Resource Vulnerability Assessment and Strategies for Management Options for the Eastern Shore of Virginia and Fisherman Island National Wildlife Refuges

Final Assessment Report
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Chapter 1. Introduction and Background

This report was developed as part of a cooperative project between the U.S. Fish and Wildlife Service (USFWS) and NatureServe to create and test a framework and handbook for refuge vulnerability assessment and alternatives development (RVA). The report is organized according to the steps outlined in the RVA technical guide (NatureServe and USFWS, in review), which follows the structure of and provides information to support a standard refuge Comprehensive Conservation Plan (CCP). Work was conducted in two phases: Phase I utilized the National Wildlife Refuge Complex (NWRC) as a pilot project to develop and test the RVA process on a limited scale. A full vulnerability assessment was conducted in Phase 2, addressing the prioritized set of resources and stressors of interest to the refuge staff. This report provides detailed results and interpretation for the entire assessment; methods are intentionally summarized more briefly. For more detailed information on the methods used in the RVA process, please refer to the RVA technical guide (NatureServe and USFWS, in review); a simplified process workflow is illustrated in Figure 1.

This vulnerability assessment was conducted for the Eastern Shore of Virginia National Wildlife Refuge (Eastern Shore of VA NWR) and Fisherman Island National Wildlife Refuge (Fisherman Island NWR) and their "supporting landscape." The refuges are located on the southern extent of the Virginia Eastern Shore, in Northampton County. These two refuges are collectively referred to as the Eastern Shore of Virginia National Wildlife Refuge Complex (Refuge Complex). Accomack and Northampton Counties were identified as the supporting landscape of the Refuge Complex based on geography and on partnerships that are active in those jurisdictions: The two counties are the operating region for the Southern Tip Partnership, a multi-agency conservation group working with the two refuges.

Figure 1. Simplified RVA Workflow Process

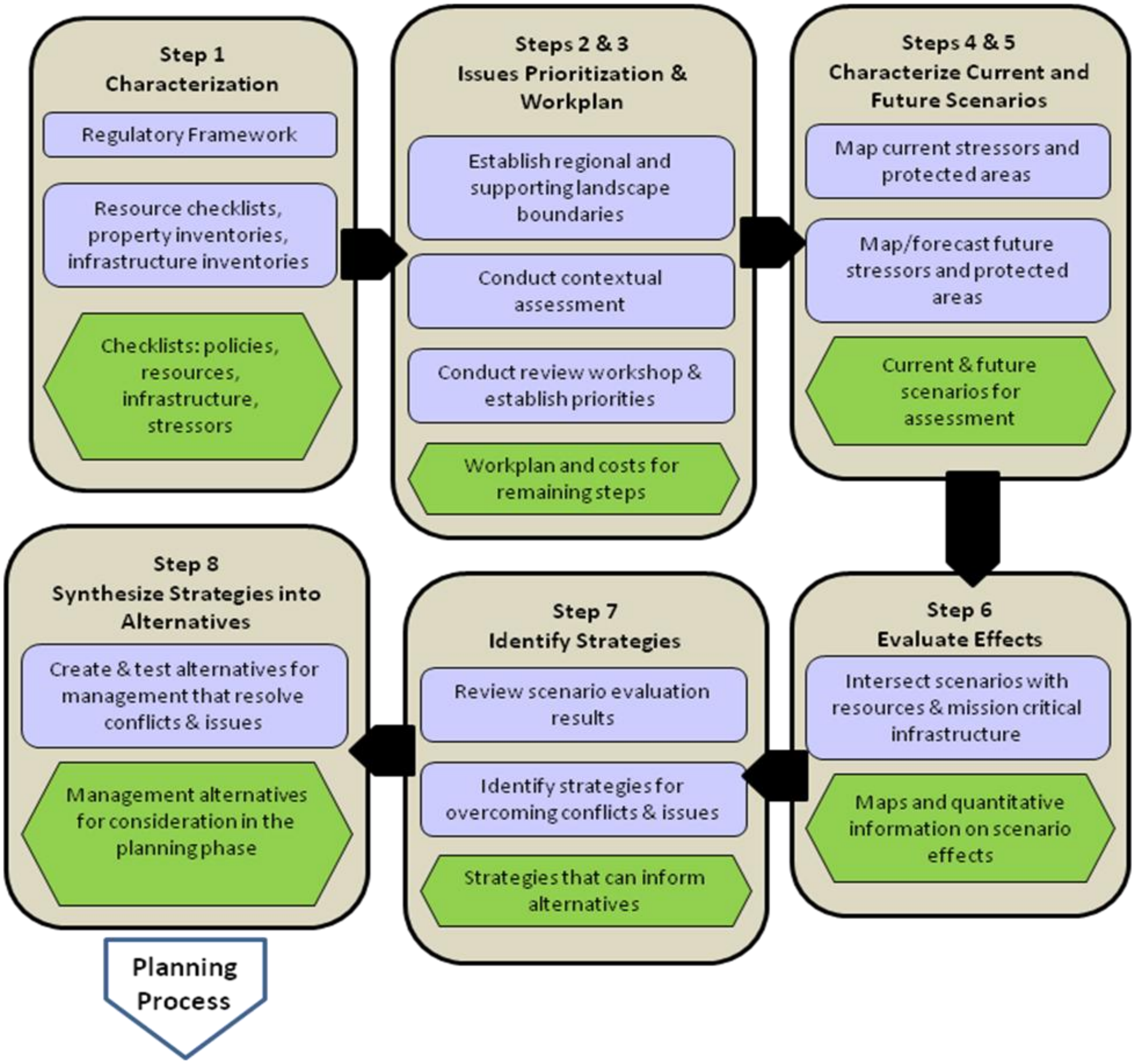


Figure 1. This simplified RVA workflow was utilized in this assessment. Rectangles indicate inputs and actions, while hexagons indicate outputs of each step, which also serve as inputs to the subsequent steps.

Application of the RVA

The results of the RVA analyses will support potential revision of the Refuge Complex CCP to account for stressors from climate change and will support Habitat Management Planning (HMP) for the Refuge Complex. Because many of the species and communities of the Refuge Complex are at either their southern or northern range limits, and because the Chesapeake Bay and development on the Delmarva Peninsula represent significant dispersal barriers, it is expected that climate change could have substantial impacts on refuge resources. Additionally, a key strategy of the 2004 CCP is expansion of the refuges within a 10km zone of the tip of the Delmarva Peninsula to increase stopover habitat for neotropical migratory birds. Therefore, it is critical to assess the degree to which climate change, particularly sea level rise, might impact the success of that expansion strategy given the low elevation throughout the area.

Furthermore, this RVA serves as a cooperative project between USFWS and NatureServe to create and test a framework and develop technical guidance for assessing refuge vulnerability and developing alternatives. Conducting this RVA assisted in refining and illustrating the RVA methodology as described in the RVA technical guide (NatureServe and USFWS, in review).

Report Organization

This report utilizes some of the same structure and headings as the Eastern Shore of Virginia and Fisherman's Island Comprehensive Conservation Plan. The use of CCP or similar headings in this RVA report is intended to relate the RVA content to the associated components of the CCP. However, the content under each of those headings is specific to the RVA and may contain less or different information than those same sections in the CCP.

The Eastern Shore of Virginia NWR and Fisherman Island NWR are treated together in this report as the Refuge Complex whenever they have consistent and overlapping goals, resources, and stressors. Differences in the refuges are noted when applicable. Assessment methods are outlined briefly in this report and the reader is referred to appendices in this report, the RVA technical guide (NatureServe and USFWS, in review), or other sources for more detailed information on methods.

Regulatory and Related Context of the Refuge Complex

The refuge purpose, legal and regulatory framework, and existing partnerships are included here to provide part of the political and social context of the refuges themselves.

Refuge Purposes

The Refuge Complex was established primarily to support important migratory bird species, especially those using the complex for resting and feeding during migratory periods of their annual cycles. The legislation outlined in Chapter 1 of the CCP provides a foundation and purpose for both the Eastern Shore of Virginia and Fisherman Island National Wildlife Refuges:

- "…authorizing land to be transferred without reimbursement to the Secretary of the Interior if the land has particular value for migratory birds." *Transfer of Certain Real Property for Wildlife Conservation Purposes Act* (16 U.S.C. 667b–667d)
- "...for use as an inviolate sanctuary, or for any other management purpose, for migratory birds." *Migratory Bird Conservation Act* (16 U.S.C. 715–715d, 715e, 715f–715r)

The Eastern Shore of Virginia NWR was also established under the following legislation:

- "…authorizing acquisition of lands and interests suitable for: 1) fish and wildlife oriented recreation, 2) protection of natural resources, and 3) conservation of endangered or threatened species..." *Refuge Recreation Act* (16 U.S.C. 460k–460k–4)

Refuge goals are created in accordance with National Wildlife Refuge System (NWRS or Refuge System) goals and act as broad statements to reflect a refuge's vision and desired future conditions. The National Wildlife Refuge System Improvement Act determined wildlife conservation to be the primary focus for the unified mission of the entire Refuge System. This cohesive mission works in tandem with goals designed for individual refuges, in turn dictating management initiatives for each specific refuge. The Refuge System Improvement Act also required all National Wildlife Refuges to have a CCP prepared to help guide management to meet end goals and fulfill the greater Refuge System mission (USFWS 2004). Goals for both refuges are described in Chapter 1 of the CCP as follows:

1. Increase the availability of forage and cover habitat for neotropical and temperate migratory birds and migrating monarch butterflies.
2. Maintain the long-term productivity, integrity, and function of the marsh, beach, and interdunal communities.
3. Actively participate in the conservation of healthy hardwood, understory, and grassland habitat for neotropical and temperate migratory birds during future development throughout Northampton County.
4. Provide wildlife-dependent recreational opportunities and community outreach with an emphasis on educating the public about the critical role the Delmarva Peninsula serves for neotropical and temperate migratory birds and migrating monarch butterflies.
5. Integrate the refuge into the larger community of the eastern shore and promote awareness of the unique value of the lower Delmarva Peninsula to neotropical and temperate migratory birds and migrating monarch butterflies.
6. Enhance and restore the quality of the soils, waters, and other abiotic components of the refuge and landscape.

Chapter 2 of the CCP outlines several specific objectives for each of the listed goals, as well as strategies to reach each objective in the short term. Objectives for refuge goals in the CCP were assessed based on findings of this study and are discussed in Chapter 4 of the CCP (USFWS 2004).

Legal and Policy Guidance

Relevant policies under which the NWRC operates are described in the CCP. This study was conducted primarily under the National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 688dd–688ee, as amended by the National Wildlife Refuge System Improvement Act of 1997). The Eastern Shore of

Virginia NWR and Fisherman Island NWR were established administratively through the *Transfer of Certain Real Property for Wildlife Conservation Purposes Act* (16 U.S.C. 667b–667d) and *Migratory Bird Conservation Act* (16 U.S.C. 715–715d, 715e, 715f–715r). Further, the Eastern Shore Refuge was also created through the *Refuge Recreation Act* (16 U.S.C. 460k–460k–4). Refer to Appendix A for additional details regarding policies and plans associated with managing the Eastern Shore and Fisherman Island National Wildlife Refuges. Chapter 1 of the CCP also addresses many step-down management plans, from larger-scale legal mandates to individual resource plans, which are used to develop management practices on the Refuge Complex.

Existing Partnerships

The following partners assisted with this RVA. This assistance was provided in the form of guidance for the project, input data for the assessment, and other information resources for interpretation of results and reporting:

- Center for Conservation Biology at the College of William and Mary
- Chincoteague Natural History Association (CNHA)
- Coastal Virginia Wildlife Observatory
- Hampton University
- Northampton County
- The Nature Conservancy
- The Trust for Public Lands
- Virginia Coastal Zone Management Program
- Virginia Department of Conservation and Recreation (DCR)
- Virginia Department of Game and Inland Fisheries
- Virginia Department of Conservation and Recreation, Division of Natural Heritage

Chapter 2. Assessment Process

Assessment Purpose

The goal of this vulnerability assessment was to examine potential effects of current and expected stressors on the stated objectives of the 2004 CCP for the refuges. The primary purpose of the refuge complex is to support migratory bird species. Given the low elevation of the Refuge Complex and projected sea level rise in this area, the assessment particularly focused on the potential impacts of climate change on the sustainability of the refuge purpose. Projected sea level rise (SLR) was analyzed for impacts on all resources included in the assessment. The impacts of other relevant and readily mapped stressors, such as development, were also assessed for all resources.

This study specifically identified resources that would be incompatible with or intolerant of expected future conditions caused by climate change, including:

- Salt-water inundation and habitat loss from SLR and increased storm surge elevations
- Changes in ecosystem/habitat composition

Assessment Area

As noted at the beginning of Chapter 1, the area evaluated in this vulnerability assessment includes both the Refuge Complex and its supporting landscape of Northampton and Accomack Counties (Figure 2). The terms “supporting landscape” and “project area” are used interchangeably throughout this report. The supporting landscape encompasses the Refuge Complex and provides a broader geographic context for identifying the most relevant conservation and management issues and appropriate locations for potential action within and around the Refuge Complex. Conducting the vulnerability assessment on the entirety of both the Refuge Complex and its supporting landscape provides the information necessary for the Refuge Complex to achieve its purpose and objectives within and beyond present refuge boundaries.

Figure 2. The Eastern Shore National Wildlife Refuge Complex (inset, right) and its Supporting Landscape (Project Area, left).

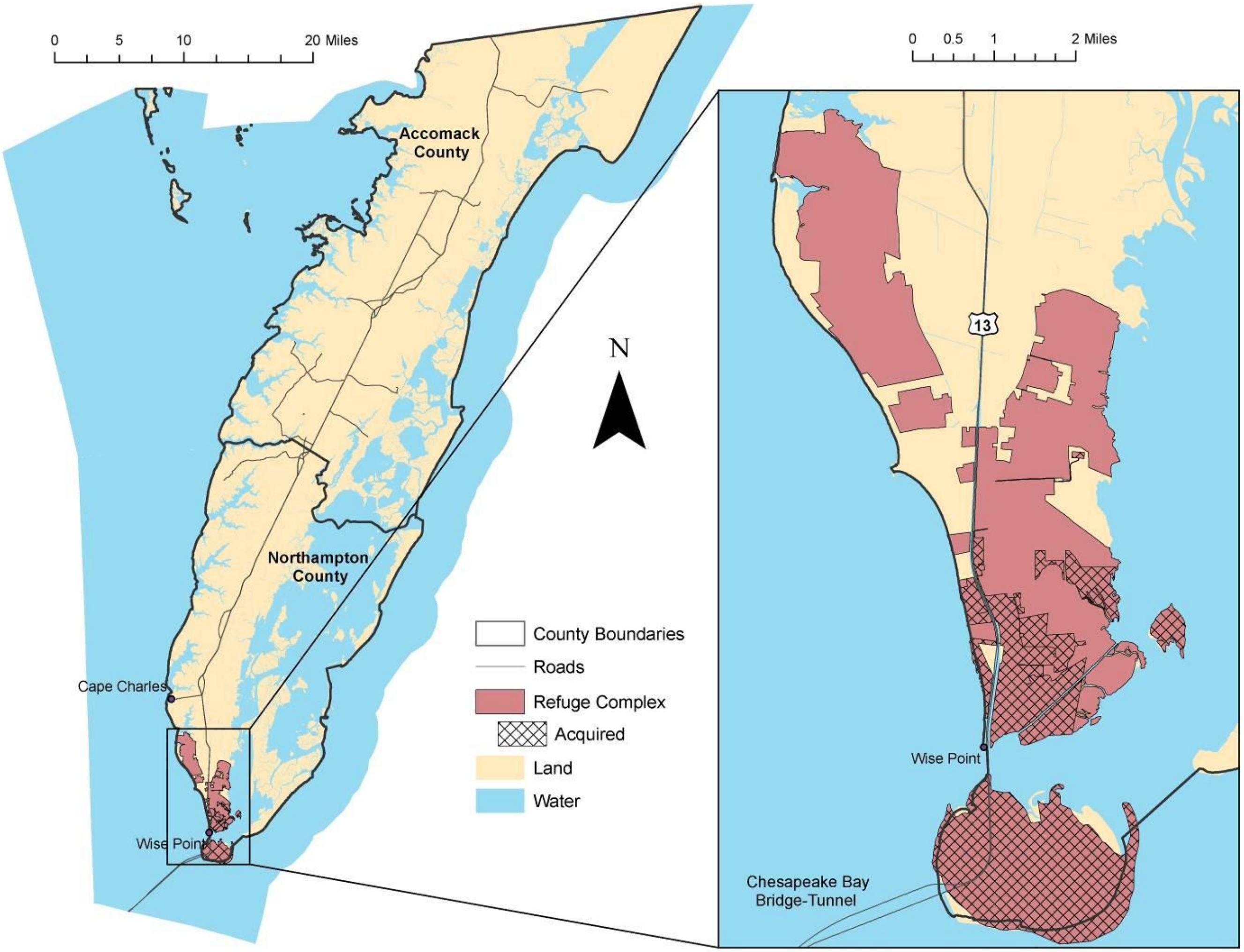


Figure 2 shows the Refuge Complex within the general context of the project area. The Refuge Complex (inset, right) consists of (1) Fisherman Island NWR, an island just off the southern tip of the Delmarva Peninsula, and (2) the Eastern Shore of Virginia NWR, consisting of a collection of parcels at the southern tip of the Virginia peninsula. The acquired boundary includes only parcels under full ownership and management by the USFWS. Approved boundaries include additional lands not currently owned by the USFWS, but that have been approved for acquisition, as timely and appropriate. This study focused on the entirety of both the Refuge Complex (inset, right) and the supporting landscape or project area (left), which consists of Accomack and Northampton Counties, Virginia.

Process Overview

This assessment of refuge vulnerability closely followed the process described in the RVA technical guide (NatureServe and USFWS, in review) but was necessarily constrained by time, funding, and data availability. For this RVA, the assessment team first characterized the management and policy framework, the biological and infrastructure resources, and the current and expected stressors affecting the resources, and then developed a series of scenarios under which stressor impacts on resources were analyzed. A cumulative effects assessment of certain stressors on priority resources over multiple timeframes (scenarios) was conducted. Brief summaries of the specific steps in the assessment process are included in the relevant sections of this report.

Planning Issues

Specific planning issues are identified in the 2004 Refuge Complex CCP (and were reconfirmed at RVA scoping workshops) as well as issue-specific step-down management plans, which are at various stages of development and implementation. While step-down plans are not addressed in this assessment, the planning issues relevant to the vulnerability assessment are listed here, along with their treatment in this assessment:

- **Wise Point Boat Ramp**: The Eastern Shore of Virginia NWR must maintain recreational access to deep water for the public via this ramp, while protecting sensitive wildlife species affected by it, and by its use.

  RVA treatment: The ramp is included in baseline and all future scenario assessments.

- **Communications towers and wind turbines**: Communications towers are recognized by private industry and Northampton County as a resource that could improve citizen quality of life. However, such structures are known to cause migratory bird fatality, especially when located in migratory flyways, such as the southern tip of the Eastern Shore. This analysis includes two towers on the Refuge Complex from a dataset dated 2008.

  Recently, a Northampton County Wind Farm Ordinance was established to allow development of wind energy facilities to support wind energy generation (i.e. turbines) consistent with the Northampton County Comprehensive Plan. Wind energy development in Virginia is expected to move forward, where specific projects are subject to a permit by rule, by the Virginia Dept of Environmental Quality. As of this RVA, one bayside project has been proposed but failed (Gamesa project). Currently, the Northampton County Wind Farm Ordinance does not include height restrictions on wind turbines, and thus migratory bird issues can be expected as projects are proposed. Given this early status, wind energy facilities and potential impacts are not included in this RVA.

  RVA treatment: Communications tower footprint data for two towers on the Refuge Complex are included in all assessments.

- **Land acquisition**: Refuge Complex lands, as well as nearby non-public lands that are in a natural vegetated state, are recognized by the USFWS and Northampton County as being critically important stopover habitat for migratory birds. Land use change away from natural conditions on the southern tip of the Eastern Shore reduces the land and resources available to these species. Successes in acquiring lands to maintain the natural state of the southern tip can help to offset these habitat losses.

  RVA treatment: The supporting landscape was included in all scenario assessments. Recommendations for land-acquisition decisions, as per Goal 3 of the CCP (2004), are also offered in Chapter 4.

- **Habitat management**: Due to the wide range of species (breeding, wintering, and migratory) that use the Refuge Complex, and the diversity of habitats required by those species throughout the year, the small area of the Refuge Complex cannot reasonably be managed to ideally meet the needs of all species. Certain habitats have to be prioritized for management based on various factors (e.g., management logistics, species-based area requirements, and climate change impacts to species and habitats).

  RVA treatment: Instead of using species data of varying quality, completeness, accuracy, and age, specific habitats identified in the Species Habitat Management Plan and by the Refuge Staff were analyzed as priority resources, or conservation elements, in scenario evaluations at all time steps.

- **Invasive plant species**: Non-native invasive plant species, namely Phragmites, kudzu, and fennel, have displaced native vegetation on the Refuge Complex and throughout the supporting landscape. These population expansions continue to encroach upon various bird species and displace the food sources and vegetation structure that are important to them in breeding, wintering, and migratory periods of their life cycles.

  RVA treatment: Phragmites data were not incorporated explicitly as a stressor in this study, but implications of invasive plant species are considered in the interpretation of results.

- **Fisherman Island (human impacts)**: Fisherman Island NWR is critical breeding habitat for many shorebirds, as it is undeveloped and allowed to naturally respond to weather and storm events. Minimizing day-to-day human impacts (e.g., recreational use) helps to minimize disturbance to breeding bird colonies.

  RVA treatment: Fisherman Island NWR was included in the most focused assessments as part of the Refuge Complex, and interpretations address the issues of breeding bird colonies on Fisherman.

- **Hunting program:** Eastern Shore of Virginia NWR currently uses an annual hunt to manage the white-tailed deer population.

RVA treatment: While data pertaining to deer populations were not specifically included as inputs to the assessment, potential impacts of deer on key bird habitat under various scenarios are addressed.

- **Cultural resources:** The Refuge Complex still includes bunkers and abandoned buildings containing materials and objects, some of which have historic value. Refuge staff must make decisions around the maintenance, protection and display of these objects.

  RVA treatment: Certain high-priority structures were included as conservation elements in the assessments at all time steps, though specific recommendations pertaining to bunkers and abandoned buildings are not offered.

- **Beach access**: A specific stretch of shoreline habitat (on Fisherman Island) for the endangered Northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*) abuts private property, where the public often accesses the refuge. This may have negative impacts on this species.

  RVA treatment: This specific area, and *C. dorsalis dorsalis* and its habitat, were included as elements in the assessment at all time steps.

Chapter 3. Refuge Environment

Geographic/Ecosystem Setting

Geography

The Eastern Shore of Virginia and Fisherman's Island National Wildlife Refuges are located in Northampton County, Virginia at the southern tip of the Delmarva Peninsula, which is one of the most important migratory bird concentration areas on the East Coast. The combination of habitat variety, geographic location, food accessibility, protective cover, and minimal human disturbance help to "funnel" migratory birds onto the Refuge Complex during spring and fall migration (USFWS 2004). Both refuges are located within the Chesapeake Bay Lowlands ecoregion as delineated by The Nature Conservancy (2009)(Figure 3). The ecoregion includes the Delmarva Peninsula (including Virginia's eastern shore) and the low-lying coastal plain east of the Fall Line from Delaware south to the James River in Virginia.

Figure 3. Regional context of the project area and Refuge Complex.

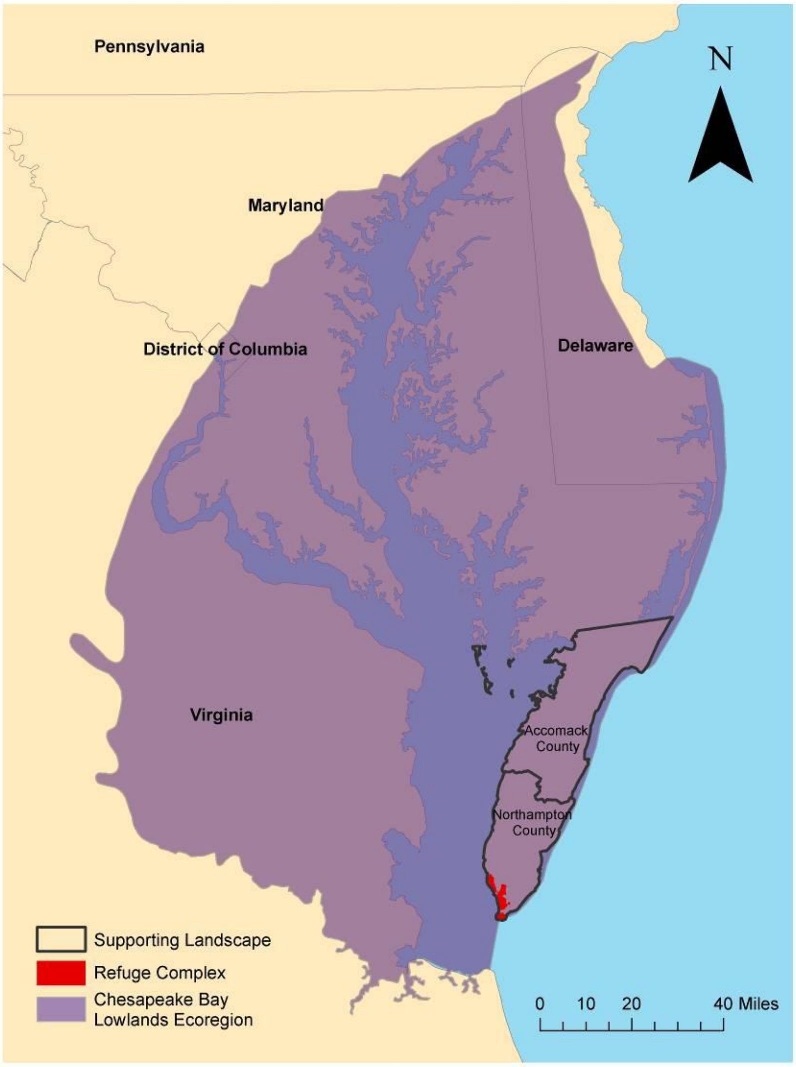


Figure 3 shows the broader geographic context for the study area. The Chesapeake Bay Lowlands ecoregion is displayed in lavender, the supporting landscape, consisting of Accomack and Northampton Counties, in gray outline and the approved boundary of the Refuge Complex, including the Eastern Shore of Virginia NWR and Fisherman Island, are in red.

The Eastern Shore itself is comprised of Accomack and Northampton Counties on the Delmarva Peninsula, with the Chesapeake Bay to the west and Atlantic Ocean to the east (Figure 2). The Eastern Shore of Virginia NWR is 1,123 acres, 108 of which occupy Skidmore Island (one mile east of the peninsula, separated from the main part of the refuge by Magothy Bay). Fisherman Island is Virginia's southernmost barrier island and is currently 1,850 acres. The island's size continues to expand due to accretion, or the movement of sand. Fisherman's Inlet separates Fisherman Island from the Eastern Shore of Virginia NWR by about half a mile (USFWS 2004). The RAMSAR Convention designated

Virginia's barrier islands as "Wetlands of International Importance" (USFWS 2004). The Eastern Shore consists of sandy plains with little topographic relief, where gentle streams and rivers drain to the Chesapeake Bay and Atlantic Ocean. This peninsula is narrowly fringed with beaches, as well as transitional tidal wetlands, while upland areas contain remnant patches of deciduous- and pine-dominated forests. Most of the uplands of the Eastern Shore of Virginia are either developed or in agricultural uses.

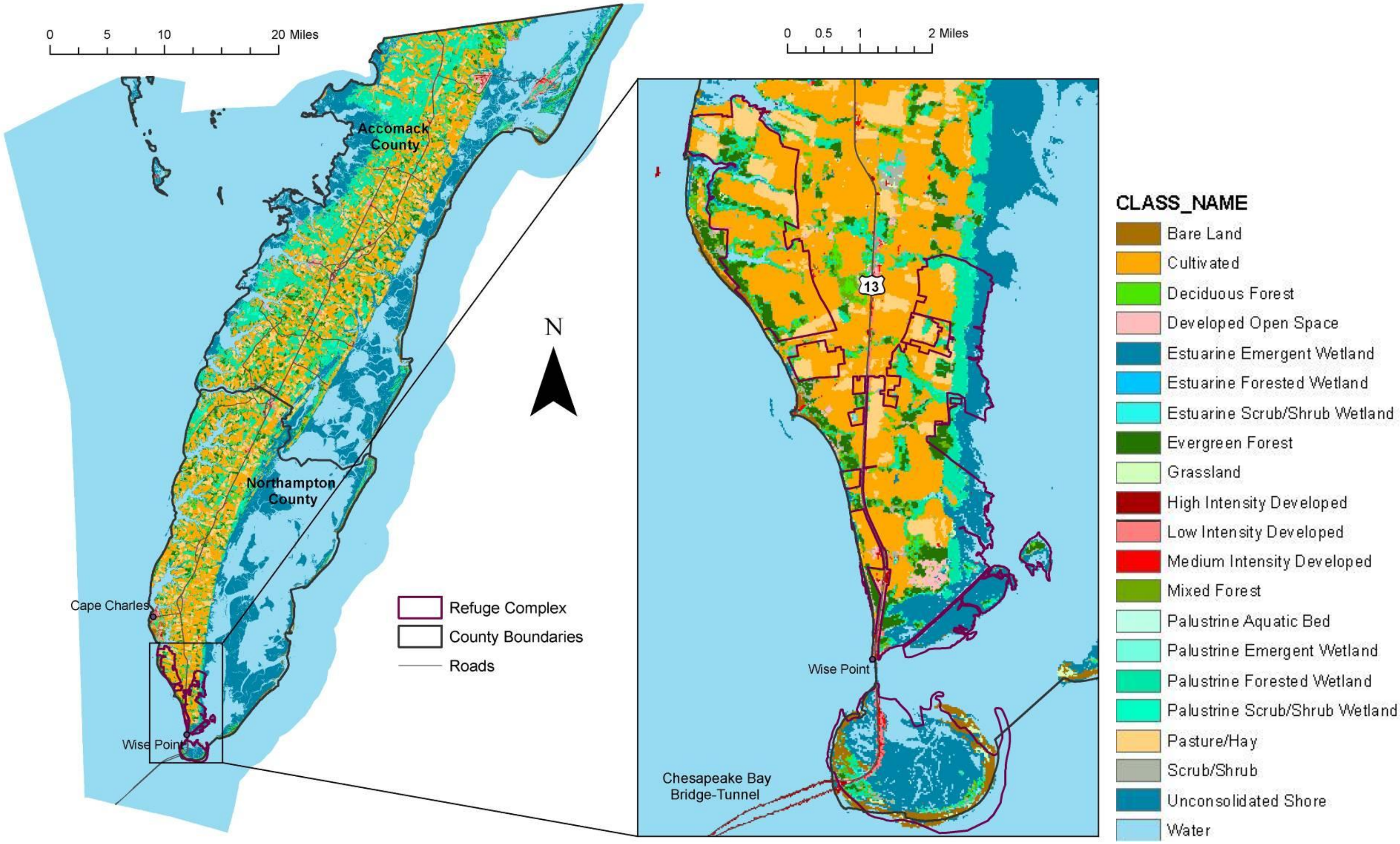
In the rest of the Chesapeake Bay Lowlands ecoregion, areas west of the Chesapeake Bay contain gently sloping lands with broad rivers draining to the Chesapeake Bay. Rivers are flanked by large wetlands and lowland forests, mostly mixed deciduous hardwoods. Much of this mainland landscape is lightly developed, with some intensively developed areas (e.g., Hampton Roads/Newport News area, and Richmond), though large expanses of second-growth forests remain throughout.

Land Use

The Eastern Shore of Virginia NWR was the site of former Fort John Custis Army Base and, later, the Cape Charles Air Force Base. Prior to its military ownership, the land was used for farming and raising livestock. Other parts of refuge land remained in farm use until 1990. Fisherman Island NWR was historically used first as an immigrant quarantine station and then by the Virginia Coastal Artillery National Guard in World War I and the U.S. Navy in World War II. Once the two refuges were established, buildings were removed and much of the land was revegetated. The Chesapeake Bay Lowlands ecoregion has been substantially transformed by a long history of agricultural use and, more recently, urbanization. Land use on the Eastern Shore has been shifting towards residential development (USFWS 2004). Slightly more than 3 percent of the supporting landscape is currently in a developed class (NOAA 2006). While the immediate surrounding area of the Refuge Complex would historically have contained marshes and inland wetlands, as well as climax vegetation of loblolly pine and mixed hardwood species, it is currently characterized by a variety of successional communities due to the past and current land uses and management. Approximately 9 percent of the supporting landscape is classified as pasture or hayfield and about 24 percent is cultivated for row crops, with tomatoes, cucumbers, wheat, squash, and peppers being important crops (VDACS 2011). Approximate land use and land cover on the Refuge Complex and the supporting landscape, as of 2006, is modeled by the 2006 Coastal Change Analysis Program (C-CAP) (NOAA 2006) (Figure 4).

This land-use history and resulting mix of communities strongly influences the use of this landscape by migratory birds, and consequently, the ways in which the Refuge Complex is managed for these species. Further detail regarding distribution and management of specific habitat types and vegetation communities can be found in the 2004 Comprehensive Conservation Plan (USFWS 2004) as well as the Habitat Management Plan (USFWS 2010).

Figure 4. Land Use and Land Cover Types of the Refuge Complex and Supporting Landscape (NOAA 2006)



Vegetation

The vegetation of the supporting landscape of the Refuge Complex includes low tidal and coastal communities, early successional grassland and shrub habitats, wetlands, and remnants of once-intact forests. The maritime zone of the Eastern Shore is vegetated with a suite of dune woodlands and scrub, dune grasslands, sparse beach vegetation, pine-dominated and to a lesser extent, hardwood-dominated forests—communities well-adapted to deep sands, periodic salt spray, and oceanic storm impacts.

The typical development of maritime vegetation in this area proceeds along a gradient from the beach inland, starting with the upper beaches and overwash flats that support a sparse assemblage of *Cakile edentula* (sea rocket), *Salsola kali* (northern saltwort), and a few other salt-tolerant, succulent annuals. The foredune and ocean-facing secondary dunes usually support more stabilized grasslands dominated by combinations of *Ammophila breviligulata* (American beachgrass), *Panicum amarum* var. *amarum* (bitter seabeach grass), *Uniola paniculata* (sea oats), *Panicum amarum* var. *amarulum* (beach panic grass), *Spartina patens* (saltmeadow cordgrass), *Schizachyrium littorale* (seaside little bluestem), *Triplasis purpurea* (purple sandgrass), *Solidago sempervirens* var. *sempervirens* (seaside goldenrod), and a few other species.

With increasing distance from the shoreline, more protected back dunes become vegetated with evergreen shrublands—primarily *Morella pensylvanica* (northern bayberry) or *Morella cerifera* (southern bayberry). On very high, xeric back dunes, a rare maritime woodland of stunted loblolly pine and *Hudsonia tomentosa* (sand-heather) occurs at several sites. Maritime forests that occupy the most protected dunes and sand flats have been greatly reduced by clearing and coastal development. The most mature maritime forests of the Eastern Shore generally consist of loblolly pine mixed with *Prunus serotina* var. *serotina* (black cherry) and several oak species. Maritime-zone wetlands include some of the state's rarest natural communities, including sea-level fens, interdunal ponds and wet grasslands, and maritime swamp forests.

Inland of the maritime zone, the original forests were probably similar to those found elsewhere in the Coastal Plain (e.g., oak/heath, oak-hickory, and mesic mixed hardwood forests). These forests have largely been cleared for agriculture. Those that remain have been repeatedly cut and are mostly represented now by successional stands of loblolly pine, sweetgum, and red maple (*Pinus taeda-Liquidambar styraciflua-Acer rubrum*). These anthropogenic disturbances throughout the supporting landscape have provided opportunities for non-native plant species to invade and alter the native vegetation species assemblage and structure. Non-native species such as Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), garlic mustard (*Alliaria petiolata*), common fennel (*Eupatorium capillifolium*), Russian olive (*Elaeagnus angustifolia)* and *Lespedeza* spp. have become well-established on the supporting landscape. These woody species may be most detrimental to migratory bird populations, via outcompeting, and reducing the cover of fruit-bearing shrubs and other native vegetation the uplands of the southern tip of the peninsula. In lower areas, such as coastal wetlands and streams, the most notorious invasive plant species is *Phragmites* sp. This reed readily out-competes native wetland plant species to dominate local vegetative cover and has thus become well-established throughout much of the wetland/upland ecotones of the supporting landscape.

Geomorphology and Topography

The Delmarva Peninsula is part of the Atlantic Coastal Plain, which slopes seaward. The peninsula originated during the last glacial retreat, in which rising sea levels filled the lower Susquehanna River valley, forming the Chesapeake Bay and separating the area from the mainland. Fluctuating sea levels over several thousand years created the marsh-lagoon system on the eastern side of the Delmarva Peninsula. Some uplift has occurred on the Peninsula since the retreat of the glaciers, but it is being balanced by rising sea levels (around 1.2mm per year). Landscape features include bottomland forests, salt marshes, and tidal creeks with fringing marshes. Tidal creeks are fed by intermittent freshwater streams, some of which are dammed to form impoundments (USFWS 2004).

Because of the influence of the ocean and the flattening effect of wind, the landscape of the Refuge Complex is typically flat with elevations usually between sea level and 20 feet. Landscape features specific to the Eastern Shore of Virginia NWR include low bluffs and a narrow beach on the western side, low-lying woods, intertidal wetlands, and small tidal creeks and ponds along the eastern side. Soils are mostly sand, silt, and shell fragments. The Eastern Shore of Virginia NWR is susceptible to winds, waves, and currents; its location relative to the Chesapeake Bay and Atlantic Ocean provide conditions for accretion and erosion of shorelines. Fisherman Island NWR is especially susceptible to geomorphic processes of sediment deposition and shoreline accretion. Indeed, Fisherman Island formed in the past 200 to 250 years, due to the displacement of sands and sediment from nearby lower shore face environments. As a result, sand and sediment dominate the soils of Fisherman Island. Terrain displays mild ridges and low areas containing scattered swales, ponds, and flats, with most ephemeral sand bars and spits around the island periphery. Fisherman Island changes considerably over time, with significant changes occurring from hurricanes and tropical storms (Allen and Oertel 2005).

Climate

Virginia's Eastern Shore experiences a mild, humid climate, with the Atlantic Ocean and Chesapeake Bay moderating temperatures. According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment estimates (Medium A1B Emission Scenario), the current average annual temperature for the Supporting Landscape ranges from 56 to 59 degrees Fahrenheit (based on data from 1951 to 2006), as shown in Figure 5 (PRISM 2007). According to the 2004 CCP, seasonal low and high temperatures range, respectively, from a January average of 44 degrees to a July average of 77 degrees Fahrenheit. The summer months are slightly wetter than the rest of the year, where precipitation is generally more evenly dispersed. The IPCC Fourth Assessment (Medium A1B Emission Scenario) estimates annual precipitation ranging from 39 to 44 inches (based on data from 1951 to 2006), as shown in Figure 6 (PRISM 2007). During the summer, the weather pattern of the Eastern Shore undergoes slight frontal activity and is subject to the "Bermuda High," with moist air coming from the south. Conversely, winter weather is governed by swift, frequent polar fronts originating from the northwest.

Figure 5. Current Average Annual Temperature for Supporting Landscape.

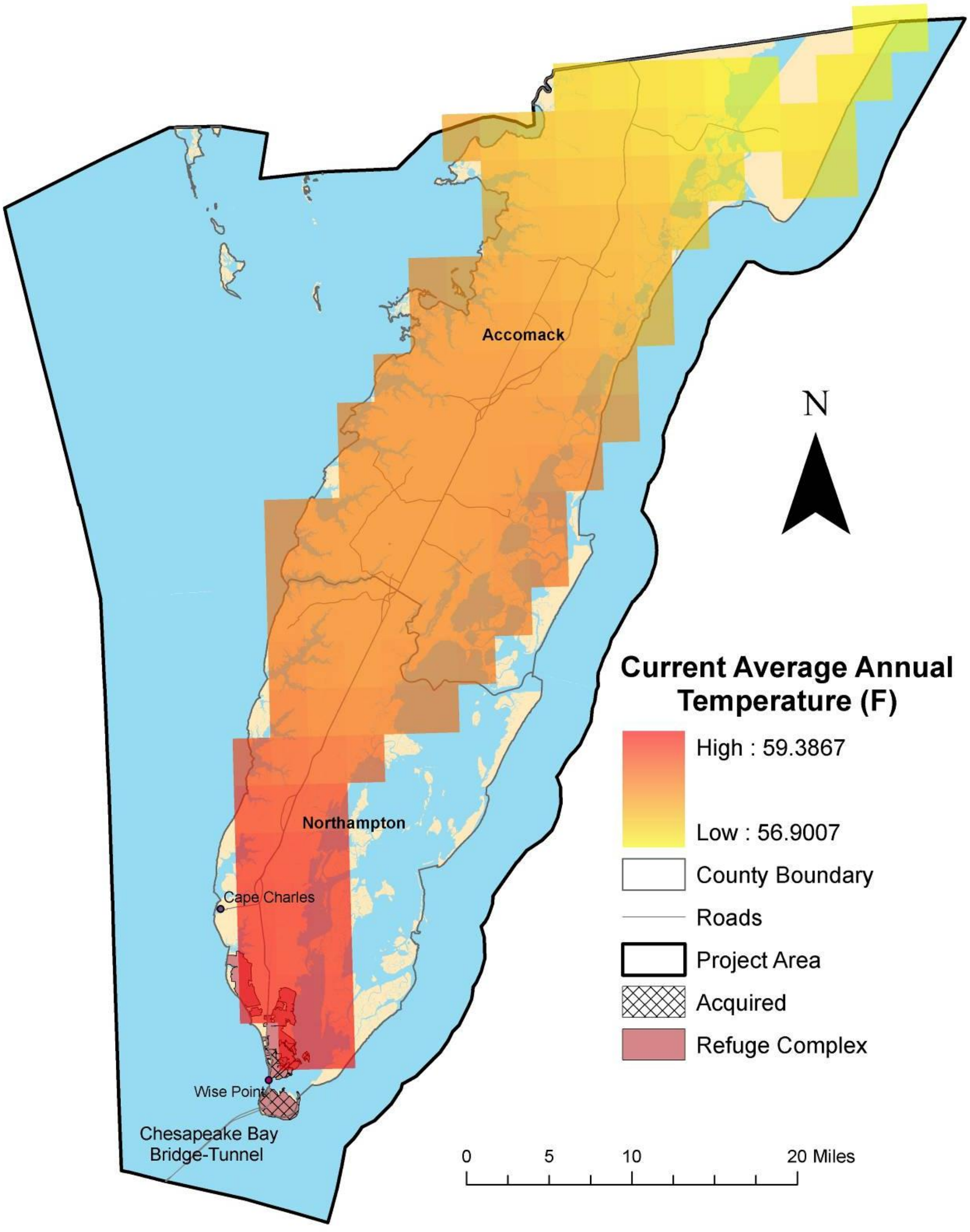


Figure 5 displays the current average annual temperature, ranging from approximately 57 to 59 F across the supporting landscape, as per 1951 – 2006 temperature data. These data were summarized and mapped using the Nature Conservancy's Climate Wizard (www.climatewizard.org).

Figure 6. Current Average Annual Precipitation for Supporting Landscape.

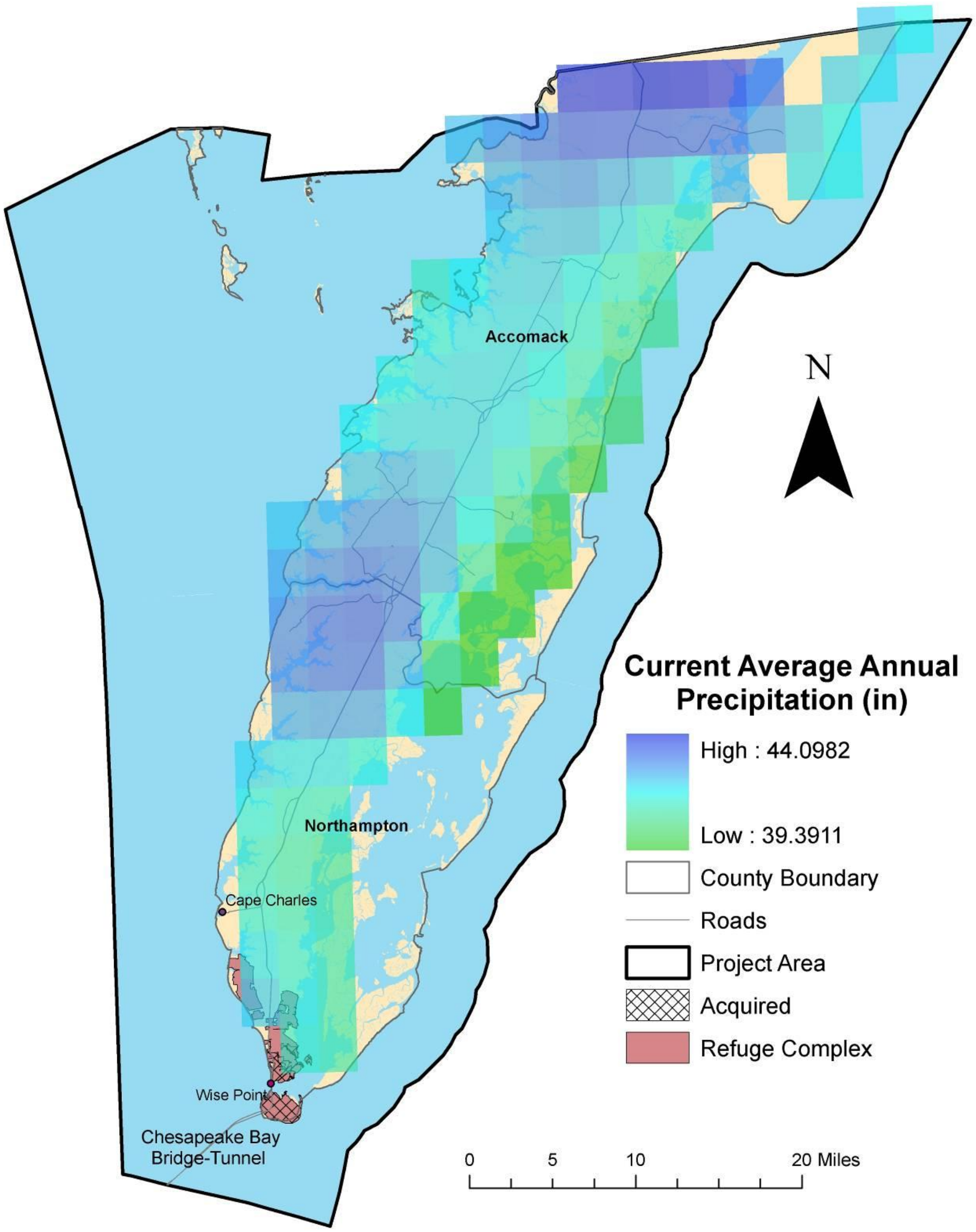


Figure 6 displays current average annual precipitation, ranging from 39 to 44 inches across the supporting landscape, as per 1951 – 2006 precipitation data. These data were summarized and mapped using the Nature Conservancy's Climate Wizard (www.climatewizard.org).

Northeasters and hurricanes, responsible for high tides, strong winds, and heavy precipitation, are the two chief storm types influencing the Eastern Shore. Northeasters are sluggish low pressure systems, generating strong northeast winds as they move up the Atlantic Coast. Northeasters usually happen during the fall, winter, or early spring. Hurricane season is June to November, with hurricanes traveling offshore, along the coast, or inland. Significant storm damage, including flooding and erosion, can be experienced but is not usually as extreme as in states farther south. A recent exceptionally devastating storm was Hurricane Isabel, in 2003. High winds (sustained over 50 mph) and storm surge (over 4 feet on Fisherman Island, resulted in significant flooding and shoreline erosion on the refuge (Allen and Oertel 2005).

Future climate projections for the assessment area are summarized using the Nature Conservancy's Climate Wizard (www.climatewizard.org), which maps temperature and precipitation based on the IPCC Fourth Assessment Future Climate Models (Maurer 2007). These projections use the Medium A1B Emission Scenario with an Ensemble Average.

The Medium A1B Emission Scenario, using the ensemble average, predicts annual average temperature on the Supporting Landscape to increase from between 1.3 and 6.4 degrees Fahrenheit by the 2050s (Figure 7), and from between 2.8 and 7.6 degrees Fahrenheit by the 2080s (Figure 8) (Maurer 2007). This scenario projects precipitation increases as well. By the 2050s, average precipitation is modeled to increase by 1 to 7 inches per year (Figure 9). Annual average precipitation for the Supporting Landscape is predicted to increase by 2.4 to 8.4 inches by the 2080s (Figure 10) (Maurer 2007).

Note that parts of the study area lack temperature and precipitation data due to the coarse resolution of the data. It is reasonable to extrapolate temperature and precipitation information and forecasts for the omitted areas based on adjacent areas containing data.

Figure 7. Projected Average Annual Temperature for the Supporting Landscape by the 2050s

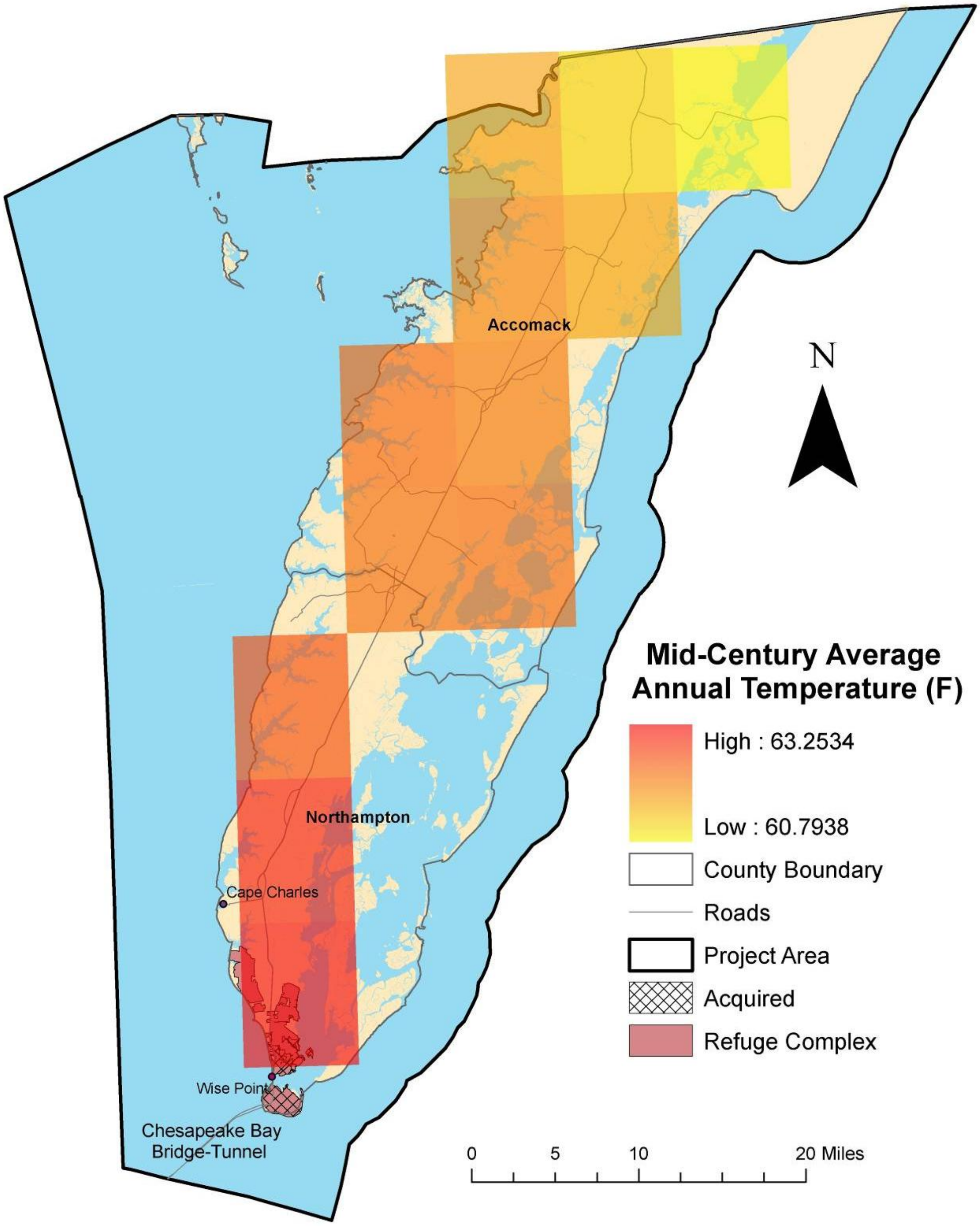


Figure 7 displays the predicted mid-century average annual temperature, ranging from approximately 61 to 63 F across the supporting landscape. These data were summarized and mapped using the Nature Conservancy's Climate Wizard (www.climatewizard.org), and based on IPCC Fourth Assessment Future Climate Models, specifically the Medium A1B Emission Scenario with an Ensemble Average (Maurer 2007).

Figure 8. Projected Average Annual Temperature for the Supporting Landscape by the 2080s

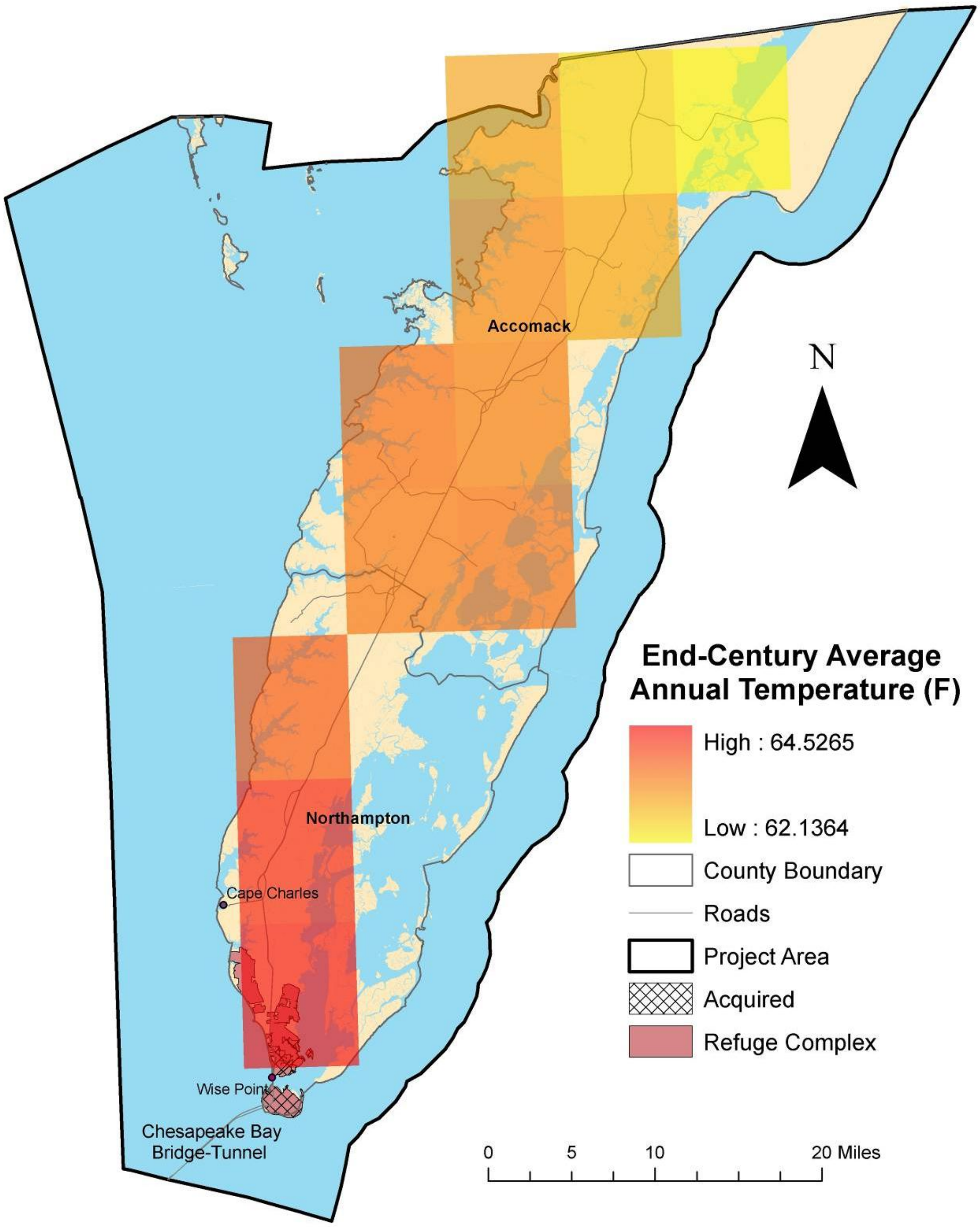


Figure 8 displays the predicted end-century average annual temperature, ranging from approximately 62 to 65 F across the supporting landscape. These data were summarized and mapped using the Nature Conservancy's Climate Wizard (www.climatewizard.org**), and based on IPCC Fourth Assessment Future Climate Models, specifically the Medium A1B Emission Scenario with an Ensemble Average (Maurer 2007).**

Figure 9. Projected Average Annual Precipitation for the Supporting Landscape by the 2050s

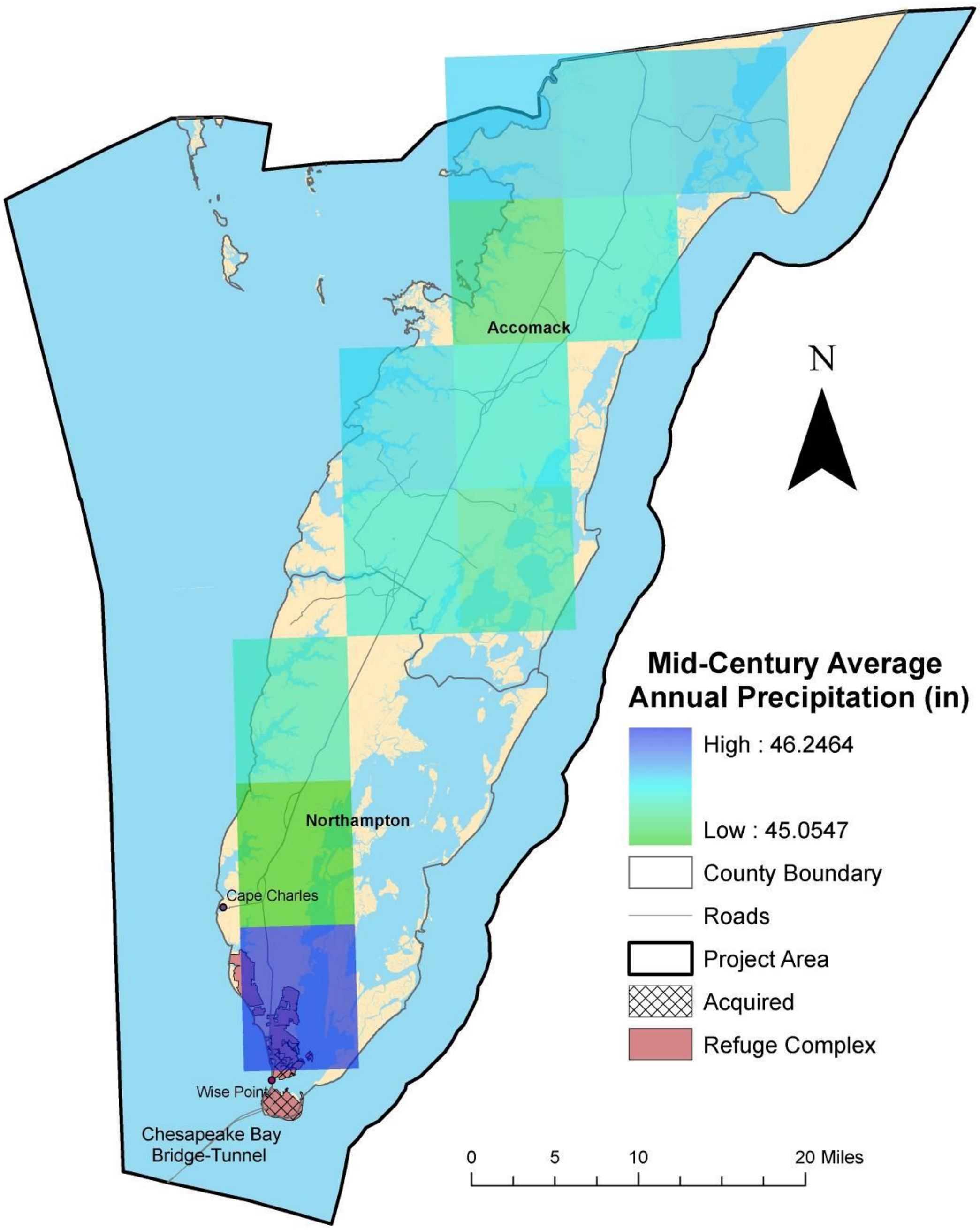


Figure 9 displays the predicted mid-century average annual precipitation, ranging from approximately 40 to 46 inches across the supporting landscape. These data were summarized and mapped using the Nature Conservancy's Climate Wizard (www.climatewizard.org), and based on IPCC Fourth Assessment Future Climate Models, specifically the Medium A1B Emission Scenario with an Ensemble Average (Maurer 2007).

Figure 10. Projected Average Annual Precipitation for the Supporting Landscape by the 2080s

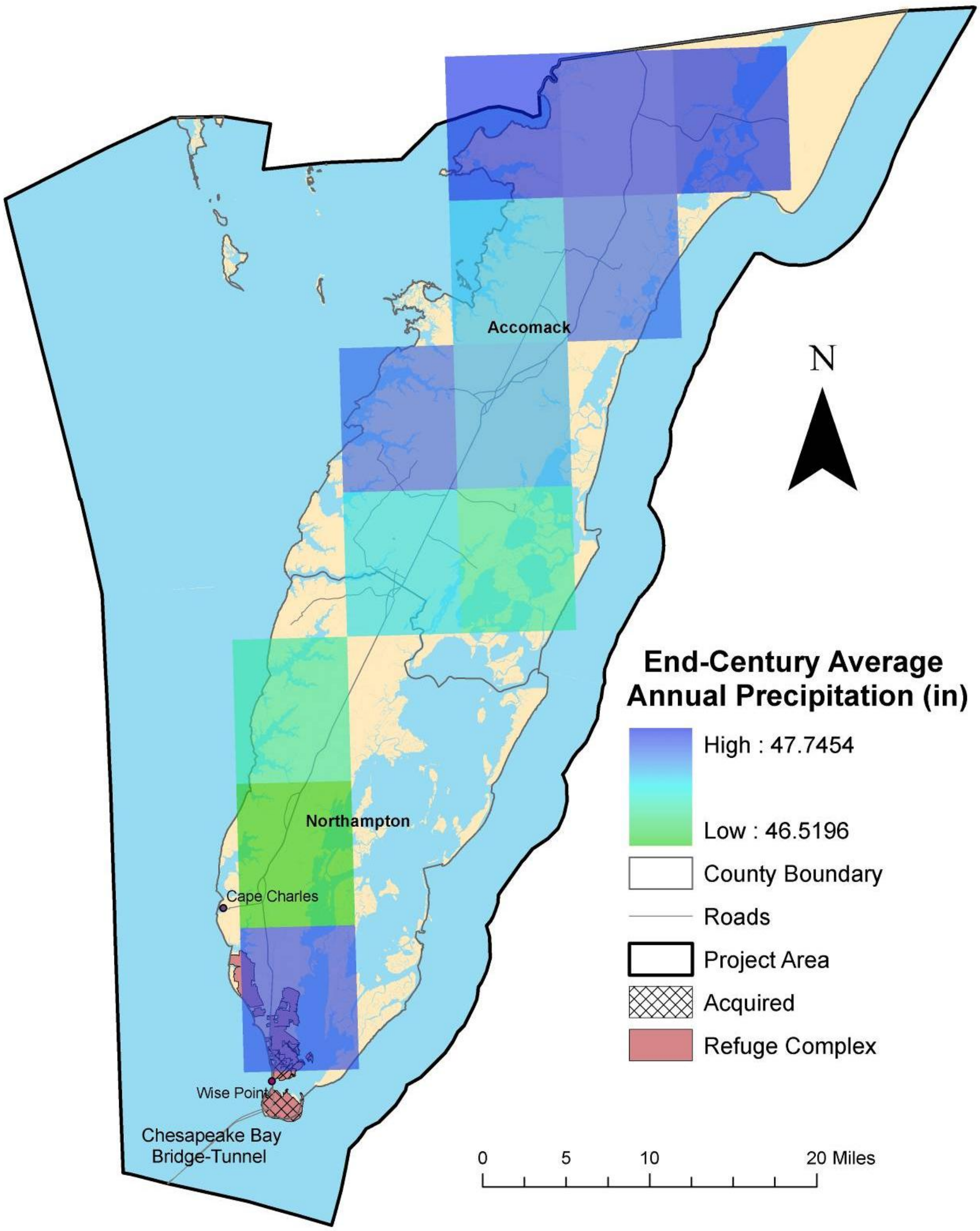


Figure 10 displays the predicted end-century average annual precipitation, ranging from approximately 47 to 48 inches across the supporting landscape. These data were summarized and mapped using the Nature Conservancy's Climate Wizard (www.climatewizard.org), and based on IPCC Fourth Assessment Future Climate Models, specifically the Medium A1B Emission Scenario with an Ensemble Average (Maurer 2007).

Potential effects of temperature and precipitation changes include shorter, wetter winters with fewer freezing days. Precipitation patterns could become more extreme, consisting of more downpours combined with more frequent short-term droughts. Increased frequency and degree of storm-related flooding is another concern (The Nature Conservancy 2010) associated with these predicted changes.

Since this RVA focuses on the impacts of sea level rise on the Refuge Complex and supporting landscape, the precipitation and temperature predictions from the Medium A1B Emission Scenario were not directly applied in this RVA. Instead, Sea Level Affecting Marshes Model data (SLAMM 2011) were used to assess sea level rise impacts. The SLAMM future sea level predictions are developed using the IPCC predictions of temperature increase, and multiple SLAMM outputs are available, based on the multiple IPCC scenarios used in their development. For the RVA, the SLAMM outputs based on the 1-meter IPCC scenario were used instead of the Medium A1B Emission Scenario, as the latter does not provide full coverage of the supporting landscape. For this overview of climate in the assessment area, temperature and precipitation projections based on the 1-meter scenario were not available via Climate Wizard, and the Medium A1B Emission Scenario was used as an alternate.

Refuge Resources, Cultural Resources, and Public Uses

Refuge Resources

The Refuge Complex harbors a diversity of biological resources, including a range of upland, maritime, and wetland vegetation communities, and 124 trust species of management concern (USFWS 2004). The primary objectives for establishment of the two refuges are to conserve and manage habitats important to a variety of bird species throughout the year, especially during migratory and wintering periods. The Refuge Complex and supporting landscape contain upland early-successional habitats (shrublands and grasslands), marshes, beach habitats and various maritime dune communities (grasslands, woodlands, scrub) that are important habitat for a broad diversity of bird species during their breeding, migratory, and wintering periods. The Refuge Complex and supporting landscape are particularly important as migratory stopover habitat for frugivorous and insectivorous passerine species. Likewise, various marsh types are used year-round by wading birds and waterfowl, as well as some passerine species. These include the piping plover, a beach-nesting, federally endangered bird species with historic and current breeding and migratory records from the Refuge Complex.

In addition to bird species and their required habitats, the Refuge Complex is home to other trust species as well. The federally endangered Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis*) is known from the western beaches of the supporting landscape, including a small population on the Eastern Shore of Virginia NWR. The southern tip of the Eastern Shore is also known as a significant migratory stopover for monarch butterflies during their fall migration to Mexico.

These species and habitats, as well as other vegetation communities and animal species (e.g., state-listed species and high-priority resources), are described in the CCP and the draft HMP. Priority resources considered and addressed in this assessment are listed in Appendix B.

Cultural Resources
The National Environmental Policy Act calls for cultural resources to be considered in federal planning endeavors. Further, the National Wildlife Refuge System Improvement Act requires archaeological and cultural values for each refuge to be identified in its CCP. The National Historic Preservation Act requires federal agencies to protect historic resources if the resources are eligible for listing in the National Register of Historic Places. The Eastern Shore of Virginia National Wildlife Refuge has a farmstead that is eligible for the National Register of Historic Places. Another potentially eligible feature is the remains of Fort John Custis of the Chesapeake Bay Harbor Defenses. Nine additional sites were evaluated, but none was eligible for the Register. Cultural resources of Fisherman Island include four Harbor Defenses buildings from WWII. Hunting and fishing cabins, and quite possibly cabin sites from the late 19th and early 20th century, also exist on the island. None of these resources on Fisherman Island have been assessed for eligibility for the Register, so it remains undetermined whether any of these locations will be preserved (USFWS 2004).

Public Uses
The main mode of public access to the Eastern Shore is U.S. Route 13 and the Chesapeake Bay Bridge-Tunnel. The Eastern Shore Railroad also operates in Accomack and Northampton Counties, which includes a car float service, though visitors cannot use the car float service to access the Eastern Shore of Virginia. Visitation to the Eastern Shore of Virginia NWR has grown since 1996 and is expected to increase along with development on the Eastern Shore. Currently, most visits serve as waypoints en route to other activities, rather than as destinations. When the Refuge Complex is used as a destination, it is usually for educational programs, by military history enthusiasts, or groups using the conference facilities. Hunting, fishing, wildlife observation, photography, and environmental education and interpretation are public-use assets of the Refuge Complex and are prioritized in one of the six management goals in the CCP (USFWS 2004). Proximity to Kiptopeke State Park, Cherrystone Campground, Chincoteague National Wildlife Refuge, Assateague Island National Seashore, the Virginia Space Flight Center, towns, and waterfront is another desirable feature to the public (USFWS 2004).

Within the Refuge Complex boundary, various infrastructure resources must be managed to allow safe and educational use by the public. These infrastructure resources include various buildings and structures for accommodating staff and volunteers and their equipment. Likewise, the Visitor Center, photo blinds, and a number of kiosks are maintained for educational purposes. There are also boat ramps for public use. All of these resources are further supported by infrastructure such as utilities, trails, roadways, gates, and signs to manage their access and maintenance.

Resources Assessed in the RVA

Resources of Management Priority
This assessment focused on the highest-priority resources managed on the Refuge Complex. Biological resources identified in the CCP and the priority habitats from the HMP provided a comprehensive list of resources for consideration in a vulnerability assessment (Appendix B). This list was further prioritized based on discussions with partners at the RVA scoping workshop, priority habitats identified in the HMP, and subsequent communications with refuge staff. Highest-priority resources for inclusion in the RVA

included rare, threatened, and endangered species known to use the Refuge Complex, vegetation communities and habitat types valuable to priority species, and certain MCI on the Refuge Complex necessary for its management and public use. Critical stressors were identified and characterized in spatial scenarios for four points in time: a current baseline, 2025, 2050, and 2100; these scenarios were analyzed to understand the effects of the stressors on refuge resources at those various points in time.

Resources included in this RVA are indicated in Appendix B as "Priority 1" resources. Issues that affect these highest-priority resources include:

- Effects of transportation and transmission line corridors in and around the Refuge Complex
- Effects of gray infrastructure features within the boundaries of the Refuge Complex (e.g., buildings, kiosks)
- Effects of land-use change (e.g., development or other land-use change from natural states) in the supporting landscape on the resources managed on the Refuge Complex
- Effects of SLR on specific vegetation community types and habitat types important to migratory and resident bird species

In this assessment, scenario outputs are interpreted to assess and summarize expected changes to Priority 1 resources resulting from stressors at four future time steps between now and 2100. Chapter 4 of this report summarizes options and recommendations for adapting management action to help assure Refuge Complex goals are met in the face of stressors.

These scenario assessments were conducted using the NatureServe Vista (Vista) ArcMap extension (NatureServe 2011). Assessment inputs and results for this part of the assessment are all stored in an accessible Vista project database, and the inputs can be manipulated to explore subsets of the resources datasets and geographic area(s) evaluated.

Infrastructure of Management Importance

A thorough list of infrastructure was compiled via the CCP and communications with refuge staff. While not all infrastructure resources could be assessed in this project, high-priority, mission-critical infrastructure (MCI) resources were assessed. The Refuge Complex's mission-critical infrastructure (MCI) is listed in Appendix C. The list also indicates whether the infrastructure feature is a priority resource to be retained (i.e., will be managed for its maintenance as MCI) and/or is a stressor on other resources. Treatment of infrastructure in the RVA can be complex; while assessing MCI is straightforward, it is more complicated to assess infrastructure that is:

A. On refuge lands (or future acquisition lands) that cannot be removed but the refuge is not responsible for maintaining it or protecting it from natural disturbance
B. Outside refuge lands but the refuge has a dependency on it

In this RVA, fine-scale features (e.g., fences, kiosks) were not addressed as we focused on ongoing or forecast future impacts at the landscape scale caused primarily by roads and utilities.

Resource Stressors

Resource stressors include land use, infrastructure, management practices, and natural or human-induced disturbances such as climate change effects and invasive species. Specific stressors as identified in the CCP (USFWS 2004) and considered for assessment are listed in Appendix D. Stressors were assessed in this study when they could be mapped or modeled as present on the Refuge Complex and in the supporting landscape, and where sufficient subject-matter expertise was accessible to determine resource response to the stressors. In some cases, infrastructure on the Refuge Complex can be considered *both* a resource if considered mission-critical *and* as a stressor if it also poses some threat to another resource of management importance. The key stressors of management interest are:

- **Infrastructure**: Transportation and utility infrastructure on the Refuge Complex and in the supporting landscape are considered both mission critical and as stressors to other resources. The Refuge Complex includes access roads (various surfaces) and transmission line rights of way; the supporting landscape includes infrastructure stressors as well, such as U.S. highways, Virginia primary highways, railways and transmission lines.
- **Development**: In the near term, the area within the supporting landscape is expected to be under high development pressure, threatening conversion of habitats within the acquisition boundary and in areas utilized by species in the refuges.
- **Climate change**: Climate change impacts primarily in the form of sea level rise that will inundate coastal marshes and other low-lying areas, increase inundation from storm surge, and cause shoreline erosion is of management concern.

The list of stressors and whether they were included in the assessment is found in Appendix D.

Chapter 4. Vulnerability Assessment

Resource Selection

The current Refuge Complex CCP lists a large number of species managed for and associated with the Refuge Complex (USFWS 2004). Ideally an RVA would assess all resources, but mapping and analyzing all species would be prohibitive in terms of cost and time. In this RVA, a shorter list of highest priority resources was identified for assessment. An initial list of priority resources was developed with the following considerations in mind:

- Legal/regulatory requirements derived from the Regulatory & Policy Framework (see Appendix A)
- Other policies and plans of the USFWS and partners (see Appendix A)
- Species and biological community global and state imperilment status as established by NatureServe (G-Ranks) and state-based natural heritage programs (S-Ranks)
- Refuge staff expertise
- Stakeholder and partner opinion
- Availability of data and expert knowledge sufficient for the analyses

We conducted a contextual analysis comparing resource representation in the refuge versus the supporting landscape and ecoregion to further inform the list of resources to be assessed (see Resources Contextual Assessment section below). Refuge staff finalized the list of resources to be evaluated in this RVA. The initial list of resources considered and those included on the final list for assessment is found in Appendix B. To conduct an assessment with practical value to Refuge Complex staff, only resources listed as “Priority 1” in Appendix B were included in this assessment.

Priority 1 resources were not limited to federally or state-listed species. A number of habitat types were included as resources to serve as surrogates for the array of priority species lacking sufficient data for this RVA. These included specific habitats identified as “Resources of Concern” on the Refuge Complex as per the HMP policy (620 FW) (USFWS 2010). The HMP policy (620 FW) defines “resources of concern” as:

> “All plant and/or animal **species, species groups, or communities** specifically identified in Refuge purpose(s), System mission, or international, national, regional, State, or ecosystem conservation plans or acts. For example, waterfowl and shorebirds are a resource of concern on a Refuge whose purpose is to protect ‘migrating waterfowl and shorebirds.’ Federal or State threatened and endangered species on that same Refuge are also a resource of concern under terms of the respective endangered species acts.”

The HMP is currently being finalized, along with its supporting list of priority resources of concern. This list is based on the priority species of greatest significance that are most likely to be impacted by management and changes to habitats found on the Refuge Complex. Given the broad array of bird species that use the Refuge Complex at various times of the year, managing for particular species is often impractical due to the limitations of refuge area, time, staff, and resources. Prioritization is necessary to focus management resources on the high-priority habitats that are included in the Habitat Management Plan (Table 3-2 and or 3-3 from the HMP). This assessment concentrated on these habitats and the projected changes in their area and distributions over time. This focus was established for this RVA based on discussions with refuge staff and due to the fact that spatial data for high-priority habitat was more readily available (and/or could be developed) than data for all bird species of concern. Habitats from the HMP included in this study are included in Appendix B.

Resources Contextual Assessment

Resource contextual assessments (Step 2 in Figure 1) are intended to identify additional resources that may not currently be management priorities for the refuge that may be candidates for the RVA because:

1. They have higher representation on the refuge relative to the supporting landscape and ecoregion contexts.

2. They have relatively low representation on lands administered by stewards with a conservation mission.

3. They have relatively low representation on lands managed for conservation purposes.

To conduct the first contextual assessment, we utilized the supporting landscape and ecoregional context to understand the representation of resources within the refuge relative to those areas. Table 1 illustrates the relative importance of the Refuge Complex for conservation of priority resources. For the second assessment we analyzed the proportion of each priority species and ecological system resource contained in the Refuge Complex relative to different categories of stewards (e.g., agencies) (Table 2). For the third assessment we analyzed representation of resources under different categories of conservation status (e.g., GAP status) (Table 3).

Although these contextual assessments were completed, they did not directly inform the identification of priority resources in this vulnerability assessment. Rather, a comprehensive list of resources was identified at the initial stakeholders meeting based on the considerations identified at the beginning of this chapter and then, via conversations at that meeting and follow-up conversations with refuge staff, was prioritized from 1 to 3, high to low. Appendix B lists all resources considered for inclusion in the RVA, though only Priority 1 resources were assessed in this RVA. However, it is useful to understand the management and conservation context of the priority resources, so the results of these contextual assessments are summarized here.

Table 1. Resource Distribution on Refuge Complex vs. Supporting Landscape

Resource name	Data Source		Occurrences of Resources on Refuge Complex		Occurrences of Resources on Supporting Landscape but Outside Refuge Complex		Area of Resource on Refuge Complex		Area of Resource on Supporting Landscape but Outside Refuge Complex		Total Area of Resource on Supporting Landscape
	EO	*derived*	*count*	*%*	*count*	*%*	*acres*	*%*	*acres*	*%*	*acres*
Maritime Dune Grassland	•		1	20	4	80	2.3	1	236.0	99	238.3
Maritime Dune Scrub	•		2	50	2	50	213.7	59	149.9	41	363.6
Maritime Dune Woodland	•		0	0	6	100	0.0	0	212.5	100	212.5
Maritime Wet Grassland (G1)	•		0	0	2	100	0.0	0	34.0	100	34.0
Maritime Wet Grassland (G3)	•		1	17	5	83	4.3	11	35.8	89	40.1
Monarch Migration Roost	•		1	100	0	0	7.9	92	0.7	8	8.5
Northeastern Beach Tiger Beetle	•		1	8	11	92	7.3	3	236.6	97	243.8
Early Successional Upland*		•	n/a	n/a	n/a	n/a	195.7	97	5.4	3	201.1
Freshwater Emergent Marsh*		•	n/a	n/a	n/a	n/a	39.6	83	8.0	17	47.5
Maritime Dune Grassland*		•	n/a	n/a	n/a	n/a	266.9	100	0.1	0	267.0
Maritime Dune Scrub*		•	n/a	n/a	n/a	n/a	119.1	98	2.5	2	121.6
Maritime Dune Woodland*		•	n/a	n/a	n/a	n/a	122.3	99	1.0	1	123.3
Maritime Upland Forest-Deciduous Dominated*		•	n/a	n/a	n/a	n/a	27.7	81	6.7	19	34.4
Maritime Upland Forest-Pine Dominated*		•	n/a	n/a	n/a	n/a	157.2	78	45.6	22	202.8
Upper Beach-Overwash Flats*		•	n/a	n/a	n/a	n/a	214.8	100	0.6	0	215.4
Tidal Polyhaline Marsh Complex*		•	n/a	n/a	n/a	n/a	933.8	99	8.8	1	942.6
Seaside High Flat^		•	n/a	n/a	n/a	n/a	126.6	2	6,538.7	98	6,665.4
Seaside High Marsh^		•	n/a	n/a	n/a	n/a	408.6	1	44,786.1	99	45,194.7
Seaside Lagoon^		•	n/a	n/a	n/a	n/a	697.2	1	130,590.6	99	131,287.8
Seaside Low Marsh^		•	n/a	n/a	n/a	n/a	525.0	2	28,783.2	98	29,308.3
Salt Flat	•		2	50	2	50	326.5	92	27.4	8	353.8
Tidal Mesohaline Polyhaline Marsh (G4)	•		0	0	2	100	0.0	0	1,067.1	100	1,067.1
Tidal Mesohaline Polyhaline Marsh (G5)	•		0	0	1	100	0.0	0	2,201.0	100	2,201.0
Upper Beach Overwash Flats	•		1	25	3	75	326.4	32	703.6	68	1,030.0

Table 1 exemplifies one aspect of a contextual assessment: an assessment of the distribution of priority resources on the Refuge Complex and supporting landscape. Area of Refuge Complex is based on actual lands owned by the USFWS, not the approved boundary, which includes many parcels owned by other entities. This table is limited to the priority resources (conservation elements) included in this RVA, which are rare species and vegetation communities tracked by the Virginia DCR-Division of Natural Heritage, as well as specific habitat types indicated in the HMP, which were derived using vegetation maps of the Refuge Complex. An * indicates a priority habitat as per the HMP on the Refuge Complex. A ^ indicates a priority habitat as per the HMP on the supporting landscape (i.e., within the approved Refuge Complex boundary). Multiple occurrences of vegetation communities, which are also priority habitat types, are present in the study area, with multiple natural heritage global rarity ranks (G-ranks). These are separated in this table based on that G-rank.

Priority resources were also assessed from management and conservation perspectives within two contexts: 1) the Refuge Complex, and 2) supporting landscape. Though this assessment was not used to identify priority resources for the RVA, Table 2 summarizes the distribution of priority resources across different agency stewards with a resource conservation mission.

Table 2. Resource Distribution in Refuge Complex and Supporting Landscape by Different Land-Steward Categories

Resource	Total Area of Resource in Study Area	Resource Conserved by Refuge Complex		USFWS (non-Refuge Complex)		NASA		TNC		NPS		VA DCR		VA DGIF		VA MRC	
	acres	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*
Maritime Dune Grassland	238.3	2.3	1	87.9	37	69.3	29	2.0	1	n/a	n/a	28.1	12	n/a	n/a	n/a	n/a
Maritime Dune Scrub	363.6	213.7	59	n/a	n/a	112.2	31	n/a	n/a	n/a	n/a	31.4	9	n/a	n/a	n/a	n/a
Maritime Dune Woodland	212.5	n/a	n/a	141.8	67	10.1	5	n/a	n/a	n/a	n/a	35.3	17	n/a	n/a	n/a	n/a
Maritime Wet Grassland (G1)	34.0	n/a	n/a	34.0	100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Maritime Wet Grassland (G3)	40.1	4.3	11	5.4	14	n/a	n/a	9.2	23	0.4	1	18.4	46	n/a	n/a	n/a	n/a
Monarch Migration Roost	8.5	7.9	92	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Northeastern Beach Tiger Beetle	243.8	7.3	3	n/a	n/a	n/a	n/a	2.0	1	n/a	n/a	56.1	23	2.2	1	n/a	n/a
Early Successional Upland *	201.1	195.7	97	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Freshwater Emergent Marsh*	47.5	39.6	83	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Maritime Dune Grassland*	267.0	266.9	100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Maritime Dune Scrub*	121.6	119.1	98	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Resource	Total Area of Resource in Study Area	Resource Conserved by Refuge Complex		USFWS (non-Refuge Complex)		NASA		TNC		NPS		VA DCR		VA DGIF		VA MRC	
	acres	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*
Maritime Dune Woodland*	123.3	122.3	99	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Maritime Upland Forest-Deciduous Dominated*	34.4	27.7	81	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Maritime Upland Forest-Pine Dominated*	202.8	157.2	78	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Upper Beach-Overwash Flats*	215.4	214.8	100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tidal Polyhaline Marsh Complex*	942.6	933.8	99	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Seaside High Flat^	6,665.4	126.6	2	104.7	2	1.7	0	125.9	2	599.7	9	6.4	0	9.7	0	75.0	1
Seaside High Marsh^	45,194.7	408.6	1	2,006.1	4	1,877.7	4	6,815.6	15	98.9	0	1,332.5	3	4,220.3	9	13,438.8	30
Seaside Lagoon^	131,287.8	697.2	1	206.3	0	353.7	0	661.7	1	3,550.9	3	162.9	0	467.7	0	1,779.6	1
Seaside Low Marsh^	29,308.3	525.0	2	293.5	1	66.0	0	6,723.8	23	22.7	0	1,406.0	5	2,228.4	8	9,141.7	31
Salt Flat	353.8	326.5	92	n/a	n/a	n/a	n/a	12.4	4	n/a	n/a	4.2	1	n/a	n/a	n/a	n/a
Tidal Mesohaline Polyhaline Marsh (G4)	1,067.1	n/a	n/a	n/a	n/a	9.2	1	n/a	n/a	n/a	n/a	695.4	65	n/a	n/a	n/a	n/a
Tidal Mesohaline Polyhaline Marsh (G5)	2,201.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2,032.7	92	n/a	n/a	n/a	n/a
Upper Beach Overwash Flat	1,030.0	326.4	32	n/a	n/a	n/a	n/a	223.7	22	n/a	n/a	140.7	14	n/a	n/a	n/a	n/a

Table 2 summarizes the percentage of each resource throughout the study that is permanently conserved on lands managed by the most prominent stewards of these resources. Additional lands supporting these priority resources are managed by other stewards, but to a lesser extent. Land steward acronyms are as follows: NASA- National Aeronautics and Space Administration, TNC- The Nature Conservancy, USFWS- United States Fish and Wildlife Service, NPS-U.S. National Park Service, VA DCR- Virginia Department of Conservation and Recreation, and VMRC- Virginia Marine Resources Commission. An * indicates a priority habitat as per the HMP on the Refuge Complex only. A ^ indicates a priority habitat as per the HMP on the Refuge Complex or supporting landscape. Multiple occurrences of vegetation communities, which are also priority habitat types, are present in the study area, with multiple natural heritage global rarity ranks (G-ranks). These are separated in this table based on that G-rank.

The distribution of priority resources across lands of varying conservation status throughout the supporting landscape was also summarized. The Biodiversity Management Intent (BMI) is a conservation status attribute maintained for all conserved land in the Virginia Natural Heritage Conservation Lands database. The BMI status code classifies lands across five categories based on known approaches to management of those lands for biodiversity conservation. These codes are similar to the four GAP biodiversity management status codes as per the Mapping and Categorizing Land Stewardship, in *A Handbook for Gap Analysis,* Version 2.1.0, accessible from www.gap.uidaho.edu/handbook/CompleteHandbook.pdf (Crist 2000), but were extended to apply more specifically to Virginia's Conserved Lands and the state Conservation Lands database. Conserved lands spatial data and BMI codes from the Virginia DCR- Division of Natural Heritage were selected over comparable national datasets because this state-level data is most up to date. Only BMI status codes 1, 2, and 3 were used in this contextual assessment; the lower a BMI score (i.e. a "1") assigned to a protected area, the greater the focus on managing that place for biodiversity conservation. Higher BMI scores (e.g., 2 and 3) are assigned to conserved lands that might also be managed for other values and uses. Though only BMI scores of 1, 2 and 3 were used in this RVA, all five BMI codes are defined below:

1. Specifically Designated for the Protection of Plant and Animal Communities: An area managed to maintain and protect natural plant and animal communities within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management. Examples include Wilderness Areas, National Forest Special Biological Areas, Research Natural Areas and Roadless Areas, Nature Conservancy Preserves, State Natural Area Preserves, and National and State Parks with a nature focus.

2. Designated for the Conservation of Plant and Animal Communities with Limited Impacts Permitted: An area managed to maintain a natural state, the use of which leads to minor degradation. Examples include many National Fish and Wildlife Refuges, most State Parks, State Wildlife Management Areas, and natural Stream Valley Parks. The managed area includes an area less than 10% in man-made vegetation and improvements.

3. Designated for Natural Resource Conservation and Recreation Use: An area managed for multiple conservation and recreation uses but only incidentally to protect natural plant and animal communities. Examples include most National Forest matrix lands that are used to generate timber; some State Parks with a cultural resource focus such as Staunton River, Sailor's Creek Battlefield, and New River Trail Parks; private timber lands that are not converted from natural forests when logged and that have a chance to become natural forests before they are logged again; and private lands under open space easement that include specific language to protect the natural land cover from conversion to agricultural or other land uses.

4. Unknown Management Intent: Managed areas for which management intent is currently unknown. These lands need to be investigated further before a management status rank is assigned

5. No Designation or Management for Conservation of Natural Conditions: Areas having no management or conservation direction to sustain, restore, or enhance natural land cover values.

Examples include state or national parks and monuments in urban settings; many county, city, and regional parks; most Virginia Outdoor Foundation easements; sportsman club properties; private agricultural lands and lands used for commodity timber production using non-native species or monocultures; residential lands; and urban lands.

Table 3. Total Area and Percentage of Resource Conserved by Biodiversity Management Intent

Resource	Total Resource on Conserved Land		BMI 1		BMI 2 (on RC)		BMI 2 (outside RC)		BMI 3		BMI 1, 2 or 3
	acres	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*acres*	*%*	*%*
Maritime Dune Grassland	193.5	81	18.7	8	2.3	43	99.3	42	73.2	31	81
Maritime Dune Scrub	357.4	98	16.0	4	213.7	63	15.4	4	112.2	31	98
Maritime Dune Woodland	187.1	88	35.3	17	0.0	67	141.8	67	10.1	5	88
Maritime Wet Grassland (G1)	34.0	100	n/a	n/a	0.0	100	34.0	100	n/a	n/a	100
Maritime Wet Grassland (G3)	37.7	94	27.6	69	4.3	24	5.4	14	0.4	1	94
Monarch Migration Roost	7.9	92	n/a	n/a	7.9	92	n/a	n/a	n/a	n/a	92
Northeastern Beach Tiger Beetle	81.8	34	46.4	19	7.3	8	11.9	5	16.3	7	34
Early Successional Upland*	195.7	97	n/a	n/a	195.7	97	n/a	n/a	n/a	n/a	97
Freshwater Emergent Marsh*	39.6	83	n/a	n/a	39.6	83	n/a	n/a	n/a	n/a	83
Maritime Dune Grassland*	266.9	100	n/a	n/a	266.9	100	n/a	n/a	n/a	n/a	100
Maritime Dune Scrub*	119.1	98	n/a	n/a	119.1	98	n/a	n/a	n/a	n/a	98
Maritime Dune Woodland*	122.3	99	n/a	n/a	122.3	99	n/a	n/a	n/a	n/a	99
Maritime Upland Forest-Deciduous Dominated*	27.7	81	n/a	n/a	27.7	81	n/a	n/a	n/a	n/a	81
Maritime Upland Forest-Pine Dominated*	157.2	78	n/a	n/a	157.2	78	n/a	n/a	n/a	n/a	78
Upper Beach-Overwash Flats*	214.8	100	n/a	n/a	214.8	100	n/a	n/a	n/a	n/a	100
Tidal Polyhaline Marsh Complex*	933.8	99	n/a	n/a	933.8	99	n/a	n/a	n/a	n/a	99
Seaside High Flat^	1,055.1	16	123.5	2	126.6	4	114.5	2	690.5	10	16
Seaside High Marsh^	30,787.2	68	5,393.1	12	408.6	15	6226.4	14	18,759.1	42	68
Seaside Lagoon^	7,994.5	6	691.2	1	697.2	1	674.1	1	5,932.0	5	6
Seaside Low Marsh^	20,457.8	70	6,917.3	24	525.0	10	2,521.9	9	10,493.6	36	70
Salt Flat	343.0	97	4.2	1	326.5	92	n/a	n/a	12.4	4	97
Tidal Mesohaline Polyhaline Marsh (G4)	704.7	66	695.4	65	0.0	0	n/a	n/a	9.2	1	66
Tidal Mesohaline Polyhaline Marsh (G5)	2,032.7	92	2,032.7	92	0.0	0	n/a	n/a	n/a	n/a	92
Upper Beach Overwash Flat	690.8	67	364.4	35	326.4	32	n/a	n/a	n/a	n/a	67

Table 3 summarizes the area (acres) and relative proportion (%) of lands harboring priority resources based on conservation status, using the Biodiversity Management Intent code from the Virginia Natural Heritage Conservation Lands database. An * indicates a priority habitat as per the

HMP on the Refuge Complex (RC). A ^ indicates a priority habitat as per the HMP on the supporting landscape. Multiple occurrences of vegetation communities, which are also priority habitat types, are present in the study area, with multiple natural heritage global rarity ranks (G-ranks). These are separated in this table based on that G-rank.

Cumulative Vulnerability Assessment

The goal of the RVA was to assess the direct cumulative impacts of mapped stressors on priority resources to inform the need for changes in management and acquisition plans for the refuge and for potential changes in land use and conservation land acquisition in the supporting landscape by relevant partners. We utilized a scenario approach that maps and assesses the effects of stressors as well as beneficial management and conservation practices across the supporting landscape at various points in time. Scenarios are developed for the current (baseline) timeframe and for future timeframes to express and assess anticipated changes in land use and climate. The climate change effect addressed in this assessment was projected sea level rise (SLR) which could be directly combined in the scenarios with other stressors. We did not conduct an assessment of changing temperature and precipitation on vegetation condition and succession; such analyses are technically feasible but the results have a fairly high level of uncertainty.

Defining Scenarios

In this RVA, mappable stressors (listed in Appendix D) were used to define the four scenarios developed for the Refuge Complex (acquired lands) as well as the supporting landscape. Mappable stressors assessed in this RVA can be generally summarized as:

1. Future projection of additional development or management stressors (e.g., expected or planned urbanization and infrastructure in addition to baseline urbanization and infrastructure)
2. Future projection of climate change effects, specifically sea level rise

All four scenarios—current baseline, and three future scenarios of 2025, 2050, and 2100—were defined using a specific combination of input GIS layers to represent land use, conservation management, and stressors. Descriptions of the data sets used to define and evaluate the four scenarios follow.

Land use-related stressors (e.g., developed areas, agriculture) and projected sea level rise associated with climate change were incorporated into the four scenarios by constructing a specific dataset for each time step: NOAA C-CAP land cover (NOAA 2006) was integrated with SLAMM spatial data, which reflects the projected extent of tidal marsh and other low-lying habitats under sea level rise. To assess the impacts of SLR on the Refuge Complex, we used results from a previous application of the Sea Level Affecting Marshes Model (SLAMM), Version 6 (SLAMM 2011). To ensure model coverage of the study area, this RVA used the 1-meter SLAMM simulation, which accounts for coastal armoring (i.e., dikes, bulkheads, and other protective measures) that prevent shores and wetlands from migrating inland and up in elevation toward developed areas (Glick et al., 2008). The 1-meter SLAMM simulation predicts eustatic SLR to increase by 13 cm (5.1 in.) by 2025, 28 cm (16.1 in.) by 2050, and 100 cm/1 meter (39.4 in.) by 2100. The SLAMM results also include projections of associated changes in tidal marsh extent and other low-lying habitats as a result of SLR, based on five major processes that affect wetland conversions and shoreline modifications. These processes are defined by Warren Pinnacle (SLAMM 2011) as:

- **Inundation:** The rise of water levels and the salt boundary are tracked by reducing elevations of each cell as sea levels rise, thus keeping mean tide level constant at zero. Spatially variable effects of land subsidence or isostatic rebound are included in these elevation calculations. The effects on each cell are calculated based on the minimum elevation and slope of that cell.
- **Erosion:** Erosion is triggered based on a threshold of maximum fetch and the proximity of the marsh to estuarine water or open ocean. When these conditions are met, horizontal erosion occurs at a rate based on site-specific data.
- **Overwash:** Barrier islands under 500 meters in width are assumed to undergo overwash at a user-specified interval. Beach migration and transport of sediments are calculated.
- **Saturation:** Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response of the fresh water table to rising sea level close to the coast.
- **Accretion:** Sea level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category. Accretion rates may be spatially variable within a given model domain.

The land cover patterns projected by SLAMM for future time frames in coastal areas were combined with the current NOAA C-CAP (NOAA 2006) land cover to map projected land cover for each of the three future scenarios. The C-CAP land cover alone was used to characterize current sea level in the baseline scenario.

Conservation management was integrated into the scenario definition for each time step using a current conservation lands layer from the Virginia DCR-Natural Heritage Conservation Lands database. This database includes a classification of the Biodiversity Management Intent (BMI) for all lands. A description of BMI ranks is provided in the previous section on the Resource Contextual Assessment. For the baseline and all three future scenarios, conservation management status was assumed to be the same and was integrated into each of the four scenarios using the current Conservation Lands database.

Transportation and utilities stressors of the Refuge Complex and on the supporting landscape were also incorporated into scenarios as stressors to the habitat- and species-based priority resources (Figure 11). Roads and highways data were provided by the Virginia Department of Transportation, utilities data (power transmission lines) were provided by the Virginia Economic Development Partnership, and railroads data were provided by the Virginia Geographic Information Network. For the purpose of this assessment, the footprint for transportation and utilities infrastructure was assumed to be the same for the baseline and the future scenarios; the current datasets for transportation and utilities were used in all four scenarios. These stressors vary in their effects on priority resources. Based on conversations with Refuge staff at the stakeholders meeting, the greatest buffers were applied to some highways to account for their disproportionately large off-site impacts, as well as their direct impacts to resources of concern. The Bridge-Tunnel (Route 13) is the single road entry to the southern end of the Delmarva Peninsula, and impacts to priority resources may be further exacerbated by the flat, penetrable landscape. Consequently, U.S. Route 13 was buffered by 400 feet (122 m) on each side. Smaller highways and roads were buffered with correspondingly smaller distances. The only Virginia primary highway not classified as limited access, Virginia Hwy 184 to Cape Charles, was assigned buffers on each roadside of 200 feet (61 m). Local roads and railways received a 100-foot (30 m) buffer on each side. Rural roads and power transmission line corridors all received 50-foot (15 m) buffers on each side.

Figure 11. Transportation and Utility Infrastructure

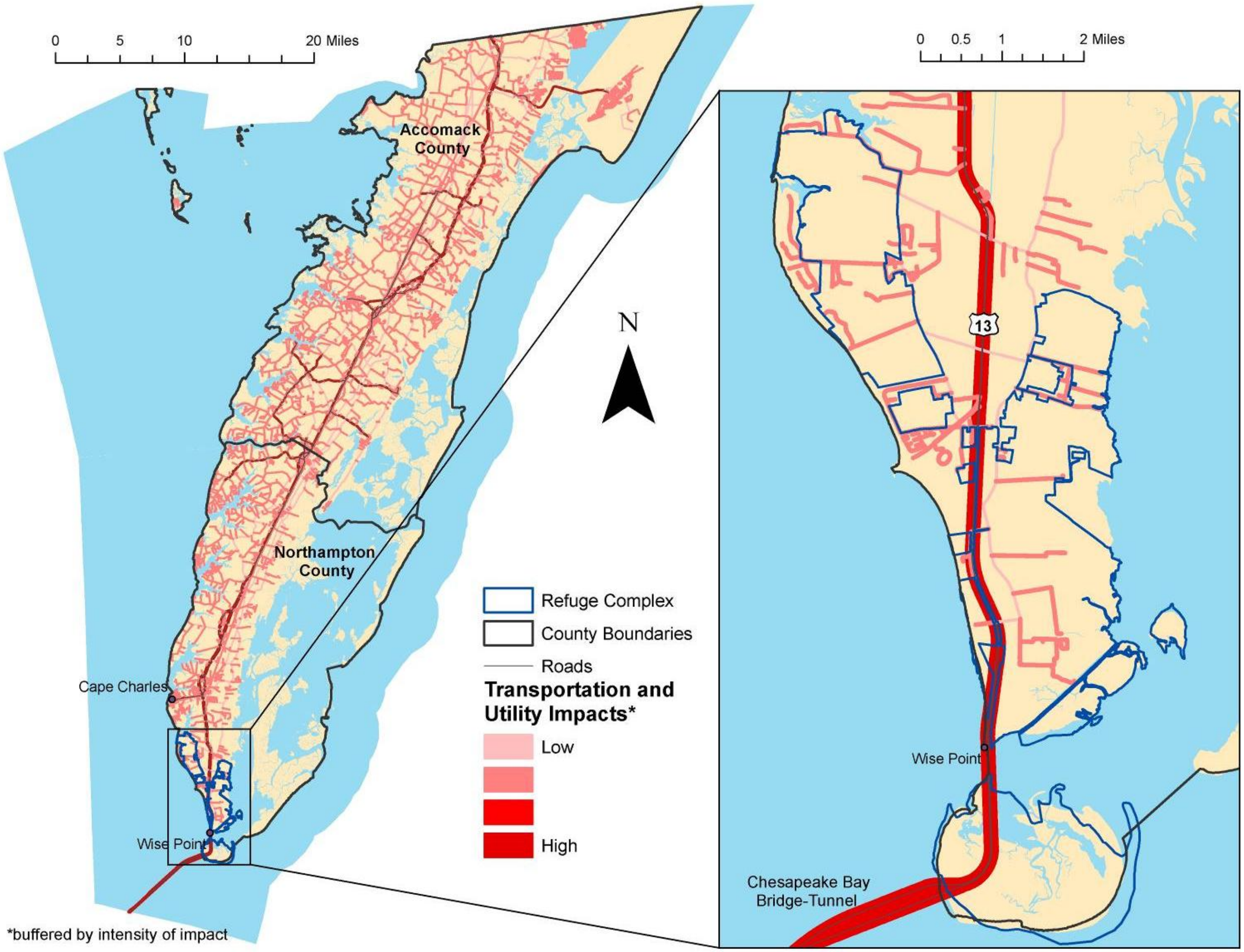


Figure 11 displays the transportation and utilities infrastructure for the Refuge Complex and supporting landscape. To address relative impacts of this infrastructure in scenarios, buffers were applied as described in text above.

Projected future development (Figure 12) was also assessed as a stressor, by incorporating a zoning build-out data layer provided by Accomack and Northampton Counties, Virginia. For all future scenarios, a 100% build-out was used; this assumes that all lands zoned for development will be developed. Inclusion of zoning allows the assessment of the effects of development on priority resources, as well as the effects of SLR on that proposed land-use change.

Figure 12. Projected Future Development

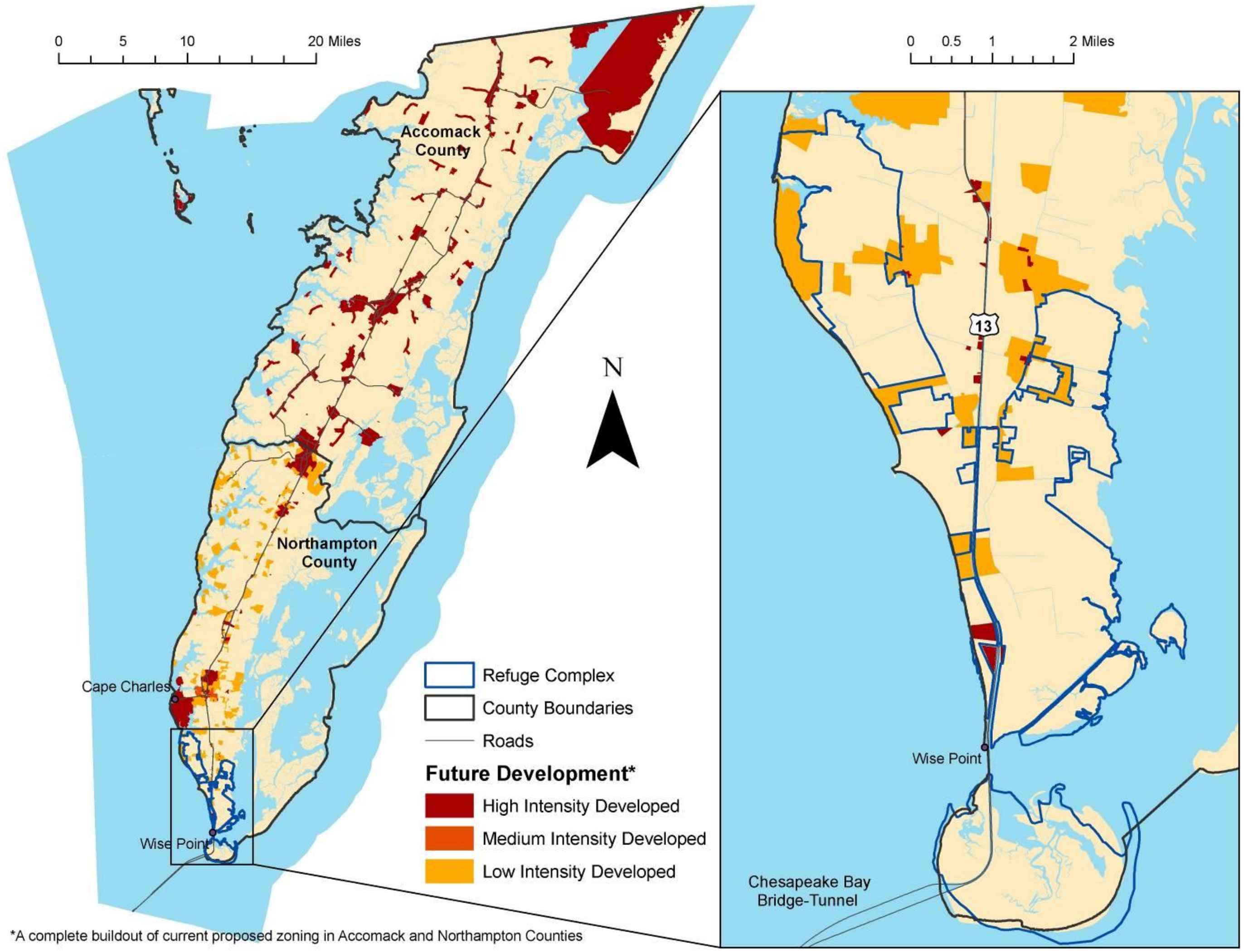


Figure 12 displays estimated future development on the supporting landscape and surrounding the Refuge Complex. This estimate is based on an assumption of 100% build-out of all lands currently zoned for development.

Resource Requirements and Responses

In order to quantify the responses of priority resources to the stressors characterized in each scenario, the conservation requirements (retention goals) of each resource and its response to stressors (compatibility ranks) were defined. All priority resources (i.e., those listed in Table 1, Table 2 and Table 3) were assigned retention goals and compatibility ranks.

The retention goals were used as a benchmark for assessing the degree to which a resource's extent and viability were retained under a given scenario. In this RVA, each resource was assigned a retention goal of 100%, aiming for all resources on the Refuge Complex and supporting landscape to be fully conserved or retained. This ideal goal was used because, as per conversations with Refuge Complex staff, this RVA focused on the highest priority resources related to (1) conservation and management of habitats important to migratory birds, as this is the primary goal of the Refuge Complex, and (2) the conservation of MCI required for everyday operations and uses of the Refuge Complex. Retention goals can be customized for each resource based on a variety of factors such as refuge policies, biologists' opinions, and partner input. Retention goals and associated conservation requirements for each resource are listed in Appendix E.

Compatibility ranks were assigned to indicate each resource's expected responses to stressors. Thus, each priority resource was assigned a rank to indicate its compatibility with 1) specific land uses (as identified in C-CAP); 2) each predicted future wetland and open water classification (SLAMM); 3) each type of transportation and utility infrastructure; and 4) each class of conservation management intent on conserved lands (i.e., Biodiversity Management Intent status). Compatibility ranks were assigned to priority resources as negative, neutral, or positive, based on the expertise of Virginia Natural Heritage Biologists. Compatibility ranks for all priority resources and stressors are listed in Appendix F.

Resource Assessment

Scenarios evaluated in this RVA are characterized by maps that integrate land use, management practices, transportation and utilities infrastructure, and climate change effects. The scenario assessments for this RVA were conducted using the NatureServe Vista (Vista) ArcMap extension (NatureServe 2011). Assessment inputs and results for this part of the assessment are all stored in an accessible Vista project database, and the inputs can be manipulated to explore subsets of the resources and geographic area(s) evaluated as well as update the scenarios and evaluation assumptions.

Each scenario —current baseline, and three future scenarios of 2025, 2050, and 2100— was evaluated by intersecting priority resource distributions with the spatially defined scenario to predict effects of stressors on resources based on resource compatibility ranks. In addition to habitat- and species-based priority resources, the evaluation at each time step also assessed the potential impacts of sea level rise on Mission Critical Infrastructure (MCI) (transportation infrastructure, utilities, etc.). Where a priority resource overlaps with one or more stressors having negative effects on the resource in question, the overlap is described as a "conflict" and the stressor is expected to cause the loss or degradation of that resource in that area of overlap. The cumulative losses caused by stressors for a particular resource are quantified and evaluated against the 100% retention goal for each resource. This section provides detailed scenario evaluations and results. **For each of the four scenarios, results are provided first for the Refuge Complex alone, and second for the entire supporting landscape, inclusive of the Refuge Complex.**

All future scenario evaluations also included comparisons of SLAMM initial condition and future habitat distributions to assess the expected change in habitat due to SLR over that time period. These results are included in the Resource Assessment results tables for each time step where SLAMM habitat types are specifically identified as “Initial Condition” or the time step year. Predicted future distributions of SLAMM habitat types were also evaluated to assess potential impacts of sea level rise on proposed zoning throughout the supporting landscape. These results are provided as maps in the Infrastructure Assessment results section.

Scenario evaluation results are reported below for each scenario with an emphasis on those achieving less than 50% of their retention goal (i.e., those resources showing the greatest potential impacts of SLR and conflicts with land-use change). Outputs for all priority resources that are provided in associated tables. These outputs, as well as details on the specific definitions and evaluations for each scenario, follow.

In general, the assessment results indicate higher levels of conflict between the priority resources and the identified stressors on the Refuge Complex as compared to the larger supporting landscape. This can be due to:

- The higher actual abundance of resources on refuge lands or the appearance of more abundant resources on refuge lands due to better documentation of resource occurrence on refuge lands relative to the supporting landscape.
    - For example, there was a lack of species-specific bird data for the supporting landscape. While some data were available for the supporting landscape, it was decided via discussions with refuge staff that this RVA would be most informative if it focused on habitat types from the HMP. If current species presence data were used for the Refuge Complex and supporting landscape, outputs would have been more informative regarding the response of these species to stressors over time, and the relative value of the Refuge Complex and supporting landscape to those populations at each time step.
    - This analysis focused on habitat types as priority resources. Priority habitat types were identified on the Refuge Complex (i.e., derived refuge resources) based on a fine-scale habitat map provided by the ESVNWR staff as well as Virginia Natural Heritage Community Element Occurrences that are indicative of those habitat types. These high priority habitat-specific data are heavily concentrated on the Refuge Complex. On the supporting landscape, the only representation of these priority resources is provided by scattered Natural Heritage Community Element Occurrence data and revisions to NWI wetlands provided by VIMS. With more data reflecting priorities on the Refuge Complex than the supporting landscape, relatively more conflicts between resources and stressors are apparent on the Refuge Complex as well.

- The geographic position of the Refuge Complex at the southern tip of the Eastern Shore and its topography make it more vulnerable to SLR. With a higher ratio of shoreline and low-lying areas to upland, a higher proportion of Refuge Complex resources would be expected to experience conflict due to SLR when compared to the relatively higher-elevation supporting landscape.

Baseline Scenario Evaluation Results

The baseline, or current scenario, was defined using 2005 C-CAP land cover data (Figure 4). Permanently conserved lands were also included and described by BMI scores, so that compatibility ranks could be developed for priority resources based on how these conserved lands are managed. Transportation and utilities layers (Figure 11) were also included as significant descriptors of current land cover.

This scenario was evaluated by analyzing all priority resources with the defined baseline map, assuming a conservation goal of 100% for those priority resources. Though using "current" data, there are still possibilities of conflict in a baseline scenario. Priority resources such as habitat and rare species populations may currently be affected by certain stressors, though the responses of those resources to stressors have yet to be observed, or recorded. Another obvious cause of potential conflict in a baseline evaluation is the use of data that are not perfectly temporally synchronized. Although all datasets used are the best available for this assessment, they were collected at different, but still recent, time frames. From a practical standpoint, a baseline evaluation is essential as a reference point against which future scenarios will be evaluated.

Refuge Complex

Several priority resources on the Refuge Complex displayed incompatibilities even with current land use. Few of these conflicts were strong in the baseline scenario due to the lack of SLR as a factor in the scenario evaluation.

Table 4. Baseline Scenario Evaluation Output for Priority Resources on Refuge Complex

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Early Successional Upland*	199	40	154	32	77
Freshwater Emergent Marsh*	47	31	15	20	32
Maritime Dune Grassland	237	5	215	3	75
Maritime Dune Grassland*	270	49	270	49	100
Maritime Dune Scrub	366	4	366	4	100
Maritime Dune Scrub*	121	61	120	61	99
Maritime Dune Woodland*	123	36	79	27	64
Maritime Upland Forest - Deciduous Dominated*	33	31	18	17	53
Maritime Upland Forest - Pine Dominated*	203	46	103	38	51
Maritime Wet Grassland G3	39	6	39	6	100
Monarch	9	3	9	3	100
Northeastern Beach Tiger Beetle	240	12	148	9	82

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Salt Flat	353	4	320	2	67
Seaside Low Marsh^	29,317	1	29,138	1	99
Tidal Polyhaline Marsh Complex*	940	198	874	184	93
Upper Beach - Overwash Flats*	215	11	212	11	99
Upper Beach Overwash Flat	1,023	4	1,023	3	100
VIMS Seaside High Flat^	6,663	1	6,630	1	100
VIMS Seaside High Marsh^	45,195	1	44,158	1	98
VIMS Seaside Lagoon^	131,309	1	131,062	1	100

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

Approximately two thirds of Freshwater Emergent Marsh appears to be incompatible with current land cover. Such incompatibilities may be due to data resolution and error, rather than actual conflict. Most likely, the resolution of habitat data used for the Refuge Complex is too coarse to accurately delineate very small patches of habitat on the Refuge Complex, and it is also quite likely that misclassification in the refuge habitat maps also contributed. A second reason for incompatibilities in the baseline could be that indeed there are real conflicts, but when habitat data were developed, stressors were either absent or the resource had not yet expressed the impacts.

Supporting Landscape

The greatest conflict between priority resources and the baseline scenario was the complete conflict of Tidal Mesohaline Polyhaline Marsh, a G5-ranked EO, with the C-CAP land cover stressors (NOAA 2006). This response can be explained by the fact that the single EO for this vegetation community on the supporting landscape is not compatible with existing C-CAP land cover. Otherwise, results of the baseline scenario evaluation at the supporting landscape scale are very similar to that of the Refuge Complex. These results can be attributed to two things. First, since there are more data for priority resources on the Refuge Complex relative to the supporting landscape, the conflicts with stressors are more apparent on the Refuge Complex. Secondly, SLR is not included as a stressor in the baseline scenario. Much of the conflict in the baseline is due to incompatibilities between C-CAP land cover data and the habitat data used to represent priority resources. Since those habitat data only pertain to mapped areas on the refuge complex (from the HMP (USFWS 2010)), no additional conflicts appear in the evaluation of the baseline scenario for the supporting landscape.

Table 5. Baseline Scenario Evaluation Output for Priority Resources on Supporting Landscape

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Early Successional Upland*	199	40	154	32	77
Freshwater Emergent Marsh*	47	31	15	20	32
Maritime Dune Grassland	237	5	215	3	75

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Maritime Dune Grassland*	270	49	270	49	100
Maritime Dune Scrub	366	4	366	4	100
Maritime Dune Scrub*	121	61	120	61	99
Maritime Dune Woodland	206	6	162	5	83
Maritime Dune Woodland*	123	36	79	27	64
Maritime Upland Forest - Deciduous Dominated*	33	31	18	17	53
Maritime Upland Forest - Pine Dominated*	203	46	103	38	51
Maritime Wet Grassland G1	32	2	32	2	100
Maritime Wet Grassland G3	39	6	39	6	100
Monarch	9	3	9	3	100
Northeastern Beach Tiger Beetle	240	12	148	9	82
Salt Flat	353	4	320	2	67
Tidal Mesohaline Polyhaline Marsh G4	1,063	2	1,049	1	100
Tidal Mesohaline Polyhaline Marsh G5	2,197	1	0	0	0
Tidal Polyhaline Marsh Complex*	940	198	874	184	93
Upper Beach Overwash Flat	1,023	4	902	3	100
Upper Beach-Overwash Flats*	215	11	212	11	99
VIMS Seaside High Flat^	6,663	1	6,630	1	100
VIMS Seaside High Marsh^	45,195	1	44,158	1	98
VIMS Seaside Lagoon^	131,309	1	131,062	1	100
VIMS Seaside Low Marsh^	29,317	1	29,138	1	99

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

2025 Scenario Evaluation Results

The 2025 scenario was defined using a combination of C-CAP land cover (NOAA 2006) and the SLAMM 2025 projected wetlands classification (SLAMM 2011). This composite land cover uses SLAMM wetland and open water classifications instead of C-CAP wherever there is spatial overlap (Figure 13).

Figure 13. 2025 SLAMM/C-CAP Composite Land Cover

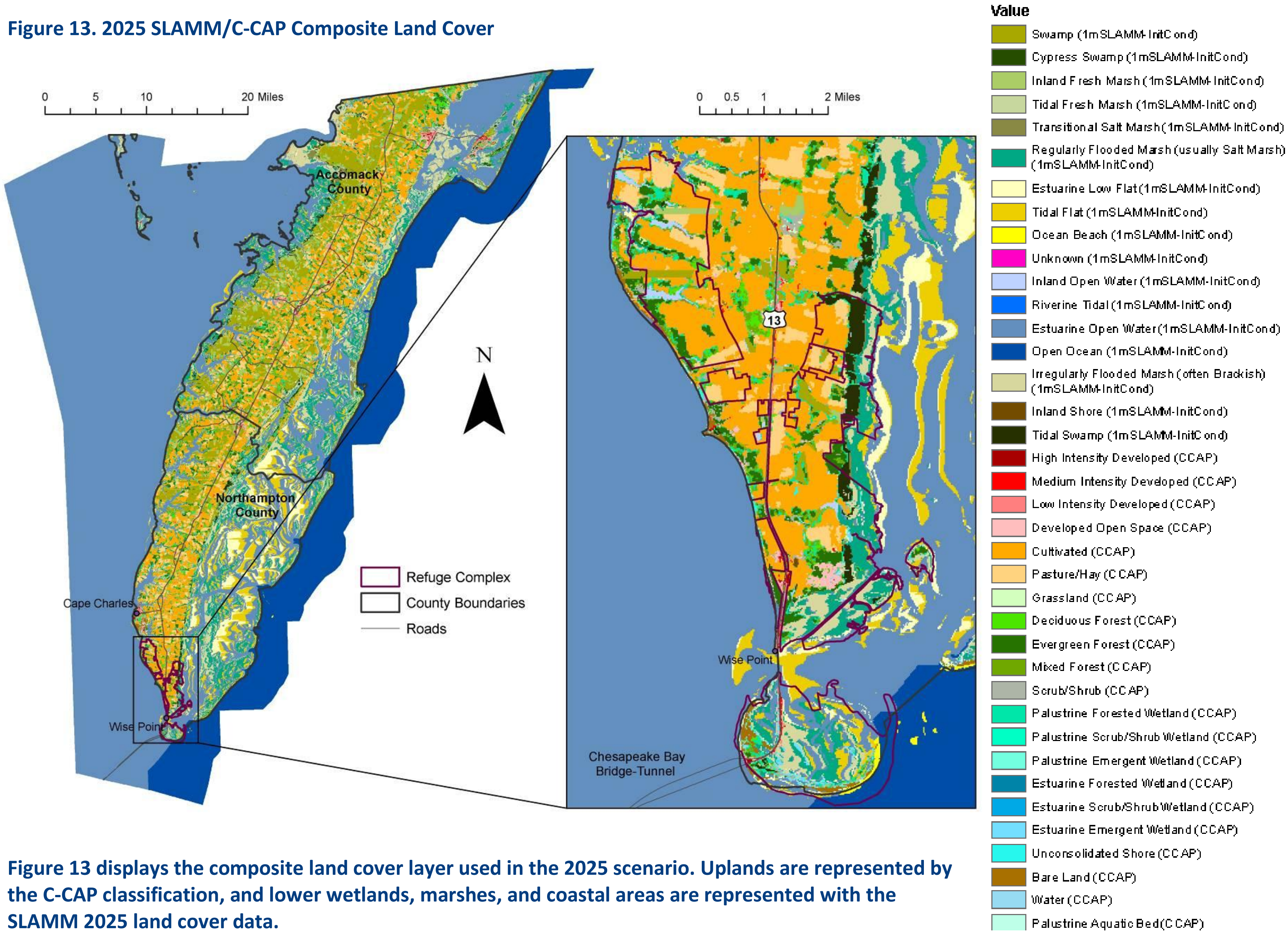


Figure 13 displays the composite land cover layer used in the 2025 scenario. Uplands are represented by the C-CAP classification, and lower wetlands, marshes, and coastal areas are represented with the SLAMM 2025 land cover data.

Refuge Complex

All priority resources display some level of conflict with predicted 2025 land cover, and several priority resources display conflicts with more than 50% of their occurrences or area on the Refuge Complex (Table 6). By 2025, more than 80% of the occurrences and area of the Northeastern Beach Tiger Beetle are predicted to be in conflict due to SLR-induced habitat loss. This result is supported by the predicted 100% loss of Upper Beach Overwash Flat habitat, which is used by this species. More than 80% and 90% of G3-ranked Maritime Wet Grassland EOs and Freshwater Emergent Marsh are predicted to be affected by land cover changes, respectively, and approximately two thirds of Salt Flat communities may be inundated. Less than half of the Maritime Upland Forest types, both Pine and Deciduous-dominated, are predicted to remain without conflict.

Table 6. 2025 Scenario Evaluation Output Table for Priority Resources on Refuge Complex

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Early Successional Upland*	199	40	150	33	75
Estuarine Low Flat (1mSLAMM-Initial Condition)	67,291	1	21,109	1	31
Estuarine Open Water (1mSLAMM-2025)	670,442	1	629,495	1	94
Estuarine Open Water (1mSLAMM-Initial Condition)	604,127	1	578,154	1	96
Freshwater Emergent Marsh*	47	31	5	11	10
Inland Fresh Marsh (1mSLAMM-2025)	11,704	1	8,842	1	76
Inland Fresh Marsh (1mSLAMM-Initial Condition)	10,969	1	8,742	1	80
Inland Open Water (1mSLAMM-2025)	2,164	1	1,142	1	53
Inland Open Water (1mSLAMM-Initial Condition)	2,119	1	1,082	1	51
Inland Shore (1mSLAMM-2025)	78	1	36	1	46
Inland Shore (1mSLAMM-Initial Condition)	121	1	48	1	39
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-2025)	44,041	1	37,306	1	85
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-Initial Condition)	65,731	1	40,467	1	62
Maritime Dune Grassland	237	5	133	2	50
Maritime Dune Grassland*	270	49	170	41	63
Maritime Dune Scrub	366	4	229	3	75
Maritime Dune Scrub*	121	61	77	50	64
Maritime Dune Woodland*	123	36	63	26	51

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Maritime Upland Forest - Deciduous Dominated*	33	31	15	15	44
Maritime Upland Forest - Pine Dominated*	203	46	96	36	47
Maritime Wet Grassland G3	39	6	1	1	17
Monarch	9	3	9	3	100
Northeastern Beach Tiger Beetle	240	12	30	2	18
Ocean Beach (1mSLAMM-Initial Condition)	3,298	1	1,945	1	59
Open Ocean (1mSLAMM-2025)	193,661	1	185,151	1	96
Open Ocean(1mSLAMM-Initial Condition)	190,497	1	182,846	1	96
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-2025)	51,227	1	14	1	28
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-Initial Condition)	40,998	1	7,548	1	18
Salt Flat	353	2	16	1	33
Seaside Low Marsh^	29,317	1	18,834	1	64
Swamp (1mSLAMM-2025)	65,400	4	49,946	1	76
Swamp (1mSLAMM-Initial Condition)	52,685	1	41,635	1	79
Tidal Flat (1mSLAMM-Initial Condition)	44,781	1	12,926	1	29
Tidal Flat (1mSLAMM-2025)	38,298	1	34,614	1	90
Tidal Fresh Marsh (1mSLAMM-2025)	1,050	1	478	1	46
Tidal Fresh Marsh (1mSLAMM-Initial Condition)	1,058	1	491	1	46
Tidal Polyhaline Marsh Complex*	940	198	621	151	66
Tidal Swamp (1mSLAMM-2025)	6,612	1	5,060	1	77
Tidal Swamp (1mSLAMM-Initial Condition)	7,058	1	5,096	1	72
Transitional Salt Marsh (1mSLAMM-2025)	3,472	1	1,866	1	54
Transitional Salt Marsh (1mSLAMM-Initial Condition)	5,506	1	941	1	17
Upper Beach - Overwash Flats*	215	11	59	10	27
Upper Beach Overwash Flat	1,023	4	0	0	0
VIMS Seaside High Flat^	6,663	1	5,538	1	83
VIMS Seaside High Marsh^	45,195	1	37,581	1	83
VIMS Seaside Lagoon^	131,309	1	115,668	1	88

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

Supporting Landscape

Relative to the baseline scenario evaluation, several additional priority habitats outside the Refuge Complex display decreased compatibility because of land cover changes in 2025 (Table 7). Pine-dominated upland forests are predicted to have greater conflict in the supporting landscape. All current areas of Maritime Dune Woodlands and Seaside High Marsh are predicted to be lost as a result of SLR. Similarly, less than 20% of the current area of Seaside Low Marsh is predicted to remain.

Table 7. 2025 Scenario Evaluation Output Table for Priority Resources on Supporting Landscape.

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Cypress Swamp (1mSLAMM-2025)	5	1	5	1	100
Cypress Swamp (1mSLAMM-Initial Condition)	5	1	5	1	100
Estuarine Low Flat (1mSLAMM-2025)	22,157	1	20,095	1	91
Estuarine Low Flat (1mSLAMM-Initial Condition)	67,291	1	21,109	1	31
Estuarine Open Water (1mSLAMM-2025)	670,442	1	629,495	1	94
Estuarine Open Water (1mSLAMM-Initial Condition)	604,127	1	578,154	1	96
Inland Fresh Marsh (1mSLAMM-2025)	11,704	1	8,842	1	76
Inland Fresh Marsh (1mSLAMM-Initial Condition)	10,969	1	8,742	1	80
Inland Open Water (1mSLAMM-2025)	2,164	1	1,142	1	53
Inland Open Water (1mSLAMM-Initial Condition)	2,119	1	1,082	1	51
Inland Shore (1mSLAMM-2025)	78	1	36	1	46
Inland Shore (1mSLAMM-Initial Condition)	121	1	48	1	39
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-2025)	44,041	1	37,303	1	85
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-Initial Condition)	65,731	1	40,467	1	62
Maritime Dune Scrub	366	4	229	3	75
Maritime Dune Woodland	206	6	116	4	67
Maritime Dune Woodland*	0	1	0	0	0

Maritime Upland Forest - Pine Dominated*	4	6	0	0	0
Maritime Wet Grassland G3	39	6	1	1	17
Monarch	9	1	9	3	100
Ocean Beach (1mSLAMM-2025)	2,197	1	1,891	1	86
Ocean Beach (1mSLAMM-Initial Condition)	3,298	1	1,945	1	59
Open Ocean (1mSLAMM-2025)	193,661	1	185,151	1	96
Open Ocean (1mSLAMM-Initial Condition)	190,497	1	182,846	1	96
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-2025)	51,227	1	14,275	1	28
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-Initial Condition)	40,998	1	7548	1	18
Riverine Tidal (1mSLAMM-2025)	9	1	7	1	78
Riverine Tidal (1mSLAMM-Initial Condition)	48	1	5	1	10
Swamp (1mSLAMM-2025)	65,400	1	49,946	1	76
Swamp (1mSLAMM-Initial Condition)	52,685	1	41,635	1	79
Tidal Flat (1mSLAMM-2025)	38,298	1	34,614	1	90
Tidal Flat (1mSLAMM-Initial Condition)	44,781	1	12,926	1	29
Tidal Fresh Marsh (1mSLAMM-2025)	1,050	1	478	1	46
Tidal Fresh Marsh (1mSLAMM-Initial Condition)	1,058	1	491	1	46
Tidal Mesohaline Polyhaline Marsh G5	2,197	1	0	0	0
Tidal Polyhaline Marsh Complex*	294	76	171	55	58
Tidal Swamp (1mSLAMM-2025)	6,612	1	5,060	1	77
Tidal Swamp (1mSLAMM-Initial Condition)	7,058	3	5,096	1	72
Transitional Salt Marsh (1mSLAMM-2025)	3,472	1	1,866	1	54
Transitional Salt Marsh (1mSLAMM-Initial Condition)	5,506	1	941	1	17
Unknown (1mSLAMM-2025)	1	1	0	0	0
Unknown (1mSLAMM-Initial Condition)	2	1	0	0	0
VIMS Seaside High Marsh^	1	1	0	0	0
VIMS Seaside Lagoon^	131,309	1	115,668	1	88

VIMS Seaside Low Marsh^	636	1	123	1	19

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

Figure 14 provides a map of predicted conflicts with priority resources. The bulk of conflict is predicted in lower coastal areas on the eastern shores and marshes of the supporting landscape, indicating that SLR is the most prevalent stressor. Otherwise, some conflict can be attributed to development as well, as indicated in the Cape Charles area and along U.S. Highway 13. The Assateague Island area also displays high conflict, due to coastal waters being zoned as incorporated town.

Figure 14. Future 2025 Conflict

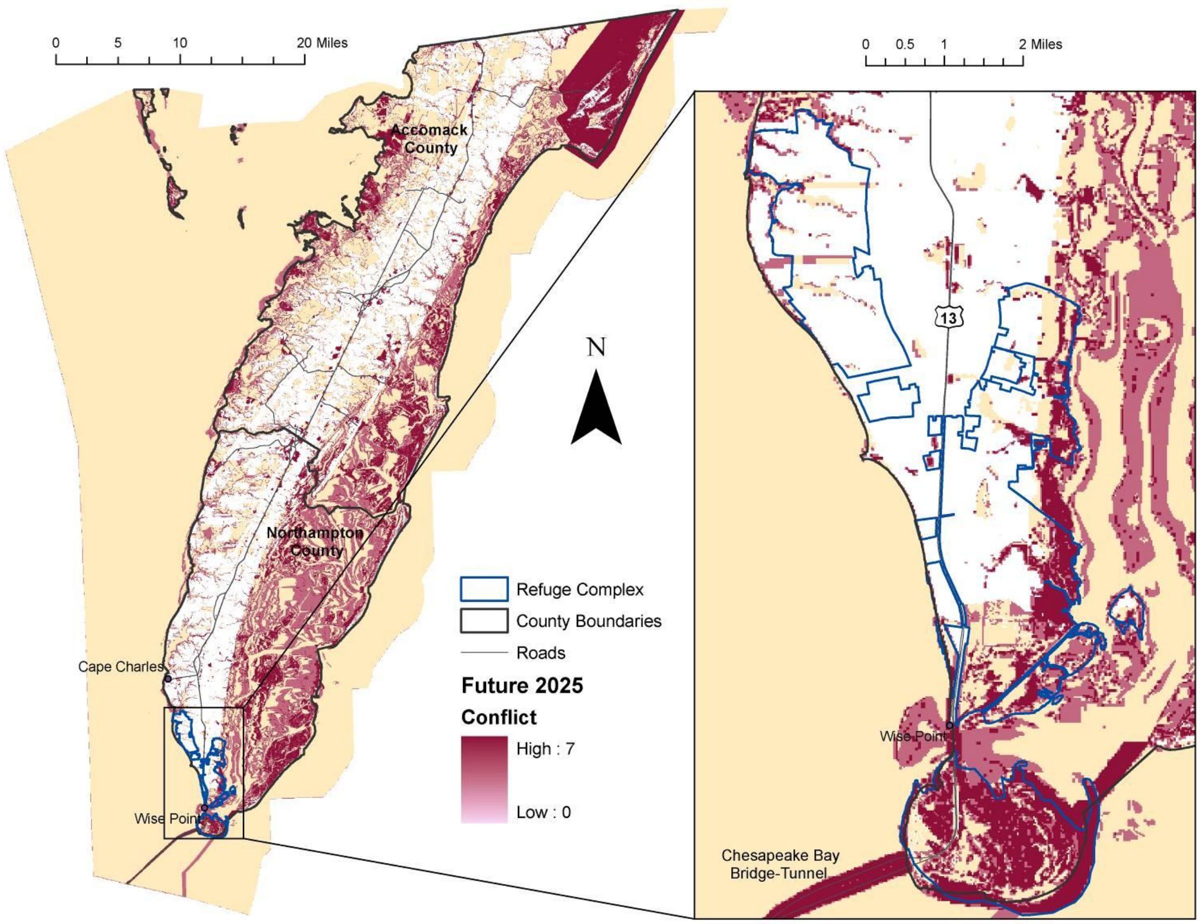
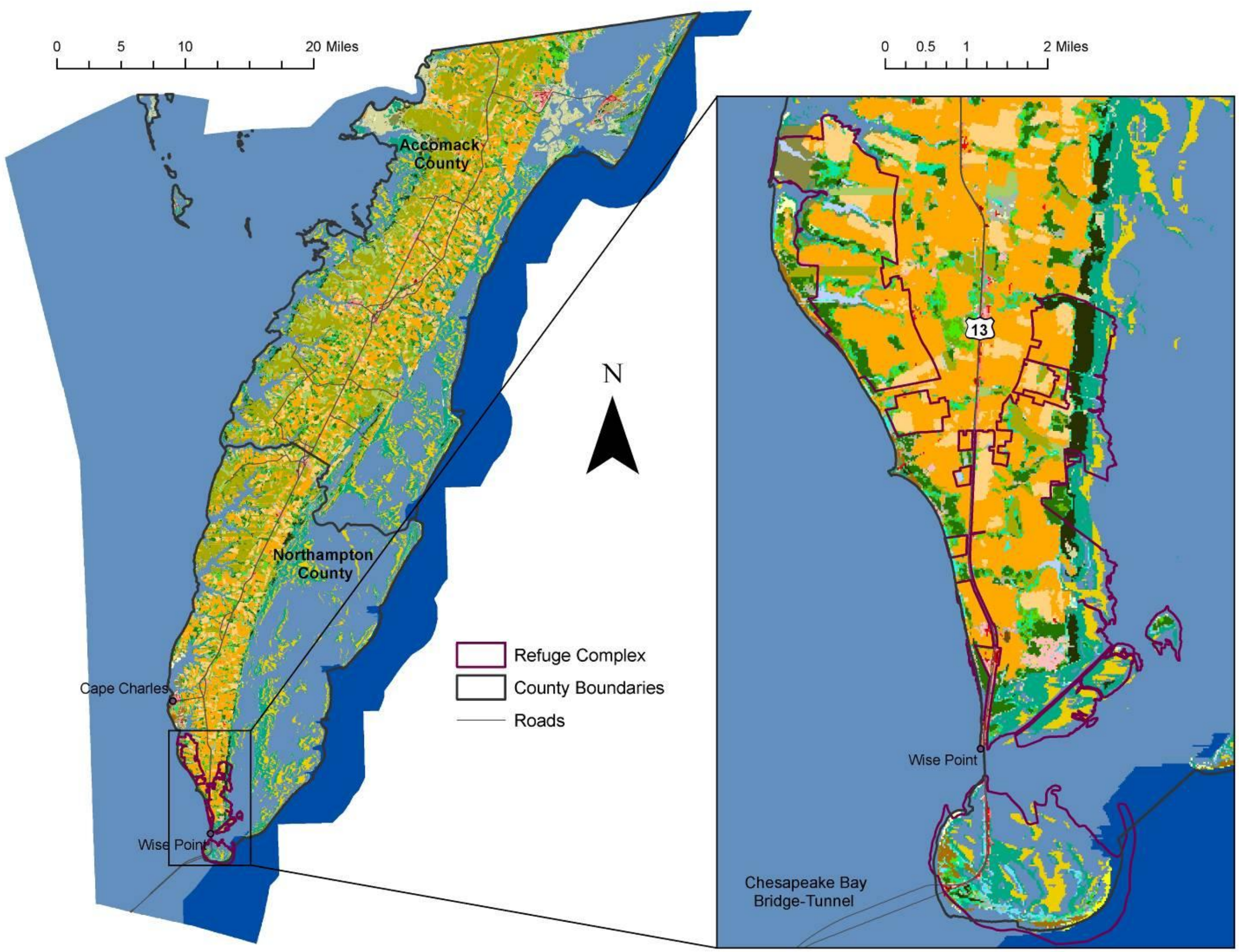


Figure 14 illustrates the predicted conflicts in 2025. All shaded areas are predicted to be vulnerable to stressors (i.e., SLR and development) included in scenario evaluations, where darker shades indicate more conflict.

2050 Scenario Evaluation Results

The 2050 scenario was defined using a combination of C-CAP land cover (NOAA 2006) and the SLAMM 2050 projected wetlands classification where SLAMM classifications replace those of C-CAP wherever there is spatial overlap in wetland areas (Figure 15). The 2050 SLAMM scenario retained projected urbanization from 2025 but did not extrapolate further growth since then.

Figure 15. 2050 SLAMM/C-CAP Composite Land Cover



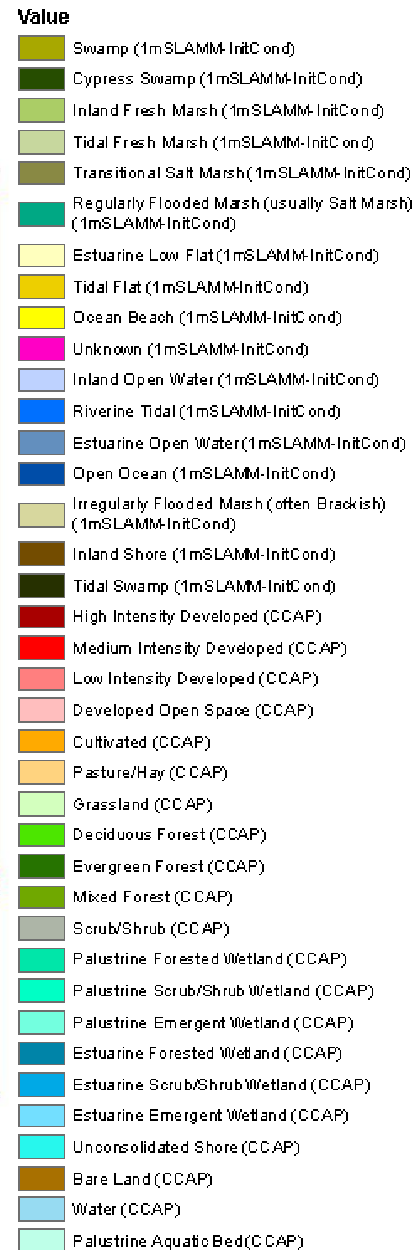


Figure 15 displays the composite land cover layer used in the 2050 scenario. Uplands are represented by the C-CAP classification, and lower wetlands, marshes, and coastal areas are represented with the SLAMM 2050 land cover data.

Refuge Complex

No further loss of Northeastern Beach Tiger Beetle was predicted between the 2025 and 2050 time steps, though Upper Beach Overwash Flats are predicted to be absent from the Refuge Complex by 2050. The 2025 extent of Salt Flat community and the one known EO for Maritime Wet Grassland (G3) are also predicted to remain without further conflict. By 2050, only half the Maritime Dune Grassland EOs are predicted to be intact.

Table 8. 2050 Scenario Evaluation Output Table for Priority Resources on Refuge Complex

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Early Successional Upland*	199	40	149	32	75
Estuarine Low Flat (1mSLAMM-2050)	2,542	1	1,380	1	54
Estuarine Low Flat (1mSLAMM-Initial Condition)	67,291	1	384	1	1
Estuarine Open Water (1mSLAMM-2050)	738,160	1	682,630	1	92
Estuarine Open Water (1mSLAMM-Initial Condition)	604,127	1	577,278	1	96
Freshwater Emergent Marsh*	47	31	5	11	10
Inland Fresh Marsh (1mSLAMM-2050)	11,784	1	8,863	1	75
Inland Fresh Marsh (1mSLAMM-Initial Condition)	10,969	1	8,731	1	80
Inland Open Water (1mSLAMM-2050)	2,143	1	1,136	1	53
Inland Open Water (1mSLAMM-Initial Condition)	2,119	1	1,076	1	51
Inland Shore (1mSLAMM-2050)	1	1	36	1	46
Inland Shore (1mSLAMM-Initial Condition)	121	1	48	1	39
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-2050)	16,020	1	12,867	1	80
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-Initial Condition)	65,731	1	13,308	1	20
Maritime Dune Grassland	237	5	131	2	50
Maritime Dune Grassland*	270	49	152	41	56
Maritime Dune Scrub	366	4	211	3	75
Maritime Dune Scrub*	121	61	73	45	61
Maritime Dune Woodland*	123	36	62	26	51

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Maritime Upland Forest - Deciduous Dominated*	33	31	14	15	43
Maritime Upland Forest - Pine Dominated*	203	46	95	36	47
Maritime Wet Grassland G3	39	6	1	1	17
Monarch	9	3	9	3	100
Northeastern Beach Tiger Beetle	240	12	27	2	18
Ocean Beach (1mSLAMM-Initial Condition)	3,298	1	911	1	28
Ocean Beach (1mSLAMM-2050)	1,303	1	1,079	1	83
Open Ocean (1mSLAMM-2050)	196,736	1	187,504	1	95
Open Ocean(1mSLAMM-Initial Condition)	190,497	1	182,853	1	96
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-2050)	41,426	1	13,654	1	33
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-Initial Condition)	40,998	1	1,862	1	5
Salt Flat	353	4	11	1	33
Seaside Low Marsh^	29,317	1	5,132	1	18
Swamp (1mSLAMM-2050)	69,602	1	52,159	1	75
Swamp (1mSLAMM-Initial Condition)	52,685	1	41,418	1	79
Tidal Flat (1mSLAMM-Initial Condition)	44781	1	2798	1	6
Tidal Flat (1mSLAMM-2050)	30,818	1	26,892	1	87
Tidal Fresh Marsh (1mSLAMM-2050)	1,041	1	476	1	46
Tidal Fresh Marsh (1mSLAMM-Initial Condition)	1,058	1	484	1	46
Tidal Polyhaline Marsh Complex*	940	198	343	112	37
Tidal Swamp (1mSLAMM-2050)	5,957	1	4,557	1	77
Tidal Swamp (1mSLAMM-Initial Condition)	7,058	1	4,591	1	65
Transitional Salt Marsh (1mSLAMM-2050)	3,887	1	1,557	1	40

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Transitional Salt Marsh (1mSLAMM-Initial Condition)	5,506	1	648	1	12
Upper Beach - Overwash Flats*	215	11	44	10	21
Upper Beach Overwash Flat	1,023	4	0	0	0
VIMS Seaside High Flat^	6,663	1	5,503	1	83
VIMS Seaside High Marsh^	45,195	1	23,366	1	52
VIMS Seaside Lagoon^	131,309	1	114,955	1	88

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

Several habitat types represented by derived spatial datasets (based on HMP priority habitats) also begin to show substantial conflict in 2050. Similar to the Upper Beach Overwash Flats EOs, nearly 80% of the Upper Beach Overwash Flats habitat as derived from Refuge Complex habitat maps is predicted to be in conflict on the Refuge Complex. Multiple marsh habitats are also predicted to decrease as a result of SLR: Freshwater Emergent Marsh is predicted to maintain approximately 10% of current extent on the Refuge Complex, Seaside Low Marsh will have 18% remaining, and less than 40% of Tidal Polyhaline Marsh Complex will remain. No additional changes in Maritime Upland Forests, nor Pine- and Deciduous-dominated types were predicted between 2025 and 2050.

Supporting Landscape

Supporting landscape EOs for Northeastern Beach Tiger Beetle, Salt Flat, and Maritime Dune Grassland and derived Upper Beach Overwash Flats, Tidal Polyhaline Marsh Complex, and Maritime Upland-Deciduous Dominated forest habitats do not differ from the Refuge Complex (see Table 8 versus Table 9 for these resources). Areas of derived Maritime Upland Pine-Dominated forest are predicted to be absent from the supporting landscape in 2050.

Table 9. 2050 Scenario Evaluation Output Table for Priority Resources on Supporting Landscape

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Cypress Swamp (1mSLAMM-2050)	5	1	5	1	100
Cypress Swamp (1mSLAMM-Initial Condition)	5	1	5	1	100
Early Successional Upland*	199	40	149	32	75
Estuarine Low Flat (1mSLAMM-2050)	2,542	1	1,380	1	54
Estuarine Low Flat (1mSLAMM-Initial Condition)	67,291	1	384	1	1
Estuarine Open Water (1mSLAMM-2050)	738,160	1	682,630	0	92

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Estuarine Open Water (1mSLAMM-Initial Condition)	604,127	1	577,278	1	96
Inland Fresh Marsh (1mSLAMM-2050)	11,784	1	8,863	1	75
Inland Fresh Marsh (1mSLAMM-Initial Condition)	10,969	1	8,731	1	80
Inland Open Water (1mSLAMM-2050)	2,143	1	1,136	1	53
Inland Open Water (1mSLAMM-Initial Condition)	2,119	1	1,076	1	51
Inland Shore (1mSLAMM-2050)	78	1	36	1	46
Inland Shore (1mSLAMM-Initial Condition)	121	1	48	1	39
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-2050)	16,020	1	12,867	0	80
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-Initial Condition)	65,731	1	13,308	1	20
Maritime Dune Grassland	237	5	131	2	50
Maritime Dune Grassland*	270	49	152	41	56
Maritime Dune Scrub	366	4	211	3	75
Maritime Dune Woodland	206	6	112	4	67
Maritime Upland Forest - Deciduous Dominated*	33	31	14	15	43
Maritime Upland Forest - Pine Dominated*	2	4	0	0	0
Maritime Wet Grassland G1	32	2	20	2	100
Monarch	9	3	9	3	100
Northeastern Beach Tiger Beetle	1	1	0	0	0
Ocean Beach (1mSLAMM-2050)	1,303	1	1,079	1	83
Ocean Beach (1mSLAMM-Initial Condition)	3,298	1	911	1	28
Open Ocean (1mSLAMM-2050)	196,736	1	187,504	1	95
Open Ocean (1mSLAMM-Initial Condition)	190,497	1	182,853	1	96
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-2050)	41,426	1	13,654	1	33

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-Initial Condition)	40,998	1	1,862	1	5
Riverine Tidal (1mSLAMM-2050)	6	1	6	1	100
Riverine Tidal (1mSLAMM-Initial Condition)	48	1	3	1	7
Salt Flat	353	4	11	1	33
Swamp (1mSLAMM-2050)	69,602	1	52,159	1	75
Swamp (1mSLAMM-Initial Condition)	52,685	1	41,418	1	79
Tidal Flat (1mSLAMM-2050)	30,818	1	26,892	1	87
Tidal Flat (1mSLAMM-Initial Condition)	44,781	1	2,798	1	6
Tidal Fresh Marsh (1mSLAMM-2050)	1,041	1	476	1	46
Tidal Fresh Marsh (1mSLAMM-Intial Condition)	1,058	1	484	1	46
Tidal Polyhaline Marsh Complex*	940	198	343	112	37
Tidal Swamp (1mSLAMM-2050)	5,957	1	4,557	1	77
Tidal Swamp (1mSLAMM-Initial Condition)	7,058	1	4,591	0	65
Transitional Salt Marsh (1mSLAMM-2050)	3,887	1	1,557	1	40
Transitional Salt Marsh (1mSLAMM-Initial Condition)	5,506	1	648	1	12
Unknown (1mSLAMM-Initial Condition)	2	1	0	0	0
Upper Beach Overwash Flats*	215	11	44	10	21
VIMS Seaside High Flat^	98	1	92	1	94
VIMS Seaside High Marsh^	7	1	0	0	0
VIMS Seaside Lagoon^	131,309	1	114,955	1	88

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

Note: The apparent total loss of Maritime Upland Pine-Dominated forest on the supporting landscape is based on a very small amount of mapped habitat data used in this RVA. This habitat type was mapped only on the Refuge Complex, and thus any habitat in the supporting landscape was not included in the analysis due to lack of data.

Figure 16 maps predicted conflicts with priority resources in 2050. As in 2025, the bulk of conflict occurs in lower coastal areas on the seaside shores and marshes of the supporting landscape, indicating that SLR is the most prevalent stressor. However, in 2025, much of the conflict along the Eastern Shore could be attributed to developed areas. In 2050, SLR impacts seem to account for most conflict on the bay side of the Eastern Shore as well. Conflict along U.S. Highway 13 appears to be relatively unchanged relative to 2025.

Figure 16. Future 2050 Conflict

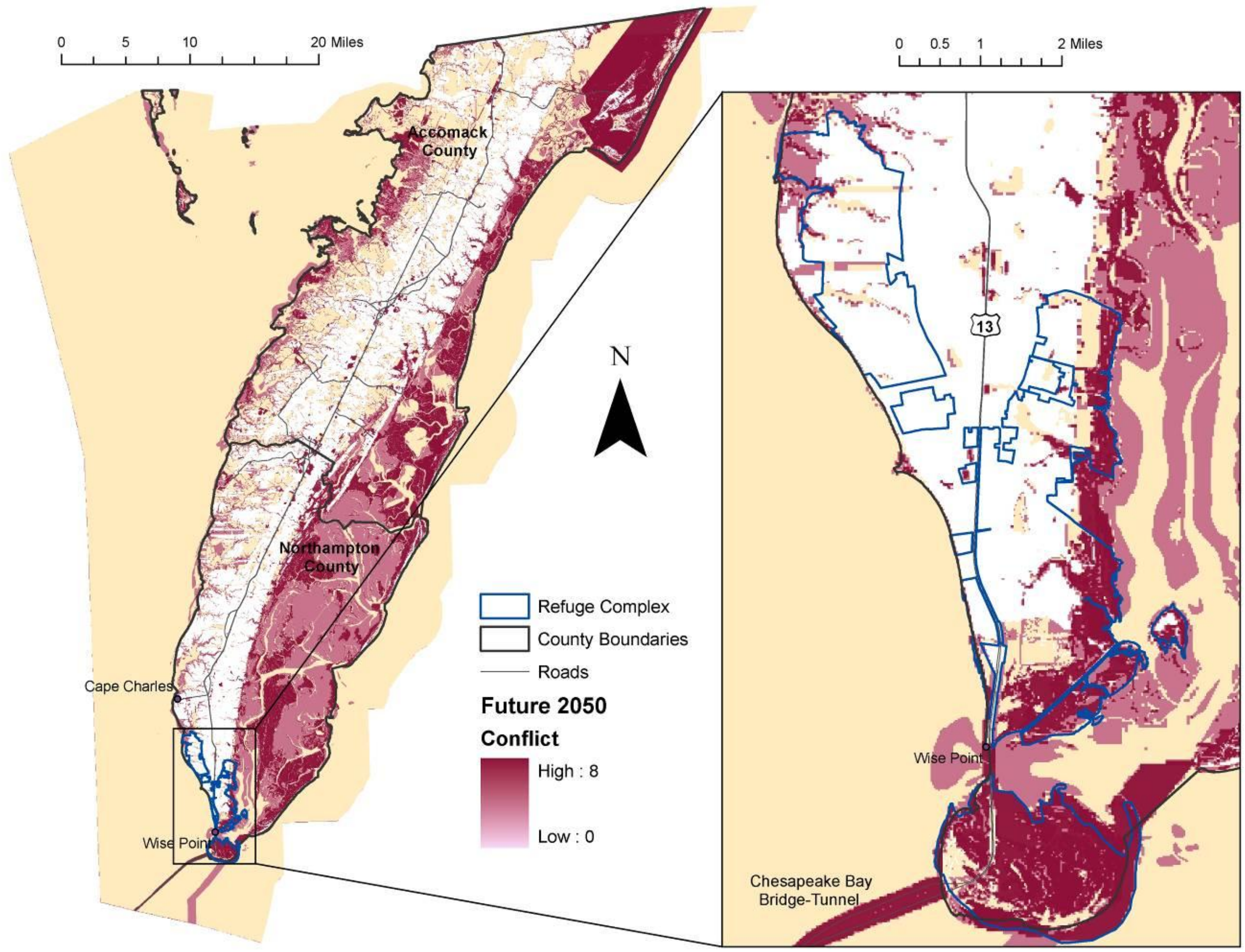
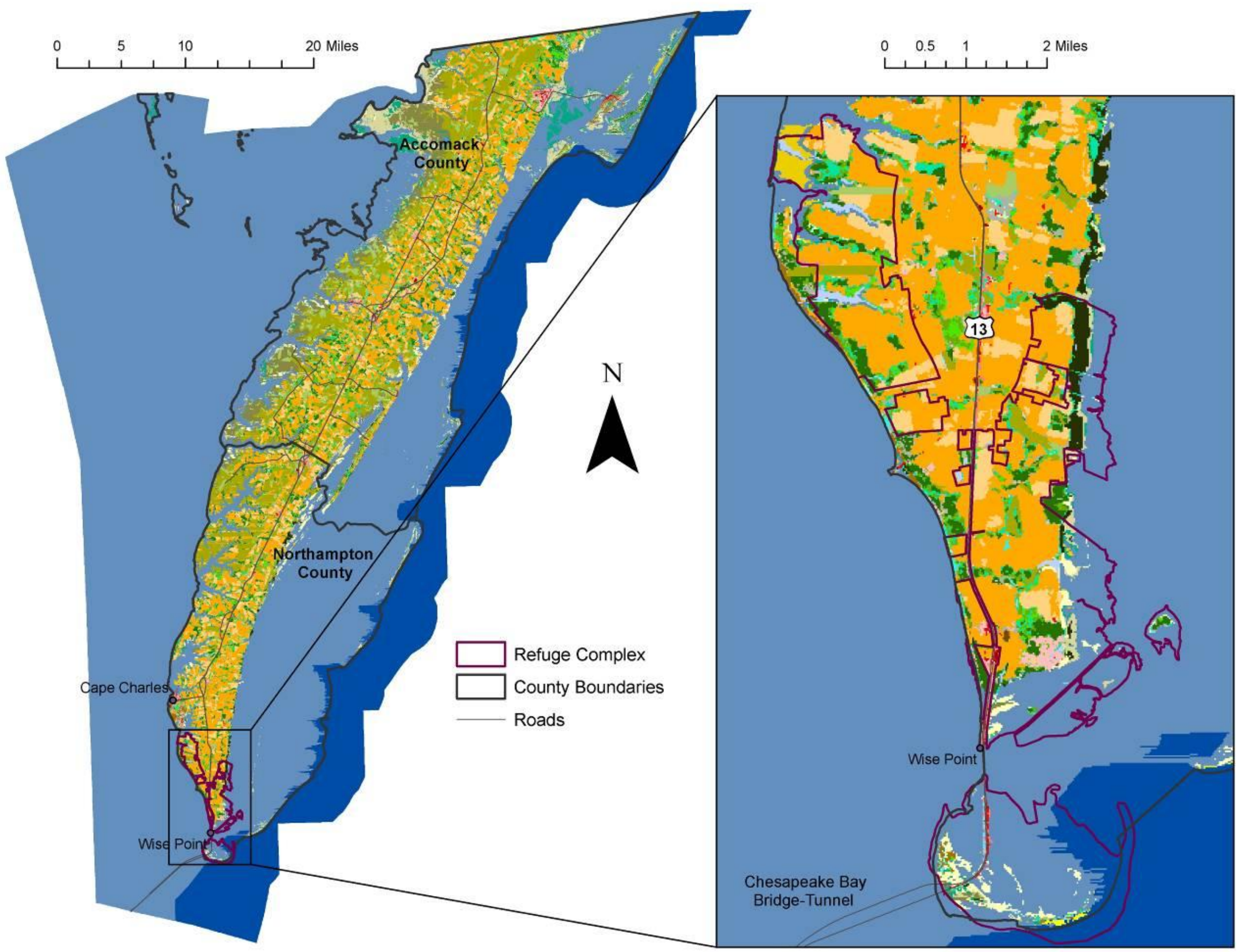


Figure 16 illustrates predicted conflicts in 2050. Shaded areas are predicted to be vulnerable to stressors of SLR and development as included in scenario evaluations, where darker shades indicate more conflict.

2100 Scenario Evaluation Results

The 2100 scenario was defined using a combination of C-CAP land cover (NOAA 2006) and the SLAMM 2100 projected wetlands classification, where SLAMM wetland classes replaced the C-CAP classes in areas of overlap (Figure 17).

Figure 17. 2100 SLAMM/C-CAP Composite Land Cover



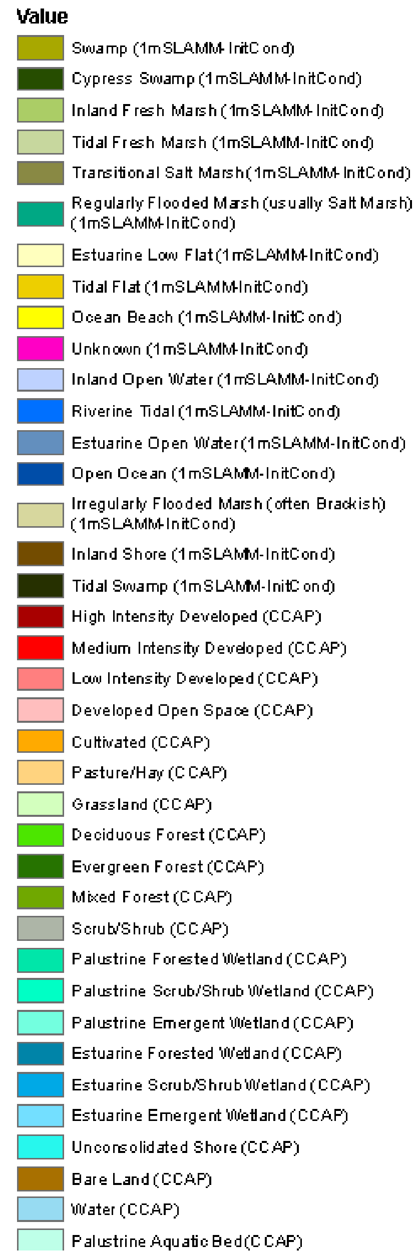


Figure 17 displays the composite land cover layer used in the 2100 scenario. Uplands are represented by the C-CAP classification, and lower wetlands, marshes, and coastal areas are represented with the SLAMM 2100 land cover data.

Refuge Complex

In 2100, no remaining Salt Flat community occurrences are predicted to occur on the Refuge Complex. Seventy-five percent of Maritime Dune Grassland and 83% of Maritime Wet Grassland (G3) community EOs are predicted to be lost or converted. Northeastern Beach Tiger Beetle EOs are unchanged from 2050, with two EOs remaining.

Several habitats derived from the HMP (USFWS 2010) also display increased conflict with stressors. Half of the 2050 area of Upper Beach Overwash Flats is predicted to remain at 2100 (less than 25 acres). Seaside Low Marsh habitat is predicted to be extirpated from the Refuge Complex, and less than 10% of Seaside High Marsh is predicted to remain. Less than 3% of each Tidal Polyhaline Marsh Complex and Freshwater Emergent Marsh types are predicted to remain on the Refuge Complex. Overall, the majority of marshes, flats, and beach habitats currently within the Refuge Complex are predicted to have been converted to open water and lagoon by 2100. Maritime Upland Forests are still predicted to remain on the Refuge Complex proper: about 35% of Pine-dominated and 40% of Deciduous-dominated forests are predicted to remain.

Table 10. 2100 Scenario Evaluation Output Table for Priority Resources on Refuge Complex

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Early Successional Upland*	199	40	145	32	73
Estuarine Low Flat (1mSLAMM-2100)	7,110	1	4,643	1	65
Estuarine Low Flat (1mSLAMM-Initial Condition)	67,291	1	163	1	0
Estuarine Open Water (1mSLAMM-2100)	808,091	1	708	1	88
Estuarine Open Water (1mSLAMM-Initial Condition)	604,127	1	574,764	1	95
Freshwater Emergent Marsh*	47	31	1	4	3
Inland Fresh Marsh (1mSLAMM-2100)	11,466	1	8,647	1	75
Inland Fresh Marsh (1mSLAMM-Initial Condition)	10,959	1	8,600	1	78
Inland Open Water (1mSLAMM-2100)	1,976	1	1,072	1	54
Inland Open Water (1mSLAMM-Initial Condition)	2,119	1	1,032	1	49
Inland Shore (1mSLAMM-2100)	121	1	46	1	38
Inland Shore (1mSLAMM-Initial Condition)	76	1	35	1	46
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-2100)	12,110	1	9,690	1	80

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Irregularly Flooded Marsh (often Brackish) (1mSLAMM-Initial Condition)	65,731	1	7,592	1	12
Maritime Dune Grassland	237	5	75	1	25
Maritime Dune Grassland*	270	49	73	28	27
Maritime Dune Scrub	366	4	66	3	75
Maritime Dune Scrub*	121	61	32	25	27
Maritime Dune Woodland*	123	36	18	17	14
Maritime Upland Forest - Deciduous Dominated*	33	31	13	12	39
Maritime Upland Forest - Pine Dominated*	203	46	70	31	35
Maritime Wet Grassland G3	39	6	1	1	17
Monarch	9	3	9	3	100
Northeastern Beach Tiger Beetle	240	12	26	2	18
Ocean Beach (1mSLAMM-2100)	296	1	227	1	77
Ocean Beach (1mSLAMM-Initial Condition)	3,298	1	0	0	0
Open Ocean (1mSLAMM-2100)	206,684	1	192,860	1	93
Open Ocean(1mSLAMM-Initial Condition)	190,497	1	182,854	1	96
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-2100)	9,990	1	2,438	1	24
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM-Initial Condition)	40,998	1	402	1	1
Salt Flat	353	4	0	0	0
Seaside Low Marsh^	29,317	1	41	1	0
Swamp (1mSLAMM-2100)	57,455	1	43,106	1	75
Swamp (1mSLAMM-Initial Condition)	52,685	1	34,605	1	66
Tidal Flat (1mSLAMM-Initial Condition)	44,781	1	203	1	0
Tidal Flat (1mSLAMM-2100)	1,686	1	1,014	1	60
Tidal Fresh Marsh (1mSLAMM-2100)	993	1	457	1	46
Tidal Fresh Marsh (1mSLAMM-Initial Condition)	1,058	1	459	1	43
Tidal Polyhaline Marsh Complex*	940	198	1	5	0
Tidal Swamp (1mSLAMM-2100)	2,054	1	1,522	1	74

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Tidal Swamp (1mSLAMM-Initial Condition)	7,058	1	1,567	1	22
Transitional Salt Marsh (1mSLAMM-2100)	22,498	1	14,331	1	64
Transitional Salt Marsh (1mSLAMM-Initial Condition)	5,506	1	630	1	11
Upper Beach - Overwash Flats*	215	11	25	8	12
Upper Beach Overwash Flat	1,023	4	0	0	0
VIMS Seaside High Flat^	6,663	1	5,234	1	79
VIMS Seaside High Marsh^	45,195	1	3,934	1	9
VIMS Seaside Lagoon^	131,309	1	112,493	1	86

* derived habitat element at the refuge level
^ derived habitat resource at the supporting landscape level

Supporting Landscape

While Northeastern Beach Tiger Beetle is predicted to remain on the Refuge Complex in 2100, it is predicted to be extirpated from the supporting landscape. Likewise, Tidal Mesohaline Polyhaline Marsh EOs, the derived Tidal Mesohaline Polyhaline Marsh Complex, and Salt Flat habitat are predicted to no longer occur on the supporting landscape. Only half of the Maritime Wet Grassland (G1) EO existing off-Refuge Complex is predicted to persist in 2100.

Several additional habitats are predicted to be absent from the supporting landscape: Freshwater Emergent Marsh, Seaside High Flat, Seaside High Marsh, and Maritime Upland Forest – Pine Dominated. Deciduous-Dominated Upland Forest is predicted in slightly less acreage than in 2050. Though not absent, Maritime Dune Grassland and Upper Beach Overwash Flats show a loss of approximately 75% by 2100 where all that remains is on the Refuge Complex. Other habitats with relatively high conflict include Maritime Dune Grassland and Upper Beach Overwash Flats, where all remaining acreage is harbored by the Refuge Complex.

Table 11. 2100 Scenario Evaluation Output Table for Priority Resources on Supporting Landscape

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Cypress Swamp (1mSLAMM - 2100)	5	1	5	1	100
Early Successional Upland*	199	40	145	32	73
Estuarine Low Flat (1mSLAMM - 2100)	7,110	1	4,643	1	65
Estuarine Low Flat (1mSLAMM - Initial Condition)	67,291	1	163	1	0
Estuarine Open Water (1mSLAMM - 2100)	808,091	1	707,522	1	88

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Estuarine Open Water (1mSLAMM - Initial Condition)	604,127	1	574,764	1	95
Freshwater Emergent Marsh*	2	3	0	0	0
Inland Fresh Marsh (1mSLAMM - 2100)	11,466	1	8,647	1	75
Inland Fresh Marsh (1mSLAMM - Initial Condition)	10,969	1	8,600	1	78
Inland Open Water (1mSLAMM - 2100)	1,976	1	1,072	1	54
Inland Open Water (1mSLAMM - Initial Condition)	2,119	1	1,032	1	49
Inland Shore (1mSLAMM - 2100)	76	1	35	1	46
Inland Shore (1mSLAMM - Initial Condition)	121	1	46	1	38
Irregularly Flooded Marsh (often Brackish) (1mSLAMM - 2100)	12,110	1	9,690	1	80
Irregularly Flooded Marsh (often Brackish) (1mSLAMM - Initial Condition)	65,731	1	7,592	1	12
Maritime Dune Grassland	237	5	75	1	25
Maritime Dune Grassland*	270	49	73	28	27
Maritime Upland Forest - Deciduous Dominated*	33	31	13	12	39
Maritime Upland Forest - Pine Dominated*	2	4	0	0	0
Maritime Wet Grassland G1	32	2	14	1	50
Monarch	9	3	9	3	100
Northeastern Beach Tiger Beetle	2	1	0	0	0
Ocean Beach (1mSLAMM - 2100)	296	1	227	1	77
Ocean Beach (1mSLAMM - Initial Condition)	3,298	1	0	0	0
Open Ocean (1mSLAMM - 2100)	206,684	1	192,860	0	93
Open Ocean (1mSLAMM - Initial Condition)	190,497	1	182,854	1	96
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM - 2100)	9,990	1	2,438	1	24

Resource Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Regularly Flooded Marsh (usually Salt Marsh) (1mSLAMM - Initial Condition)	40,998	1	402	1	1
Riverine Tidal (1mSLAMM - 2100)	3	1	3	1	100
Salt Flat	353	4	0	0	0
Swamp (1mSLAMM - 2100)	57,455	1	43,106	1	75
Tidal Flat (1mSLAMM - 2100)	1,686	1	1,014	1	60
Tidal Fresh Marsh (1mSLAMM - 2100)	993	1	457	1	46
Tidal Fresh Marsh (1mSLAMM - Initial Condition)	1,058	1	459	1	43
Tidal Mesohaline Polyhaline Marsh G4	1,063	2	0	0	0
Tidal Mesohaline Polyhaline Marsh G5	2,197	1	0	0	0
Tidal Polyhaline Marsh Complex*	940	198	1	5	0
Tidal Swamp (1mSLAMM - 2100)	2,054	1	1,522	1	74
Tidal Swamp (1mSLAMM - Initial Condition)	59	1	8	1	14
Transitional Salt Marsh (1mSLAMM - Initial Condition)	5,506	1	630	1	11
Transitional Salt Marsh (1mSLAMM - 2100)	22,498	1	14,331	1	64
Unknown (1mSLAMM - Initial Condition)	2	1	0	1	0
Upper Beach - Overwash Flats*	215	11	25	8	12
VIMS Seaside High Flat^	4	1	0	0	0
VIMS Seaside High Marsh^	0	1	0	0	0
VIMS Seaside Lagoon^	131,309	1	112,493	1	86

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

Figure 18 displays the most drastic predictions of all time steps in terms of stressors, namely SLR. All shorelines and streams of the Eastern Shore, seaside and bay side, are predicted to show conflict. In many cases, habitats are predicted to have changed significantly as a result of inundation or altered hydrology.

Figure 18. Future 2100 Conflict

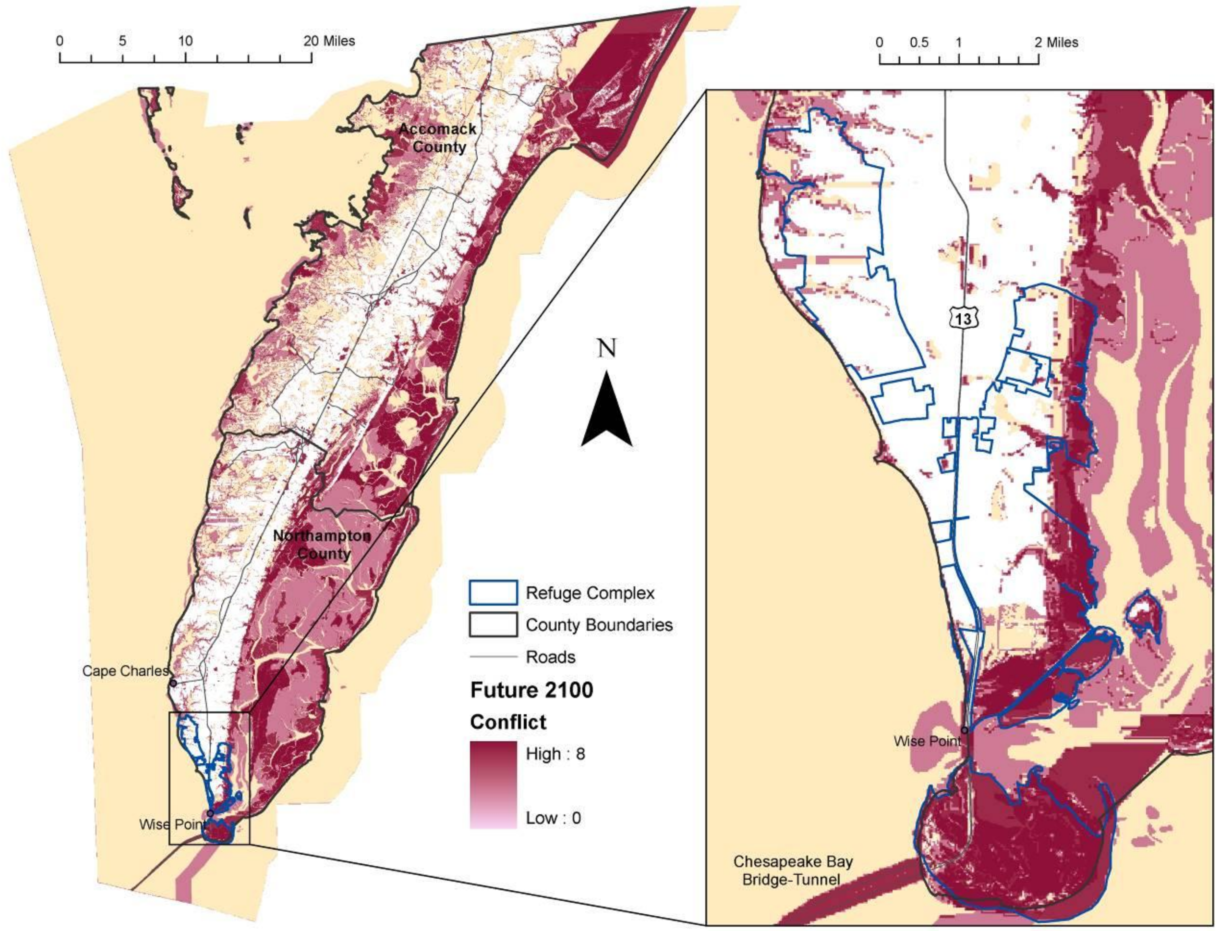


Figure 18 illustrates predicted conflicts in 2100. Shaded areas are predicted to be vulnerable to stressors of SLR and development as included in scenario evaluations, where darker colors indicate greater conflict.

Infrastructure Assessment

Mission Critical Infrastructure for the Refuge Complex (Appendix B) was evaluated as a priority resource via scenarios as defined in the previous Resource Assessment section for each time step—baseline, 2025, 2050, and 2100. Overall, baseline evaluation outputs for the supporting landscape do not differ significantly from that of the Refuge Complex. Refuge Complex MCI do not occur throughout the supporting landscape, but only on refuge lands and small, unacquired parcels within the approved refuge boundary and supporting landscape. Thus Refuge Complex infrastructure on the supporting landscape consists only of those small representations in these interspersed areas, leading to very similar evaluation outputs for the Refuge Complex versus the supporting landscape at each time step.

In addition to MCI, some focus was placed on the projected impacts of SLR on development throughout the supporting landscape. This interpretation might identify interactions between proposed zoning (i.e., anticipated development and other future land-use change) and expected changes in the distribution of marshes and other wetlands. Identification of lands with these potential conflicts could help inform the identification of new Refuge Complex lands.

Baseline Scenario Evaluation Results

All priority infrastructure resources on the Refuge Complex and supporting landscape show 100% compatibility with current, baseline land cover and stressors. It is not until future scenarios that these resources begin to show conflict with stressors. Note that we did not analyze whether excessive use or inadequate maintenance threatened infrastructure resources.

2025 Scenario Evaluation Results

Refuge Complex

The Wise Point Boat Ramp and associated boat launch are predicted to be completely lost by 2025 due to expected SLR, as the boat ramp and gravel lot are functionally at and below sea level currently.

Table 12. 2025 Scenario Evaluation Output for Refuge Infrastructure on Refuge Complex

Infrastructure Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Bridge -Tunnel through Fisherman Island	20	2	20	2	100
Building - Maintenance	1	3	1	3	100
Building - Refuge Residence	3	7	3	7	100
Building - Visitor Center	0.2	1	0.2	1	100
Building - Workamper	0.4	1	0.4	1	100
Building - Refuge Headquarters	0.2	1	0.2	1	100
Communications Tower	0.4	2	0.4	2	100
Parking - Asphalt	2	3	2	3	100
Parking - Gravel	2	1	0	0	0
Road - Asphalt	22	1	18	1	75
Road - Gravel	3	4	3	3	100
Road - Native	4	2	2	2	50
Trail - Gravel	0.2	1	0.2	1	100
Trail - Mowed	1	1	1	1	100
Wise Point Boat Ramp and Dock	0.4	1	0	0	0

Other resources that show reduced compatibility are roads with asphalt and non-gravel native cover (i.e., soil) on the Refuge Complex, where native roads appear to be most vulnerable due to their lower elevations and expected SLR. Roads on the eastern portion of the complex show these first signs of conflict based on SLAMM predictions of SLR. No other infrastructure-related resources show conflict in 2025.

Supporting Landscape

Roads with native cover were the only resource to show conflict on the supporting landscape. Technically, roads within the approved boundary but outside the acquired boundary are on the supporting landscape. These small segments, used for refuge purposes, result in the conflicts of refuge infrastructure on the supporting landscape.

Table 13. 2025 Scenario Evaluation Output for Refuge Infrastructure on Supporting Landscape

Infrastructure Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Bridge -Tunnel through Fisherman Island	20	2	20	2	100
Building – Maintenance	1	3	1	3	100
Building - Refuge Headquarters	0.2	1	0.2	1	100
Canoe - Kayak Launch	0.2	1	0.2	1	100
Road – Gravel	3	2	3	2	100
Road – Native	4	2	2	1	50
Trail – Mowed	1	1	1	1	100

Future scenario evaluations included an assessment of proposed zoning (specifically areas zoned for development) on the supporting landscape against predicted SLAMM wetland distributions at each time step. Outputs from these evaluations can indicate areas were development plans are in conflict with expected land cover changes due to SLR. Figure 19 displays areas currently proposed for development that are predicted to be in a wetland or marsh state at this time step. These outputs are further discussed later in this report.

Figure 19. Conflict Between Future Zoning and SLAMM Wetlands (2025)

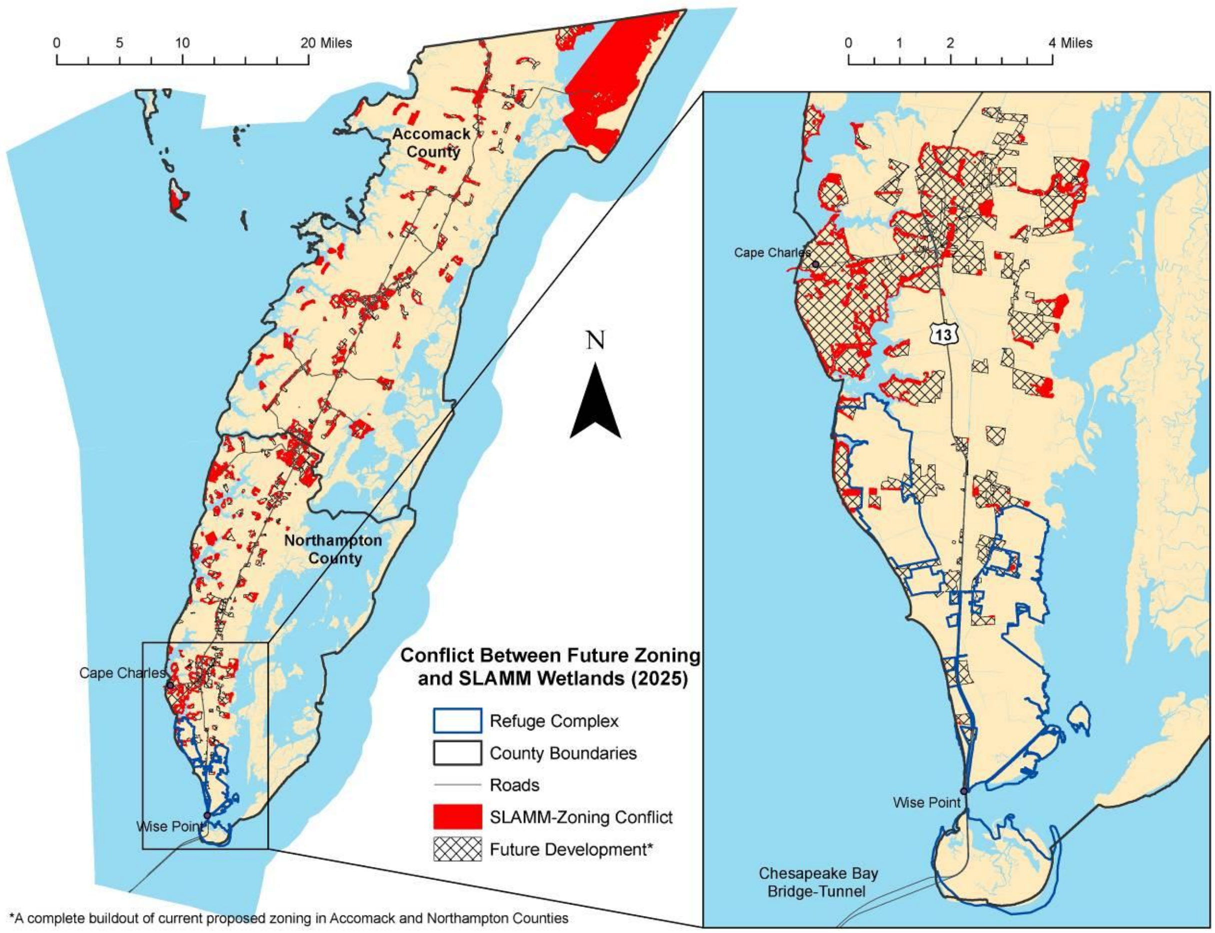


Figure 19 displays areas (red) within the approved Refuge Complex boundary and supporting landscape that are zoned for development (crosshatching) and that are predicted to be in some wetland state in 2025. Note that since the 1-meter SLAMM simulation was utilized for this RVA, developed areas appear to be protected from inundation. In the SLAMM 1-meter simulation, areas currently protected by coastal armoring (e.g. those developed areas upland of dikes, bulkheads and other protective measures) are not modeled to change to wetland and open water types, due to the assumption that this armoring will remain in place.

2050 Scenario Evaluation Results

Refuge Complex

No changes in predicted impacts of SLR on infrastructure resources were observed from 2025 to 2050 on the Refuge Complex.

Supporting Landscape

Future 2050 evaluation outputs for the supporting landscape do not differ markedly from that of the Refuge Complex. Some gravel parking and asphalt roads were the only resources to show conflict on the supporting landscape. Technically, parking lot area and roads within the approved boundary but outside the acquired boundary are on the supporting landscape. These portions are used for refuge purposes and are the source of the conflicts of refuge-specific infrastructure on the supporting landscape.

Table 14. 2050 Scenario Evaluation Output for Refuge Infrastructure on Supporting Landscape

Infrastructure Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Bridge-tunnel through Fisherman Island	20	2	20	2	100
Building - Maintenance	1	3	1	3	100
Building - Refuge Headquarters	0.2	1	0.2	1	100
Building - Refuge Residence	3	7	3	7	100
Building - Visitor Center	0.2	1	0.2	1	100
Building - Workamper	0.4	1	0.4	1	100
Canoe - Kayak Launch	0.2	1	0.2	1	100
Communications Tower	0.4	2	0.4	2	100
Parking - Concrete	0.2	1	0.2	1	100
Parking - Gravel	2	1	0	0	0
Road - Asphalt	22	4	18	3	75
Road - Gravel	3	2	3	2	100
Trail - Gravel	0.2	1	0.2	1	100

Figure 20 displays areas currently proposed for development which are predicted to be in a wetland or marsh state at this time step. These outputs are further discussed later in this report.

Figure 20. Conflict Between Future Zoning and SLAMM Wetlands (2050)

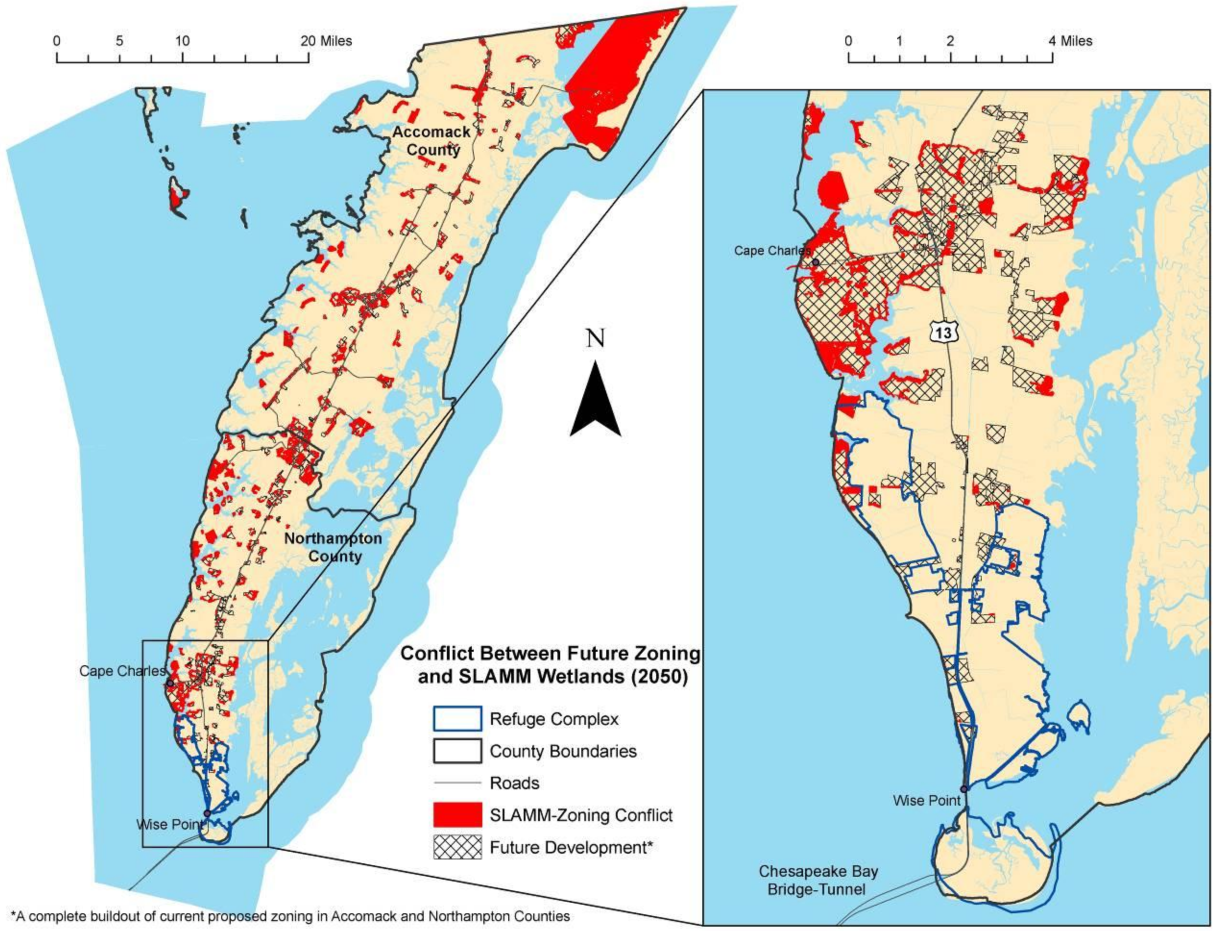


Figure 20 displays areas (red) within the approved Refuge Complex boundary and supporting landscape that are zoned for development (crosshatching) and that are predicted to be in some wetland state in 2050. Note that since the 1-meter SLAMM simulation was utilized for this RVA, developed areas appear to be protected from inundation. In the SLAMM 1-meter simulation, areas currently protected by coastal armoring (e.g. those developed areas upland of dikes, bulkheads and other protective measures) are not modeled to change to wetland and open water types, due to the assumption that this armoring will remain in place.

2100 Scenario Evaluation Results

Refuge Complex

By 2100, asphalt roads begin to show a greater conflict with expected SLR. Through all scenarios, models do not predict SLR conflicts with other infrastructure, including refuge buildings, the raised bridge-tunnel section bisecting Fisherman Island, trails, and asphalt parking.

Table 15. 2100 Scenario Evaluation Output for Refuge Infrastructure on Refuge Complex

Infrastructure Type	Current Area (ac)	Current Occurrences (#)	Compatible Area (ac)	Compatible Occurrences (#)	% Goal Achieved
Bridge - Tunnel through Fisherman Island	20	2	20	2	100
Building - Maintenance	1	3	1	3	100
Building - Refuge Residence	3	7	3	7	100
Building - Visitor Center	0.2	1	0.2	1	100
Building - Workamper	0.4	1	0.4	1	100
Building - Refuge Headquarters	0.2	1	0.2	1	100
Communications Tower	0.4	2	0.4	2	100
Parking - Asphalt	2	3	2	3	100
Parking - Gravel	2	1	0	0	0
Road - Asphalt	22	4	15	2	50
Road - Gravel	3	2	3	2	100
Road - Native	4	2	2	1	50
Trail – Gravel	0.2	1	0.2	1	100
Trail - Mowed	1	1	1	1	100
Wise Point Boat Ramp and Dock	0.4	1	0	0	0

Supporting Landscape

Future 2100 evaluation outputs for the supporting landscape do not differ from that of the Refuge Complex. The proportions of gravel parking areas, asphalt roads, and roads of native cover retained in the supporting landscape are consistent with the proportions retained on the Refuge Complex.

Future scenario evaluations included an assessment of proposed zoning (specifically areas zoned for development) on the supporting landscape, against predicted SLAMM wetland classifications at each time step. Outputs from these evaluations can indicate areas were development plans are in conflict with expected land cover changes due to SLR. Figure 21 displays areas currently proposed for development which are predicted to be in a wetland or marsh state at this time step. These outputs are further discussed later in this report.

Figure 21. Conflict Between Future Zoning and SLAMM Wetlands (2100)

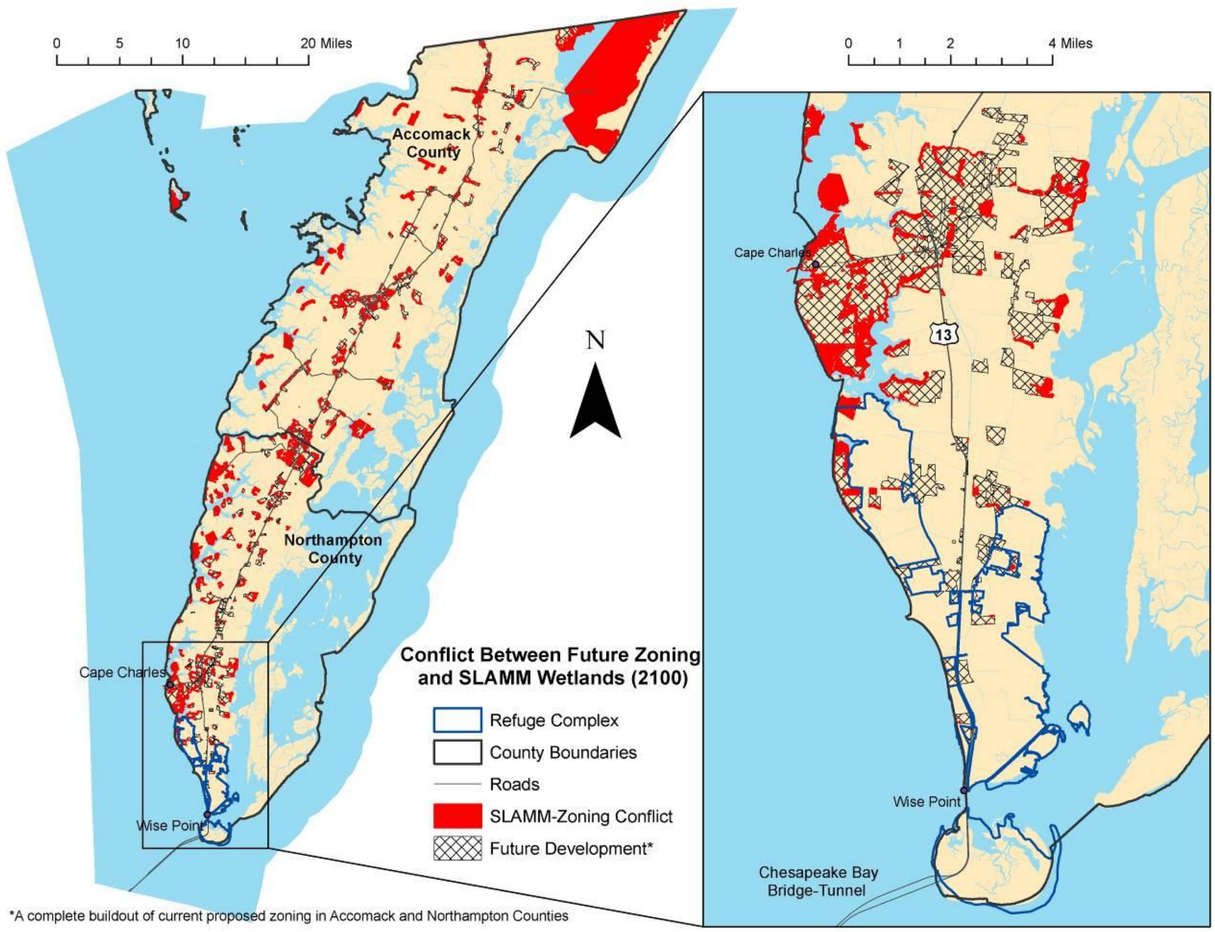


Figure 21 displays areas (red) within the approved Refuge Complex boundary and supporting landscape that are zoned for development (crosshatching) and that are predicted to be in some wetland state in 2100. Note that since the 1-meter SLAMM simulation was utilized for this RVA, developed areas appear to be protected from inundation. In the SLAMM 1-meter simulation, areas currently protected by coastal armoring (e.g., those developed areas upland of dikes, bulkheads and other protective measures) are not modeled to change to wetland and open water types, due to the assumption that this armoring will remain in place.

Chapter 5. Refuge Management Direction: Goals, Objectives, and Strategies

This study is primarily focused on assessing priority resources to gain a better understanding of how sea level rise (SLR) and development may impact them on the Refuge Complex and throughout the supporting landscape.

To address how management planning on the Refuge Complex might use RVA findings, we present some interpretation in light of existing CCP goals (USFWS 2004) and priority resources assessed. The CCP, as a reference document and a tool, is complimented by the RVA process, as the RVA offers findings to help adapt management objectives on the ground. Likewise, the HMP can also be practically coupled with the RVA. The HMP identified the habitats that served as priority resources in this study and RVA findings thus apply specifically to the habitats of management interest to refuge staff. These interpretations are framed around these two Refuge Complex planning documents.

It should be noted that RVA results for this study area would be vastly more informative if priority resources included species-specific data, particularly for migratory songbirds, and if consistent habitat data were available throughout the study area. Results would then include projections of how habitat distributions might change at a landscape scale; how bird populations of trust species might respond to SLR on the Refuge Complex and in the region; and how Refuge staff and the USFWS might monitor those changes so that the contribution of the Refuge Complex to the surrounding landscape can be maximized. Nonetheless, findings from this RVA clearly provide information useful for the revision of the CCP, the finalization of the HMP and for management of priority resources on the two refuges.

Strategy Development Process and Options

The previous chapter provides scenario evaluation results for Refuge Complex infrastructure and for habitat- and species-related priority resources, with a focus on those resources meeting less than 50% of their retention goal at each time step (i.e., those resources showing the greatest potential impacts of stressors.) This text and these table summaries provide comparative analysis of resource responses to stressors and thus can inform what management strategies may be most appropriate for certain resources.

The RVA results can be taken at least one step further in the RVA process: interpretations allow exploration of management and conservation alternatives, which can be evaluated in additional alternative future scenarios in NatureServe Vista. Evaluating alternative scenarios can thus allow better decision-making for allocating resources (i.e., refuge funds and staff) to conservation, management, and monitoring. To illustrate this process in this RVA, one exemplary alternative strategy was developed and mapped.

In general, the results of the scenario evaluations indicated that most coastal resources (overwash flats, Northeastern Beach Tiger Beetle populations, salt flats) and marshes are predicted to be impacted soonest and to the greatest extent. Maritime Upland forests are also among those habitats showing the greatest degrees of conflict with SLR. These habitats—beaches, marshes, and upland forests—are of particular importance to the migratory and wintering bird species for which the refuges were established and are managed, and are also addressed in a suggested strategy for refining the existing management attention on them.

Neither these habitats, nor the impacts to them, are restricted to the existing Refuge Complex, and thus efforts to conserve and manage these habitats should include the supporting landscape. Indeed, the existing CCP takes this approach via goals of collaboration with partner agencies, non-government organizations (NGOs), and landowners, and of public engagement. This proposed strategy also includes supporting landscape parcels that are not currently conserved or managed.

As is the case in the existing CCP, strategies for meeting conservation and management goals must include partners beyond USFWS and lands beyond the Refuge Complex boundary. To develop a strategy to address the resources with greatest potential conflicts in scenario evaluations, a map was developed to identify the following:

1. Acquired refuge lands that are currently conserved and managed for priority resources.

2. Other lands conserved and/or managed by government agencies, NGOs, and landowners via conservation easements. Management and monitoring on these lands could also benefit priority resources.

3. Non-conserved, privately owned lands in a current wetland or forested state, where potential for management action may exist via land acquisition or collaboration with landowners.

4. Privately owned lands in an agricultural state (not zoned for development) which present some opportunity for restoration to upland habitats (e.g., upland forests, scrub-shrub or grasslands).

5. Privately owned lands in current agricultural use, but zoned for development, where this RVA has also indicated a conflict with predicted SLR effects by the year 2050. Conflicts with predicted future land cover types, due to SLR, may present opportunities for local zoning amendments that benefit priority resources on the supporting landscape and avoid hazards to human developments.

This example strategy map extends beyond the approved and acquisition boundaries of the Refuge Complex, but it does not include all of the supporting landscape (Figure 22). It is restricted to the boundary of the VA DCR- Division of Natural Heritage's "Landbird Migratory Concentration Area" Element Occurrence, which includes both "Critical Significance Areas" and "Special Significance Areas" for migratory bird use. This area was chosen because of the significance of the southern tip of the Delmarva Peninsula to the migratory birds the Eastern Shore of VA NWR was established to manage, and because priority resources data used in this RVA are concentrated in this area. Figure 23 is provided to show more detail in the vicinity of the acquisition boundary.

The strategy map is constructed from various datasets that would contribute to planning efforts pertaining to land acquisition, management of public lands on and outside the Refuge Complex and the potential restoration of public and private lands throughout the southern tip of the Eastern Shore of Virginia. A description of datasets and legend items included in the strategy map are provided below.

Strategy Map Extent

Landbird Migratory Concentration Area EO boundary: Provided by the DCR-Division of Virginia Natural Heritage, the outermost boundary of the strategy map is consistent with this EO boundary. This EO was developed, and integrated into the Biotics database at Virginia Natural Heritage, to establish this area as a priority area for inventory, monitoring and land conservation work of the Virginia conservation community, in the interest of conserving and managing valuable migratory bird stopover habitats.

Base Map and Land Cover Classification

2001 National Land Cover Dataset: The base land and water cover classification used in the strategy map is provided by the 2001 USGS National Land Cover Dataset (NLCD) (Homer et al. 2004).

2005 NOAA Coastal Change Analysis Program (C-CAP): The upland land cover classification used in the strategy map is provided by the 2005 NOAA C-CAP (NOAA 2006). The NOAA C-CAP is a change analysis conducted on the 2001 National Land Cover Dataset classification. Small white areas of misalignment are apparent along shorelines (seaside marshes in particular), illustrating the data misalignments that are common in such uses of datasets that are each snapshots of a rapidly changing landscape.

Landownership and Management

Refuge Complex boundaries: Aside from the obvious value of these boundaries in the RVA strategy map, the Acquired Refuge Boundary and Approved For Acquisition boundaries are included in the strategy map because management and ownership vary based on these boundaries.

Virginia Conservation Lands Database: This dataset integrated current permanently conserved lands into the strategy map, so that decisions might be made in the context of land management and ownership.

Accomack and Northampton County Zoning: County zoning data are included to provide land ownership context as well as information about expected fate of privately owned lands. The strategy map only display those lands zoned for development.

Strategy Map Legend Items

Zoned for Development: These lands, in gray cross-hatching, are those zoned for development as per current Accomack and Northampton County land use plans

Restoration Opportunity: These lands (lighter orange) are predominantly agricultural lands, or those classified in the 2005 C-CAP as Bare Land, Cultivated, Grassland, Pasture/Hay, or Scrub/Shrub. Restoration Opportunity lands vary in current management and land ownership status. Defined solely by land cover type, these non-forested, non-wetland and non-developed lands might offer opportunities for collaboration with landowners on reforestation or restoration of early successional habitat.

Restoration Opportunity in Conflict Area: These areas (dark orange) consist of areas identified as Restoration Opportunities which are also slated for development (gray cross-hatching) based on county land use plans. These lands might indicate opportunities where zoning changes could release lands with conservation and restoration potential.

Upland Forest: These lands (green) are classified as Deciduous, Forest, Evergreen and Mixed Forest classes in the 2005 C-CAP. These three classes are lumped in the strategy map to indicate forested areas that are (1) potentially valuable for conservation in their own right, or (2) adjacent to existing, or future conserved lands.

Wetland: These wetlands (blue) consist of seven wetland classes from the 2005 C-CAP (see legend in Figure 4). These classes are combined and included with the same rationale as "Upland Forest" described above.

Conserved Land: These lands consist of all permanently conserved lands per the Virginia Conservation Lands Database.

Figure 22. Sample Strategy Map

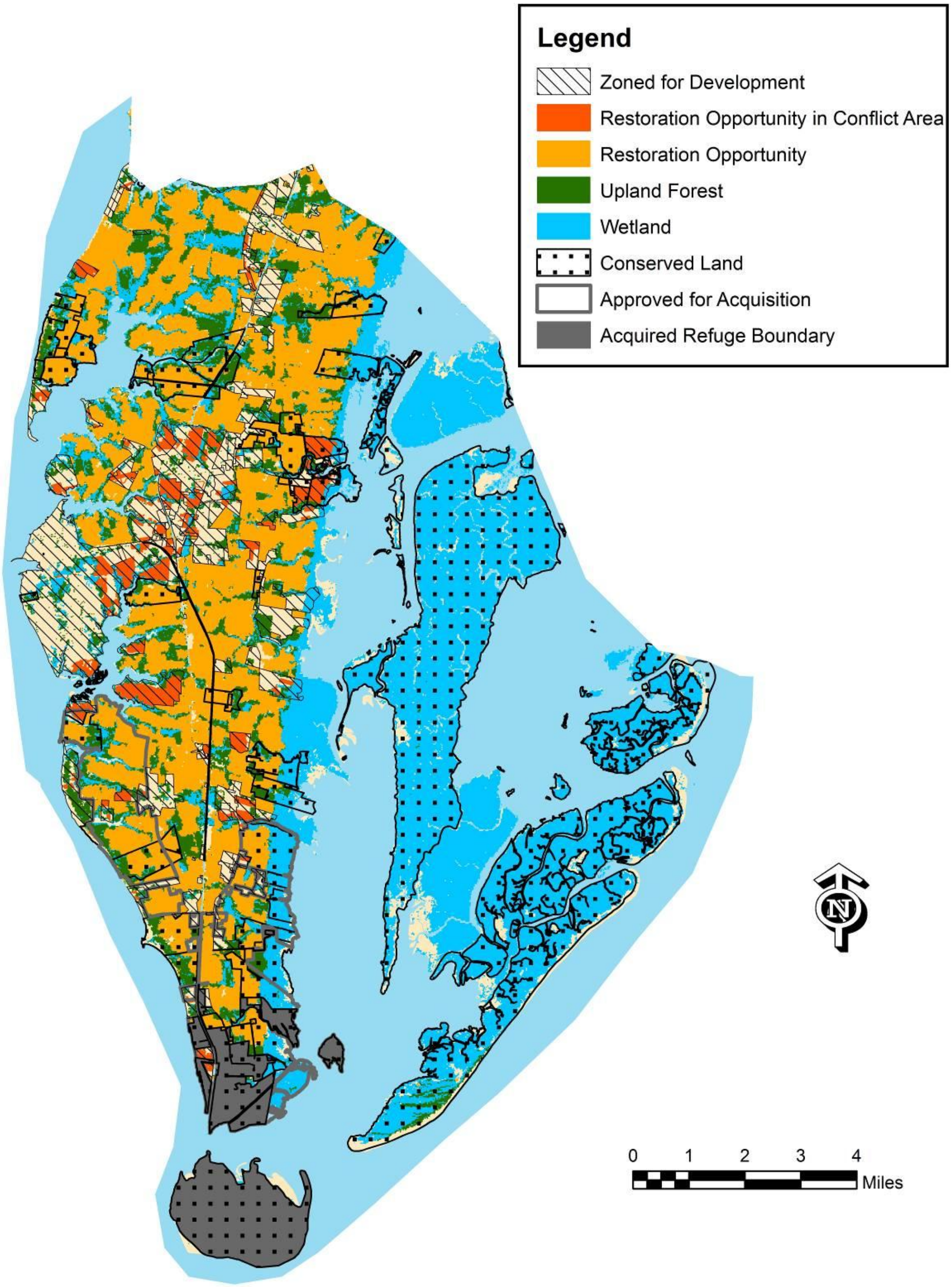


Figure 22 provides an example of how findings from RVA evaluations might be used to develop a strategy for pursuing objectives in the CCP (USFWS 2004). This map uses predicted 2050 land cover and contains spatial representations of lands currently managed and other intact priority habitats, as well as opportunities for restoration of habitat based on current land cover and zoning.

Figure 23. Sample Strategy Map – Vicinity of Acquisition Boundary

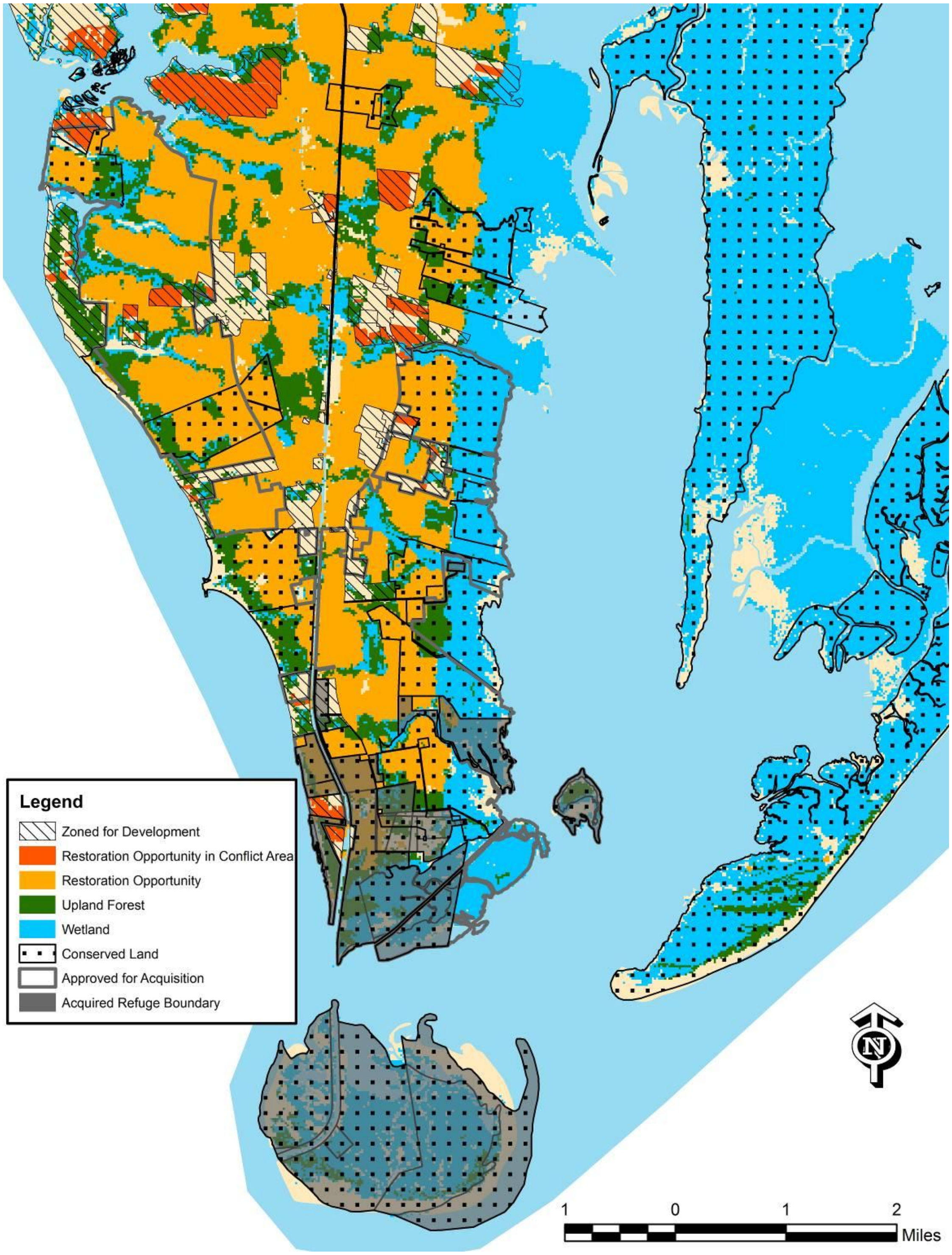


Figure 23 is a subset of Figure 22, focused on the vicinity of the acquisition boundary to show more detail.

Inputs to and interpretation of this strategy map are described relative to CCP goals in the following section. A discussion of how this strategy map might be used to refine existing CCP goals and management actions is also offered in the following section.

Refuge Options and Recommendations

The current CCP devotes substantial attention to a variety of refuge resources that require active management for the Refuge Complex to be a valuable and viable resource to wildlife, to the communities of the Eastern Shore, and to the greater public (see Chapter 2: Management Direction) (USFWS 2004). Findings of this RVA do not necessarily suggest significant changes to CCP goals and objectives, but rather indicate that SLR impacts should be strategically woven into a revision of these goals. The following text provides some examples of how findings from this assessment, via a proposed strategy, might inform a CCP revision and execution.

Goal 1. Increase the availability of forage and cover habitat for neotropical and temperate migratory birds and migrating monarch butterflies

Currently habitat management pertaining to the CCP Goal 1 management objectives is conducted in the dark grey areas (Refuge Complex) in the sample strategy map (Figure 22). However, this management recommendation could be applied to lands owned/managed by other state agencies and conservation organizations (those symbolized with lavender). If acquired lands and other conserved lands are managed with like intention, one can visualize how the benefits might be realized on more of the supporting landscape.

While predictions of change in habitat distributions vary, it is relatively obvious that there will be less terrestrial habitat area. These reductions in extent of terrestrial habitat may lead to greater densities of wildlife, namely migratory land birds, utilizing the remaining stopover habitat. The impacts of SLR on habitats are expected to be compounded by existing stressors of invasive species (e.g., encroaching honeysuckle and fennel in upland communities) and herbivory of native plants (due to insects and deer browsing). While efforts to manage and restore critical upland habitat (grasslands, scrub shrub, and forests) for migratory birds will be important in the short and long terms, efforts to maximize the *quality* of existing forage and cover habitat could be a key adaptation measure to SLR. This would entail monitoring vegetation structure and fruit production as existing habitats change, and as restored habitats develop, so that habitats can be adaptively managed to create optimal value for migratory birds. Ongoing monitoring would continue to focus on the impacts of these existing stressors so that management actions (e.g., modified hunting policy, insect/plant eradication efforts, prescribed fire) could be identified and implemented to maintain the population goals for species.

An assessment of current experimental plots, based on SLAMM projections, could help to assure that these areas, representative of both vulnerable and resilient habitats, via landscape context, are used for monitoring and data collection, so that the impacts to habitats on the broader landscape is better understood. For example, this monitoring could indicate that some areas would be best managed as early-successional versus late-successional upland habitat types, due to the predicted impacts of SLR.

These impacts might be inundation, higher vulnerability to storm surge, or even indirect effects of greater predicted encroachment by certain invasive species.

The three known migratory roost sites for Monarch butterflies were included in this assessment. In no scenarios did the Monarch occurrences show conflict with expected land-use changes on the Refuge Complex. This is because all three Monarch roosts are in relatively high-elevation locations on the Refuge Complex and therefore did not overlap with SLAMM projections of sea level rise. Although the occurrences themselves are not inundated, a review of the conflict maps in all future scenarios indicates that all Monarch occurrences are adjacent to inundated areas. Other stressors not addressed in this assessment, whether related to climate change or not, may play a role in the future and deem these roost sites unsuitable. These three occurrences do not fully represent the habitats used by migrating Monarchs, and it can be expected that lower-lying stopover habitat will be impacted in the future. A better spatial representation of Monarch roost sites on the supporting landscape would help to assess impacts beyond these three sites. Continuous habitat quality monitoring for Monarchs use will help to assure that valuable stopover habitats persist as the supporting landscape changes.

Goal 2. Maintain the long-term productivity, integrity, and function of the marsh, beach, and interdunal communities

Continued monitoring of beach dynamics along shorelines, barrier islands, and on Fisherman Island will continue to be important. Engineering efforts to maintain these naturally shifting habitats to lessen their responses to SLR is impractical, and in the longer term, unrealistic. However, for this reason, a regional conservation strategy could be useful for adaptation to SLR. A regional strategy, including the Delmarva Peninsula as a whole, the barrier islands of more southern states, or the Chesapeake Bay Lowlands ecoregion, could use vulnerability assessments to identify where these habitats might persist or shift in the future. These analyses could identify what local habitats are most likely to support viable populations and habitats, and how adaptive management might best be planned there. Current Refuge Complex beach and interdunal communities are included in the grey-shaded acquired Refuge Complex boundary (Figure 22), as well as on seaside marshes and barrier islands managed by other conservation entities (lavender marshes on the seaside of the Eastern Shore). Continued collaboration with these entities in similar monitoring efforts can help assure that most valuable information is gleaned from these more ephemeral habitats, so that any regional efforts are based on current and consistent data.

Continued monitoring of bird use and reproductive success of beach-nesting birds on Fisherman Island will provide some understanding of how shoreline accretion may provide new habitat for nesting colonial birds, as well as Piping Plover and Northeastern Beach Tiger Beetle, in the short term. Likewise, continued monitoring of changes in predator populations and human uses will be necessary for planning effective management action. Moreover, monitoring salinity, hydrology, vegetation communities, and bird use of existing marshes on the seaside Eastern Shore will improve understanding of how mobile these communities might be as sea level rises, thereby informing future habitat management further inland. The rather rapid predicted changes to these marshes may also help to plan efforts to effectively eradicate Phragmites in areas where it is anticipated to invade as hydrology changes.

Goal 3. Actively participate in the conservation of healthy hardwood, understory, and grassland habitat for neotropical and temperate migratory birds during future development throughout Northampton County

Considering the relatively small size of the Refuge Complex, the suite of stressors impacting the supporting landscape, and that the entire supporting landscape provides points of critical migratory stopover habitat, including lands throughout the supporting landscape (not just one county) will allow more adaptive management for migratory land birds. Moreover, since upland habitats are not predicted to respond to SLR as soon as lower elevation coastal areas, potential to conduct meaningful habitat management in a realistic timeframe is more likely in the uplands.

The proposed strategy map would allow prioritization of lands that would protect existing migratory bird stopover habitat, as well as lands that would add to this resource if acquired and/or restored. Existing upland habitats, such as forests and scrub-shrub habitats (green-shaded areas in the strategy map, Figure 22) and existing wetlands (blue-shaded areas) not zoned for development and within the approved Refuge Complex boundary (grey outline) are used by migratory species now and may present some of the best opportunities to expand the stopover habitats of the Refuge Complex. To a greater extent, existing upland agricultural lands can also be targeted as opportunities to restore upland habitats, through acquisition or collaboration with landowners. These opportunities have also been displayed (orange on the strategy map) on lands outside the approved Refuge Complex boundary, as opportunities for meaningful conservation and management on the supporting landscape may occur there as well.

Many other opportunities occur in areas zoned for development by Northampton County (cross-hatched areas in Figure 22). Some fragments of intact habitat (uplands and wetlands) do occur within these zoning designations, as well as some larger parcels of agricultural lands. While conservation and management of these lands may not appear practical, RVA scenario evaluation outputs can suggest areas where zoning may be amended due to impacts of SLR. The proposed strategy map (Figure 22) includes an analysis of restoration opportunity lands (currently agricultural) that are proposed for development, but that are also predicted to become wetland and marsh habitats in the future, per the SLAMM 2050 model (green- and blue-shaded areas within cross-hatched zoning). Parcels zoned for development with SLAMM conflicts that include existing agricultural lands are also identified (dark orange), as restoration opportunities. In some cases these lands could expand upon existing or restored habitat and/or link other valuable habitat. These lands may offer unique opportunities for collaboration with local governments to conserve or manage lands as priority resource habitat types.

Goal 4. Provide wildlife-dependent recreational opportunities and community outreach with an emphasis on educating the public about the critical role the Delmarva Peninsula serves for neotropical and temperate migratory birds and migrating monarch butterflies

Activities and management action towards this goal can also be conducted throughout the supporting landscape. This goal realizes the biological values of managing wildlife-related public-use opportunities on the Refuge Complex. The public can help to manage existing stressors on the Refuge Complex (particularly through hunting) that may be exacerbated by the SLR impacts in certain habitat types. Ongoing monitoring of deer populations and their impacts will inform modifications to hunt programs (e.g., lengthening season, increasing limits, establishing doe hunts), so that the public can provide a service to, while also reaping the recreational benefits of, the Refuge Complex. Such activities would aid habitat management efforts on and off-refuge by decreasing deer browse pressure on upland native vegetation. The service of hunting might also be expanded beyond deer and their habitats. Mesopredator pressure on colonial breeding birds might also be reduced through non-breeding season hunting and trapping in more coastal areas.

These activities can most readily benefit priority resources and habitats on the acquired Refuge Complex, but there are also opportunities to collaborate with other conserved-land managers (lavender-shaded lands on the strategy map) and on privately owned lands. Engaging with private landowners to achieve consistent management of deer populations on private lands can extend the benefits of controlled deer populations throughout the supporting landscape.

There is also implicit value in this engagement. If willing landowners realize the connectedness of their lands to the Refuge Complex—and its value to migratory birds, to the tourist economy of the shore, and its susceptibility to climate change stressors—an increased awareness of the importance of community support and action around land management may result. Existing forests (green shading) throughout the supporting landscape, as well as conservation lands and easements, might offer this opportunity.

The importance of commercial and public boating and fishing access are also addressed in the CCP (Goal 4) and this RVA, and most obvious conflicts indicated in scenario evaluations involve SLR impacts to the Wise Point Boat Ramp, dock, and parking area. Demand for public use of this ramp is increasing due to its convenience and the overall paucity of ramps and suitable ramp sites on the southern Eastern Shore. Unfortunately, the qualities deeming Wise Point a great place for open-water boat access also make it extremely susceptible to SLR; all scenarios in this RVA indicate that the Wise Point area infrastructure will be impacted significantly and soon.

This facility is given considerable attention in the CCP, due to the great importance to the public and commercial fisheries. Most strategies in the CCP relate to refuge intentions to expand the capacity and improve access to the boat ramp at Wise Point, and many actions have been taken in recent years. Since the 2001 purchase of Wise Point Boat Ramp, many practical repairs and improvements have been made. Rather than multiple docking areas, as was the case, one permanent dock has been put in place. The entrance road has also been replaced with a 2-lane natural surface road, with a low-water concrete drainage. Thus the road is free to flood and drain, which is common on especially high tides. A new parking area has also been constructed with over 70 parking spaces. This construction increased the parking area by one foot elevation, but does not include pavement, as the area still floods periodically. There is no freshwater nor electricity at the Wise Point Boat Ramp, though there are solar lights and a restroom facility. These improvements have adapted this area for the anticipated increase in flooding and storm surge from SLR.

In a CCP revision, efforts to continue the adaptive management of this facility might be well-served by what is learned from these improvements since the 2004 CCP. Additionally, considering the predicted long-term SLR impacts to this area (Figure 16 and Figure 18), alternative or additional locations of public boat ramps associated with the Refuge Complex may be considered using the results of this assessment. Areas where SLR and development show minimal conflicts with priority resources (species and habitats) can be identified from scenario outputs, and opportunities to work with landowners and local governments to establish new, or additional, boat access facilities can be identified in shoreline areas where zoning conflicts with predicted sea level rise (Figure 19 and Figure 20 and Figure 21).

Potential conflicts with Wildlife Viewing Opportunities are not specifically addressed in this RVA, as photo blinds and kiosks were not assessed as Priority 1 resources (Appendix B). However, output maps from this RVA do provide some valuable information as decisions are made around the maintenance of these existing resources and the potential location of new ones. As more accurate and current satellite imagery and LiDAR become available, RVAs can more thoroughly help with these aspects of planning and management on the Refuge Complex.

Some of the more implicit and qualitative findings of this RVA indicate that efforts around environmental education and wildlife interpretation cannot be overemphasized. This assessment paints a clear picture of the connectedness of this landscape, providing evidence that successful response and adaptation to predicted conflicts (due to development and SLR) must extend beyond the Refuge Complex boundaries and beyond the work of the refuge staff. These findings provide a tool for advancing the environmental education efforts of the Refuge Complex. The butterfly and neotropical migratory bird focus of the Eastern Shore of Virginia NWR sets a stage for incorporating climate change into refuge educational programs. While it is well-known that these taxa and their habitats provide an ecological litmus for understanding biological impacts of climate change, this Refuge Complex provides an invaluable resource for teaching the public about these impacts in short term. The physiographic location of the Eastern Shore, and moreover the resources on the Refuge Complex, can be used to teach citizens how climate change is impacting the landscape and thus natural and human communities.

Goal 5. Integrate the refuge into the larger community of the Eastern Shore and promote awareness of the unique value of the lower Delmarva Peninsula to neotropical and temperate migratory birds and migrating Monarch butterflies

In addition to using the biological and geographic context of the Eastern Shore to educate the public about climate change, outreach and education efforts of the Refuge Complex can also reinforce the importance of collaboration in the refuges' conservation message. Working though challenges that Eastern Shore communities are facing regarding land use and climate change stressors provides opportunities for the Refuge Complex to work with local governments and other conservation partners, setting an example for the public. This collaboration would support a regional effort to maintain and grow a healthy nature-based tourist economy, which will in turn benefit the communities of the Eastern Shore. Public exposure to the RVA approach can help relay a message that the Refuge Complex seeks to use science, education, and outreach to maintain functioning ecosystems and local economies throughout the supporting landscape.

Goal 6. Enhance and restore the quality of the soils, waters, and other abiotic components of the refuge

These RVA findings do not directly address concerns around contaminants and the firearms range. However, a more extensive RVA would consider the compounded impacts of climate change stressors in conjunction with these abiotic stressors. Findings did indicate no expected conflicts with communications towers due to SLR. While this might be expected considering the location of the tower, other aspects of these structures (i.e., threats to migrating birds) are more important in deciding its value on the Refuge Complex. These issues are addressed in the existing CCP.

Chapter 6. Maintaining and Updating the Project Database

The project database consists of various components:

1. The NatureServe Vista, ESRI ArcGIS, and Microsoft Access project databases (note that these function jointly through the Vista software). This includes shapefiles of Priority 1 resources included in Appendix B and Appendix C.

2. C-CAP 2006 land cover data

3. Transportation and utilities data

4. Conservation Lands Database

5. Natural Heritage data

6. Built-assets data for the Refuge Complex

7. Zoning data from Accomack and Northampton Counties

8. The Sea Level Affecting Marshes Model simulations for current, 2025, 2050, and 2100 time steps

9. Vista baseline and future scenario output data

10. Documentation, ArcGIS methods, and references

Following are recommendations for basic maintenance and updates to these data, as well as key data gaps that were encountered in the assessment.

Database Maintenance and Updates

NatureServe Vista database

Generally, we recommend that the NatureServe Vista tool and database be updated as new or improved information is developed or acquired such as:

- LiDAR data, which would be used to update and refine the SLAMM results and shoreline mapping to achieve more precise inputs to Vista.
- Updated data from federal and state agencies for trust species distributions, rare or exemplary vegetation communities, fine-scale vegetation maps, species distribution models, and conserved lands.
- Updated SLAMM models, as well as models and resources for modeling other climate change stressors.
- Better information on resource conservation requirements and responses to stressors which can come from additional local and regional studies and observations.

- Maps reflecting current scenario components (actual land use, management status and activities, additional stressors (e.g., land use and off-shore wind development), conservation acquisitions, or policy changes).
- Refined/revised future scenario development proposals and plans.
- Improved climate change effects information such as refined SLR forecasts (coupled with the LiDAR data above) and models for any changes to hydrology and upland vegetation.

This new and improved information will be used in Vista to:

1. Update the Vista database including resource distributions. We recommend updating current distributions and then updating distributions at regular intervals in the future (e.g., in five-year increments or as appropriate to the pace of change). Saving the resource name with the year (e.g., Salt Flat 2015) and storing each timeframe's representation of that resource to document changes in distribution due to changes in management and climate.

2. Update and maintain the baseline scenario. Similar to updating the resource distributions and other database components, we suggest saving snapshot scenarios in five-year increments to document and track change that can be calibrated to observed ecological changes. The resulting scenario and scenario evaluation record can prove highly valuable for back-casting and calibrating future evaluations.

3. Obtain more refined resource evaluations by revising resource parameters such as how resources respond to stressors based on monitoring data and field observation and new published work.

4. Target inventory and monitoring to assess accuracy of climate change predictions, (e.g., ability of vegetation communities to shift as sea level rises and microclimates change in marshes and upland habitats).

Data Gaps

- **Bird data.** A wealth of bird data exist from the Refuge Complex and the supporting landscape, both historic and recent, that would increase the accuracy and utility of RVA evaluation findings. Many datasets are not currently shared with refuge staff and efforts to secure them should be a priority. This inaccessibility of bird data required this RVA to use habitat types as surrogates for priority resources, based on HMP vegetation communities. These communities could not be assigned accurately beyond Refuge Complex boundaries and rather inaccurate crosswalking had to be done. For example, a revised RVA using actual bird data could more thoroughly assess the values of different habitats to different species, throughout their annual life cycles.
- **An official list of species and habitat-related priority resources.** The ability to focus on a suite of top-priority species in various efforts will help assure that assessments, management, and monitoring efforts consistently target species of concern.

- **Fine-scale vegetation maps of the Refuge Complex proper.** These should be developed and updated on a regular basis (e.g., decadally) so that changes in vegetation structure and habitat types can be monitored and can contribute to habitat management in the short and long terms. Vegetation or habitat classifications used in these fine-scale maps should be easily relatable to other classifications so that landscape-level assessments are useful for management planning outside the Refuge Complex boundaries. Any opportunities to conduct fine-scale mapping outside the acquired boundary could further focus efforts to conserve and manage lands with partners elsewhere.
- **Higher-resolution land-cover data for the supporting landscape.** This would reduce errors caused by use of coarser products derived from LandSat™ data.
- **LiDAR data.** The detail and richness of LiDAR data would significantly increase the power of a revised RVA of the refuges, supporting landscape, and ecoregion. LiDAR data should include both surface-elevation data as well as vegetation-related data to assess vegetation structure.
- **CCP time intervals.** Consider planning CCP updates and using planning time horizons that are better synchronized with projected time frames in sea level rise models since management action will largely be in response to that stressor in the future.

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Appendix A. Regulatory and Policy Framework

This table identifies (from the 2004 CCP) the relevant laws, policies, and plans the Refuge Complex is using to guide its planning and management. "Explicit" indicates resources directly addressed in the associated regulation, policy or plan. "Inferred" indicates a resource not specifically addressed but relevant, or indirectly addressed in the associated regulation, policy or plan.

Regulation, Policy, or Plan	Applicable (Y/N)	Resource (E-explicit/I-inferred)	Management Influence
2004 CCP	Y	Habitat (avian focus) and refuge infrastructure (E)	Outlines goals and objectives for all conservation and management planning and action on refuge complex
Habitat Management Plan		Migratory and Wintering birds (E)	Identifies specific habitat types of conservation value to these species
Migratory Bird Conservation Act	Y	Migratory birds (E)	Management and conservation of priority bird species
Endangered Species Act	Y	Northeastern beach tiger beetle, piping plover (E)	
Marine Mammal Protection Act	N	Strandings, seal resting habitat (I)	
Transfer of Certain Real Property for Wildlife Conservation Purposes Act	Y	Migratory birds (E)	
Refuge Recreation Act	Y	Fish and wildlife, natural resources, endangered or threatened species (E)	
National Wildlife Refuge System Improvement Act	Y	Priority Species and Mission Critical Infrastructure (I)	
Land Acquisition Policy	Y	Lands approved for acquisition (I)	
National Environmental Policy Act	Y	Habitats (I)	
North American Waterfowl Management Plan (Atlantic Coast Joint Venture—Delmarva Peninsula Focus Area)	Y	Wetlands, waterfowl, black ducks (E)	
Partners in Flight (Mid-Atlantic Coastal Plain Physiographic Area)	Y	Land bird species and habitats—seaside sparrow, prairie warbler, clapper rail, American black duck, northern bobwhite, eastern	Suggested conservation and management actions for priority bird species

Regulation, Policy, or Plan	Applicable (Y/N)	Resource (E-explicit/I-inferred)	Management Influence
		towhee, field sparrow, yellow billed cuckoo (E)	
U.S. Shorebird Conservation Plan (North Atlantic Planning Region)	Y	Undeveloped wetlands, beaches, piping plover (if found), American oystercatcher, sanderling, whimbrel, American woodcock (E)	Suggested conservation and management actions for priority bird species
Neotropical Migratory Songbird Coastal Corridor Study	Y	Neotropical migratory birds (E)	Land protection plan
Delaware River/Delmarva Coastal Ecosystem Plan	Y	Migratory birds and migration stopovers, wetlands, interior forests, endangered and threatened species, interjurisdictional fish (E)	Suggested conservation and management actions for priority bird species
Regional Wetland Concept Plan, Emergency Wetlands Resource Act, Northeast Region	Y	Wetlands (specific named sites are Butlers Bluff, Fisherman Island, Magothy Bay, Plantation Creek (E)	
Species Recovery Plans	Y	Northeastern beach tiger beetle, piping plover (if found), seabeach amaranth (if found), bald eagle, peregrine falcon (E)	
MD & VA State Wildlife Action Plans	?	T&E and priority animal species (E) (I)	
National Historic Preservation Act	Y	Farm homestead, Fort John Custis remains, Chesapeake Bay Harbor Defenses	
Landscape Conservation Cooperative	Y	Not indicated in CCP, as LCCs did not exist at that time. To date, no specific influences of the LCC in the project area.	

Appendix B. Resources Checklist

The 2004 CCP lists approximately 120 trust species of management concern. This checklist identifies the resources that were considered for this vulnerability assessment and was informed by the regulatory and policy framework of the Refuge Complex (as summarized in Appendix A.) A shorter list of priority resources was identified in the initial RVA stakeholders workshop, to be candidates for the RVA. These candidate resources were assigned, by FWS staff, priorities of 1, 2 or 3. Via follow-on discussions with refuge staff, it was decided that only Priority 1 resources (i.e. essentially threatened and endangered animal species, habitat types, and mission-critical infrastructure) would be explicitly addressed in this RVA (see those with "Assessment" status in Appendix B table). Those that were considered but not assessed are listed as "candidate." The "Experts" field lists those known to be most knowledgeable about the resource as per discussions at the initial project workshop. The "Purpose" field documents the purpose the resource serves in Refuge Complex management, e.g., "fulfill regulation," "provides recreation," or "serve as an indicator." Since Priority 2 and 3 resources were not ultimately included in the RVA, efforts to obtain pertinent datasets, identify experts and determine the purposes of those resources were not carried out. Consequently, many cells for Priority 2 and 3 species are not populated.

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Habitat Types					
Early Successional Upland*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Freshwater Emergent Marsh*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Upland Forest - Pine Dominated*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Dune Grassland	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Priority habitat for at least one priority species
Maritime Dune Grassland*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Maritime Dune Scrub	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Priority habitat for at least one priority species
Maritime Dune Scrub*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Dune Woodland	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Priority habitat for at least one priority species
Maritime Dune Woodland*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Upland Forest - Deciduous Dominated*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Maritime Wet Grassland G1	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Maritime Wet Grassland G3	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Salt Flat	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Seaside High Flat^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species
Seaside High Marsh^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species
Seaside Lagoon^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species
Seaside Low Marsh^	1	Ross, P.G. and M.W. Luckenbach 2009.	VIMS	Assessment	Priority habitat for at least one priority species

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Tidal Mesohaline Polyhaline Marsh G4	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Tidal Mesohaline Polyhaline Marsh G5	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Tidal Polyhaline Marsh Complex*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Upper Beach Overwash Flat	1	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Assessment	Rare Natural Heritage Community type; Priority habitat for at least one priority species
Upper Beach- Overwash Flats*	1	ESVNWR Land Cover Maps from Les Vilchek at Blackwater NWR		Assessment	Priority habitat for at least one priority species
Active beach intertidal	3			Candidate	
Agricultural land	3	NRCS	Tina Jerome	Candidate	
Aquaculture sites (clams & oyster) existing vs. potential	3	DEQ	Marcia Berman- VIMS, Hank Badger- VMRC	Candidate	
Freshwater ponds	3	NWI		Candidate	
Freshwater streams	3	NHD+		Candidate	
Grasslands	3	NOAA-C-CAP		Candidate	
Hydric forest	3	NWI & NOAA-C-CAP		Candidate	
Impoundments (fresh and salt)	3	NWI		Candidate	
Interdune pond	3	NWI		Candidate	
Open water (Chesapeake Bay/ Atlantic)	3	DEQ	Bryan Watts -W&M - CCB	Candidate	
Oyster reefs	3	DEQ	Mark Luckenback - VIMS	Candidate	
Sea level fen	3	Virginia Natural Heritage Data	Gary Fleming –Virginia DCR Natural Heritage Program	Candidate	
Seagrass meadows	3	DEQ	Bob Orth- VIMS	Candidate	

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Birds					
American black duck	3		Gary Costanzo - DGIF	Candidate	High marsh potential habitat (breeding)
American oystercatcher	3		Pam Denmon (FWS), Alexandra Wilke (TNC) and Ruth Boettcher (DGIF); AMOY working Group studying winter distribution via breeding season banding.	Candidate	Beach Nester requiring to have feeding and nesting adjacent. Requires marshes for foraging in winter. Sandy habitat for nesting in spring/ summer.
American woodcock	3		Pam Denmon (FWS), Barry Truit (TNC), Bryan Watts (CCB), David Krementz (U of Arkansas)	Candidate	Upland forest bird, winters on ES
Bald eagle	3		Bryan Watts (CCB), VA NHP	Candidate	
Beach nesters	3			Candidate	Species guild containing at least priority species
Beach shorebirds	3			Candidate	Species guild containing at least priority species
Black rail	3		Bryan Watts (CCB)	Candidate	High marsh nester
Clapper rail	3		Bryan Watts (CCB); Pam Denmon (FWS) may have some survey data	Candidate	Marsh nester
Eastern towhee	3		Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Early successional scrub-affiliate songbird
Field sparrow	3		Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Early successional scrub-affiliate songbird
High marsh birds	3			Candidate	Species guild containing at least priority species
Low marsh birds	3			Candidate	Species guild containing at least priority species
Mudflat shorebirds	3			Candidate	Species guild containing at least priority species
Northern bobwhite	3			Candidate	Upland species

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Peregrine falcon	3		Libbey Mojica (CCB)	Candidate	Not a resident on the shore, but representative of raptor species that use the ES during fall migration.
Piping plover	3			Candidate	Beach nester
Prairie warbler	3		Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Early successional scrub-affiliate species
Raptors	3			Candidate	
Salt marsh sharp tail sparrow	3	Study underway during RVA. Data available from mist netting at sites on Refuge Complex and in far north of supporting landscape.	Fletcher Smith (CCB); Bryan Watts (CCB), as an editor of the Mid-Atlantic database with PIF, may have access to banding data	Candidate	Indicator of effects of SLR on preferred marsh habitat(s).
Sanderling	3		Bryan Watts (CCB)	Candidate	
Seaside sparrow	3		Fletcher Smith (CCB)	Candidate	
Waterbirds	3			Candidate	
Waterfowl	3			Candidate	
Whimbrel	3		Fletcher Smith (CCB)	Candidate	
Yellow billed cuckoo	3		Bryan Watts (CCB) via banding data from the ES	Candidate	Species breeds and migrates on the ES
Yellow-rumped warbler	3		Bryan Watts (CCB) via banding data from the ES	Candidate	Upland shrubland, maritime dune indicator. Migrant on uplands of Eastern Shore.
Insects					
Ghost tiger beetle	3		Barry Knisley	Candidate	
Monarch	1	Virginia Natural Heritage Data	Lincoln Brower and Larry Brindza (Monarch Migration Program)	Assessment	Important Migration Roosts on southern tip of Eastern Shore
Northeastern beach tiger beetle	1	Virginia Natural Heritage Data	Barry Knisley Mike Drummond -FWS	Assessment	Federally endangered
Rare bees	3		Sam Droege - USGS PWRC	Candidate	
Mammals					

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Delmarva fox squirrel	3		Karen Twilliger and Ray Dueser	Candidate	
Marine mammals (harbor seal haulout site)	3		Mark Swingle, Virginia Aquarium Stranding Center (VAQS)	Candidate	
Plants					
Sea beach amaranth	3			Candidate	Federally Threatened
Other state listed rare plants	3			Candidate	
Reptiles					
Diamondback terrapins	3			Candidate	
Loggerhead sea turtles	3		Ruth Boettcher - DGIF Mark Swingle, Virginia Aquarium Stranding Center (VAQS)	Candidate	
Cultural resources					
Chesapeake Bay Harbor Defenses	3			Candidate	Consists of public use resources
Fort John Custis remains	3			Candidate	Consists of public use resources
Historic Farm Homestead	3			Candidate	Consists of public use resources
Mission Critical Infrastructure					
Bridge -Tunnel through Fisherman Island	1	Virginia Geographic Information Network (VGIN) Road Centerline Program Data		Assessment	
Building - Maintenance	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Building - Refuge Headquarters	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Building - Refuge Residence	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Building - Visitor Center	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Building - Workamper	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Canoe - Kayak Launch	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Communications Tower	1	Extracted from layer (Virginia_08_towers) provided by Les Vilchek at Blackwater NWR		Assessment	
Parking - Asphalt	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Parking - Concrete	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Parking - Gravel	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Road - Asphalt	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Road - Gravel	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	

Resource	Priority	Source of Distribution Information	Experts	Assessment Status	Purpose/ Species indicator for habitat types
Road - Native	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Trail - Gravel	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Trail - Mowed	1	Federal Highway Administration-Central Federal Lands, Refuge Inventory		Assessment	
Wise Point Boat Ramp and Dock	1	Digitized from Virginia Base Mapping Program 2009 Data using refuge maps for reference.		Assessment	
Coastal Changes Due to Sea Level Rise					
Current Marsh/Open Water Distributions	2	Sea Level Affecting Marshes Model--Initial Condition		Assessment	Assess changes in habitats, assess impacts on critical infrastructure, and identify conflicts with zoning.
Year 2050, future Marsh/Open Water Distributions	2	Sea Level Affecting Marshes Model--2050		Assessment	Assess changes in habitats, assess impacts on critical infrastructure, and identify conflicts with zoning.
Year 2100, future Marsh/Open Water Distributions	2	Sea Level Affecting Marshes Model--2100		Assessment	Assess changes in habitats, assess impacts on critical infrastructure, and identify conflicts with zoning.

* derived habitat element at the refuge level ^ derived habitat resource at the supporting landscape level

Appendix C. Infrastructure Checklist

This checklist identifies those infrastructure features/types that were treated 1) as resources retained and assessed for threats to them and 2) as features that act as stressors on other resources. Resources that are retained are listed as "retention targets."

Infrastructure Feature Name/Type	Is a Retention Target?	Stressor on Resources
Wise Point Boat Ramp	Y	Y
Access roads	Y	Y
Visitor Center	Y	N
Chesapeake Bay Bridge-Tunnel through Fisherman Island	Y	Y
Communications Tower (in future acquisition lands)	DEPENDS ON AGREEMENT	Y
Parking (gravel, concrete and asphalt)	Y	Y
Refuge headquarters	Y	N
Workamper Sites	Y	N
Four maintenance buildings	Y	N
Seven refuge residences	Y	N
Photo blind	Y	N
Kiosks	Y	N
Canoe/Kayak Launch	Y	N
Trails (including planned)	Y	Y
Power Transmission lines	Y	Y
Water control structures	N	N
Gates	N	N
Signs	N	N
Constructed ponds	N	N

Appendix D. Stressors Checklist

This checklist identifies those stressors currently known or assumed on the Refuge Complex and those reasonably anticipated in the future. It was used to obtain maps or develop models for those stressors included in scenarios and assessed for impacts on resources. An “X” indicates that the given stressor is either known or expected to have the listed effects on resources, and a “?” indicates less general certainty. The “Future” box indicates if the stressor is expected (under current plans) to continue into the future or is not currently in the assessment region but anticipated to be in the future. Current stressors are assumed to continue unless mitigated.

Stressor Name/Type	Effects	Current	Future	Included in Assessment
Chesapeake Bay-Bridge Tunnel	Wildlife fatalities, air pollution, noise pollution, increased wildlife avoidance/fragmentation	X	X	Y
Wise Point Boat Ramp	Noise, pollution, boat traffic	X	X	Y
Pound net adjacent to refuge	Noise (temporary), localized fatality (entrapment)	X	X	N
Aquaculture (e.g., bivalve)	Impacts shorebird feeding (e.g., via temporary turbidity affects), daily human presence/noise resulting in habitat abandonment	X	X	N
Crab pots	Terrapin drowning	X	X	N
Other boat ramps	Noise, pollution, boat traffic	X	?	N
County firearms range	Noise, toxins	X	?	N
Communications tower	Bird impact	X	?	Y
Military on refuge (previous)	Toxins (highly localized)	X	?	N
Military/NASA Wallops Island	?	?	?	N
Agricultural contaminants (e.g., active spraying)	Sedimentation, Toxins—decreasing abundance of invertebrates and other avian food sources; direct toxicity to resources	X	X	N

Stressor Name/Type	Effects	Current	Future	Included in Assessment
Water diversion and alteration	Stream flow regime, habitat alteration	X	X	N
Conflicting habitat management (on refuge & outside, by others (Virginia State Parks, Natural Heritage, DGIF, TNC)	Promotion of some habitats/species over others	X	X	N, though addressed in interpretation
Invasive species	Habitat alteration via vegetation structural changes and changes in species composition; loss of native food species via displacement of natives	X	X	N, though addressed in interpretation
Deer hunting	Disturbance via human foot traffic, noise	X	X	N, though addressed in interpretation
Beach access	Recreation impacts on beach species (foot traffic, pets, pollution and litter)	X	X	N, though addressed in interpretation
Suburban growth	Loss of refuge expansion opportunity, encroachment, introduction of invasive plants and free ranging introduced mesopredators (e.g., house cats)	X	X	Y
Utility transmission lines	Habitat fragmentation, bird collisions	X	X	Y
Roads and Highways/Auto traffic	Wildlife fatalities, air pollution, noise pollution, increased wildlife avoidance/fragmentation	X	X	Y
Storm surge and winds	Inundation, wind damage to vegetation, wildlife fatalities	X	X	N, though addressed in interpretation
Non-point source water pollution	Nitrification and toxins in water bodies	X	X	N

Stressor Name/Type	Effects	Current	Future	Included in Assessment
Oil/chemical spills along roadways	Toxic runoff into water bodies	X	X	N
Former military toxins sites	Toxins in soil and toxic runoff into water bodies including organo-chlorine	X	X	N
Elevated Predation (gulls, raccoons, foxes)	Population impacts on imperiled wildlife	X	X	N, though addressed in interpretation
Hiking Trails	Disturbing wildlife behavior	X	X	Y
Human pedestrian & dogs activity (trespass and permitted)	Chasing wildlife, disturbing the wildlife behavior, displacing wildlife	X	X	N, though addressed in interpretation
Boat traffic (wakes)	Wash over nests, eroding shoreline, noise, contaminants on water quality, trash that directly harms wildlife	X	X	N
Shipping spills	Spills—direct fatality, habitat damage	X	X	N
Offshore breakwaters and hardening, jetties	Habitat removal, habitat alteration, down current erosion	X	X	N
Air pollution deposition e.g., mercury	Inhibition of breeding success, (e.g., salt marsh sharp tail sparrow)	X	X	N
Energy development (offshore and land based wind)	Habitat alteration, direct mortality via collision	?	X	Y
Saltwater intrusion	Saltwater inundation, rising groundwater levels and changes in groundwater salinity, altered hydrology and salinity in open water habitats	X	X	N, though addressed in interpretation
Wildlife disease		?	X	N

Stressor Name/Type	Effects	Current	Future	Included in Assessment
Climate Change Stressors				
Sea level rise (SLR)	Direct habitat flooding, shoreline erosion, freshwater/saline wetland conversion	X	X	Y
Extreme weather events (frequency/intensity)	Increased storm surge height, windthrow, nest flooding, blowdown, salt spray effects on flower/fruits	X	X	N
Increased air temperature	Heat stress on vegetation and wildlife, decreased soil moisture, drought intensity	?	X	N
Decreased air temperature	Drought frequency/intensity	?	X	N
Increased precipitation	Raised groundwater levels, alteration of soil moisture, nest flooding	?	X	N
Decreased precipitation	Drought frequency/intensity, fire frequency	?	X	N
Changed phenology	Uncoupling of wildlife-vegetation-prey relationships, impacts on feeding and reproduction. Insect and fruit availability (ripening occurrence) during songbird fall migration.	?	X	N

Appendix E. Resource Requirements and Responses

This table documents the conservation requirements (unit of assessment, minimum required occurrence size, importance weighting, and the supporting landscape retention goal) for each resource.

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
Migration Roosts (EO)	Monarch Migration Roost EO	occurrence	1	100
Invertebrate Animal (EO)	Cicindela dorsalis dorsalis	occurrence	5	100
Community (EOs)	Salt Flat	occurrence	10	100
	Maritime Wet Grassland G1	occurrence	1	100
	Maritime Wet Grassland G3	occurrence	1	100
	Upper Beach Overwash Flat	occurrence	184	100
	Tidal Mesohaline Polyhaline Marsh G4	occurrence	9	100
	Tidal Mesohaline Polyhaline Marsh G5	occurrence	2200	100
	Maritime Dune Woodland	occurrence	9	100
	Maritime Dune Scrub	occurrence	16	100
	Maritime Dune Grassland	occurrence	18	100
Refuge	VIMS Seaside Lagoon^	area	1	100
	VIMS Seaside High Marsh^	area	1	100

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	Seaside Low Marsh^	area	1	100
	VIMS Seaside High Flat^	area	1	100
	Early Successional Upland*	area	1	100
	Freshwater Emergent Marsh*	area	1	100
	Maritime Dune Grassland*	area	1	100
	Maritime Dune Scrub*	area	1	100
	Maritime Dune Woodland*	area	1	100
	Maritime Upland Forest-Deciduous Dominated*	area	1	100
	Maritime Upland Forest-Pine Dominated*	area	1	100
	Upper Beach-Overwash Flat*	area	1	100
	Tidal Polyhaline Marsh Complex*	area	1	100
Refuge Priority Infrastructure	Trail-Gravel	area	0.2	100
	Trail-Mowed	area	0.2	100
	Road-Asphalt	area	0.2	100
	Road-Gravel	area	0.2	100
	Road-Native	area	0.2	100
	Parking-Asphalt	area	0.2	100
	Parking-Concrete	area	0.2	100
	Parking-Gravel	area	0.2	100
	Bridge-tunnel Through Fisherman Island	area	0.2	100
	Communications Tower	area	0.2	100
	Wise Point Boat Ramp and Dock	area	0.2	100
	Canoe-Kayak Launch	area	0.2	100
	Building-Visitor Center	area	0.2	100
	Building-Refuge Headquarters	area	0.2	100
	Building-Workamper Site	area	0.2	100

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	Building-Maintenance	area	0.2	100
	Building-Refuge Residence	area	0.2	100
	Photo Blind	area	0.2	100
	Kiosk	area	0.2	100
SLAMM Wetland Cover	SLAMM Swamp (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Cypress Swamp (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Inland Fresh Marsh (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Tidal Fresh Marsh (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Transitional Salt Marsh (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Regularly Flooded Marsh (usually Salt Marsh) (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Estuarine Low Flat (Initial Condition, 2025, 2050, 2100) (formerly Estuarine Beach)	area	1	100
	SLAMM Tidal Flat (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Ocean Beach (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Unknown (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Inland Open Water (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Riverine Tidal (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Estuarine Open Water (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Open Ocean (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Irregularly Flooded Marsh (often Brackish) (Initial	area	1	100

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	Condition, 2025, 2050, 2100)			
	SLAMM Inland Shore (Initial Condition, 2025, 2050, 2100)	area	1	100
	SLAMM Tidal Swamp (Initial Condition, 2025, 2050, 2100)	area	1	100
Animal Assemblage	Bird Nesting Colony	occurrence	1500	N/A
	Colonial Wading Bird Colony	occurrence	5	N/A
	Landbird Migratory Concentration Area	occurrence	49119	N/A
Community	Coastal Plain Piedmont Acidic Seepage Swamp	occurrence	11	N/A
	Coastal Plain Piedmont Seepage Bog	occurrence	4	N/A
	Interdune Pond G1	occurrence	1	N/A
	Interdune Pond G3	occurrence	2	N/A
	Maritime Shrub Swamp	occurrence	303	N/A
	Maritime Swamp Forest G2	occurrence	18	N/A
	Maritime Swamp Forest G3	occurrence	6	N/A
	Maritime Upland Forest G1	occurrence	18	N/A
	Maritime Upland Forest G2	occurrence	25	N/A
	Non-Riverine Flatwood Swamp	occurrence	3	N/A
	Sea-Level Fen	occurrence	1	N/A
	Semipermanent Impoundment	occurrence	1	N/A
	Tidal Oligohaline Marsh	occurrence	1	N/A
Invertebrate Animal	Spectral Tiger Beetle	occurrence	5	N/A
	Delta-spotted Spiketail	occurrence	50	N/A
	Graphic moth	occurrence	70	N/A
	Bronze Copper	occurrence	70	N/A
	Seaside Goldenrod Stem Borer	occurrence	70	N/A

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	A Flower Moth	occurrence	70	N/A
Nonvascular Plant	Puerto Rico Peatmoss	occurrence	50	N/A
Vascular Plant	Seabeach Amaranth	occurrence	50	N/A
	Blue maiden-cane	occurrence	50	N/A
	Prairie False-indigo	occurrence	50	N/A
	False Hop Sedge	occurrence	50	N/A
	Sea-beach Sedge	occurrence	50	N/A
	Southern Beach Spurge	occurrence	50	N/A
	Sawgrass	occurrence	50	N/A
	Low Frostweed	occurrence	50	N/A
	Hazel Dodder	occurrence	50	N/A
	Smartweed Dodder	occurrence	50	N/A
	Umbrella Flatsedge	occurrence	50	N/A
	Engelmann's Umbrella-sedge	occurrence	50	N/A
	A Galingale Sedge	occurrence	50	N/A
	Creamflower Tick-trefoil	occurrence	50	N/A
	Blue Witch Grass	occurrence	50	N/A
	Oval-fruited Panic Grass	occurrence	50	N/A
	Dwarf Burhead	occurrence	50	N/A
	Horse-tail Spikerush	occurrence	50	N/A
	Salt-marsh Spikerush	occurrence	50	N/A
	White-top Fleabane	occurrence	50	N/A

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	White Buttons	occurrence	50	N/A
	Ten-angle Pipewort	occurrence	50	N/A
	Seaside Heliotrope	occurrence	50	N/A
	Coastal-plain Penny-wort	occurrence	50	N/A
	Northern St. John's-wort	occurrence	50	N/A
	Big-head Rush	occurrence	50	N/A
	Brown-fruited Rush	occurrence	50	N/A
	Sheep-laurel	occurrence	50	N/A
	Golden Puccoon	occurrence	50	N/A
	Elongated Lobelia	occurrence	50	N/A
	Low Water-milfoil	occurrence	50	
	Big Floating-heart	occurrence	50	N/A
	Wild Olive	occurrence	50	N/A
	Joint Paspalum	occurrence	50	N/A
	Sticky Ground-cherry	occurrence	50	N/A
	Seaside Plantain	occurrence	50	N/A
	Sea-beach Knotweed	occurrence	50	N/A
	Salt Marsh Goosegrass	occurrence	50	N/A
	Awned Mountain-mint	occurrence	50	N/A
	White Beakrush	occurrence	50	N/A
	Few-flowered Beakrush	occurrence	50	N/A
	Long-beaked Baldrush	occurrence	50	N/A
	Slender Marsh Pink	occurrence	50	N/A
	Whorled Nutrush	occurrence	50	N/A
	One-flower Sclerolepis	occurrence	50	N/A
	Elliott Goldenrod	occurrence	50	N/A

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	A Goldenrod (*Solidago tortifolia*)	occurrence	50	N/A
	Bog Fern	occurrence	50	N/A
	Spanish Moss	occurrence	50	N/A
	Fraser's Marsh St. John's-wort	occurrence	50	N/A
	Virginia Least Trillium	occurrence	50	N/A
	Southern Bladderwort	occurrence	50	N/A
	Large Cranberry	occurrence	50	N/A
	Columbia Water-meal	occurrence	50	N/A
Vertebrate Animal	Cooper's Hawk	occurrence	450	N/A
	Spotted Sandpiper	occurrence	3	N/A
	Saltmarsh Sharp-tailed Sparrow	occurrence	125	N/A
	Seaside Sparrow	occurrence	13	N/A
	American Black Duck	occurrence	5	N/A
	Gadwall	occurrence	90	N/A
	Great Egret	occurrence	10	N/A
	Great Blue Heron	occurrence	3	N/A
	Cattle Egret	occurrence	1	N/A
	Green Heron	occurrence	3	N/A
	Loggerhead Shrike	occurrence	20	N/A
	Swainson's Thrush	occurrence	1	N/A
	Brown Creeper	occurrence	1	N/A
	Piping Plover	occurrence	5	N/A
	Semipalmated Plover	occurrence	1	N/A
	Wilson's Plover	occurrence	1	N/A
	Northern Harrier	occurrence	125	N/A
	Marsh Wren	occurrence	13	N/A

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	Yellow-billed Cuckoo	occurrence	50	N/A
	Northern Bobwhite	occurrence	3	N/A
	Yellow-rumped Warbler	occurrence	1	N/A
	Magnolia Warbler	occurrence	1	N/A
	Little Blue Heron	occurrence	1	N/A
	Snowy Egret	occurrence	1	N/A
	Tricolored Heron	occurrence	1	N/A
	Yellow-bellied Flycatcher	occurrence	1	N/A
	Least Flycatcher	occurrence	1	N/A
	White Ibis	occurrence	1	N/A
	Peregrine Falcon	occurrence	1	N/A
	Gull-billed Tern	occurrence	1	N/A
	Blue Grosbeak	occurrence	13	N/A
	American Oystercatcher	occurrence	1	N/A
	Bald Eagle	occurrence	200	N/A
	Black-necked Stilt	occurrence	1	N/A
	Caspian Tern	occurrence	1	N/A
	Black Rail	occurrence	125	N/A
	Laughing Gull	occurrence	7	N/A
	Yellow-crowned Night-Heron	occurrence	1	N/A
	Black-Crowned Night-Heron	occurrence	1	N/A
	Brown Pelican	occurrence	3	N/A
	Double-crested Cormorant	occurrence	1	N/A
	Eastern Towhee	occurrence	3	N/A
	Glossy Ibis	occurrence	1	N/A
	Black-bellied Plover	occurrence	1	N/A

Type	Name	Viability Unit of Assessment	Minimum Area for Viability (ac)	Retention Goal (%)
	Sora	occurrence	1	N/A
	King Rail	occurrence	3	N/A
	Virginia Rail	occurrence	13	N/A
	Clapper Rail	occurrence	3	N/A
	Golden-crowned Kinglet	occurrence	1	N/A
	Bank Swallow	occurrence	5	N/A
	Black Skimmer	occurrence	1	N/A
	Delmarva Fox Squirrel	occurrence	75	N/A
	American Woodcock	occurrence	185	N/A
	Ovenbird	occurrence	250	N/A
	Northern Waterthrush	occurrence	1	N/A
	Brown-headed Nuthatch	occurrence	9	N/A
	Field Sparrow	occurrence	5	N/A
	Forster's Tern	occurrence	1	N/A
	Common Tern	occurrence	1	N/A
	Least Tern	occurrence	1	N/A
	Royal Tern	occurrence	1	N/A
	Sandwich Tern	occurrence	1	N/A
	Willet	occurrence	10	N/A
	Winter Wren	occurrence	1	N/A
	Blue-winged Warbler	occurrence	1	N/A
	Nashville Warbler	occurrence	1	N/A
	Canada Warbler	occurrence	1	N/A

* derived habitat element at the refuge level

^ derived habitat resource at the supporting landscape level

Appendix F. Resource Responses

This table documents the categorical response of each resource to each current and expected stressor in the supporting landscape: negative (–), neutral (=), and positive (+).

Name	Monarch Migration Roost EO	Cicindela dorsalis dorsalis	Salt Flat	Maritime Wet Grassland G1	Maritime Wet Grassland G3	Upper Beach Overwash Flat	Tidal Mesohaline Polyhaline Marsh G4	Tidal Mesohaline Polyhaline Marsh G5	Maritime Dune Woodland	Maritime Dune Scrub	Maritime Dune Grassland	VIMS Seaside Lagoon^	VIMS Seaside High Marsh^	VIMS Seaside Low Marsh^	VIMS Seaside High Flat^	Early Successional Upland*	Freshwater Emergent Marsh*	Maritime Dune Grassland*	Maritime Dune Scrub*	Maritime Dune Woodland*	Maritime Upland Forest-Deciduous Dominated*	Maritime Upland Forest-Pine Dominated*	Upper Beach-Overwash Flat*	Tidal Polyhaline Marsh Complex*	Trail-Gravel	Trail-Mowed	Road-Asphalt	Road-Gravel	Road-Native	Parking-Asphalt	Parking-Concrete	Parking-Gravel	Bridge-tunnel Through Fishermans Island	Communications Tower	Wise Point Boat Ramp and Dock	Canoe-Kayak Launch	Building-Visitor Center	Building-Refuge Headquarters	Building-Workamper Site	Building-Maintenance	Building-Refuge Residence	Photo Blind	Kiosk	Swamp (SLAMM~)	Cypress Swamp (SLAMM~)	Inland Fresh Marsh (SLAMM~)	Tidal Fresh Marsh (SLAMM~)	Transitional Salt Marsh (SLAMM~)	Regularly Flooded Marsh (usually Salt Marsh) (SLAMM~)	Estuarine Low Flat (SLAMM~) (formerly Estuarine Beach)	Tidal Flat (SLAMM~)	Ocean Beach (SLAMM~)	Unknown (SLAMM~)	Inland Open Water (SLAMM~)	Riverine Tidal (SLAMM~)	Estuarine Open Water (SLAMM~)	Open Ocean (SLAMM~)	Irregularly Flooded Marsh (often Brackish) (SLAMM~)	Inland Shore (SLAMM~)	Tidal Swamp (SLAMM~)	Tidal Creek (SLAMM~)
Residential & Commercial	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
High Density Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Med Density Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Low Density Residential	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Commercial & Industrial Areas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Developed Recreational Sites and Public Access Areas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agricultural and Aquaculture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cropland / Horticulture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Active Silvicultrue	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pasture and Livestock Farms	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aquaculture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Energy Production and Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mines and Quarries	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Name	Monarch Migration Roost EO	Cicindela dorsalis dorsalis	Salt Flat	Maritime Wet Grassland G1	Maritime Wet Grassland G3	Upper Beach Overwash Flat	Tidal Mesohaline Polyhaline Marsh G4	Tidal Mesohaline Polyhaline Marsh G5	Maritime Dune Woodland	Maritime Dune Scrub	Maritime Dune Grassland	VIMS Seaside Lagoon^	VIMS Seaside High Marsh^	VIMS Seaside Low Marsh^	VIMS Seaside High Flat^	Early Successional Upland*	Freshwater Emergent Marsh*	Maritime Dune Grassland*	Maritime Dune Scrub*	Maritime Dune Woodland*	Maritime Upland Forest-Deciduous Dominated*	Maritime Upland Forest-Pine Dominated*	Upper Beach-Overwash Flat*	Tidal Polyhaline Marsh Complex*	Trail-Gravel	Trail-Mowed	Road-Asphalt	Road-Gravel	Road-Native	Parking-Asphalt	Parking-Concrete	Parking-Gravel	Bridge-tunnel Through Fishermans Island	Communications Tower	Wise Point Boat Ramp and Dock	Canoe-Kayak Launch	Building-Visitor Center	Building-Refuge Headquarters	Building-Workamper Site	Building-Maintenance	Building-Refuge Residence	Photo Blind	Kiosk	Swamp (SLAMM~)	Cypress Swamp (SLAMM~)	Inland Fresh Marsh (SLAMM~)	Tidal Fresh Marsh (SLAMM~)	Transitional Salt Marsh (SLAMM~)	Regularly Flooded Marsh (usually Salt Marsh) (SLAMM~)	Estuarine Low Flat (SLAMM~) (formerly Estuarine Beach)	Tidal Flat (SLAMM~)	Ocean Beach (SLAMM~)	Unknown (SLAMM~)	Inland Open Water (SLAMM~)	Riverine Tidal (SLAMM~)	Estuarine Open Water (SLAMM~)	Open Ocean (SLAMM~)	Irregularly Flooded Marsh (often Brackish) (SLAMM~)	Inland Shore (SLAMM~)	Tidal Swamp (SLAMM~)	Tidal Creek (SLAMM~)
Transportation and Service Corridors	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Roads - County and State	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Roads - rural	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Railroads	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Utility Corridors	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biological Resource Use	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vacant / Undeveloped Land	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Public Fishing Areas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Human Intrusions and Disturbance	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural System Modifications	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dams & Reservoirs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Invasive and Other Problematic Species and Genes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Invasive Species	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pollution	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water Pollution - Non-point Source	-	-	-	-	-	=	-	-	=	=	=	-	-	-	-	=	-	=	=	=	=	=	=	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Landfill / Solid Waste	-	-	-	-	-	-	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Name	Monarch Migration Roost EO	Cicindela dorsalis dorsalis	Salt Flat	Maritime Wet Grassland G1	Maritime Wet Grassland G3	Upper Beach Overwash Flat	Tidal Mesohaline Polyhaline Marsh G4	Tidal Mesohaline Polyhaline Marsh G5	Maritime Dune Woodland	Maritime Dune Scrub	Maritime Dune Grassland	VIMS Seaside Lagoon^	VIMS Seaside High Marsh^	VIMS Seaside Low Marsh^	VIMS Seaside High Flat^	Early Successional Upland*	Freshwater Emergent Marsh*	Maritime Dune Grassland*	Maritime Dune Scrub*	Maritime Dune Woodland*	Maritime Upland Forest-Deciduous Dominated*	Maritime Upland Forest-Pine Dominated*	Upper Beach-Overwash Flat*	Tidal Polyhaline Marsh Complex*	Trail-Gravel	Trail-Mowed	Road-Asphalt	Road-Gravel	Road-Native	Parking-Asphalt	Parking-Concrete	Parking-Gravel	Bridge-tunnel Through Fishermans Island	Communications Tower	Wise Point Boat Ramp and Dock	Canoe-Kayak Launch	Building-Visitor Center	Building-Refuge Headquarters	Building-Workamper Site	Building-Maintenance	Building-Refuge Residence	Photo Blind	Kiosk	Swamp (SLAMM~)	Cypress Swamp (SLAMM~)	Inland Fresh Marsh (SLAMM~)	Tidal Fresh Marsh (SLAMM~)	Transitional Salt Marsh (SLAMM~)	Regularly Flooded Marsh (usually Salt Marsh) (SLAMM~)	Estuarine Low Flat (SLAMM~) (formerly Estuarine Beach)	Tidal Flat (SLAMM~)	Ocean Beach (SLAMM~)	Unknown (SLAMM~)	Inland Open Water (SLAMM~)	Riverine Tidal (SLAMM~)	Estuarine Open Water (SLAMM~)	Open Ocean (SLAMM~)	Irregularly Flooded Marsh (often Brackish) (SLAMM~)	Inland Shore (SLAMM~)	Tidal Swamp (SLAMM~)	Tidal Creek (SLAMM~)
Managed Areas - BMI	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BMI 1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BMI 2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BMI 3	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BMI 4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BMI 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Land / Water Management	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RIBITS (wetland mitigation)	-	-	- *	- *	- *	- *	- *	- *	- *	- *	- *	-	-	-	-	- *	- *	- *	- *	- *	- *	- *	- *	- *	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SLAMM/C-CAP Composite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coastal Barrier Resources Act Unit boundaries	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swamp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cypress Swamp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inland Fresh Marsh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tidal Fresh Marsh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Transitional Salt Marsh	-	-	-	-	-	-	+	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Regularly Flooded marsh (Usually Salt marsh)	-	-	-	-	-	-	+	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-

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Estuarine Low Flat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Tidal Flat	-	-	+	+	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Ocean Beach	-	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Unknown	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inland Open Water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Riverine Tidal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Estuarine Open Water	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Open Ocean	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Irregularly Flooded marsh (often brackish)	-	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Inland Shore	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Tidal Swamp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Tidal Creek	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
High Intensity Developed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Medium Intensity Developed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Low Intensity Developed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Developed Open Space	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cultivated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Name	Monarch Migration Roost EO	Cicindela dorsalis dorsalis	Salt Flat	Maritime Wet Grassland G1	Maritime Wet Grassland G3	Upper Beach Overwash Flat	Tidal Mesohaline Polyhaline Marsh G4	Tidal Mesohaline Polyhaline Marsh G5	Maritime Dune Woodland	Maritime Dune Scrub	Maritime Dune Grassland	VIMS Seaside Lagoon^	VIMS Seaside High Marsh^	VIMS Seaside Low Marsh^	VIMS Seaside High Flat^	Early Successional Upland*	Freshwater Emergent Marsh*	Maritime Dune Grassland*	Maritime Dune Scrub*	Maritime Dune Woodland*	Maritime Upland Forest-Deciduous Dominated*	Maritime Upland Forest-Pine Dominated*	Upper Beach-Overwash Flat*	Tidal Polyhaline Marsh Complex*	Trail-Gravel	Trail-Mowed	Road-Asphalt	Road-Gravel	Road-Native	Parking-Asphalt	Parking-Concrete	Parking-Gravel	Bridge-tunnel Through Fishermans Island	Communications Tower	Wise Point Boat Ramp and Dock	Canoe-Kayak Launch	Building-Visitor Center	Building-Refuge Headquarters	Building-Workamper Site	Building-Maintenance	Building-Refuge Residence	Photo Blind	Kiosk	Swamp (SLAMM~)	Cypress Swamp (SLAMM~)	Inland Fresh Marsh (SLAMM~)	Tidal Fresh Marsh (SLAMM~)	Transitional Salt Marsh (SLAMM~)	Regularly Flooded Marsh (usually Salt Marsh) (SLAMM~)	Estuarine Low Flat (SLAMM~) (formerly Estuarine Beach)	Tidal Flat (SLAMM~)	Ocean Beach (SLAMM~)	Unknown (SLAMM~)	Inland Open Water (SLAMM~)	Riverine Tidal (SLAMM~)	Estuarine Open Water (SLAMM~)	Open Ocean (SLAMM~)	Irregularly Flooded Marsh (often Brackish) (SLAMM~)	Inland Shore (SLAMM~)	Tidal Swamp (SLAMM~)	Tidal Creek (SLAMM~)
Pasture/Hay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grassland	+	-	-	+	+	-	-	-	-	-	+	-	-	-	-	+	-	+	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Deciduous Forest	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Evergreen Forest	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mixed Forest	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scrub/Shrub	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Palustrine Forested Wetland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Palustrine Scrub/Shrub Wetland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Palustrine Emergent Wetland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Estuarine Forested Wetland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Estuarine Scrub/Shrub Wetland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Estuarine Emergent Wetland	-	-	-	-	-	-	+	+	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unconsolidated Shore	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bare Land	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Water	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Palustrine Aquatic Bed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Developed Dry Land	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Undeveloped Dry Land	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* derived habitat element at the refuge level
^ derived habitat resource at the supporting landscape level
~ SLAMM simulations for four years were used in this analysis: initial condition, 2025, 2050, and 2100. SLAMM resources are only compatible with themselves.