bay Estuary. Wells National Estuarine Research Reserve. Available at: https://www.cascobayestuary.org/publication/mapping-restoration-inventory-fringing-marsh-habitat-casco-bay-estuary-project-report/	Casco Bay, Maine (mainland)	Fringing marsh, salt marsh, salt marsh restoration, shoreline buffers	Roads, houses, lawns	Coastal bluff hazards, invasive species, sea level rise, erosion

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Resilient Sites for Terrestrial Conservation in Eastern North America Anderson, M.G., A. Barnett, M. Clark, C. Ferree, A. Olivero Sheldon, J. Prince. 2016. Resilient Sites for Terrestrial Conservation in Eastern North America. The Nature Conservancy, Eastern Conservation Science. Available at: http://climatechange.lta.org/wp-content/uploads/cct/2016/07/Resilient_Sites_for_Terrestrial_Conservation.pdf	Maine, Massachusetts, Connecticut, Vermont, Rhode Island, New Hampshire, New York, Pennsylvania, Tennessee, New Jersey, Virginia, West Virginia, Maryland, Delaware, Kentucky, Florida, Alabama, Mississippi Portions of: Ohio, Indiana, Illinois, Louisiana Canadian Provinces of Nova Scotia, New Brunswick, Prince Edward Island Portions of: Quebec	Resilient landscapes, connected habitat, land conservation, restoration, plants, herptiles, mammals, invertebrates, fish, birds, riparian corridors, wetlands, beach, dune, floodplain, landscape permeability, natural heritage program priority species	Energy infrastructure, forest management, roads, railroads, future development	Increasing intense storms, droughts, floods, fires, roads as barriers to aquatic and terrestrial species, fragmented natural landscapes, increasing development, temperature changes, habitat range shifts, changing precipitation
Divergence of species responses to climate change Fei, S., Desprez, J.M., Potter, K.M., Jo, I., Knott, J.A., Oswalt, C.M. 2017. Divergence of species	Eastern United States	Forests tree species migration, ecosystem shifts, land conservation	Forest management	Forest community shifts, increasing temperatures, drought, changing precipitation, invasive species

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
responses to climate change. *Science Advances: 3.* Available at: http://advances.sciencemag.org/content/3/5/e1603055				
Maine's Wildlife Action Plan Maine Dept. of Inland Fisheries and Wildlife. 2015. Maine's Wildlife Action Plan. Maine Dept. of Inland Fisheries and Wildlife, Augusta, ME. Available at: https://www.maine.gov/ifw/docs/2015%20ME%20WAP%20All_DRAFT.pdf	Maine	Endangered, threatened, and special concern species, species of greatest conservation need	Biological resource use, transportation and service corridors, energy production and mining, agriculture and aquaculture, residential and commercial development	Habitat shifting, droughts, temperature extremes, extreme precipitation and wind events, pollution, invasive species, natural systems modifications, human intrusions and disturbance
CLIMATE *CHANGE AND STORM IMPACTS*				
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. Available at: http://nca2014.globalchange.gov/report/regions/northeast	Northeast states: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, Pennsylvania, New Jersey, Deleware, Maryland, Washington D.C., West Virginia	Commercially important fish and shellfish species, cod, lobster, brook trout, bass, forests, grasslands, coastal zones, beaches, dunes, wetlands	Marine and freshwater fisheries, communications, energy, transportation, water and waste infrastructure; cultural and historical landmarks, agricultural land, green space, evacuation routes, lifelines, low-lying coastal metropolitan areas, rural areas, culverts, roads, railroads, public health	Rising temperatures, sea level rise, coastal flooding, storm surge, extreme precipitation events, declining water quality and clarity, saltwater intrusion, increasing frequency, intensity, and duration of heat waves, increasing risk of seasonal droughts, increased vulnerability of the region's most disadvantaged residents, warmer winters with increased risk of frost and

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				freeze damage, increased weed and pest pressure
Final Report of the Commission to Study the Effects of Coastal and Ocean Acidification and Its Existing and Potential Effects on Species that are Commercially Harvested and Grown Along the Maine Coast 2015. Final Report of the Commission to Study the Effects of Coastal and Ocean Acidification and Its Existing and Potential Effects on Species that are Commercially Harvested and Grown Along the Maine Coast: State of Maine 126th Legislature Second Regular Session Available at: https://www.maine.gov/legis/opla/oceanacidificationrpt.pdf	Maine	Cold water corals, crustaceans (lobsters, crabs, shrimp), mollusks (mussels, oysters, clams, scallops, periwinkles), echinoderms (sea urchins, starfish, sea cucumbers), annelids (bloodworms, sandworms), macroalgae (calcareous macroalgae, red algae, brown algae, green algae), plankton (phytoplankton, zooplankton including pteropods and copepods), finfish (cod, herring, halibut, flounder)	Coastal marine fisheries, aquaculture	Coastal and ocean acidification, stormwater runoff, increase in average annual rainfall, increase in frequency of extreme precipitation events
Historic Flooding in Major Drainage Basins, Maine ENSR Corporation. 2007. Historic Flooding in Major Drainage Basins, Maine. Document No.: 12092-003-B. Available at: https://www.maine.gov/dacf/flood/docs/maineriverbasin/maineriverbasinreport.pdf	Maine	Rivers	Dams and reservoirs, cities and towns, businesses and homes	Flooding, storm events, ice dams
Hurricanes & Tropical Storms: Their Impact on Maine and Androscoggin County	Maine	N/A	Roads, buildings, power lines, evacuation routes,	Hurricanes, tropical storms, storm surge,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Cotterly, W. 1996. Hurricanes & Tropical Storms: Their Impact on Maine and Androscoggin County. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.692.8379&rep=rep1&type=pdf			disaster preparedness, railroads, bridges, emergency services, water mains	storm tide, flooding, drought
What Climate Change Means for Maine EPA. 2016. What Climate Change Means for Maine. EPA 430-F-16-021. Available at: https://digital.library.unt.edu/ark:/67531/metadc948770/	Maine	Wetlands, beaches, osprey, heron, deer, brook trout, brown trout, lobsters, clams, striped bass	Fishing, agriculture, winter recreation, human health, coastal communities, homes, roads, rail lines, communication infrastructure, energy infrastructure, wastewater management infrastructure, maple syrup production	Warmer temperatures, more precipitation, more heavy rainstorms, hotter and drier summers, sea level rise, ocean acidification, warmer ocean temperatures, earlier snowmelt, less snow, more droughts in summer and fall, flooding, erosion, changing migration and bloom times that lead to mismatches for species and their food source or pollinators, overpopulation of deer, invasive species, increases in vector borne diseases, increased pollen season
Climate Change in the Gulf of Maine Ecosystem Indicator Partnership. 2011. Climate Change in the Gulf of Maine. Gulf of Maine Council on the Marine Environment.	Gulf of Maine: Massachusetts, New Hampshire, Maine, New	Beaches, dunes, coastal wetlands	Fisheries, coastal infrastructure, human health, tourism, transportation,	Temperature increases, changing storm and precipitation patterns, sea level rise, increased ocean temperature,

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Available at: http://www.gulfofmaine.org/esip/ESIPFactClimateChangefinal.pdf	Brunswick, Nova Scotia		agriculture, wastewater treatment	decreased ocean salinity, coastal development, habitat degradation, pollution, invasive species, increased prevalence of fish and shellfish diseases, fragmentation and loss of coastal wetland habitat, increased frequency and intensity of storm events, erosion, flooding, increased precipitation, less snow, combined sewer overflows
Watching the Tides: The 100th Anniversary of the Portland, Maine Tidal Station Slovinsky, P.A. 2012. Watching the Tides: The 100th Anniversary of the Portland, Maine Tidal Station. Maine Geological Survey. Available at: https://digitalmaine.com/mgs_publications/471/	Portland, Maine	N/A	N/A	Sea level rise, storm surge, coastal flooding
Portland Tide Gauge and Waterfront Dickson, S.M. 2007. Portland Tide Gauge and Waterfront. Maine Geological Survey. Available at: https://digitalmaine.com/mgs_publications/409/	Portland, Maine	Coastal sand dunes, bluffs, salt marshes, mudflats, beaches, rocky ledges	Shoreland zoning, coastal infrastructure, Portland waterfront	Coastal erosion, sea level rise, coastal flooding, storm surge, northeasters

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Virtual Tour of Maine's Geologic Hazards Maine Geological Survey. Virtual Tour of Maine's Geologic Hazards. Available at: https://www.maine.gov/dacf/mgs/hazards/virtual/virtual_hazards.pdf	Maine	Beaches, coastal bluffs, dunes, rivers	Seawalls, coastal properties and homes	Coastal erosion, flooding, sea level rise, landslides, ice jams, storm events
Climate Literacy: The Essential Principles of Climate Science U.S. Global Change Research Program. 2009. Climate Literacy: The Essential Principles of Climate Science. U.S. Global Change Research Program. Washington DC. Available at: https://www.globalchange.gov/browse/reports/climate-literacy-essential-principles-climate-science-high-resolution-booklet	United States	Carbon storage / sequestration	National security, human health, climate literacy, economic stability, infrastructure, renewable energy, coastal properties	Increased temperatures, sea level rise, increasing heat waves, increasing droughts, increasing floods, greenhouse effect, saltwater inundation, less winter snowpack, ocean acidification
Climate Trends in the Casco Bay Region Casco Bay Estuary Partnership. 2015. Climate Trends in the Casco Bay Region. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/climate-trends-casco-bay-region/	Casco Bay, Maine	American lobsters, winter flounder, Atlantic cod, silver hake, shellfish, wetlands, sea grass	Shellfish harvesting, drinking water, roads, infrastructure, wastewater treatment systems, utilities, coastal properties, bridges, aquaculture	Warmer summers, warmer winters, warmer waters, increased drought, increased storm frequency, intensity, and total precipitation, sea level rise, ocean acidification, population growth, habitat fragmentation and destruction, invasive species, vector borne diseases, harmful algal blooms, flooding, combined sewer

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
				overflows, stormwater runoff, coastal acidification, erosion, tidal restrictions
A Changing Casco Bay Friends of Casco Bay. 2015. A Changing Casco Bay. Friends of Casco Bay. Available at: https://www.cascobayestuary.org/wp-content/uploads/2018/02/A-Changing-Casco-Bay-FOCB-2015-pdf.pdf	Casco Bay, Maine - 13 coastal communities	Waterbirds, pilot whales, eelgrass, salt marsh, river otters, seals, American lobster, soft-shell clams, mudflats, mussels, oysters	Working waterfront, historic waterfront, causeway, sewer systems, boat pumpouts	Polluted runoff, tidal restriction, plankton blooms, nitrogen pollution, ocean acidification, coastal acidification, fish kills, warming temperatures, invasive species
Highest Astronomical Tide on the Maine Coast Adams, C. 2014. Highest Astronomical Tide on the Maine Coast. Maine Geological Survey. Available at: https://digitalmaine.com/mgs_publications/500/	Maine	Salt marsh	Storm drains, roads	Storm surge, sea level rise, nuisance flooding, king tides
Latest Trends in Sea Level Rise and Storm Surge in Maine Slovinsky, P (Maine Geological Survey). Latest Trends in Sea Level Rise and Storm Surge in Maine, presented at Island Institute's Sea Level Rise Symposium (Staying Above High Water: Helping Prepare Maine's Coastal Communities for Coastal Flooding and Sea Level Rise), 28 November 2017. Available at: http://www.islandinstitute.org/sea-level-rise-symposium	Maine	N/A	Waterfront infrastructure	Sea level rise, storm surge, storm tide, flooding, nuisance flooding, king tide

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Global and Regional Sea Level Rise Scenarios for the United States Sweet, W.V., Kopp, R.E., Weaver, C.P., Obeysekera, J., Horton, R.M., Thieler, E.R., Zervas, C. (2017). Global and Regional Sea Level Rise Scenarios for the United States (NOAA Technical Report NOS CO-OPS 083). Silver Spring, MD: National Ocean Service Center for Operational Oceanographic Products and Services. Available at: https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf	United States	N/A	Coastal property, critical infrastructure, coastal preparedness planning, groundwater and fossil fuel extraction, seawalls, elevated houses, waste and stormwater systems, transportation infrastructure, power plants, seawalls	Sea level rise, flooding, hurricanes, storm surge, waves, ecological regime shifts, water pollution, nuisance flooding
The Role of the SLOSH Model in National Weather Service Storm Surge Forecasting Bob Glahn, Arthur Taylor, Nicole Kurkowski, Wilson A. Shaffer. The Role of the SLOSH Model in National Weather Service Storm Surge Forecasting. NOAA/National Weather Service Meteorological Development Laboratory: Silver Spring, Maryland. Volume 33 Number 1. Available at: https://slosh.nws.noaa.gov/docs/Vol-33-Nu1-Glahn.pdf	United States	N/A	Emergency management, hurricane evacuation planning	Storm surge, hurricanes, extratropical storms (nor'easters), waves, flooding
Maine's Climate Future: An Initial Assessment Jacobson, G.L., I.J. Fernandez, P.A. Mayewski, and C.V. Schmitt (editors). 2009. Maine's Climate Future: An Initial Assessment. Orono, ME: University of Maine	Maine	Spruce, loons, chickadees, lynx, marten, halibut, moose, brook trout, loons, puffins, black capped chickadee, piping plover, salt marsh	Commercial fisheries, forest products industry, agriculture, tourism, recreation, railways, roads, bridges, culverts, dams, wastewater	Increased average air temperatures, increased ocean temperatures, sea level rise, harmful algal blooms, invasive species, earlier snow melt and

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Available at: https://climatechange.umaine.edu/wp-content/uploads/sites/439/2018/08/Maines_Climate_Future.pdf		sharp-tailed sparrow, sugar maples, oaks, bobcat, summer flounder, deer, endangered, threatened and species concern species, cod, American lobster, herring, halibut, clams, mussels, sea urchins, barnacles, coralline algae, right whales, oysters, salt marshes, beaches, coastal bluffs, shorebirds, wetlands, lakes, ponds, streams, rivers, alewives, habitat connectivity, Atlantic salmon, forests, carbon sequestration, land conservation	treatment plants and sewer systems, indigenous communities, coastal properties, seawalls, emergency response, waterfront infrastructure (docks, piers), drinking water, irrigation, winter sports, historical sites, public health, renewable energy infrastructure	lake ice out, increased precipitation, increased frequency and intensity of storms, hurricanes, ocean acidification, vector borne diseases, longer growing season, changing plankton composition, storm surge, water pollution, fish passage barriers, changing forest communities, movement of fish and wildlife species, drought, changing hardiness zones, increased evapotranspiration, development pressure, air pollution
Maine's Climate Future: 2015 Update Fernandez, I.J., C.V. Schmitt, S.D. Birkel, E. Stancioff, A.J. Pershing, J.T. Kelley, J.A. Runge, G.L. Jacobson, and P.A. Mayewski. 2015. Maine's Climate Future: 2015 Update. Orono, ME: University of Maine. 24pp. Available at: https://climatechange.umaine.edu/wp-content/uploads/sites/439/2018/08/Maines_Climate_Future_2015_UpdateFinal-1.pdf	Maine	Northern shrimp, American lobster, Atlantic salmon, shellfish, calms, oysters, salt marshes, beaches	Maple syrup production, roads, culverts, bridges, public health, storm drains, sewers and wastewater treatment systems, ski industry, snowmobile industry, recreation, agriculture, commercial fisheries, homes and coastal properties, flood insurance	Hurricanes, droughts, flooding, rising sea levels, increased air temperatures, more hot days, vector borne diseases, invasive species, increased annual precipitation, increased number of extreme precipitation events, rising ocean temperatures, less snow,

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				water pollution, algae blooms, air pollution, species migration north, ocean acidification, coastal acidification, storm surge
Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS). Available at: https://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/confronting-climate-change-in-the-u-s-northeast.pdf	Northeast: New Jersey, New York, Massachusetts, New Hampshire, Vermont, Rhode Island, Connecticut, Maine, Pennsylvania	Cod, lobster, brook trout, Atlantic salmon, hemlocks, sugar maple, beech, birch, spruce, balsam fir, songbirds, Bicknell's thrush, Atlantic salmon, amphibians, beaches, salt marshes, barrier islands, dunes, beach nourishment, coastal bluffs, shellfish, water quality, rivers, lakes, streams, waterfowl, migratory birds, endangered species, clams, bay scallop, sea scallop, conch, winter flounder, menhaden, alewife, herring, sharks, oysters, bluefish, striped bass, shrimp, right whales, plankton, green heron, snowy egret, great egret, red-shouldered hawk, evening grosbeak, cedar waxwing, great	Agriculture, commercial fisheries, winter recreation, snowmobiling, skiing, outdoor recreation, timber harvesting, forest products industry, coastal properties, buildings, coastal infrastructure, emergency response, jetties, bulkheads, seawalls, roads, railways, tunnels, water and sewer systems, communication systems, electric utilities, subways, dams, critical facilities, water and sewage treatment plants, hospitals, tourism, National Flood Insurance Program, drinking water, combined sewer overflows, vulnerable populations	Warmer air temperatures, less snow, earlier ice-out, warmer ocean temperatures, sea level rise, decreased salinity in the Gulf of Maine, increased annual precipitation, increased winter precipitation, increased frequency and intensity of storm events, invasive species, vector borne diseases, more very hot days, droughts, flooding, tropical storms, hurricanes, increased hurricane intensity, nor'easters, erosion, lower summer stream flow, storm surge, water pollution, harmful algal blooms, forest community shifts, saltwater intrusion, wildfires, ice storms, warmer stream temperatures, increased

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		cormorant, Canada lynx, American marten, snowshoe hare, ruffed grouse, black capped chickadee, American goldfinch, song sparrow, cedar waxwing, Baltimore oriole, purple fish, Baltimore oriole, wetlands, American bittern, common loon, sora, Blackburnian warbler		evapotranspiration, increased CO_2 availability, flash flooding, air pollution, urban heat islands
Maine: Confronting Climate Change in the U.S. Northeast Union of Concerned Scientists. 2007. Maine: Confronting Climate Change in the U.S. Northeast. Union of Concerned Scientists: Cambridge, MA. Available at: https://www.maine.gov/dacf/municipalplanning/docs/NortheastClimateImpactsAssessment(MaineSummary).pdf	Maine	Atlantic salmon, forests, Canada lynx, Bicknell's thrush, snowshoe hare, brook trout, hemlock, cod, lobster, wetlands, beaches	Forest products industry, recreation, snowmobiling, skiing, coastal property, agriculture	Warmer average temperatures, increased winter precipitation, less snow, earlier ice out on lakes, drought, lower summer stream flows, sea level rise, erosion, forest composition changes, mud season, invasive species, warming ocean temperatures, storm surge, flooding, longer growing season, decreased air quality, increased vector borne diseases
People and Nature Adapting to a Changing Climate: Charting Maine's Course 2010. People and Nature Adapting to a Changing Climate: Charting Maine's Course. A	Maine	Beaches, dunes, wetlands, carbon sequestration	Business, trade, agriculture, forestry, public health, transportation,	Invasive species, sea level rise, raising water temperatures, increasing winter precipitation, less

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Summary of the Report Presented by The Maine Department of Environmental Protection to The Joint Standing Committee on Natural Resources of the 124th Maine Legislature. Available at: https://www.cascobayestuary.org/publication/people-nature-adapting-changing-climate-charting-maines-course/			conservation, state government, municipal government, commercial fishing, roads, rails, waterfronts and waterfront infrastructure, wastewater treatment plants, tourism, stormwater management, emergency response, drinking water, energy infrastructure, homes, buildings	snow, increasing frequency and intensity of storms, more variables temperatures and precipitation, droughts, altered freshwater flows, saltwater intrusion, shifting natural communities
VULNERABILITY ASSESSMENTS AND ADAPTATION PLANNING				
Monitoring, Mapping, Modeling, Mitigation, and Messaging: Maine Prepares for Climate Change 2014. Monitoring, Mapping, Modeling, Mitigation, and Messaging: Maine Prepares for Climate Change. Summary and Recommendations from the Environmental and Energy Resources Working Group. Department of Environmental Protection. Available at: https://www.maine.gov/dep/sustainability/climate/Working%20Group%20maine%20prepares.pdf	Maine	Priority fish and wildlife species, Moose, Canada lynx, brook trout, saltmarsh birds, rusty blackbirds, dragonflies, damselflies, species of conservation concern, threatened and endangered species, lobster, sea urchins, scallops, northern shrimp, black sea bass, dunes, wetlands, salt marshes, land conservation	Engineering, water and wastewater infrastructure operations, natural resource based industries, commercial fisheries, agriculture, silviculture, emissions, transportation infrastructure, drinking water, fuel storage facilities, shoreland zoning	Severe storms, changing rainfall, diseases and insect pests, invasive species, wildfire, poorly designed or malfunctioning road culverts and impoundments, sea level rise, storm surge, harmful algal blooms, vector-borne diseases
Maine Prepares for Climate Change - 2018 Update	Maine	Groundwater, dunes, beaches, coastal bluffs, freshwater streams and	Transportation infrastructure, working forests, wastewater	Flooding, changing snowpack, increasing water temperatures,

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Maine Interagency Climate Adaptation Work Group. 2018. Maine Prepares for Climate Change - 2018 Update. Available at: https://www.maine.gov/dep/sustainability/climate/mica.html https://www.maine.gov/dep/sustainability/climate/MainePreparesforClimateChange2018Update.pdf		rivers, beach nourishment, species of greatest conservation need, amphibians, reptiles, endangered and threatened species, saltmarsh birds, brook trout, moose, Canada lynx, dragonflies and damselflies, rusty blackbird, eelgrass, northern shrimp, lobster, clams, coastal wetlands, land conservation	treatment facilities, drinking water, public health, agriculture, shoreland zoning, fuel storage facilities, energy infrastructure, critical infrastructure, emergency preparedness	increasing air temperatures, storm surge, sea level rise, increasing ocean temperatures, ocean acidification, coastal acidification, increasing precipitation intensity and duration, poorly designed or malfunctioning road culverts and impoundments, harmful algal blooms, water pollution, vector-borne diseases, increased extreme heat events, habitat fragmentation, invasive species, erosion, water pollution, increasing number of very hot days, drought, hurricanes
Climate Change and Biodiversity in Maine: Vulnerability of Habitats and Priority Species Whitman, A., A. Cutko, P. deMaynadier, S. Walker, B. Vickery, S. Stockwell, and R. Houston. 2013. Climate Change and Biodiversity in Maine: Vulnerability of Habitats and Priority Species. Manomet Center for Conservation Sciences (in collaboration with Maine Beginning with Habitat Climate Change	Maine	Maine plant and wildlife species (major taxanomic groups, threatened or endangered plant species, invertebrate taxa, bird taxa), Maine habitats, Maine natural communities	N/A	Temperature change, fragmented populations, southern edge of range, shift food webs and prey availability, sea level rise, hydrology changes, decrease in snow and boreal conditions, vulnerable to invasive species

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Working Group) Report SEI-2013-03. 96 pp. Brunswick, Maine. Available at: https://www.manomet.org/sites/default/files/publications_and_tools/2013%20BwH%20Vulnerability%20Report%20CS5v7_0.pdf				
Adaptation Planning for the National Estuary Program EPA, Climate Ready Estuaries. Adaptation Planning for the National Estuary Program. EPA, Climate Ready Estuaries: Whitepaper – May 2009. Available at: https://www.epa.gov/cre/adaptation-planning-national-estuary-program	United States	Estuaries	Climate change vulnerability assessment, climate change adaptation planning	N/A
Climate Change Adaptation Report: Georgetown, Maine Georgetown Conservation Commission. 2015. Climate Change Adaptation Report: Georgetown, Maine. A special publication by the Georgetown Conservation Commission. May 2015, 34 pp. Available at: http://gtownconservation.com/wp-content/uploads/2015/08/Georgetown-Adaptation-Report-ALL-chapters-FINAL-8.75x11.25-v10forPDFonlineV2.pdf	Georgetown, Maine	American lobster, coastal aquifers, cod, black sea bass, softshell clams, wetlands, land conservation, forest community changes, increasing whitetail deep populations, salt marshes, birds, mammals, amphibians	Homeowner's insurance, human health, commercial fisheries, public property, private property, water supply, roads, tourism, recreation, emergency preparedness, cultural and historical assets, bridges, culverts, wells, overboard discharges, septic systems, tourism, National Flood Insurance Program, town dock, comprehensive planning, energy audits, plant hardiness zones, boat ramps	Increasing air temperatures, increasing water temperatures, increasing precipitation, sea level rise, storm surge, increasing intensity of coastal storms, increased hurricane activity, extreme rainfall, extreme wind events, ocean acidification, increasing vector borne diseases, drought, wildfire, invasive species, undersized culverts,

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				saltwater intrusion, drought, water pollution, harmful algal blooms
Resiliency Assessment: Casco Bay Region Climate Change U.S. Department of Homeland Security Regional Resiliency Assessment Program. 2016. Resiliency Assessment: Casco Bay Region Climate Change. U.S. Department of Homeland Security. Available at: https://www.cascobayestuary.org/publication/resiliency-assessment-casco-bay-region-climate-change/	Casco Bay Region, Maine - the Casco Bay watershed, which primarily encompasses Cumberland County	Coastal aquifers	Critical infrastructure (energy, transportation, water /wastewater, telecommunications), emergency planning and response, rail lines, ferry terminals, roads, bridges, seaport terminals, electrical generation and transmission facilities (power plants, electrical substations), petroleum storage facilities and distribution infrastructure, drinking water supplies, homes businesses, stormwater drainage systems, culverts, hospitals, emergency services, wharves, wastewater treatment facilities, private wells, microgrid planning	Changes in precipitation patterns, increasing air temperatures, increasing ocean temperatures, increasing freshwater temperatures, increasing frequency and intensity of storm events, storm surge, sea level rise, increasing power and force of tropical storms and hurricanes, wind, increasing high temperature days, saltwater intrusion, stormwater runoff, nuisance flooding, water pollution, invasive species, algal blooms
Sea Level Rise Vulnerability Assessment Yakovleff, D. 2013. Sea Level Rise Vulnerability Assessment. Sustain Southern Maine. Available at: https://www.cascobayestuary.org/publication/	Southern Coastal Maine - Brunswick to Kittery	Marsh migration, marshlands, salt marsh, endangered species, shellfish, sand dunes, coastal bluff, ledges, beach nourishment, dune restoration, beach,	Tourism, commercial fisheries, emergency management response, sewer infrastructure, wastewater facilities, water infrastructure, road infrastructure, bridge,	Coastal flooding, sea level rise, storm surge, water pollution, erosion, storm events, saltwater intrusion, tidal restrictions, landslides,

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sustain-southern-maine-sea-level-rise-vulnerability-assessment/		wetland restoration, barrier beach	nursing home, fire station, library, evacuation routes, public facilities, retail stores, commercial businesses, hospitals, dams, shoreland zoning, private properties, railroads, nursing facility, ferry terminal, wharves, coastal development, berm, boat launch, Coast Guard Station, petroleum storage facilities, developmental retreat, elevated freeboard ordinance, parking areas, naval shipyard, comprehensive planning	combined sewer overflows
Casco Bay Community Guidebook: Building a Resilient Future Greater Portland Council of Governments. 2017. Casco Bay Community Guidebook: Building a Resilient Future. Greater Portland Council of Governments. Available at: https://www.cascobayestuary.org/publication/casco-bay-community-guidebook-building-resilient-future/	Casco Bay coast, Maine - Cape Elizabeth, Chebeague Island, Cumberland, Falmouth, Freeport, Long Island, Portland, South Portland Yarmouth, Scarborough	Lakes, coastal waters, salt marshes, upland forest, land conservation, vernal pools, shellfish	Roads, roofs, sewers, green infrastructure, comprehensive plans, hazard mitigation plans, climate change vulnerability assessments, publicly-owned infrastructure, ferry piers, culverts, buildings, sewer treatment plant, stormwater infrastructure, shoreland zoning, National Flood Insurance Program, overboard discharges,	Sea level rise, stormwater runoff, coastal flooding, increased frequency and intensity of storms, increased average temperatures, habitat degradation, storm surge, king tides, non-point source pollution, combined sewer overflows

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
			transfer of development rights, rain gardens	
Casco Bay Climate Change Vulnerability Report Casco Bay Estuary Partnership, Natural Choices, Waterview Consulting. 2017. Casco Bay Climate Change Vulnerability Report. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/casco-bay-climate-change-vulnerability-report/	Casco Bay Watershed, Maine	American lobster, winter flounder, silver hake, Atlantic cod, tidal wetlands, coastal aquifers, clams, scallops, oysters, marsh migration, eelgrass, land conservation, habitat connectivity, fish passage, anadromous fish, northern shrimp, living shorelines, saltmarsh sparrows	Human health, electricity grid and infrastructure, drinking water, groundwater wells, National Flood Insurance Program, coastal properties, roads, bridges, ports, water infrastructure, waterfront infrastructure, wastewater treatment plants, sewer lines, aquaculture, culverts, green infrastructure, stormwater management	Warmer summers, warmer winters, warmer water, increasing drought, increasing storminess, sea level rise, ocean acidification, population growth, habitat fragmentation and destruction, resource depletion, vector-borne diseases, earlier lake ice-out, changing precipitation regime, harmful algal blooms, stormwater runoff, combined sewer overflows, flooding, wildfire, coastal acidification, bacterial pollution, nutrient pollution, storm surge, erosion, saltwater intrusion, invasive species
Bowdoinham Inventory and Analysis: Sea Level Rise and Climate Change Town of Bowdoinham. 2014. Bowdoinham Inventory and Analysis: Sea Level Rise and	Bowdoinham, Maine	Land conservation, tidal marshes, sand dunes, marsh migration	Roads, bridges, railroads, drains, buildings, FEMA Flood Insurance Program, shoreland zoning, National Flood Insurance	Sea level rise, storm surge, increasing precipitation, increasing frequency and intensity of storm events, flooding,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Climate Change. Town of Bowdoinham Comprehensive Plan. p. 151-181. Available at: http://www.bowdoinham.com/comprehensive-plan			Community Rating System, shoreland zoning	impervious surface, isostatic rebound
Adapting to Maine's Changing Climate: A Worksheet for Municipalities Maine Municipal Planning Assistance Program. Adapting to Maine's Changing Climate: A Worksheet for Municipalities. Department of Agriculture Conservation, and Forestry. Municipal Planning Assistance Program. Available at: https://www.maine.gov/dacf/municipalplanning/docs/ClimateChangeWorksheet.doc	Maine	Salt marshes, marsh migration	Buildings, bridges, roads, stormwater infrastructure, wastewater treatment plants, tourism, fisheries, agriculture, businesses, water supply, emergency services, power, public health	Increasing temperatures, increasing annual precipitation, more short-term droughts, more severe storms, sea level rise, invasive species, vector borne diseases, coastal flooding
Coastal Vulnerability Analysis: Brunswick and Harpswell Krista Bahm, Maryellen Hearn, Melissa Anson, Liza LePage, Tom Marcello, Woody Mawhinney, Leah Wang, Phil Camill, Eileen Johnson. 2011. Coastal Vulnerability Analysis: Brunswick and Harpswell. Bowdoin College, Environmental Studies Department. Available at: http://www.harpswell.maine.gov/vertical/Sites/%7B3F690C92-5208-4D62-BAFB-2559293F6CAE%7D/uploads/2010-_Coastal_vulnerability.pdf	Harpswell, Maine	Marshes, conserved land, marsh migration	Buildings, roads, piers, parcels, land value	Sea level rise, flooding, storm surge
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Brunswick Edition	Brunswick, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads,	Increased air temperature, increased ocean temperature, sea

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Brunswick Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-brunswick-edition/			railroads, trails, dams, coastal properties, golf course, homes, marine, US Route 1	level rise, tidal restrictions, flooding, undersized culverts
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – Cape Elizabeth Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Cape Elizabeth Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-cape-elizabeth-edition/	Cape Elizabeth, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, coastal properties	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – Falmouth Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Falmouth Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/	Falmouth, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, coastal development, golf course, wastewater treatment plant outfall, US Route 1, wharf, restaurants, town landing, homes	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
sea-level-rise-casco-bays-wetlands-look-potential-impacts-falmouth-edition/				
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – Freeport Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Freeport Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-freeport-edition/	Freeport, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, buildings, commercial businesses	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – Phippsburg Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Phippsburg Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-phippsburg-edition/	Phippsburg, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, coastal properties, homes, businesses	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – Portland Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Portland Edition. Casco Bay Estuary Partnership.	Portland, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, water lines, sewer lines, coastal property, wharfs and piers	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts

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Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-portland-edition/				
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – South Portland Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – South Portland Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-south-portland-edition/	South Portland, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, private property, wastewater treatment facility, bridge, cemetery, oil terminal	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – West Bath Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – West Bath Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-west-bath-edition/	West Bath, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, US Route 1, coastal property	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – Yarmouth Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco	Yarmouth, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams,	Increased air temperature, increased ocean temperature, sea level rise, tidal

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Bay's Wetlands: A Look at Potential Impacts - Yarmouth Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-yarmouth-edition/			boatyards, marinas, public boat launch, commercial properties, interstate highway, restaurants	restrictions, flooding, undersized culverts
Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts – Harpswell Edition Curtis Bohlen, Marla Stelk, Matthew Craig, Caitlin Gerber. 2013. Sea Level Rise and Casco Bay's Wetlands: A Look at Potential Impacts - Harpswell Edition. Casco Bay Estuary Partnership. Available at: https://www.cascobayestuary.org/publication/sea-level-rise-casco-bays-wetlands-look-potential-impacts-harpswell-edition/	Harpswell, Maine	Marsh migration, tidal wetlands, dunes, beaches	Commercial fishing, shellfishing, outdoor recreation, roads, railroads, trails, dams, boatyard, homes, businesses, restaurants, private roads	Increased air temperature, increased ocean temperature, sea level rise, tidal restrictions, flooding, undersized culverts
Town of Boothbay Harbor: Flood Impact Preliminary Engineering Study Milone & Macbroom, Inc. 2017. Town of Boothbay Harbor: Flood Impact Preliminary Engineering Study. Town of Boothbay Harbor Maine, Lincoln County Regional Planning Commission, and Maine Coastal Program. Available at: https://www.lcrpc.org/uploads/visual_edit/boothbay-harbor-flood-project-final-report.pdf	Boothbay Harbor, Maine	N/A	FEMA flood insurance rate maps, harbor, restaurants, stores, hotels, lobster wharfs, fish piers and marinas, individual property adaptation, infrastructure, utility lines, buildings, risks and vulnerabilities, adaptation, emergency preparedness, wet floodproofing buildings, dry floodproofing buildings,	Sea level rise, flooding, waves, erosion, increased development, population growth, high winds, structural damage to buildings

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
			elevating buildings, historic buildings	
Mapping Potential Sea Level Rise and Storm Surge in Boothbay Harbor, ME Slovinsky, P. 2016. Mapping Potential Sea Level Rise and Storm Surge in Boothbay Harbor, ME. Boothbay Harbor Rotary Club. Available at: http://www.lcrpc.org/coastal-projects-planning/mapping-potential-sea-level-rise-and-storm-surge-in-boothbay-harbor-me	Boothbay Harbor, Maine	Coastal wetlands, sand dunes	Buildings, roads, emergency management planning and response, FEMA flood maps, wastewater treatment facility, governmental structures, commercial structures	Sea level rise, storm surge, storm tide, hurricanes, flooding
Areas of Potential Inundation from a Category 1 Hurricane: Lincoln County, Maine Lincoln County Regional Planning Commission. 2015. Areas of Potential Inundation from a Category 1 Hurricane: Lincoln County, Maine. Lincoln County Regional Planning Commission. Available at: https://www.lcrpc.org/uploads/visual_edit/lincolncounty-full-v5.pdf	Lincoln County, Maine	N/A	Emergency planning and preparedness, roads, buildings	Hurricane, storm surge, storm tide, flooding
Adaptation Planning Study: Downtown Waterfront Area- Damariscotta, Maine Milone & MacBroom, Inc. 2014. Adaptation Planning Study: Downtown Waterfront Area-Damariscotta, Maine. Coastal Communities Grant Oversight Committee, Damariscotta, Maine. Available at: https://www.lcrpc.org/uploads/visual_edit/20150202-finalreport-revised.pdf	Damariscotta, Maine	N/A	Downtown buildings, infrastructure, storefront entrances, Nonstructural measures (preparedness, emergency response, retreat, and regulatory and financial measures to reduce risk), structural measures (dikes, seawalls, groins, jetties, temporary flood barriers), structure	Sea level rise, flooding

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
			floodproofing, stormwater system, sewer lines, propane tanks	
Boothbay Harbor, Maine Wastewater Facilities Sea Level Rise & Storm Surge Impact Assessment Wright-Pierce. 2017. Boothbay Harbor, Maine Wastewater Facilities Sea Level Rise & Storm Surge Impact Assessment. Wright-Pierce. Available at: https://www.bbhsd.org/sites/boothbaysewer/files/uploads/coastal_resiliency_study-finalreport-01-18-17.pdf	Boothbay Harbor, Maine	N/A	Wastewater treatment facility, pump stations, sewer lines, roads, piers, docks, shoreline stabilization, sea wall, flood gates, temporary flood barriers, elevate structures, Flood Insurance Rate Maps	Coastal flooding, sea level rise, storm surge, changing rainfall precipitation
Increased risk of groundwater contamination due to saltwater intrusion driven by climate change in Casco Bay, Maine Guiang, M. and M.R. Allen. 2015. "*Increased risk* of *groundwater contamination due* to *saltwater intrusion driven* by *climate change* in *Casco Bay*, *Maine*" (in press). Oak. Ridge, TN: Oak Ridge National Laboratory. Available at: https://almeriaanalytics.com/wp-content/uploads/2015/08/DHS_SWI_Paper.pdf	Casco Bay, Maine	Aquifer, fractured bedrock aquifers	Wells	Changing precipitation, sea level rise, saltwater intrusion, increasing population
Harpswell Coastal Flooding Risk Assessment Midcoast Council of Governments. 2015. Harpswell Coastal Flooding Risk Assessment. Midcoast Council of Governments. Available at: http://www.harpswell.maine.gov/vertical/Sites/%7B3F690C92-5208-4D62-BAFB-	Harpswell, Maine	Coastal marshes, marsh migration	Roads, culverts, dams, bridge, emergency services and access, private roads	Storm surge, sea level rise, flooding, tidal restrictions from dams and undersized culverts

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
2559293F6CAE%7D/uploads/Coastal_FloodingRiskAsses_SeaLevRise_ReportFinalDraft.pdf				
Wiscasset, Maine Wastewater Treatment & Collection Facilities Coastal Hazard Resilience Study Wright-Pierce. 2017. Wiscasset, Maine Wastewater Treatment & Collection Facilities Coastal Hazard Resilience Study. Wright-Pierce. Available at: https://www.lcrpc.org/uploads/visual_edit/11370m-wwtf-resiliency-final.pdf	Wiscasset, Maine	N/A	Wastewater treatment plant, pump station, sewer lines, railroad, sea wall, flood gates, temporary flood barriers, Flood Insurance Rate Maps	Coastal flooding, sea level rise, storm surge, changing rainfall precipitation
New England and Northern New York Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the New England Climate Change Response Framework Project Maria K. Janowiak, Anthony W. D'Amato, Christopher W. Swanston, Louis Iverson, Frank R. Thompson III, William D. Dijak, Stephen Matthews, Matthew P. Peters, Anantha Prasad, Jacob S. Fraser, Leslie A. Brandt, Patricia Butler-Leopold, Stephen D. Handler, P. Danielle Shannon, Diane Burbank, John Campbell, Charles Cogbill, Matthew J. Duveneck, Marla R. Emery, Nicholas Fisichelli, Jane Foster, Jennifer Hushaw, Laura Kenefic, Amanda Mahaffey, Toni Lyn Morelli, Nicholas J. Reo, Paul G. Schaberg, K. Rogers Simmons, Aaron Weiskittel, Sandy Wilmot, David Hollinger, Erin Lane, Lindsey Rustad, and Pamela H. Templer. 2018. New England and Northern New York Forest Ecosystem Vulnerability Assessment and	New England region: Connecticut, Maine, Massachusetts, New Hampshire, northern New York, Rhode Island, Vermont	Forest ecosystems, central hardwood-pine, low-elevation spruce-fir, lowland and riparian hardwood, lowland mixed conifer, montane spruce-fir, northern hardwood, pitch pine-scrub oak, transition hardwood, balsam fir, red spruce, black spruce, red maple, northern red oak, black cherry, American basswood, landscape connectivity	Forest products industries, recreation, snowmobiling, skiing	Increasing air temperatures, more annual precipitation, more extreme precipitation events, less snowfall, sea level rise, reduction in lake ice, longer growing season, changing plant and animal phenology, shorter period of frozen ground in winter, carbon dioxide fertilization, drought, fragmentation and land-use change, altered nutrient cycling, wildfire regime shifts, invasive species, forest diseases, insect pests, overbrowsing, extreme weather events, flooding,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Synthesis: A Report from the New England Climate Change Response Framework Project. United States Department of Agriculture, Forest Service Northern Research Station: General Technical Report NRS-173. Available at: https://www.nrs.fs.fed.us/pubs/55635				saltwater intrusion, storm surge, erosion, changes in annual soil moisture patterns, shifts in forest composition, impacts on tree regeneration and recruitment
Preparing For Climate Change: A Guidebook for Local, Regional, and State Governments Snover, A.K., L. Whitely Binder, J. Lopez, E. Willmott, J. Kay, D. Howell, and J. Simmonds. 2007. Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments. In association with and published by ICLEI – Local Governments for Sustainability, Oakland, CA. Available at: http://cses.washington.edu/db/pdf/snoveretalgb574.pdf	United States (Developed in Washington state)	Dunes, beaches, wetlands, streams, rivers, salmon, land conservation, forests	Public services, environmental quality or compliance, economic development, land use planning and zoning, fiscal responsibility and risk management, capital investments, emergency response, water resources management, public health, coastal zone management, port management, ecosystem management, stormwater management, transportation infrastructure, climate change preparedness team, climate change vulnerability assessment, climate change risk assessment, preparedness goals and actions, community resilience, agriculture, recreation,	Increasing temperatures, less snowpack, longer growing season, shifting ranges of plants and animals, sea level rise, drought, flooding, forest fires, disease, invasive species, landslides, saltwater intrusion, erosion, ocean acidification, increased annual precipitation, more extreme weather events, decreased ice cover and earlier ice out, rising sea surface temperatures, changes in composition of ecological communities, changing phenology of ecological events

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
			energy, tourism, drinking water	
Integrating Storm Surge and Sea Level Rise Vulnerability Assessments and Criticality Analyses into Asset Management at MaineDOT Merrill, S., Gates, J. 2014. Integrating Storm Surge and Sea Level Rise Vulnerability Assessments and Criticality Analyses into Asset Management at MaineDOT. Maine Department of Transportation and US Department of Transportation Federal Highway Administration. Available at: https://www.fhwa.dot.gov/environment/sustainability/resilience/pilots/2013-2015_pilots/maine/final_report/index.cfm	6 towns in Maine - Bath, Bowdoinham, Phippsburg, Georgetown, Topsham, Scarborough	Marsh migration, salt marsh	Roads, bridges, culverts, tourism, water treatment facilities	Storm surge, sea level rise, increasing frequency and intensity of storm events, flooding, king tides
NOAA. Peer-to-Peer Casc Study: Community Resilience Planning on a Budget. NOAA Office for Coastal Management Digital Coast. Available at: https://coast.noaa.gov/digitalcoast/training/lincoln-county-maine.html	Lincoln County, Maine	N/A	Coastal infrastructure, downtowns, waterfront buildings, seawalls, freeboard regulations, Flood Insurance Rate Maps, wastewater treatment plants	Sea level rise, storm surge, flooding
Sagadahoc Region, Maine Climate Change Adaptation Plan Walberg, E., VanDoren, W., Sartoris, J. 2013. Sagadahoc Region, Maine Climate Change Adaptation Plan. Manomet Center for Conservation Sciences	Sagadahoc Region of Maine - Richmond, Dresden, Bowdoinham, Woolwich, Topsham, Brunswick,	Riparian areas, conserved lands, large habitat blocks, wading birds, waterfowl, seabirds, vernal pools, shorebirds, brook trout, deer, endangered species, threatened species,	Food security, agriculture, local governance, comprehensive planning, downtowns, drinking water, zoning, stormwater infrastructure, culverts, open space planning, transportation	Flooding, water pollution, sea level rise, development, storm water runoff, flooding, increased air temperatures, earlier peak spring stream flow, longer growing season,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Available at: https://www.cakex.org/sites/default/files/documents/Sagadahoc%205-13.pdf	Harpswell, West Bath, Bath, Phippsburg, Arrowsic, Georgetown, Westport Island	special concern species, rare and exemplary natural communities, rivers, streams, freshwater wetlands, salt marshes, beaches, mudflats, migratory fish, shellfish, lobster, urban forests, marsh migration, oysters, snails, clams, urchins	infrastructure, utilities, homes, businesses, septic systems, coastal infrastructure, green infrastructure	increased frequency and intensity of storm events, hurricanes, tropical storms, increasing sea surface temperatures, drought, storm surge, more very hot days, fewer frost days, wind, waves, ocean acidification
FLOOD PLANNING				
Flood Risk Report: Cumberland County, Maine FEMA. 2014. Flood Risk Report: Cumberland County, Maine. Available at: https://msc.fema.gov/portal https://map1.msc.fema.gov/data/FRP/FRR_23005C_20140930.pdf?LOC=e06865eae623dc96cda69ab73929f9fd	Cumberland County, Maine	N/A	Count of affected structures, count of affected population, assets that include residential, commercial, essential facilities, and infrastructure	Flooding, the impacts of dams, levees, embankments, coastal hardening structures, areas of significant land use change, and streamflow restrictions on flooding impacts
Flood Risk Report: Knox County, Maine FEMA. 2014. Flood Risk Report: Knox County, Maine. Available at: https://msc.fema.gov/portal https://map1.msc.fema.gov/data/FRP/FRR_23013C_20140606.pdf?LOC=474964c246a032396a5537b9fc4053ef	Knox County, Maine	N/A	Count of affected structures, count of affected population, assets that include residential, commercial, essential facilities, and infrastructure	Flooding, the impacts of dams, levees, embankments, coastal hardening structures, areas of significant land use change, and streamflow restrictions on flooding impacts
Flood Risk Report: Lincoln County, Maine	Lincoln County, Maine	N/A	Count of affected structures, count of	Flooding, the impacts of dams, levees,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
FEMA. 2014. Flood Risk Report: S Lincoln County, Maine. Available at: https://msc.fema.gov/portal https://map1.msc.fema.gov/data/FRP/FRR_23015C_20140528.pdf?LOC=fbb7654e329c9be84426026440d0c076			affected population, assets that include residential, commercial, essential facilities, and infrastructure	embankments, coastal hardening structures, areas of significant land use change, and streamflow restrictions on flooding impacts
Flood Risk Report: Sagadahoc County, Maine FEMA. 2014. Flood Risk Report: Sagadahoc County, Maine. Available at: https://msc.fema.gov/portal https://map1.msc.fema.gov/data/FRP/FRR_23023C_20140528.pdf?LOC=cd53e3a34acad75f0bea07a15bdb301e	Sagadahoc County, Maine	N/A	Count of affected structures, count of affected population, assets that include residential, commercial, essential facilities, and infrastructure	Flooding, the impacts of dams, levees, embankments, coastal hardening structures, areas of significant land use change, and streamflow restrictions on flooding impacts
Flood Risk Report: Waldo County, Maine FEMA. 2014. Flood Risk Report: Waldo County, Maine. Available at: https://msc.fema.gov/portal https://map1.msc.fema.gov/data/FRP/FRR_23027C_20140630.pdf?LOC=6d0b592355d281995389c2516d1b4802	Waldo County, Maine	N/A	Count of affected structures, count of affected population, assets that include residential, commercial, essential facilities, and infrastructure	Flooding, the impacts of dams, levees, embankments, coastal hardening structures, areas of significant land use change, and streamflow restrictions on flooding impacts
Maine Flood Resilience Checklist Sherwin, Abbie, 2017, Maine Flood Resilience Checklist; A self-assessment tool for Maine's coastal communities to evaluate vulnerability to flood hazards and increase resilience: Maine Geological Survey, Open-File Report 17-15,	Maine	Open space, beaches, dunes, wetlands, marsh migration, conserved lands, significant natural areas	National Flood Insurance Program, coastal properties, critical infrastructure and facilities, roads, bridges, dams, wastewater	Flooding, coastal storms, sea level rise, storm surge, coastal erosion, vulnerable populations

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
report 44 p.. Maine Geological Survey Publications. 521. Available at: https://digitalmaine.com/mgs_publications/521/			treatment, power grid, energy networks, stormwater system, drinking water system, railways, emergency services, schools, piers, wharves, public works, evacuation routes, economic incentives for flood risk reduction practices, comprehensive plan, hazard mitigation plan, disaster response and recovery plan, mutual aid agreements with neighboring communities, social capital, saltwater intrusion, septic systems, landfills, brownfields, superfund sites, tailings ponds and mining waste sites	
Updates to Maine Coastal Flood Insurance Rate Maps: What a Local Official Should Know Curtis, J. 2016. Updates to Maine Coastal Flood Insurance Rate Maps: What a Local Official Should Know. Maine Floodplain Management Program - Department of Agriculture, Conservation, and Forestry. Available at: https://www.maine.gov/dacf/flood/docs/coastal_map_updates_for_local_officials.pdf	Maine	Coast, rivers, floodplains	Flood Insurance Rate Maps, special flood hazard areas, building codes	Waves, erosion, flooding, hurricanes

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Increasing Maine's Resiliency to Flood Hazards through the Community Rating System Sherwin, A. 2016. Increasing Maine's Resiliency to Flood Hazards through the Community Rating System. Maine Geological Survey. Available at: https://digitalmaine.com/mgs_publications/514/	Maine	Land conservation	National Flood Insurance Program, homes, businesses, municipal structures, Community Rating System credits, freeboard requirements	Flooding, storm surge, sea level rise, waves, erosion
Maine Floodplain Management Handbook: A Resource Tool for Land Use Certification in the Code Enforcement Officer Training and Certification Program and a Reference for Other Professionals State Planning Office. 2007. Maine Floodplain Management Handbook: A Resource Tool for Land Use Certification in the Code Enforcement Officer Training and Certification Program and a Reference for Other Professionals. Available at: https://www.maine.gov/dacf/flood/handbook.shtml	Maine	Floodplains, lakes, ponds, rivers, streams, coast, wetlands, dunes, beach nourishment	National Flood Insurance Program, roads, bridges, private property, Flood Insurance Rate Maps, homes, businesses, recreation, hydropower, emergency preparedness, dams, levees, floodplain management ordinance, development permitting, septic tanks, wharf, weir, breakwater, bank stabilization, permanent moorings, boat ramps, dams, sewage treatment facilities, hazardous materials, sewer lines, manufactured housing, freeboard, elevating structures, floodproofing structures, historic structures, Community Rating System	Flooding, storm surge, erosion, coastal storms, runoff, ice jams, stormwater runoff, waves

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
State of Maine Risk MAP Business Plan Maine Floodplain Management Program. 2016. State of Maine Risk MAP Business Plan. Available at: https://www.maine.gov/dacf/flood/docs/MaineRiskMAPBusinessPlan3-31-16.pdf	Maine	Floodplain, stream connectivity, wetlands, dunes	Flood Insurance Rate Maps, shoreland zoning, emergency services, levees, floodwalls, buildings, culverts	Flooding, hurricanes, storm surge, erosion, undersized culverts
Coastal Erosion Assessment for Maine FIRMs and Map Modernization Plan Dickson, S.M., Sidell, W.L. 2003. Coastal Erosion Assessment for Maine FIRMs and Map Modernization Plan. Available at: https://www.maine.gov/dacf/mgs/explore/marine/firms/contents.htm	Maine	Beaches, intertidal zone, coastal bluffs, floodplains, dunes, beach nourishment	Flood Insurance Rate Maps, seawalls, jetties, dredging, houses, sewer pipelines, wastewater treatment facility	Sea level rise, storm surge, flooding, waves, erosion
National Flood Insurance Program: Answers to Questions About the NFIP FEMA. 2011. National Flood Insurance Program: Answers to Questions About the NFIP. Available at: https://www.fema.gov/media-library/assets/documents/272	United States	Floodplains of rivers, streams, coasts, and lakes, dunes	National Flood Insurance Program, buildings, dams, levees, seawalls, coastal development	Flooding, storm surge
Chapter 1000: Guidelines For Municipal Shoreland Zoning Ordinances Department of Environmental Protection. 2015. Chapter 1000: Guidelines For Municipal Shoreland Zoning Ordinances. Available at: https://www.maine.gov/sos/cec/rules/06/096/096c1000.docx	Maine	Great ponds, rivers, freshwater wetlands, coastal wetlands, streams, fish spawning grounds, waterfowl and wading bird habitat, vegetative buffer, beach	Shoreland zoning, coastal development, archaeological and historic resources, commercial fishing and maritime industries, dock, wharf, pier, septic systems, public sewer, agriculture, aquaculture, timber harvesting, roads, mineral	Water pollution, flooding, erosion, stormwater runoff

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
			exploration or extraction, private or commercial buildings, campgrounds, marinas, National Flood Insurance Program, public boat launches, driveways, parking areas, roads, culverts, bridges	
EPA Stormwater Calculator Demonstration for Planning Boards Faunce, B. 2014. EPA Stormwater Calculator Demonstration for Planning Boards. Lincoln County Regional Planning Commission. Available at: https://www.maine.gov/dacf/municipalplanning/docs/LCRPC%20Stormwater%20Calculator%20Tech%20Bulletin.pdf	Lincoln County, Maine	N/A	Detention ponds, berms, impervious areas, low impact development, buildings, EPA National Stormwater Calculator	Stormwater runoff
How to Look Up A Regulatory "Effective" Flood Insurance Rate Map (FIRM) How to Look Up A Regulatory "Effective" Flood Insurance Rate Map (FIRM). Maine Floodplain Management Program - Department of Agriculture, Conservation, and Forestry. Available at: https://www.maine.gov/dacf/flood/docs/accessing_preliminary_pending_and_effective_maps_msc_mfhm.pdf	Maine	N/A	Coastal property, floodplain property, flood insurance	Flooding
Maine Coastal Property Owner's Guide to Erosion, Flooding, and Other Hazards Slovinsky, P. 2011. Maine Coastal Property Owner's Guide to Erosion, Flooding, and Other	Maine	Beaches, dunes, salt marshes, cosatal wetlands, mudflats, coastal bluffs, rocky	Coastal property, buildings, roads, utilities, floodproofing, jetties, dams, recreation, tourism,	Flooding, erosion, hurricanes, harmful algal blooms, water pollution, sea level rise, waves,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Hazards (MSG-TR-11-01). Orono, ME: Maine Sea Grant College Program. Available at: http://www.seagrant.umaine.edu/coastal-hazards-guide		shorelines, beach nourishment, land conservation, dune enhancement, marine worms, clams, birds, fish, marsh migration, vegetative buffer, marsh restoration	seawalls, bulkheads, riprap, gabions, public property, Flood Insurance Rate Maps, shoreland zoning, trails, piles, culverts, septic systems, hunting, fishing, elevating structures	wind, storms, storm surge, landslides, undersized culverts, invasive species
Management Work Plan Community Assistance Program/State Support Services Element (CAP/SSSE) Maine Floodplain Management Program: Maine State Planning Office. 2010. Management Work Plan Community Assistance Program/State Support Services Element (CAP/SSSE). Available at: https://www.maine.gov/dacf/flood/docs/5yearFPMplan2010-06-07.pdf	Maine	Great ponds, rivers, freshwater wetlands, coastal wetlands, tidal wetlands, streams, floodplain, endangered species, land conservation	National Flood Insurance Program, comprehensive plans, development, land use planning, fishing, recreation, roads, highways, culverts, shoreland zoning, building freeboard regulations, commercial businesses, homes, Community Rating System	Flooding, coastal storms, stormwater runoff, ice jams, sea level rise, erosion
HAZARD MITIGATION PLANS				
2017 Multi-Jurisdictional Hazard Mitigation Plan For Select Municipalities In Waldo County, Maine Waldo County Emergency Management Agency. 2017. 2017 Multi-Jurisdictional Hazard Mitigation Plan For Select Municipalities In Waldo County, Maine. Available at: http://www.waldocountyme.gov/ema/user/Waldo_County_Hazard_Mitigation_Plan.pdf	Waldo County, Maine	Rivers, streams, lakes, floodplain, wetland, land conservation, beaches	Coastal infrastructure, including wastewater treatment plants, coastal businesses, shipyards, nursing home, shoreline access points, ferry landings, roads, town office, fire station, railroad, oil tanks, homes, tourism losses, disaster preparedness, National	Flooding, severe winter storm events, hurricanes, tropical storms, microbursts, coastal erosion, drought, sea level rise, wildfire, blights/ infestation

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
			Flood Insurance Program; includes a list of projects within the county that will help to mitigate the impact of hazards	
Cumberland County Hazard Mitigation Plan: Section IV – Risk Assessment and Section V – Mitigation Strategies Cumberland County Emergency Management Agency. 2017. Cumberland County Hazard Mitigation Plan: Section IV – Risk Assessment and Section V – Mitigation Strategies. Available at: https://www.cumberlandcounty.org/DocumentCenter/View/1591/Section-V--Strategy-APA?bidId	Cumberland County, Maine	Rivers, streams, wetlands, floodplain, beaches	Dams, roads, bridges, crops and livestock, power and communication infrastructure, ferry terminals, residential buildings, commercial buildings, critical facilities including: Municipal Office, Fire Station, Police Station, Water Treatment, WWTP, Schools, Shelters, Hospital/Clinic, Airport/Seaport, Dams, Rescue, Electrical Sub-Stations, Telecom Structures; includes a list of projects within the county that will help to mitigate the impact of hazards	Temperature changes, precipitation changes, flooding, severe summer storms, severe winter storms, wildfire, coastal erosion, sea level rise, storm surge, drought, stormwater runoff, dam failure
Sagadahoc County Hazard Mitigation Plan – 2016 Update: Section 4 – Risk and Section 5 – Mitigation Strategies Sagadahoc County Emergency Management Agency. 2016. Sagadahoc County Hazard Mitigation Plan – 2016 Update: Section 4 – Risk and Section 5 – Mitigation Strategies.	Sagadahoc County, Maine	Floodplains, rivers	Dams, roads, bridges, utility infrastructure, critical facilities: municipal offices, fire and police stations, post offices, town garages and sand/salt sheds, hospitals and clinics, schools identified	Temperature changes, precipitation changes, flooding, severe winter storms, severe summer storms, wildfires, coastal erosion, dam failure

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Available at: http://sagcounty.com/wp-content/uploads/2014/06/SECTION-5-STRATEGY-revised-17Jan17.pdf			as shelters, electrical, communication, and pipeline utilities, water and wastewater treatment facilities, hazardous material sites, airports, dams, bridges, rail systems, National Flood Insurance Program; includes a list of projects within the county that will help to mitigate the impact of hazards	
Androscoggin County Hazard Mitigation Plan Androscoggin Valley Council of Governments. 2011. Androscoggin County Hazard Mitigation Plan. Available at: http://www.androscogginema.org/HazMit.pdf	Androscoggin County, Maine	Rivers, lakes, floodplains	Storm drains, sewer systems, private property, dams, commercial buildings, homes, bridges, roads, electricity infrastructure, telephone infrastructure, internet infrastructure, critical facilities (Fire and Police Stations, Regional Communication, Emergency Medical Service, Shelters), culverts, comprehensive planning, hospitals, schools, National Flood Insurance Program; includes a list of projects within the county that will help to mitigate the impact of hazards	Flooding, dam failure, severe winter storms, severe summer storms, wildfire, drought, ice jams, erosion, ice storm, hurricanes

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Kennebec County Hazard Mitigation Plan – 2016 Update Kennebec County Emergency Management Agency. 2016. Kennebec County Hazard Mitigation Plan – 2016 Update. Available at: http://kcema.org/assets/2016MitigationPlan.pdf	Kennebec County, Maine	Wetlands, rivers, streams, floodplains	Forest products industries, culverts, roads, dams, bridges, homes, businesses, sewer systems, storm water systems, agriculture, public buildings, drinking water wells, emergency services, railroads, National Flood Insurance Program, critical facilities (municipal offices, fire and police stations, post offices, town garages and sand/salt sheds, hospitals and clinics; electric and communication utilities; water and wastewater treatment facilities; hazardous material sites; schools that have been inventoried as shelters), zoning, landfill; includes a list of projects within the county that will help to mitigate the impact of hazards	Temperature increases, vector borne diseases, incrased precipitation, increased extreme precipitation events, severe winter storms, less snow, flooding, wildfire, severe summer storms, drought, ice jams, stormwater runoff, ice storms
Oxford County Hazard Mitigation Plan – 2017 Update: Section 4 - Risk Assessment and Section 5 - Mitigation Strategies Oxford County Emergency Management Agency. 2017. Oxford County Hazard Mitigation	Oxford County, Maine	Wetlands, forests, lakes, rivers, streams, floodplain	Dams, roads, agriculture, homes, bridges, public buildings, sanitation infrastructure, culverts, commercial buildings,	Increased temperatures, increased annual precipitation, increased frequency and intensity of storms, less snow,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Plan – 2017 Update: Section 4 - Risk Assessment and Section 5 - Mitigation Strategies. Available at: https://drive.google.com/file/d/0Bwsh8E2BNkuSaEVSdmZEcWo4QW8/view https://drive.google.com/file/d/0Bwsh8E2BNkuSYTFQcVJzbTVSR0U/view			electrical and communication infrastructure, National Flood Insurance Program, critical facilities (fire and police stations, regional communication centers, shelters, hospitals, wastewater and water treatment facilities, emergency medical services) ; includes a list of projects within the county that will help to mitigate the impact of hazards	flooding, dam failure, severe summers storms, hurricanes, severe winter storms, wildfire, drought, ice jam, stormwater runoff, erosion
Knox County Hazard Mitigation Plan – 2012 Update Knox County Hazard Mitigation Planning Team and Knox County Emergency Management Agency. 2012. Knox County Hazard Mitigation Plan – 2012 Update. Available at: https://www.knoxcountymaine.gov/vertical/sites/%7BE350B1EF-00F9-4556-86A6-16B2CB50F02D%7D/uploads/2012_Knox_County_HMP-_Final_w.Adoptions__Approval.pdf	Knox County, Maine	Rivers, streams, lakes, coastal bluffs, wetlands	Dams, roads, culverts, bridges, electricity and communication infrastructure, agriculture, emergency response, ferry service, homes, businesses, railroad, National Flood Insurance Program, drinking water infrastructure, wastewater treatment plants, shoreland zoning, medical facilities, law enforcement, school/library, fire stations, residential care facilities, town offices, public works, airports,	Flooding, severe summer storm events, hurricanes, sever winter storm events, ice storms, dam failure, drought, landslides, erosion, wildfire, ice jams, sea level rise, waves

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
			town wharves; includes a list of projects within the county that will help to mitigate the impact of hazards	
Maine State Hazard Mitigation Plan 2018 Maine Emergency Management Agency. 2018. Maine State Hazard Mitigation Plan 2018. Available at: https://www.maine.gov/mema/hazards/mitigation-grants/plans	Maine	Rivers, floodplain, beaches, dunes	Critical infrastructure, levees, dams, roads, bridges, agriculture, water supplies, National Flood Insurance Program, power and communication infrastructure, tourism, businesses, homes, drinking water supplies and infrastructure, emergency services	Increased temperatures, increased annual precipitation, decreased annual snowfall, sea level rise, severe summer weather, severe winter weather, flooding, wildfire, drought, hurricane, erosion, earthquake, landslides (mass wasting), storm surge, invasive species
RESILIENCE AND GREEN INFRASTRUCTURE				
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). Available at: https://www.nature.com/articles/s41598-017-09269-z	Northeastern United States: 12 states affected by Hurricane Sandy	Coastal wetlands, estuaries	Coastal townships, coastal roads, highways, coastal properties, houses, private assets, urbanized areas, artificial defenses, seawalls, levees, critical facilities and infrastructure	Damages from Hurricane Sandy, storm surge flooding, wave-induced damages, debris, sea level rise
A Volunteer's Guide for Monitoring New England Salt Marshes Carlisle, B.K., A.M. Donovan, A.L. Hicks, V.S. Kooken, J.P. Smith, and A.R. Wilbur. 2002. A	Massachusetts (Applicable elsewhere in New	Saltmarsh, brackish marshes, wetlands, economically important fish and	Limiting shoreline erosion, water filtration, recreational hunting and fishing	Direct wetland filling, point source pollution, nonpoint source

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Volunteer's Handbook for Monitoring New England Salt Marshes. Massachusetts Office of Coastal Zone Management, Boston, MA. Available at: https://www.mass.gov/service-details/czm-coastal-habitat-program-a-volunteers-handbook-for-monitoring-new-england-salt	England, the Gulf of Maine, and south along the Atlantic seaboard)	shellfish such as crabs, mussels, and clams, shorebirds, Menhaden, flounder, sea trout, spot, and striped bass, killifish and mummichogs, bluefish, crabs, Atlantic silverside, American eel, blueback herring, migratory birds, shorebirds, aquatic invertebrates		pollution, and restriction of tide flow by road and railroad crossings, historic ditching and dredging, invasive species, tidal restrictions, shoreline erosion, coastal development
Stream Barrier Removal Monitoring Guide Collins, M., K. Lucey, B. Lambert, J. Kachmar, J. Turek, E. Hutchins, T. Purinton, and D. Neils. 2007. Stream Barrier Removal Monitoring Guide. Gulf of Maine Council on the Marine Environment. www.gulfofmaine.org/streambarrierremoval. Available at: http://www.gulfofmaine.org/streambarrierremoval/Stream-Barrier-Removal-Monitoring-Guide-12-19-07.pdf	The Gulf of Maine Watershed: Maine Portions of: New Hampshire, Massachusetts, Nova Scotia, New Brunswick, Quebec	Streams, rivers, diadromous fish, riparian zones, wetlands, macroinvertebrates, brook trout, white sucker	Dams, roads	Stream barriers – aging dams and improperly sized culverts, flooding
Stream Smart Road Crossing Pocket Guide Aquatic Resource Management Strategy Forum. Stream Smart Road Crossing Pocket Guide. Available at: http://www.maineaudubon.org/wp-content/uploads/2017/08/SSpocket-guide-FINAL-spread.pdf	Maine	Rivers, intermittent or perennial streams, aquatic organisms that depend on above habitats for part of their life: fish, herptiles, invertebrates, mammals	Roads, culverts, bridges	Barriers to fish passage, flooding and road washouts, storm events

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Marshes on the Move: A Manager's Guide to Understanding and Using Model Results Depicting Potential Impacts of Sea Level Rise on Coastal Wetlands Roger Fuller, Nate Herold, Zach Ferdaña, Adam Whelchel, Nancy Cofer-Shabica, Nate Herold, Keil Schmid, Brian Smith, Doug Marcy, Dave Eslinger, Peter Taylor. 2011. Marshes on the Move: A Manager's Guide to Understanding and Using Model Results Depicting Potential Impacts of Sea Level Rise on Coastal Wetlands. The Nature Conservancy- Global Marine Team, NOAA National Ocean Service- Coastal Services Center. Available at: https://coast.noaa.gov/data/digitalcoast/pdf/marshes-on-the-move.pdf	United States	Coastal wetlands, marsh migration,	Emergency management, coastal armoring	Sea level rise, anthropogenic obstacles to marsh movement (buildings, roads, seawalls, berms, dikes)
Synthesis of Adaptation Options for Coastal Areas U.S. EPA (2009). Synthesis of Adaptation Options for Coastal Areas. Washington, DC, U.S. Environmental Protection Agency, Climate Ready Estuaries Program. EPA 430-F-08-024, January 2009. Available at: https://www.epa.gov/cre/synthesis-adaptation-options-coastal-areas	United States	Estuaries, coastal marshes, beaches, wetlands, mudflats, marsh migration, submerged aquatic vegetation, birds, fish, shellfish, land conservation, sediment additions to wetlands, seagrass, beach nourishment, dunes, vegetative buffers, living shorelines	Human health, adaptation planning, bulkheads, sewer infrastructure, transportation infrastructure, culverts, coastal development, landfills, hazardous waste dumps, mine tailings, toxic chemical facilities, dikes, seawalls, revetments, breakwaters, drinking water, impervious surface	Altered frequency and intensity of precipitation, sea level rise, warmer water temperatures, more intense storm events, erosion, saltwater intrusion, algal blooms, invasive species, stormwater runoff, water pollution, disruption of predator prey availability (fish), disruption in the synchronicity of food and reproduction (birds), drought, flooding, ocean

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
				acidification, tidal restrictions
Guidance language for considerations of climate change in comprehensive plans Maine State Planning Office. Guidance language for considerations of climate change in comprehensive plans. Maine State Planning Office. Available at: https://www.maine.gov/dacf/municipalplanning/docs/GuidanceCompPlanClimateChangeLanguage.doc	Maine	Coastal marshes, beaches, marsh migration, land conservation	Floodplain maps, stormwater management infrastructure, community planning and preparedness, coastal development, comprehensive planning, reducing energy consumption, freeboard regulations, shoreland zoning, emergency services, building codes, recreation	Flooding, greenhouse gas emissions, increased frequency and intensity of precipitation events, erosion, landslides, invasive species
Make Way for Marshes Northeast Regional Ocean Council. 2015. Make Way for Marshes. Northeast Regional Ocean Council. Available at: https://www.northeastoceancouncil.org/committees/coastal-hazards-resilience/resilient-shorelines/make-way-for-marshes/	New England: Maine, Massachusetts, Connecticut, Rhode Island, New Hampshire	Tidal marshes, fish nurseries, wildlife habitat, marsh migration	Roads, seawalls, culverts, bridges, coastal hazard preparedness, railroads, infrastructure, community planning, power plants	Storm surge, coastal erosion, coastal flooding, sea level rise, water pollution, invasive plants, tidal restrictions
Living Shorelines: From Barriers to Opportunities Restore America's Estuaries. 2015. Living Shorelines: From Barriers to Opportunities. Arlington, VA. Available at: https://www.estuaries.org/images/stories/RAEReports/RAE_LS_Barriers_report_final.pdf	United States	Estuaries, carbon sequestration, mudflat, salt marsh, seagrass beds, beaches, dunes, coastal bluffs, marsh migration, essential fish habitat, endangered species	Living shorelines, piers, seawalls, bulkheads, revetments, homes, buildings, jetties, breakwaters, riprap, revetment, recreation, permitting, navigation, commercial fisheries	Sea level rise, erosion, flooding, storm surge, hurricanes, waves, water pollution

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Coastal Stormwater Management Through Green Infrastructure: A Handbook for Municipalities US Environmental Protection Agency National Estuary Program. 2014. Coastal Stormwater Management Through Green Infrastructure: A Handbook for Municipalities. US Environmental Protection Agency. Available at: https://www.epa.gov/nep/coastal-stormwater-management-through-green-infrastructure-handbook-municipalities-0	Massachusetts	Land conservation, groundwater, water quality, wetlands, floodplains, wetland restoration, beaches, shellfish beds, open space, salt marshes, seagrass beds, diadromous fish runs, shorebird habitat and nesting sites, streams, lakes, dunes, areas of critical environmental concern	Green infrastructure, rain gardens, permeable pavements, green roofs, vegetated filter strips, bioretention, constructed stormwater wetlands, tree box filters, sand filter, grassed swales, water quality swales, rain barrel, impervious surface, cluster/ consolidated development, buildings, landscaped areas, parking lots, bike lanes, property values, permitting, stormwater infrastructure, dams, public drinking water supplies, roads, parks, driveways, sidewalks	Stormwater runoff, storm events, erosion, water pollution, invasive species, coastal flooding
Natural Defenses from Hurricanes and Floods: Protecting America's Communities and Ecosystems in an Era of Extreme Weather Patty Glick, John Kostyack, James Pittman, Tania Briceno, Nora Wahlund. 2014. Natural Defenses from Hurricanes and Floods: Protecting America's Communities and Ecosystems in an Era of Extreme Weather. National Wildlife Federation. Available at: https://www.nwf.org/~/media/PDFs/Global-	United States	Coast, rivers, streams, wetlands, beaches, dunes, riparian zones, living shorelines, natural open space, natural infrastructure, oyster reefs, barrier islands, submerged aquatic vegetation, fish, benthic organisms, shellfish, waterfowl, endangered species, floodplains, land	Recreation, tourism, seawalls, levees, jetties, dikes, bulkheads, flood insurance, National Flood Insurance Program, ports, harbors, commercial fisheries, agriculture, coastal development, private homes and businesses, infrastructure, drinking water, floodproofing structures, roads, utilities, emergency	Hurricanes, flooding, sea level rise, storm surge, stormwater runoff, more intense coastal storms, increased number and intensity of extreme precipitation events, increased sea surface temperatures, erosion, wind storms

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Warming/2014/Natural-Defenses-Final-Embargoed-Until-102114-10amET.pdf		conservation, salt marsh, marsh migration	services, managed retreat, Community Rating System credits, hazard mitigation plans	
Assessing Suitability of Living Shorelines on Coastal Bluffs Slovinsky, P., Yakovleff, D. 2017. Assessing Suitability of Living Shorelines on Coastal Bluffs. Maine Stormwater Conference. Available at: https://maineswc.files.wordpress.com/2017/10/02-yakovleff-and-slovinski.pdf	Maine, Casco Bay	Living shoreline, coastal bluffs, coastal wetlands, beaches, dunes	Coastal property	Erosion, flooding, storm surge
Gardening to Conserve Maine's Native Landscape: Plants to Use and Plants to Avoid University of Maine Cooperative Extension. 2017. Gardening to Conserve Maine's Native Landscape: Plants to Use and Plants to Avoid. UMCE Bulletin #2500. Available at: https://extension.umaine.edu/publications/2500e/	Maine	Native plants	N/A	Invasive species
Increasing the Resiliency of Forests in New England: A Weather-Wise Resource Guide for Urban Forests and Community Planning Whitman, A., Wilkerson, E., Balch, S. 2015. Increasing the Resiliency of Forests in New England: A Weather-Wise Resource Guide for Urban Forests and Community Planning. Manomet Center for Conservation Sciences. Available at: https://www.urbanforestrysouth.org/research/	New England: Maine, Massachusetts, New Hampshire, Vermont, Rhode Island, Connecticut, New York	Forest habitat, wetlands, vernal pools, carbon sequestration	Logging, working woodlands, roads	Temperature changes, precipitation changes, increasing storm intensity, wildfire, sea level rise, invasive species, ice storms, flooding

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
nucfac/managing-urban-forest-to-increase-community-resiliency-to-climate-change-11-dg-11420004-041/Manomet_WeatherWiseResourceGuide_CommunityPlanning_Jan2015.pdf/at_download/file				
Increasing the Resiliency of Forests in New England: A Weather-Wise Worksheet for Homeowners Whitman, A., Wilkerson, E. 2014. Increasing the Resiliency of Forests in New England: A Weather-Wise Worksheet for Homeowners. Manomet Center for Conservation Sciences. Available at: https://www.stgeorgemaine.com/sites/stgeorgeme/files/uploads/d14manomet_weatherwise worksheetresourceguide_suburbanlandowner_sept2014_1.pdf	New England: Maine, Massachusetts, New Hampshire, Vermont, Rhode Island, Connecticut, New York	Vegetative buffers, streams, lakes, rivers, carbon sequestration and storage, birds, vernal pools, pollinators	Hardiness zones, homes and yards, driveways, sidewalks, rain barrel, rain garden, home heating and cooling	Warmer temperatures, increased precipitation, increased frequency and intensity of storms, more periods of extreme heat, increased frequency and severity of drought, invasive species, wildfires, ice storms, runoff
Increasing the Resiliency of Forests in New England: A Weather-Wise Worksheet for Private Woodland Owners Whitman, A., Wilkerson, E., Wynne, R. 2014. Increasing the Resiliency of Forests in New England: A Weather-Wise Worksheet for Private Woodland Owners. Manomet Center for Conservation Sciences. Available at: http://www.rifco.org/RIWP-IncreasingResiliency.pdf	New England: Maine, Massachusetts, New Hampshire, Vermont, Rhode Island, Connecticut, New York	Forests, carbon storage/sequestration, vernal pools, wildlife habitat, vegetative buffers, streams, habitat connectivity, land conservation	Working woodlands, forest management plans, roads, forest products, bridges, culverts	Warmer temperatures, increased precipitation, increased frequency and intensity of storms, more periods of extreme heat, increased frequency and severity of drought, invasive species, wildfire, fish passage barriers, vector borne diseases, flooding, sea level rise, reduced snow and winter length, ice storms

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Casco Bay Watershed Fish Barrier Priorities Atlas Abbot, A., Craig, M. 2012. Casco Bay Watershed Fish Barrier Priorities Atlas. Casco Bay Estuary Partnership and US Fish and Wildlife Service Gulf of Maine Coastal Program. Available at: https://www.cascobayestuary.org/publication/casco-bay-watershed-fish-barrier-priorities-atlas/	Casco Bay Watershed, Maine (primarily includes Cumberland County, Maine)	Stream habitat, brook trout, Atlantic salmon, wetlands	Roads, dams, culverts, railroads, bridges, culverts	Fish passage barriers, flooding
Gravel Road Maintenance Manual: A Guide for Landowners on Camp and Other Gravel Roads Kennebec County Soil and Water Conservation District and Maine Department of Environmental Protection. 2016. Gravel Road Maintenance Manual: A Guide for Landowners on Camp and Other Gravel Roads. Maine Department of Environmental Protection. Available at: https://www.maine.gov/dep/land/watershed/camp/road/gravel_road_manual.pdf	Maine	Wetlands, surface waters, vegetated buffers, fish passage	Private roads, culverts, bridges	Erosion, undersized culverts, runoff
Lessons Learned from the Climate Ready Estuaries Program New England Climate Ready Estuaries. 2012. Lessons Learned from the Climate Ready Estuaries Program. Climate Ready Estuaries, EPA. Available at: https://www.epa.gov/sites/production/files/2014-04/documents/cre_lessonslearned_ne_508.pdf	New England	Land conservation and stewardship, habitat restoration, salt marsh, fish passage restoration	Infrastructure, roads, adaptation planning	Flooding, undersized culverts, extreme precipitation events, sea level rise, storm surge, increasing development and impervious surface, stormwater runoff

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Living Shorelines in New England: State of Practice Woods Hole Group. 2017. Living Shorelines in New England: State of Practice. The Nature Conservancy. Available at: https://www.conservationgateway.org/ConservationPractices/Marine/Pages/new-england-living-shorelines.aspx	New England: Maine, New Hampshire, Massachusetts, Connecticut, Rhode Island	Living shorelines [Dune Restoration (Natural), Dune Restoration (Engineered Core), Beach Nourishment, Coastal Bank Protection (Natural), Coastal Bank Protection (Engineered Core), Natural Marsh Creation/ Enhancement, Marsh Creation/ Enhancement (w/Toe Protection), Living Breakwaters]	Seawalls	Sea level rise, storms, erosion, flooding, ice, invasive species
Living Shoreline Stacker Northeast Regional Ocean Council. Living Shoreline Stacker Available at: http://northeastoceancouncil.org/committees/coastal-hazards-resilience/resilient-shorelines/living-shorelines-stacker/	Northeastern United States	Living shorelines, wetlands, salt marsh, dunes	Coastal property	Flooding, storms, waves, erosion
Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas (Fourth Edition) FEMA. 2011. Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas (Fourth Edition). P-55: Volume I.	United States	Dunes, beach, beach nourishment, floodplain, coastal bluff, barrier islands	Homes, condominiums, residential structures (detached single-family homes, attached single-family homes (townhouses), low-rise (three-story or less) multi-family buildings), freeboard regulations, National Flood Insurance	Flooding, tropical storms, hurricanes, nor'easters, high winds, wind-borne debris, tornados, earthquakes, tsunamis, sea level rise, subsidence and uplift, salt spray and moisture, rain, hail, termites, wildfire, floating ice, snow,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Available at: https://www.fema.gov/media-library/assets/documents/3293			Program, Flood Insurance Rate Maps, Community Rating System, levees, roads, seawalls, revetment, utilities and communication infrastructure, wells, septic systems, sewer systems, municipal water systems, piers	atmospheric ice, waves, flood-borne debris, erosion, overwash and sediment burial, landslides, storm surge, snow loads, wildfire
Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine Neckles, H.A. and Dionne, M. Editors. 2000. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME. 21 p. plus appendices. Available at: http://www.gulfofmaine.org/2/wp-content/uploads/2014/12/GPAC-salt-marsh-monitoring-1999.pdf	Gulf of Maine: New Brunswick, Nova Scotia, Maine, New Hampshire, Massachusetts	Tidal wetlands, tidal marsh restoration, fish, shrimp, crabs, birds, salt marsh sharp-tailed sparrows, waterfowl	Roads, railroads, culverts	Invasive species, undersized culverts
Conserving Nature in a Changing Climate: A Three-Part Guide for Land Trusts in the Northeast 2016. Conserving Nature in a Changing Climate: A Three-Part Guide for Land Trusts in the Northeast. Open Space Institute and the North Atlantic Landscape Conservation Cooperative.	Northeast: southeastern Virginia to Atlantic Canada and southern Quebec	Land conservation, climate resilient landscapes, wetlands, carbon sequestration, floodplains, connected habitats, habitat blocks, beaches, tidal marshes, marsh migration, vegetative buffers	Roads, rail lines, homes, agriculture, working forests, dams	Increasing temperatures, flooding, droughts, increasing storm severity and frequency, changing weather patterns, changes in snow accumulation, hurricanes, wildfire, invasive species, fish passage barriers, water pollution,

Title, Citation, and Link (if available)	Geography Covered	Fish and Wildlife Relevance	Human Asset Relevance	Flooding Threats Relevance
Available at: https://s3.amazonaws.com/osi-craft/OSI-Climate-Guide-FINAL.pdf?mtime=20170213114541				development, sea level rise, stormwater runoff
A Conservation Vision for Maine Using Ecological Systems Schlawin, J., Cutko, A. 2014. A Conservation Vision for Maine Using Ecological Systems. Maine Natural Areas Program- Maine Department of Agriculture, Conservation and Forestry. Available at: https://www.maine.gov/dacf/mnap/about/publications/ra.htm	Maine	Land conservation, wetlands, diverse ecological systems, large habitat blocks	Forest management	Wildfire, wind, ice storms, flooding, drought, landslides
An Assessment of the Economics of Natural and Built Infrastructure for Water Resources in Maine Colgan, C.S., Yakovleff D., Merrill S.B. 2013. An Assessment of the Economics of Natural and Built Infrastructure for Water Resources in Maine. Available at: https://www.maine.gov/dacf/municipalplanning/docs/Economics_of_Natural_&_Built_Infrastructure.pdf	Maine	Land conservation, riparian buffers, sustainable forests, freshwater wetlands, coastal wetlands, floodplains, groundwater aquifers, estuaries, open space, sand dunes, beaches, natural infrastructure, lakes, rivers, marsh migration, coastal bluffs, shellfish flats, mudflats, vernal pools, Atlantic salmon, carbon sequestration	Drinking water, culverts, stormwater infrastructure, public water systems, low impact development, recreation, agriculture, sewer systems, combined sewer overflows, separated stormwater systems, commercial fisheries, private wells, dams, levees, seawalls, roads, rail lines, stormwater detention basins, street trees, rain gardens, artificial wetlands, permeable pavement, blue roofs, green roofs, recreation	Flooding, stormwater runoff, water pollution, drought, coastal storms, tropical storms, sea level rise, undersized culverts, increased frequency and intensity of storm events, more extreme precipitation events, increase in precipitation, increase in air temperature

Glossary and Key to Acronyms and Abbreviations Used in this Report

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

- A species listed as 'endangered', 'threatened', or 'candidate' under the provisions of Endangered Species Act (ESA)[10]
- A species with a NatureServe global imperilment rank of G1, G2, or G3[11]
- A species with a NatureServe state imperilment rank of S1, S2, or S3
- A State Species of Greatest Conservation Need (SGCN) as recorded in current State Wildlife Action Plans [12]

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

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

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

CVS: See Conservation Value Summary.

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

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

EBTJV: Eastern Brook Trout Joint Venture

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

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

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

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

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

Essential Fish Habitat (EFH): Those waters and substrate necessary for the spawning, breeding, feeding, or growth to maturity of a particular 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 particular 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. (Forfor more information, see this useful resource: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1042207.pdf)

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

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

LCC: See Landscape conservation cooperative.

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

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

LCM: See Landscape condition model.

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

MDIFW: Maine Department of Inland Fisheries and Wildlife

MEGIS: Maine Office of GIS

MENAP: Maine Natural Areas Program

MGS: Maine Geological Survey

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

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

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

NEMAC: National Environmental Modeling and Analysis Center

NFWF: National Fish and Wildlife Foundation

NHD: see National Hydrography Dataset.

NOAA: National Oceanic and Atmospheric Administration

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

NWI: National Wetlands Inventory (USFWS product)

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

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

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

SGCN: See Species of Greatest Conservation Need.

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

SLR: Sea level rise

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

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

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

SCDNR: South Carolina Department of Natural Resources

TNC: The Nature Conservancy

USACE: U.S. Army Corps of Engineers

USFWS: U.S. Fish and Wildlife Service

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

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

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