NORTH ATLANTIC COAST COMPREHENSIVE STUDY
NACCS
UNITED STATES ARMY CORPS OF ENGINEERS

North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk

Environmental and Cultural Resources Conditions Report

Final Report
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US Army Corps of Engineers®
North Atlantic Division

ENVIRONMENTAL AND CULTURAL RESOURCES CONDITIONS REPORT

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INTRODUCTION

This report presents existing environmental and cultural resource conditions and future conditions for the states of New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, and Virginia. Existing conditions account for current and known implementation actions through 2018. While much planning may be underway or undertaken soon, the future conditions assessment does not account for those additional implementation actions that do not have a secure funding source at the time of this report. Each state's (and District of Columbia) information on existing coastal and cultural resource characteristics, habitat impacts from Hurricane Sandy, and future environmental conditions is presented in a bulleted list of details and provided in a state-specific chapter. This approach was selected to facilitate state-level use of the final document, for study and project reports and National Environmental Policy Act (NEPA) documentation, whereby each interested parties are able to easily locate and review applicable information, and reproduce in hard copy only that portion which specifically pertains to their interests.

When considering future environmental conditions, potential impacts of sea level rise were considered using the USACE High sea level change scenario presented in the North Atlantic Coast Comprehensive Study. The range of impacts in terms of mean sea level inundation varies across the vast study area because the rate of sea level rise varies across the NACCS study area. Each respective state chapter presents the potential impacts from sea level rise inundation. Overall, coastal habitat of the North Atlantic Coast includes areas that may be could be squeezed between open water and developed or agricultural areas, perhaps without adequate transition areas as sea level rises. Impacts to habitat would occur over time as terrestrial habitats are converted to open water.

Other impacts of climate change may include increased intensity of hurricanes; however, climate science projections for intensity and intense hurricane numbers suggest relatively large uncertainty at present (NOAA 2012). High magnitude storm events such as hurricanes and Nor'Easters could have extensive direct and indirect impacts to habitat, ranging from erosion from wave attack, salt water intrusion from inundation, as well as water quality impacts from developed areas experiencing inundation from floodwaters. Additionally, temporary and permanent impacts to habitat could occur across a broad temporal reference along the North Atlantic Coast. Some habitat areas could be exposed to different impacts based on the time of the year the storm occurs. Combined with sea level rise, extreme water levels may exacerbate coastal storm impacts to habitats over the long-term planning horizon. Futher consideration of the future conditions of habitat impacts for each of the respective states would be required for subsequent environmental assessments or environmental impact statements.

The North Atlantic Coast comprises a vast and rich coastal ecosystem which includes: barrier islands; beaches and dunes; salt, brackish, and fresh marshes; tidal mud flats and maritime forests; rocky shorelines; submerged aquatic vegetation; oyster and rock reefs, shallow bays and bay islands; terrestrial uplands, floodplains, and riparian zones. These habitats contain a remarkable array of biodiversity and are recognized as an important ecological resource for migratory birds including waterfowl, wading birds, shorebirds, and other species that depend upon these areas during their lifetime. Due to the scale of this environmental conditions report, habitats and/or resources may have been combined for areas with similar characteristics or geographic locations.

Significant habitats along the coast include coastal wetlands, waterbird islands, and Essential Fish Habitat (EFH). Some area beaches provide critical habitat for horseshoe crab spawning, other areas support threatened and endangered species such as Least and Common Terns. Additionally, the entire study area is part of the Atlantic Flyway which is home to thirty two priority bird species.

This report also includes a U.S. Fish and Wildlife Services's NACCS Planning Aid Report (PAR) (Attachment A) which contains the following information: 1) identification and geographic location of priority biological resources that are expected to be vulnerable; and 2) descriptions of the risk to important coastal National Wildlife Refuges. The priority biological resource information is focused primarily on federally listed threatened and endangered species, and waterbird nesting colonies. The refuge information discusses vulnerability and steps that are being taken to reduce risk.

Within the study area, a variety of historic properties include: architectural properties, archaeological sites, historic buildings and structures, and submerged historic properties (shipwrecks and inundated archaeological sites). Each state and the District of Columbia has documentation available for known and recorded historic properties within their jurisdiction that have been identified through surveys and other studies. Therefore, where known, areas of archaeological sensitivity are noted, should be considered in long range planning and may require historic and/or archaeological survey to determine the presence of unrecorded historic properties.

National Historic Landmarks (NHLs) are historic properties of national significance and Federal agencies are required to minimize adverse impacts to these resources. Many historic properties are also listed on the National Register of Historic Places (NRHP), thereby affording them consideration prior to any activity that may impact them. Lastly, are properties not formally listed on the NRHP but have been found to be eligible for listing on the NRHP. These eligible properties are afforded the same level of protection as those formally listed on the NRHP.

Further, consultation with Federally recognized Tribes with interests in the study area may identify other sites of sacred, spiritual or ceremonial significance that are not included in the historic properties stipulated above. Many of these Tribal locations are considered extremely sensitive and precise details and information may not be available. Further consultation would be required so that sites of Tribal importance are fully considered in the planning stages of risk reduction strategies and projects.

References

NOAA 2012. www.nrc.noaa.gov/sites/nrc/...Hurricanes_and_Climate_FINAL_May2012.pdf.

1. New Hampshire: Environmental Existing and Future Conditions

I. Coastal Characterization - New Hampshire

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Pebble Shoreline

- There are 192 acres of coastal sand dunes located in Rockingham, NH. The majority of the dunes are in the southern portion of the state at Seabrook Beach (http://www.nhdfl.org/about-forests-and-lands/bureaus/natural-heritage-bureau/photo-index/SystemPhotos/coastalsanddune.aspx).

- Mixed sand and gravel beaches comprise about 3 miles of shoreline in Rockingham. For just gravel beaches, there are approximately 13.5 miles of gravelly beaches in NH (http://www.granit.unh.edu/data/downloadfreedata/alphabetical/databyalpha.html).

- In NH, sandy (fine-medium grain) beaches make up about 2.5 miles of coastline (http://www.granit.unh.edu/data/downloadfreedata/alphabetical/databyalpha.html).

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

- In Rockingham County there are 94 miles of saltwater/brackish marshes along the coast (http://www.granit.unh.edu/data/downloadfreedata/alphabetical/databyalpha.html).

- The estimated acreage of wetlands in New Hampshire ranges between 290,000 acres, estimated from the National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service (USFWS), and 576,386 acres, estimated from soil surveys by the Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture (Tiner 2007). Accordingly, wetlands occupy between 5 percent and 10 percent of New Hampshire's landscape. Of these wetlands, about 6,200 acres are salt marsh (NH DES 2004).

- In Rockingham County, NH there are less than 0.5 miles of intertidal mud flats (http://www.granit.unh.edu/data/downloadfreedata/alphabetical/databyalpha.html).

- A study by the U.S. Fish and Wildlife Service in 1995, there are 1,100 acres of maritime forest in New Hampshire (Bellis 1995).

- The Great Bay Estuary and Hampton-Seabrook Estuary were designated by the USEPA as "estuaries of national significance" in 1995. In 2007 the New Hampshire watershed area of Great Bay was expanded to include the Maine portion of the Great Bay Estuary watershed (Piscataqua Region Estuaries Partnership et al. 2010). Rivers flowing from 52 communities in

New Hampshire and Maine converge with the waters of the Atlantic Ocean to form these two estuaries. The watershed covers 1086 square miles. These bays provide critical wildlife habitat, nurseries for seafood production, buffering from coastal flooding, recreational enjoyment, and safe harbor for marine commerce (Piscataqua Region Estuaries Partnership 2013).

Submerged Aquatic Vegetation

- In Great Bay, NH there are approximately 2,430 acres of eelgrass. Other species of submerged aquatic vegetation were not taken into account in that survey, but there are many more acres of other seagrasses in Great Bay and other areas along the coast of NH (http://www.granit.unh.edu/data/downloadfreedata/category/databycategory.html).

Oyster Reefs

- In 2009, The Nature Conservancy (TNC) and University of New Hampshire (UNH) developed methods to restore oyster reefs by “planting” shell on firm channel bottom using primarily surf-clam shell (Spisula solidissima) acquired in bulk from a seafood processor. In total, 2010 work in the Oyster River produced a standing-stock of 210,000 oysters (38/m2) across the 1.5 acre restored areas. In 2011, they scaled-up their work to construct 2.0 acres of clamshell reefs at the mouth of the Lamprey River in Newmarket using a total of 200 cubic yards of surf-clam shell. In 2012, the UNH, TNC, and a local oyster farmer set a goal to construct 2.0 new acres of oyster reef in the Great Bay Estuary. Their efforts advance the Piscataqua Region Estuaries Partnership goal of twenty acres of oyster reef restored by 2020 (https://prod.nrcs.usda.gov/Internet/fse_documents/stelprdb1081550.pdf).

Rock Reefs

- Rye on the Rocks at Rye Ledge in Rockingham, New Hampshire hosts a rocky reef (http://ryereflections.org/servlet/pluto?state=303034706167653030375765625061676530303269643030343737393335).

Rocky Shorelines

- In Rockingham County, NH there about 2.5 miles of rocky shoreline along the coast (http://www.granit.unh.edu/data/downloadfreedata/alphabetical/databyalpha.html).

Shallow Bay Habitat/ Bay Islands

- There are 1.4 sq. miles of coastal islands off of the coast of Rockingham County, NH. In the Piscataqua estuary the islands include: Fishing Island, Four Tree Island, Pierces Island, Little Island, Goat Island, Shapleigh Island, Pest Island, Lady Isle, Leachs Island, Clampit Island, and Goose Island (NH Fish and Game 2005)

Terrestrial Upland

- The Granite State is the second most forested state in the United States (trailing Maine). Forests occupy 84 percent, or 4.8 million acres. The area of forest land has declined by 134,500 acres (2.7 percent) since 1983 and is now about the same as in 1948. Three-fourths of the decline occurred in the southern part of the state, where rapid commercial and residential development has extended into previous forested areas. In the past, additions to forest land resulting from abandoned farm land reverting to forest more than offset losses due to development. Recently, reversion of farm land has continued, but gains from abandoned farms have been less than losses to development (http://www.nhdfl.org/library/pdf/Maps/Statemap-Sept%202007.pdf).

Floodplains/Riparian

- There are 11,644 acres of floodplains in Rockingham, NH (http://www.granit.unh.edu/data/downloadfreedata/alphabetical/databyalpha.html).

Coastal Protected Areas

Marine Sanctuaries/Coastal Reserves

- Great Bay National Estuarine Research Reserveis located on the New Hampshire and Maine border; it is New Hampshire's largest estuarine system. The Great Bay Reserve offers a diversity of land and water area, including upland forest, salt marsh, mudflats, tidal creeks, rocky intertidal, eelgrass beds, channel bottom/subtidal and upland field habitats. The reserve encompasses 10,235 acres, including approximately 7,300 acres of open water and wetlands. The Bay's cultural heritage is equally diverse, from Paleo-Indian villages 6,000 years ago to colonial transportation and industrial use and ultimately protection in the face of a proposed oil refinery in 1973 (http://www.greatbay.org/about/ index.htm).

National Estuary

- Piscataqua Region Estuaries Partnership (http://www.stateofourestuaries.org/about-prep/)
  - Total Watershed Drainage Area is 1086 square miles: Great Bay Estuary (drainage area 1,023 square miles); Hampton-Seabrook Estuary (drainage area 46 square miles); Other Relatively Small Estuaries between Great Bay Estuary and Hampton-Seabrook Estuary (drainage area 17 square miles)
  - 52 communities (42 in NH/10 in ME)
  - Atlantic Coastline: 18 miles/Total Tidal Shoreline at High Tide: Great Bay Estuary 204 miles; Hampton-Seabrook Estuary 131 miles

State/County Parks

- Rockingham County (http://www.nhstateparks.com/nhforests.html)
    - Hampton Beach State Park
    - Jenness State Beach
    - Kingston State Park
    - North Beach
    - North Hampton State Beach
    - Odiorne Point State Park
    - Rye Harbor State Park
    - Wallis Sands State Park

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

- The Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. Only 1.8 miles of New Hampshire coastline is suitable for piping plover breeding activity. Seabrook and Hampton beaches generally support five to seven breeding pairs per year. The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986. A detailed discussion of Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

- The Federally endangered roseate tern has a breeding colony on the Seavey and White Islands located about six miles off the coast of Rye, New Hampshire within the island group called Isle of Shoals. This colony was established in 2001 and lives, as is typical, within a colony of common terns (Attachment A).

- The Gulf of Maine Destinct Population Segment (GOM DPS) for Atlantic salmon was listed as endangered in a final rule on November 17, 2000 by the National Marine Fisheries Service (NMFS) and the USFWS (collectively “the Services”). Atlantic salmon return to rivers from the sea and migrate to their natal stream in New England beginning in the spring and continues into the fall to spawn (Federal Register vol. 74, no. 117, June 19, 2009).

- The GOM DPS for Atlantic sturgeon was listed as threatened in a final rule on February 6, 2012 by NMFS. Atlantic sturgeon spawn in spring and early summer in freshwater and migrate into estuarine and marine waters where they spend most of their lives (http://www.nmfs.noaa.gov/pr/species/fish/atlanticsturgeon.htm). Atlantic sturgeons have been documented in the Piscataqua River. The Piscataqua River forms the lower boundary between the States of New Hampshire and Maine (Federal Register vol 77, no. 24, February 6, 2012).

- The shortnose sturgeon is an anadromous fish which lives mainly in the slower moving riverine waters or nearshore marine waters before migrating periodically into faster moving freshwater to spawn. Shortnose sturgeon can also be found in the Piscataqua River. They were listed as endangered throughout its range on March 11, 1967 under the Endangered Species Act of 1966 (http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm).

- Species of Concern listed by NMFS, and associated area of concern include the anadromous and highly migratory river herring (alewife and blueback herring) found in the Atlantic Ocean from Newfoundland to North Carolina, the pelagic and highly migratory Atlantic bluefin tuna found throughout the the North Atlantic Ocean and adjacent seas, the Atlantic halibut found from Labrador to southern New England in the Northwest Atlantic Ocean, the dusky shark found in the Western Atlantic Ocean, the porbeagle shark found in the Nortwest Atlantic Ocean, the anadromous rainbow smelt found in rivers and coastal areas of eastern North America from Labrador to New Jersey, and the sand tiger shark found in the Western Atlantic Ocean (http://www.nmfs.noaa.gov/pr/species/concern/).

- The American eel was petitioned to be listed as threatened on September 29, 2011 in the Federal Register (vol. 76, no. 189) by the USFWS. Eels spawn in the Sargasso Sea. Juveniles arrive in coastal waters and river systems which are accessible by the oceanic currents of the western North Atlantic Ocean for development. This fish occupies fresh, brackish and marine waters (FR, vol 76. No. 189).

Waterbird Islands

- Isle of Shoals Group – Star Island, Lunging Island, Square Rock, and Seavey Island (tern restoration), White Island (Kushlan et al. 2002)

Essential Fish Habitat /Fish

- The area provides EFH for (http://www.nero.noaa.gov/hcd/STATES4/smaine.htm):
    - American plaice: eggs, larvae, juveniles, adults
    - Atlantic cod: eggs, larvae, juveniles, adults
    - Atlantic halibut: eggs, larvae, juveniles, adults
    - Atlantic herring: eggs, larvae, juveniles, adults

- Atlantic mackerel: eggs, larvae, juveniles, adults
- Atlantic salmon: eggs, larvae, juveniles, adults
- Atlantic sea scallops: eggs, larvae, juveniles, adults
- Black sea bass: larvae, juveniles, adults
- Bluefish: juveniles, adults
- Butterfish: eggs, larvae, juveniles, adults
- Haddock: eggs, larvae, juveniles, adults
- Ilex squid: juveniles, adults
- Loligo: eggs, juveniles, adults
- Monkfish: eggs, larvae, juveniles, adults
- Ocean pout: eggs, larvae, juveniles, adults
- Ocean quahog: juveniles, adults
- Pollock: eggs, larvae, juveniles, adults
- Red hake: eggs, larvae, juveniles, adults
- Redfish: eggs, larvae, juveniles, adults
- Scup: juveniles, adults
- Spiny dogfish: juveniles, adults
- Summer flounder: eggs, larvae, juveniles, adults
- Surf clams: juveniles, adults
- Tilefish: eggs, larvae, juveniles, adults
- White hake: eggs, larvae, juveniles, adults
- Whiting: eggs, larvae, juveniles, adults
- Windowpane flounder: eggs, larvae, juveniles

- Winter flounder: eggs, larvae, juveniles, adults
- Witch flounder: eggs, larvae, juveniles, adults
- Yellowtail flounder: eggs, larvae, juveniles, adults
- Skates: juveniles, adults
- Habitat Areas of Particular Concern: None

II. Habitat Impacts from Hurricane Sandy - New Hampshire, Massachusetts, Rhode Island, and Connecticut

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

According to the National Fish and Wildlife Foundation (2012):

- Most of the shoreline along Long Island Sound experienced Low Damage. A few areas generally associated with exposed points and islands such as Hammonasset Point and the Norwalk Island in CT, experienced Moderate Damage. The damage rating was based on damage to the three habitats discussed below: dune/beach, tidal marsh, and maritime forest.

- For beach/dunes in Long Island Sound – 13% experienced no impact, 59% low impact (thinning of beach (<50'), debris deposited), 28% moderate impact (evidence of overwash; loss of dune vegetation; moderate thinning of beach - 50 to 100'), and 0% high impact (new overwash channels opened connecting ocean to bay; major loss of dune vegetation leaving largely barren areas, major thinning or migration of beach - >100'). Hurricane Sandy impact to areas north of Cape Cod were minimal (USACE 2013).

- Beach Dune and Erosion occurred at the following locations (The National Fish and Wildlife Foundation 2012):
    - Milford Point, Milford, CT
    - Sandy Point, Morse Point, West Haven, CT
    - Salt Island, off the coast of Westbrook, CT
    - Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
    - Silver Sands State Park, Milford, CT

- Pattagansett Marsh Preserve, East Lyme, CT
- Rocky Neck State Park, East Lyme, CT
- Hatchetts Point Natural Area, Old Lyme, CT
- Griswold Point, Old Lyme, CT
- Woodmont Beach, Milford, CT (Reference for this beach and below: USACE 2013)
- Gulf Beach, Milford, CT
- Prospect Beach, West Haven, CT
- Sherwood Island State Beach, Westport, CT
- Southport Beach, Fairfield, CT
- Misquamicut Beach, Westerly, RI
- Oak Bluffs Town Beach, Oak Bluffs, MA
- Plum Island Beach, Newbury, MA
- Revere Beach, Revere, MA
- North Scituate Beach, Scituate, MA
- Quincy Shore Beach, Quincy, MA

- Existing Beach/Dune Habitat was moved or new habitat was created at the following locations (The National Fish and Wildlife Foundation 2012; USACE 2013):
  - Long Beach, Stratford, CT
  - Sand Point Island, West Haven, CT
  - Mumford, Cove and Bluff Point State Park, Groton, CT
  - Harkness Memorial State Park, Waterford, CT
  - Griswold Point, Old Lyme, CT
  - Meunketesuck, Salt and Duck Island, Westbrook, CT
  - Hammonasset Beach State Park, Madison, CT

- Falkner Island, Guilford, CT
- Morse Point, Milford, CT
- Pleasure Beach, Bridgeport, CT
- Cockenone Island, Westport, CT
- Greater Norwalk Islands, Great Captains Island, Greenwich, CT
- Sea Bluff Beach, West Haven, CT

Barrier Islands/Inlets

- Falkner Island which is home to rosate and common terns lost approximately 1/3 of its area (The National Fish and Wildlife Foundation 2012).
- Menunketesuck Island and Duck Island had excessive shoreline erosion (The National Fish and Wildlife Foundation 2012).
- Channel blockage/tidal flow interference occurred at the following locations (The National Fish and Wildlife Foundation 2012):
  - Waterford Town Beach and Pleasure Island – breaches of the barrier dune and beach erosion are causing sand to erode into Alewife Cove which is obstructing the cove's outlet to Long Island Sound.
  - At Rocky Neck State Park, accumulated sand prevented flow and proper tidal flushing of the Bride Brook Channel. This is one of the largest alewife runs in CT.
  - Harkness Memorial State Park – the outlet of Goshen Cove, an estuarine embayment and tidal creek, is currently blocked by sand and sediment.
  - Lynde Point – the storm pushed a dune into the tidal marsh blocking the flow of a tidal creek. Water is accumulating behind this blockage transforming the tidal marsh into freshwater swamp.

Salt / Brackish Marsh

- Coastal salt marshes were impacted to a much lesser degree showing much higher resistance to storm damage (The National Fish and Wildlife Foundation 2012).
- For marsh in Long Island Sound – 28% experienced no impact, 56% low impact (evidence of new wrack and debris deposited), 16% moderate impact (minor erosion/loss of marsh edge; small areas of sand deposited; medium size areas of wrack/debris) and 0% high impact (major

erosion/loss of bayward marsh edge; large areas of sand and wrack deposites within marsh proper; rearrangement of tidal creek channels) (The National Fish and Wildlife Foundation 2012).

- Erosion of beaches and dunes left adjacent salt marsh habitat vulnerable to inundation from winter storms and high tides. These areas include (The National Fish and Wildlife Foundation 2012):
  - Waterford Town Beach, Waterford Pleasure Beach, Waterford, CT
  - Pattagansett Marsh Preserve, East Lyme, CT
  - Hattchetts Point Natural Area, Old Lyme, CT
- Lynde Point, Old Saybrook, CT – Storm surge pushed a dune into a tidal marsh and created a dam that which blocked the flow of the tidal creek, preventing it from reaching the adjacent marsh. As a result the area is quickly converting into a freshwater swamp (The National Fish and Wildlife Foundation 2012).
- An earthen berm at Sunken Meadow State Park adjacent to Sunken Meadow Creek in CT was destroyed by the storm. This berm had been scheduled to be removed to restore 100 acres of salt marsh as part of an anadromous fish project. This is considered a positive impact from Hurricane Sandy (The National Fish and Wildlife Foundation 2012).

Maritime Forest

- According to The National Fish and Wildlife Foundation (2012), impacts to the forests in Long Island Sound were as listed:
  - 66% experienced no impact
  - 33% low impact (evidence of a few 5% fallen trees)
  - 1% moderate impact (5-25% trees fallen creating numerous small canopy gaps <1 acre in size)
  - 0% high impact (>25% of trees fallen creating large [>1 acre in size])

Submerged Aquatic Vegetation

- According to The National Fish and Wildlife Foundation (2012), there was significant eelgrass damage at Ninigret Pond, Charlestown, RI.

Rock Reefs

- According to The National Fish and Wildlife Foundation (2012), Penfield Reef in Fairfield, CT "largely washed away" as a result of the storm.

National Park Service Areas

Stewart B. McKinney

- Stewart B. McKinney
    - At Falkner Island, 1/3 of the island was lost as s result of the storm. This area is home to roseate terns and common terns (The National Fish and Wildlife Foundation 2012).

- The following State Parks experienced overwashing of dunes and significant erosion and/or the movement of existing habitat and creation of new habitat from Hurricane Sandy (The National Fish and Wildlife Foundation 2012; USACE 2013).
    - Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
    - Silver Sands State Park, Milford, CT
    - Pattagansett Marsh Preserve, East Lyme, CT
    - Rocky Neck State Park, East Lyme, CT
    - Hatchetts Point Natural Area, Old Lyme, CT
    - Mumford, Cove and Bluff Point State Park, Groton, CT
    - Hammonasset Beach State Park, Madison, CT
    - Sherwood Island State Beach, Westport, CT
    - Misquamicut Beach, Westerly, RI

Critical/Significant Habitat

- Beaches above that experienced erosion above would have an impact on the species that nest on beaches, including piping plover, least terns, and rosette terns

- Coastal flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013).

Quality

- According to The National Fish and Wildlife Foundation (2012):
    - Ledyard, CT – a backup generator for the Town's treatment plant failed causing officials to pump approximately 60,000 gallons of raw sewage into Set Williams Brook.
    - Branford, East Lyme, Fairfield, Greenwich, New Hartford, and New Haven, CT – Similar problems and releases were reported.
    - Bridgeport, CT – 15 to 20 million gallons of partially treated sewage was discharged into Long Island Sound when the city's two treatment plants were inundated tidal surges.

III. Future Without Action Conditions - New Hampshire

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- New Hampshire's 18 mile coastline is the shortest of the U.S. ocean-bordering States.

- Coastal dunes are considered one of New Hampshire's most at-risk habitats. They are used by many birds for breeding, migration, or wintering. Loss of dune or salt marsh habitat will result in reduction, or elimination, of certain rare shorebird and salt marsh species nesting in New Hampshire (NH Fish and Game Department 2012).

- According to NH Fish and Game Department (2012), the areas of dune and salt marsh that currently lie adjacent to undeveloped land with gradual slopes have the most potential of maintaining accretion rates to keep pace with the rise in relative sea level. However, these opportunities to migrate inland are exceedingly limited as a result of heavy development and extensive habitat loss in dune and salt marsh habitat is likely.

- Beaches, dunes and salt marsh habitats provide significant functional services, most importantly natural flood control, to both the biological and human environment. Sea level rise will have profound effects by increasing flooding frequency and inundating low-lying coastal areas. Beaches and barrier islands may be degraded or lost by flooding. These habitats are also expected to face increasingly intense coastal storms, which may cause impacts such as destruction of coastal dunes, breaches in barrier islands, and shoreline erosion. By 2068 much of New Hampshire's coastline could be inundated, while by 2118 almost all of the coastline and shoreline of Great Bay could be inundated by the projected sea level rise.

- It is expected that the beaches at Hampton Beach in Hampton and Wallis Sands State Beach in Rye, which were both originally constructed as shore protection/beach fill projects by the USACE, would continue to receive sand from the local sponsor to meet their design criteria.

Other State and/or Town beaches in New Hampshire may also be expected to maintain their beaches, especially those beaches that are used recreationally. However, continued sea level rise may make this difficult to maintain in the future.

Coastal Wetlands

- Salt marshes are particularly vulnerable to the higher rates of sea level rise. The normal process of accretion, the built-up of live and decaying plants and sediments, will not keep pace. As salt marshes become submerged, they migrate inland. Existing development along the coast has decreased the amount of open space adjacent to the salt marshes, limiting their ability to migrate landward. The problem will be exacerbated in locations where bulkheads, causeways and other man-made structures interfere with the migration. Also, if the rate of sea level rise increased dramatically, then the salt marshes may not be able to match the change in vertical elevation. An increase in the rate of sea level rise will result in significant losses of coastal salt marsh habitat (New Hampshire Fish and Game Department 2012).

- In marsh areas where accretion rates cannot keep up with sea-level rise, marsh will eventually revert to unvegetated flats and eventually open water (New Hampshire Fish and Game Department 2012). In some cases where tidal range increased with increased rates of sea-level rise, there may be an overall increase in the acreage of tidal flats. In low energy shores with sediment supplies, where sediments accumulate in shallow waters, flats may become vegetated as low marsh encroaches towards the water, which will increase low marsh at the expense of tidal flats. If sediment inputs are not sufficient, tidal flats will convert to subtidal habitats, which may or may not be vegetated depending on substrate composition and water transparency (US Climate Change Science Program 2009).

- The loss of wetlands would cause wetland dependent species of fish and birds to have reduced population sizes. The National Marine Fisheries Service estimates that approximately 1/3 of commercial fish and shellfish collected in New England are directly dependent on estuaries and salt marshes (Stedman and Hanson 1997).

Submerged Aquatic Vegetation

- Although increasing depths of estuarine and marine waters from sea level rise could expand the horizontal coverage submerged aquatic vegetation habitat, a reduction in available sunlight for submerged aquatic vegetation (SAV) could impact growth and ecological function. SAVs provide food for waterfowl and act as vital protective spawning and nursery habitats for fish and shellfish, including many commercially, recreationally, and ecologically important species. Additionally contiguous expanses of SAVs provide travel corridors sheltered from predation to multiple fish and shellfish species. The distribution patterns of these important plants, that promote water oxygenation and sediment stabilization as well as having direct habitat benefits to wildlife and fish, will likely change over time in response to relative sea level rise (NH Fish and Game Department 2012).

Oyster Reefs

- Sea level rise is not expected to change the functions of a rock reef substantially. However, climate change could alter some of the species which utilize this habitat.

Rock Reefs/Rocky Shorelines

- Rocky shore, which is a less dynamic habitat, will be unable to migrate in response to relative sea level rise. This habitat will instead experience direct flooding. Littoral zone biota are likely to respond to changing tide heights by shifting vertically where space allows it. Winds will increase direct wave exposure on seaweed growing in rocky intertidal zones and on associated invertebrates upon which multiple wildlife species forage. For example, eider ducklings less than three weeks old can't dive for mussels like adult ducks; instead they depend on the seaweed canopy to forage for amphipods (NH Fish and Game Department 2012).

- Sea level rise is not expected to change the functions of a rock reef substantially. However, climate change could alter some of the species which utilize this habitat.

Shallow Bay Habitat/ Bay Islands

- Shallow waters of the Piscataqua River estuary and Hampton Harbor and other important shallow water habitat may be expected to increase as the sea rises along with shoreline erosion and the drowning of coastal wetlands and shorelines. The islands off the coast of New Hampshire and in the Piscataqua estuary would be expected to experience some of flooding of their low lying areas from sea level rise.

Terrestrial Upland

- Sea level rise is expected to have a greater impact in the towns of Hampton and Seabrook which have substantially more low-lying area than the towns of Portsmouth and New Castle (Ward and Adams 2001).

- Forests dominate 84% of the New Hampshire landscape which provides wildlife habitat, protecting watersheds and conserving soil among other benefits. Climate change has the potential to dramatically alter the character of the State's forests. For example, New Hampshire's hemlock trees which shade streams, providing cool conditions required by native brook trout and other fish could face shrinking suitable habitat from increased temperatures. In addition, the northward migration of the hemlock woolly adelgid, an invasive insect that has destroyed hemlock stands from Georgia to Connecticut could also affect the hemlock stands in the State (Union of Concerned Scientists 2007).

- In addition, the length of the winter snow season could be significantly reduced.

Floodplains/Riparian

- Floodplains will likely become increasingly vulnerable to flooding without human intervention. In tidal areas, the tidal inundation characteristics of the floodplain may change with the range of tide and associated tidal currents increasing with sea level rise. With this inundation, floodplains will be vulnerable to increased coastal erosion from waves, river and tidal currents, storm-induced flooding, and tidal flooding. Upland floodplain boundaries will be vulnerable to horizontal movement.

Coastal Protected Areas

- The ecologically important Great Bay estuary and more than 6,200 acres of salt marshes provides feeding grounds for migrating waterfowl and nursery habitat for important commercially and recreational fish such as striped bass. Accelerated sea level rise from climate change threatens New Hampshire's coast by increasing the frequency of damaging coastal flooding and potentially inundating valuable coastal wetlands (Union of Concerned Scientists 2007).

Critical/Significant Habitats

Waterbird Islands

- According to NH Fish and Game Department (2012), "seabird nesting colonies, particularly on the Isle of Shoals, are likely to be affected by storms as energetic costs of incubation are increased and foraging opportunities decrease. Increased severity of storms, combined with summer droughts, will also affect nesting seabirds by changing the amount of water deposition and consequently the fertility of the maritime meadow soils on the islands. In addition, early season storms may result in coastal ground nesting birds, such as piping plovers and least terns, to suffer direct nest or chick losses."

Essential Fish Habitat (EFH)

- Fish will remain in their preferred temperature range by shifting to higher latitudes and depths where water temperatures are cooler and more stable. Warming coastal waters are likely to result in a decrease in the presence of northern boreal species, such as haddock, and an increase of southern species off the coast of New Hampshire (NH Fish and Game Department 2012).

- Water temperature is one of the most important factors controlling growth, development, seasonal migration, and ultimately the rate of population growth for coldblooded species. In general, there has been a shift in dominance by more cold water fish and vertebrate assemblages to more warm water species such as butterfish and lobster in New Hampshire. Overall declines in commercially important marine fisheries are predicted by global climate models. Because these changes are complex, warmer temperatures in the Gulf of Maine will positively influence the growth of adult cod, but negatively impact survival of cod in early life stages (NH Fish and Game Department 2012).

Atlantic Flyway

- The Great Bay is a waterfowl focus area (http://www.acjv.org/bcr30.htm). Coastal marshes provide valuable wintering habitat since most inland wetlands freeze during the winter. Mudflats are used by migrating shorebirds. A combination of sea level rise and marsh subsidence could put some of the most important coastal marshes at risk of being lost. There could be a loss or reduction in intertidal habitat.

T&E Species/Species of Concern

Fish

- Species, such as salmon which are dependent on cold, fast-flowing streams and rivers to spawn are being affected by warming and by reduced stream flows caused by less snow melt.

Marine Turtles

- These turtles do not nest in NH and may rarely be found in the summer months. With increasing temperatures, it may be possible that these species may utilize the open waters for foraging.

Marine mammals

- Freshwater input, along with temperature changes make vertical mixing of the water column more difficult in marine systems. Increased stratification prevents nutrients that phytoplankton need to grow from being brought to the surface water layer. The reduction in biomass at this basic trophic level will have effects that cascade throughout the food web, rapidly impacting larger organisms like fish and marine mammals. In particular, the phytoplankton feeding zooplankton *Calanus finmarchicus* is a major food item of many fish species, and the primary food source of the endangered right whales. The reproductive success of these mammals is dependent on the abundance and distribution of *C. finmarchicus*. Changes in the magnitude and timing of the peak abundance of *C. finmarchicus* could significantly alter whale migration, behavior, and population abundance. In other words, shifts in food sources could affect marine mammals (NH Fish and Game Department 2012).

Birds (Nesting)

- Nesting habitat for piping plover, least tern, rosette tern, and red knot is likely to diminish with the reduction in available coastal beaches and potential decrease in intertidal habitat, increased storm activity, and reduction in habitat quality on nesting islands.

Shellfish/Shellfish beds

- Habitat conditions for shellfish could be impacted by strong storms and increased frequency of rain events which can result in increased sedimentation.

- Increase freshwater evens can also lead to decreases in salinity. As a result, lobsters will move downstream towards the more saline coastal tidal mouth. During extreme events, even these behavioral adaptations may not be adequate. For example, in May 2006, 11.5 inches of rain fell over three consecutive days; this lowered the salinity in Great Bay to 1.6 ppt. Despite moving towards the coast, many lobsters died during this freshet. Similarly, many other organisms cannot tolerate rapid shifts in salinity and will die (NH Fish and Game Department 2012).

- Sea level rise could reduce the availability of intertidal habitat which would limit the available habitat for some species such as oysters and blue mussels. Increase in ocean acidification has been known to affect the larvae and reduce the ability to build calcium carbonate shells. New Hampshire/Gulf of Maine is likely to become the new southern limit for lobsters as they move from north to their new southern limit (NECIA 2007).

Quality

Water Quality/Impaired Waters

- Tidal tributaries to the Great Bay and Hampton-Seabrook Harbor estuaries currently suffer regular periods of hypoxia, or oxygen depletion, during summer months. This has a detrimental effect on multiple aquatic organisms because fish, crabs, and many other aquatic organisms use gills to extract dissolved oxygen from water. With climate change, increased level and duration of higher water temperatures will likely result in more frequent and longer duration of hypoxia and sometimes result in pockets of anoxia or "dead zones" (NH Fish and Game Department 2012).

- Turbidity in estuaries and nearshore marine environments is strongly influenced by major rainfall events. Increased run off from precipitation and storm events will result in higher turbidity levels; which shapes the physical conditions and influences biological processes in the coastal environment. The growth of phytoplankton, benthic macroalgae and seagrass is hindered when high concentrations of suspended particles reduce light penetration in the water column. This impacts wildlife that depends on these aquatic plants for food and shelter. In addition, fine particles in the water column can also damage fish gills and interfere with filter feeding by shellfish (NH Fish and Game Department 2012).

- Nutrient loading, especially from nitrogen and phosphorus, will likely increase with greater precipitation as inputs such as agricultural and lawn fertilizers, septic systems and animal waste wash more rapidly into coastal habitats. Sudden blooms of phytoplankton and nuisance macroalgae that reduce habitat quality and destabilize food webs can be triggered by high nutrient levels into the coastal environment (NH Fish and Game Department 2012).

Toxins/Contaminants (HTRW) – Coordinate EPA and at the State Level

- Storm water systems have been built to function at present day sea levels. More pollution is anticipated due to storm water systems that have not been retrofitted to withstand future sea level rise from climate change (NH Fish and Game Department 2012).

Cultural Resources

- Sea level rise impacts to cultural resources range from increased tidal and wave erosion to inundation. Cultural resources within coastal zones will be subjected to gradual sea level rise impacts exacerbated by event-specific impacts such as high tide events and storms. The frequency and intensity of damage from event-specific impacts is expected to increase as sea level rises (Karl et al., 2009). In addition, high regional subsistence rates are expected to increase rates of sea level rise and associated impacts (Johnson 2000).

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2. Massachusetts: Environmental Existing and Future Conditions

I. Coastal Characterization - Massachusetts

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Pebble Shoreline

- Along the barrier beaches off of the coast of Massachusetts there are 11,712 acres of sand dunes (Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee 2011).

- There are approximately 320 linear miles of sandy (coarse and fine-medium grain) beaches are present in the study counties (http://response.restoration.noaa.gov/esi).

- In Dukes, Plymouth, Barnstable, Norfolk, and Essex there are approximately 32 linear miles of gravel beaches. As for mixed sand and gravel beaches, there are approximately 156 linear miles of gravelly-sand beaches across the counties of concern (http://response.restoration.noaa.gov/esi).

Barrier Islands/Inlets

- There are 86 (System Units: 61; Otherwise Protected Areas: 25) Coastal Barrier Resources System (CBRS) Units (http://www.fws.gov/CBRA/Maps/Locator/MA.pdf).

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

- Much of Massachusetts' coastline is made up of salt and brackish marshes. Approximately 45,376 acres of salt marsh exist along the shoreline of the study counties (Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee 2011).

- There are 18,944 acres of tidal flats in the Massachusetts study area counties (Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee 2011).

- There are approximately 270,620 acres of freshwater marsh across the counties of concern (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/depwetlands112000.html).

- There are approximately 1.80 acres of wooded swamp of coniferous trees in Bristol. There are 9.95 acres of deciduous marsh in Essex. In Middlesex there are approximately 0.3 acres of deciduous swamp. Along the barrier beaches off of Massachusetts there are approximately 14 acres of coniferous swamps and 109.5 acres of deciduous swamps. According to a study by the

U.S. Fish and Wildlife Service there are 27 forested barrier islands in Massachusetts with a total of 37,600 acres of forest (Bellis 1995).

Submerged Aquatic Vegetation

- In Plymouth, MA there are many areas that have seagrasses. Scituate Harbor hosts 10.3 acres of seagrass, in the Weweantic River there are 18 acres of seagrass, Boston Harbor has 116.3 acres of seagrasses, Plymouth Harbor holds 1,909 acres of seagrass, Sippican Harbor is home to 492.5 acres of SAV, and Wareham River has 3 acres of seagrasses.

- Onset Bay in Barnstable has 297 acres of seagrasses. Also in Barnstable, Waquoit Bay has 15 acres of SAV, Pleasant Bay supports a large area of submerged aquatic vegetation with 1,382 acres present in the Bay, Chatham Harbor holds 466 acres of seagrass, Pocasset Harbor is home to 192 acres of seagrass, Quissett Harbor has 53 acres of SAV, West Falmouth Harbor has 51 acres of submerged aquatic vegetation, and Wild Harbor is home to 14.4 acres of seagrass.

- In Dukes County, there are 529 acres of seagrasses in Cape Pogue Pond, Elizabeth Islands has 1,149 acres of seagrass, Lagoon Pond holds 51 acres of SAV, Lake Tashmo is home to 19 acres of seagrass, Menemsha Pond has 319 acres of submerged aquatic vegetation, and Sengekontacket Pond holds 5.5 acres of SAV.

- In Norfolk County, Cohasset Harbor holds 112 acres of seagrasses.

- Gloucester Harbor in Essex is home to 60 acres of seagrasses. Broad Sound in Essex supports approximately 700 acres of SAV, Ipswich Bay holds approximately 28 acres of seagrass, Sandy Bay has 2 acres of submerged aquatic vegetation, and Salem Harbor holds around 36 acres of seagrass.

- In Nantucket County, Madaket Harbor is home to 605 acres of submerged aquatic vegetation.

- New Bedford Harbor in Bristol County, MA holds 122 acres of SAV. Also, Westport River in Bristol has approximately 500 acres of seagrasses.

(http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/eelgrass0607.html)

Oyster Reefs

- In 2009, Mass Audubon worked with The Nature Conservancy, NOAA, and the Town of Wellfleet to restore a wild-set oyster reef on intertidal flats owned by Mass Audubon, the first such attempt in Massachusetts. They placed an artificial oyster reef in Wellfleet Bay and have been monitoring it for productivity and water quality (http://www.scseagrant.org/icsr10/faherty.poster.pdf).

Rock Reefs

- In Massachusetts there are several natural rock reefs. They are spread across the coast, but naturally occurring reefs have been identified in Hull, Beverly, near Lovell Island in Boston, and Marblehead (Barber et al. 2009).

Rocky Shorelines

- There are approximately 1190 acres of rocky intertidal shoreline in the study counties (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/depwetlands112000.html).

Shallow Bay Habitat/ Bay Islands

- The islands of Massachusetts range from barren, almost completely submerged rocks in Massachusetts Bay (e.g. Abbott Rock) to the large, famous and heavily visited Martha's Vineyard and Nantucket. Massachusetts has over 200 islands off its coast, with some lying in the Connecticut River (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/coloroq.html).

Terrestrial Upland

- There are 3.2 million acres of privately owned forest land in Massachusetts and 310,000 acres of State Forests and Parks (http://www.mass.gov/eea/agencies/dcr/conservation/forestry-and-fire-control/forestry.html; downloaded June 26, 2014).

Floodplains/Riparian

- There are 105,806 acres of floodplains in Massachusetts (http://www.mass.gov/ anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/nfhl.html).

Coastal Protected Areas

Marine Sanctuaries/Coastal Reserves

- Stellwagen Bank National Marine Sanctuary: located 25 miles east of Boston between Cape Ann and Cape Cod. Area: 842 square miles (http://stellwagen.noaa.gov/).

- Waquoit Bay National Estuarine Research Reserve: The Waquoit Bay Reserve is located on the south shore of Cape Cod Massachusetts, on the border of the towns of Falmouth and Mashpee. The Reserve's more than 2,700 acres encompass open waters, salt and fresh marshes, barrier beaches, sand dunes, rivers, mixed pine and oak forests, and sandplain grasslands. The Reserve includes 1,286 acres of upland, and about 1,359 acres of estuarine waters, freshwater ponds, tributary streams, vernal pools and substantial groundwater resources. Freshwater in tributary streams, ponds and vernal pools supports unique vegetation and animal communities including amphibians and anadromous fish. Waquoit Bay, approximately 825 acres, is the dominant water feature of the Reserve and once supported one of the most diverse estuarine fish communities in the state. The Bay is still important to commercial and recreational shellfish and finfish fisheries (http://www.waquoitbayreserve.org/about/).

National and State Estuary Program

- The Massachusetts Estuaries Program (MEP) was developed in 2001 to determine current nutrient loads and assist in the evaluation of future nutrient load scenarios for 89 estuaries located in 32 Southeastern Massachusetts coastal communities. The number of estuaries targeted under the MEP was reduced to 70 in 2009 due to project process challenges and delays and/or lack of local matching funds (http://www.mass.gov/eea/agencies/massdep/water/watersheds/the-massachusetts-estuaries-project-mep.html).

- There are two nationally-significant estuaries under the EPA National Estuary Program (NEP). They are the Massachusetts Bays Program (MBP) which became part of the NEP in 1990 and the Buzzards Bay NEP which joined the NEP in 1987. The MBP stretchs from the New Hampshire border to the tip of Cape Cod and includes 50 coastal communities which border both the Massachusetts Bay and the Cape Cod Bay. The Buzzards Bay NEP includes the western most end of Cape Cod, southeastern MAand the Elizabeth Islands.

- Massachusetts Bay Program
    - Area: New Hampshire border to the tip of Cape Cod
    - Population: 1.7 million people in 50 coastal communities
    - >800 miles of coastline an area of 1,650 square miles
    - Watershed land drainage: >7,000 square miles (50% MA/ 50% NH)
    - Tourism: $1.5 billion/yr, supports nearly 81,000 jobs

- Buzzards Bay
    - Bay is 28 miles long, 8 miles wide, mean depth of 36 feet.
    - Area: 233 square miles
    - Coastline: > 350 miles
    - Watershed: 434 square miles (MA and RI)

  - Watershed population: 260,000

(http://gispub2.epa.gov/NEPMap/index.html)

National Wildlife Refuges

- Monomoy National Wildlife Refuge (NWR) is one of eight refuges that comprise the Eastern Massachusetts NWR Complex, which is headquartered in Sudbury, Massachusetts. Monomoy NWR stretches for 8 miles off the elbow of Cape Cod in the Town of Chatham, Barnstable County, Massachusetts. About half of the refuge is a wilderness area, the only wilderness area in southern New England; it is also designated an Important Bird Area, Western Hemisphere Shorebird Reserve Network Regional site, and a Marine Protected Area (Attachment A).

- Parker River National Wildlife Refuge was established in 1941 to provide feeding, resting, and nesting habitat for migratory birds. It is located within the towns of Newbury, Rowley, and Ipswich, while the refuge headquarters is located within the city of Newburyport, Massachusetts. This 4,727-acre refuge includes sand dunes, saltmarsh, freshwater marsh, glacial upland, and more than six miles of ocean beach along the eastern side of Plum Island. The most abundant habitat on the refuge is its 3,000+ acres of salt marsh, one of the most productive ecosystems in nature. Parker River provides pristine coastal habitat for over 300 species of resident and migratory birds, as well as a large variety of mammals, insects, fish, reptiles and amphibians. Parker River has been designated a Western Hemispheric Shorebird Reserve Network (WHSRN), Important Bird Area (IBA), and Area of Critical Environmental Concern (ACEC). The refuge also provides breeding habitat for the federally threatened piping plover (USFWS 2014).

- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

National Park Service Areas

- Boston Harbor Islands National Recreational Area: Youth programs, visitor services, research, wildlife management, and more are coordinated on the park's 34 islands and peninsulas by the Boston Harbor Islands Partnership.

- Cape Cod National Seashore: The great Outer Beach described by Thoreau in the 1800s is protected within the national seashore. Forty miles of pristine sandy beach, marshes, ponds, and uplands support diverse species. Lighthouses, cultural landscapes, and wild cranberry bogs offer a glimpse of Cape Cod's past and continuing ways of life. Swimming beaches and walking and biking trails beckon today's visitors.

- Essex National Heritage Site: The Essex National Heritage Area begins just 10 miles north of Boston and covers 500 square miles of eastern Massachusetts to the New Hampshire border. The Area includes hundreds of historical sites, miles of intact landscapes, glistening coastal regions and lifetimes of rich experiences that chronicle the history of our region and of our nation.

(http://www.nps.gov/hfc/cfm/carto-states.cfm?state=ma)

State/County Parks

- Barnstable County
- Cape Cod Rail Trail – 22 miles
- Nickerson State Park on 1,900 acres
- Shawme-Crowell State Forest on 700 acres
- South Cape Beach State Park
- Bristol County
    - Borderland State Park on 1,570 acres (also Norfolk County)
    - Demarest Lloyd State Park
    - Dighton Rock State Park on 85 acres
    - Fall River Heritage State Park on 8.5 acres
    - Fort Phoenix State Reservation
    - Horseneck Beach state Reservation on 600 acres
    - Massasoit State Park
    - Watson Pond State Park on 10 acres
    - Freetown-Fall River State Forest on 5,441 acres
- Dukes County
    - Manuel F. Correllus State Forest on 5,100 acres
- Essex County
    - Bradley Palmer State Park on 721 acres
    - Breakheart Reservation on 640 acres
    - Graycourt State Park

- Halibut Point State Park
- Lawrence Heritage State Park on 23 acres
- Lynn Heritage State Park
- Lynn Shore Reservation
- Maudslay State Park
- Nahant Beach Reservation
- Rumney Marsh Reservation on 600 acres (also located in Suffolk County)
- Salisbury Beach State Reservation on 521 acres
- Sandy Point State Reservation on 77 acres
- Georgetown-Rowley State Forest on 1,112 acres
- Harold Parker State Forest
- Willowdale State Forest

- Middlesex County
  - Alewife Brook Reservation on 120 acres
  - Ashland State Park on 470 acres
  - Beaver Brook Reservation on 59 acres
  - Callahan State Park on 820 acres
  - Charles River Reservation 17 miles long (also located in Suffolk County)
  - Cochituate State Park
  - Great Brook Farm State Park on 1,000 acres
  - Hammond Pond Reservation
  - Hemlock Gorge Reservation on 23 acres
  - Hopkinton State Park on 1,450 acres

  - Lowell Heritage State Park
  - Middlesex Fells Reservation on 2,575 acres
  - Mystic River Reservation
  - Nashua River Rail Trail
  - Pearl Hill State Park on 1,000 acres
  - Sudbury Reservoir on 4,943 acres (also located in Worcester County)
  - Upper Charles River Reservation (also located in Norfolk and Suffolk Counties)
  - Walden Pond State Reservation on 462 acres
  - Whitehall State Park
  - Lowell-Dracut-Tyngsboro State Forest on 1,140 acres
- Nantucket County
  - None
- Norfolk County
  - Blue Hills Reservation on 7,000 acres
  - Boston Harbor Islands State Park on 1,570 acres (also located in Plymouth and Suffolk Counties)
  - Cutler Park on 700 acres
  - Elm Bank Reservation on 182 acres
  - Quincy Quarries Reservation on 22 acres
  - Quincy Shores Reservation
  - Squantum Point Park
  - Webb Memorial State Park
  - Weymouth Reservation

  - Wilson Mountain Reservation on 213 acres
- Plymouth County
  - Ames Nowell State Park on 700 acres
  - Ellisville Harbor State Park
  - Fort Revere on 8 acres
  - Myles Standish Monument State Reservation
  - Nantasket Beach Reservation
  - Nasketucket Bay State Reservation
  - Pilgrim Memorial State Park
  - Wompatuck State Park on 4,000 acres
  - Myles Standish State Forest
- Suffolk County
  - Belle Isle Marsh Reservation on 152 acres
  - Castle Island on 22 acres
  - Chestnut Hill Reservation
  - Dorchester Shores Reservation
  - Lower Neponset River Trail
  - Neponset River Reservation
  - Pope John Paul II Park Reservation
  - Revere Beach Reservation
  - Roxbury Heritage State Park

- Southwest Corridor Park on 52 acres
- Stony Brook Reservation on 475 acres

(http://www.mass.gov/eea/agencies/dcr/massparks/places-to-go/)

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

- The Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986.

- Roseate tern (*Sterna dougallii*) is a medium-sized, black-capped sea tern about 15 inches long and weighs about four ounces. On November 2, 1987, the USFWS determined the population that nests in the Northeast to be endangered, and the population that nests in the Caribbean to be threatened.

- The Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis*) was listed by the USFWS as threatened in August 1990. Currently in New England, northeastern beach tiger beetles are restricted to beaches in Martha's Vineyard and Chatham, Massachusetts.

- A detailed discussion of USFWS managed Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

- The Gulf of Maine Destinct Population Segment (GOM DPS) for Atlantic salmon was listed as endangered in a final rule on November 17, 2000 by the National Marine Fisheries Service (NMFS) and the USFWS (collectively "the Services"). Atlantic salmon return to rivers from the sea and migrate to their natal stream beginning in the spring in New England and continues into the fall to spawn (Federal Register vol. 74, no. 117, June 19, 2009).

- The GOM DPS for Atlantic sturgeon was listed as threatened and the New York Bight (NYB) DPS listed as endangered in a final rule on February 6, 2012 by NMFS. Atlantic sturgeon spawn in spring and early summer in freshwater and migrate into estuarine and marine waters where they spend most of their lives (http://www.nmfs.noaa.gov/pr/species/fish/atlanticsturgeon.htm). Atlantic sturgeons have been documented in the Merrimack River. Dams may impede access to some spawning habitat in the Tauton River and at the site of the Holyoke Dam on the Connecticut River in Massachusetts (Federal Register vol 77, no. 24, February 6, 2012).

- The shortnose sturgeon is an anadromous fish which lives mainly in the slower moving riverine waters or nearshore marine waters before migrating periodically into faster moving freshwater to spawn. Shortnose sturgeon can be found in the lower Merrimack River. They were listed as endangered throughout its range on March 11, 1967 under the Endangered Species Act of 1966 (http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm).

- Species of Concern listed by NMFS, and associated area of concern include the anadromous and highly migratory river herring (alewife and blueback herring) found in the Atlantic Ocean from Newfoundland to North Carolina, the pelagic and highly migratory Atlantic bluefin tuna found throughout the the North Atlantic Ocean and adjacent seas, the Atlantic halibut found from Labrador to southern New England in the Northwest Atlantic Ocean, the dusky shark found in the Western Atlantic Ocean, the porbeagle shark found in the Nortwest Atlantic Ocean, the anadromous rainbow smelt found in rivers and coastal areas of eastern North America from Labrador to New Jersey, and the sand tiger shark found in the Western Atlantic Ocean (http://www.nmfs.noaa.gov/pr/species/concern/).

- The American eel was petitioned to be listed as threatened on September 29, 2011 in the Federal Register (vol. 76, no. 189) by the USFWS. Eels spawn in the Sargasso Sea. Juveniles arrive in coastal waters and river systems which are accessible by the oceanic currents of the western North Atlantic Ocean for development. This fish occupies fresh, brackish and marine waters (FR, vol 76. No. 189).

Waterbird Islands

- Bird Island and Ram Island are located just offshore the western shoreline of Buzzards Bay, northeast of the city of New Bedford, in the vicinity of the Towns of Marion and Antassawamock, respectively. These areas consist entirely of public lands and waters. Ram Island is owned by the State of Massachusetts, Division of Fisheries and Wildlife; Bird Island is owned by the Town of Marion and managed by the Massachusetts Audubon Society. Both islands are approximately an acre in size and are located about a half mile from the western mainland shoreline of Buzzards Bay. Bird Island is rocky and densely covered with herbaceous plants including beach grass (*Ammophila breviligulata*), bindweed (*Convolvulus sepium*), seaside goldenrod (*Solidago sempervirens*), black mustard (*Brassica nigra*), seaside angelica (*Coelopleurum lucidum*) and lamb's quarters (*Chenopodium album*). Ram Island is a low island composed of sand, gravel and larger stones with elevations in the center high enough to support vegetation such as beachgrass and seaside goldenrod. The Bird Island population of roseate terns (*Sterna dougallii*), a U.S. Endangered species, is the single largest breeding colony of this species in North America, roughly 1500 nesting pairs, comprising approximately half the known breeding population Currently, no roseate terns nest on Ram Island, although this island is targeted for restoration. Common terns (*Sterna hirundo*) also nest in significant numbers on Bird Island, approximately 800 pairs (http://library.fws.gov/pubs5/necas/web_link/34_buzzards%20bay.htm).

- Nantucket Sound Barrier Beach\Bay Complex – three separate areas located along the Nantucket Sound shoreline of Cape Cod, Massachusetts, from East Falmouth to South Yarmouth in the towns of: Barnstable, Dennis, Falmouth, Mashpee, Yarmouth – County: Barnstable. This complex includes the three major barrier beach-bay systems and nearshore waters of 1) Waquoit Bay, just east of East Falmouth; 2) Cotuit Bay**,** between the communities of Cotuit and Osterville; and 3) Bass River in South Yarmouth. The sand beaches along the barrier islands in each of the systems identified here are regionally important nesting areas for colonial beach-nesting birds, especially for piping plover (*Charadrius melodus*), a U.S. Threatened species, roseate tern (*Sterna dougallii*), a U.S. Endangered species, least tern (*S. antillarum*) and common tern (*S. hirundo*). The enclosed bay waters are important wintering waterfowl concentration areas, and species of special emphasis which commonly overwinter here include American black duck (*Anas rubripes*), Atlantic brant (*Branta bernicla*), greater and lesser scaup (*Aythya marila*, *A. affinis*), Canada goose (*Branta canadensis*), common goldeneye (*Bucephala clangula*), bufflehead (*Bucephala albeola*) and common loon (*Gavia immer*). Scoters (*Melanitta* spp.), oldsquaw (*Clangula hyemalis*) and common eider (*Somateria mollissima*) often winter in nearby offshore waters in large concentrations. Breeding birds of the tidal and freshwater marshes in these systems include: green-backed heron (*Butorides striatus*), snowy egret (*Egretta thula*), American black duck, mallard (*Anas platyrhynchos*) and osprey (*Pandion haliaetus*) (http://library.fws.gov/pubs5/necas/web_link/36_nantucket%20sound.htm).

- Muskeget and Tuckernuck Islands are located just west of Nantucket Island and south of Cape Cod. Muskeget Channel is a shallow water area of temporary shoals and permanent islands. Muskeget and Tuckernuck Islands were originally formed by the terminal moraine of the last glacial episode. Tuckernuck still retains remnants of the moraine as low hills, but the southern half of the island consists of outwash plains characterized by coastal heathland, a globally restricted and endangered plant community. This community occurs only from Long Island, NY, to Cape Cod, MA. The shallow waters and shoals of Muskeget Channel and the areas surrounding the islands are highly productive for marine fish, shellfish, and eelgrass (*Zostera marina*), providing rich feeding grounds for terns and gulls in summer and sea ducks in winter. The largest concentration of oldsquaws (*Clangula hyemalis*) in the western Atlantic occurs here (counts of over 150,000 have been recorded), along with thousands of common eiders (*Somateria mollissima*) and three species of scoter (*Melanitta* spp.). In late summer a thousand or more roseate terns (*Sterna dougallii*), a U.S. Endangered species, feed here in preparation for their southward migration. These islands support many State and Federally rare species including: Nantucket shadbush (*Amelanchier nantucketensis*), a candidate species for listing under the Act, several pairs of short-eared owl (*Asio flammeus*), piping plover (*Charadrius melodus*), a U.S. Threatened species, least tern (*Sterna antillarum*), northern harrier (*Circus cyaneus*) and common tern (*Sterna hirundo*). Muskeget Island is a designated National Natural Landmark, due primarily to the presence of breeding gray seals and beach voles (http://library.fws.gov/pubs5/necas/web_link/39_muskeget.htm).

- The island of Martha's Vineyard is bounded on the northwest by Vineyard Sound, on the northeast by Nantucket Sound, on the east by Muskeget Channel and on the south and southeast by the Atlantic Ocean. This extensive complex of glacial outwash sandplains and coastal beaches encompasses a large interior section of south-central Martha's Vineyard, an area known as the Great Plains, and beaches along the southern and eastern shorelines of the island. Martha's Vineyard is southern New England's largest island and is located south of Falmouth, Cape Cod. The ownership of the area is exceedingly mixed, and includes many privately-owned parcels, local Land Trusts, Massachusetts Audubon Society and The Nature Conservancy preserves, and various municipal, State and Federal government-owned lands.

About 20% of the island of Martha's Vineyard is preserved in some way, of which nearly half of these preserved lands are in public ownership. The sandplains area includes all of Martha's Vineyard State Forest, about 4,000 acres (1,620 ha). Most of this sandplains area, however, is privately-owned. Nomans Land Island is owned by the U.S. Military (Navy) and jointly managed by the U.S. Fish and Wildlife Service. The long stretch of nearly continuous sand beaches around the periphery of Martha's Vineyard, particularly from the vicinity of Cape Poge at the northeastern end of Chappaquiddick Island south and westward along the Atlantic Ocean shoreline to Squibnocket Point and Long Beach at the southwestern end of the island, is potentially perhaps the most important beach-nesting area for piping plovers (*Charadrius melodus*), a U.S. Threatened species, and least tern (*Sterna antillarum*) in the study region. A few small isolated beaches and islands in this area also provide essential nesting habitat for common tern (*S. hirundo*) and roseate tern (*S. dougallii*), a U.S. Endangered species, which also nested on Nomans Land Island, and American oystercatcher (*Haematopus palliatus*). In recent years, many of the tern and piping plover nesting areas have been abandoned, likely the result of predation and/or human disturbances during the nesting season. There is still a colony of black-crowned night-heron (*Nycticorax nycticorax*) and snowy egret (*Egretta thula*) on Nomans Land Island, which fly over to Martha's Vineyard to feed. The large ponds and embayments behind (landward of) the south-facing barrier beaches fronting the Atlantic Ocean, including Great Tisbury Pond, Edgartown Great Pond and Katama Bay, are important wintering waterfowl concentration areas, particularly for American black duck (*Anas rubripes*), lesser scaup (*Aythya affinis*), Atlantic brant (*Branta bernicla*), Canada goose (*Branta canadensis*) and red-breasted merganser (*Mergus serrator*). Bald eagles (*Haliaeetus leucocephalus*), forally listed by the USFWS as endangered, occasionally overwinter in these areas. Commercially and recreationally important shellfish beds of American oyster (*Crassostrea virginica*), hard-shelled clam (*Mercenaria mercenaria*) and bay scallop (*Aequipecten irradians*) occur in these ponds and bays. The mudflats along their shores are often visited by large numbers of migrating shorebirds, including dunlin (*Calidris alpina*), black-bellied plover (*Pluvialis squatarola*), ruddy turnstone (*Arenaria interpres*) and semi-palmated plovers (*Charadrius semipalmatus*). Peregrine falcons (*Falco peregrinus*), a U.S. Endangered species, are common during fall and spring migrations. The nearshore Atlantic Ocean waters are important sea duck wintering areas, especially for common eider (*Somateria mollissima*) and scoters (*Melanitta* spp.) (http://library.fws.gov/pubs5/necas/web_link/40_martha's%20vineyard.htm).

- Boston Harbor Island – Green Island, Little Calf Island, Shag Rocks, Middle Brewster, Outer Brewster, Greater Brewster, Spectacle Island, Calf Island, Hangman Island (http://www.fws.gov/birds/waterbirds/MANEM/Site%20Map/JPG/masea2_named.jpg).

- North of Boston – Ram Island, Tinker's Island, Great Misery, Little Misery, Chubb, Bakers, Pope Head, North and South Gooseberry, Eagle Island, Coney Island, Cat and South of Cat Island, Great Haste Island, Graves, Kettle, Thacher, Milk, Plum Island, Woodbridge, Chaces Island (http://www.fws.gov/birds/waterbirds/MANEM/Site%20Map/JPG/masea1_named.jpg).

- A detailed discussion of Waterbird Nesting Colonies in Massachusetts can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Essential Fish Habitat (EFH)/Fish

- The area provides EFH for (http://www.nero.noaa.gov/hcd/index2a.htm):
  - American plaice: eggs, larvae, juveniles, adults
  - Atlantic cod: eggs, larvae, juveniles, adults
  - Atlantic halibut: eggs, larvae, juveniles, adults
  - Atlantic herring: eggs, larvae, juveniles, adults
  - Atlantic mackerel: eggs, larvae, juveniles, adults
  - Atlantic salmon: eggs, larvae, juveniles, adults
  - Atlantic sea scallops: eggs, larvae, juveniles, adults
  - Black sea bass: eggs, larvae, juveniles, adults
  - Bluefish: juveniles, adults
  - Butterfish: eggs, larvae, juveniles, adults
  - Haddock: eggs, larvae, juveniles, adults
  - Ilex squid: juveniles, adults
  - Loligo: eggs, juveniles, adults
  - Monkfish: eggs, larvae, juveniles, adults
  - Ocean pout: eggs, larvae, juveniles, adults
  - Ocean quahog: juveniles, adults
  - Offshore hake: eggs, larvae, juveniles, adults
  - Pollock: eggs, larvae, juveniles, adults
  - Red hake: eggs, larvae, juveniles, adults
  - Redfish: eggs, larvae, juveniles, adults
  - Scup: eggs, larvae, juveniles, adults

- Spiny dogfish: juveniles, adults
- Summer flounder: eggs, larvae, juveniles, adults
- Surf clams: juveniles, adults
- Tilefish: eggs, larvae, juveniles, adults
- White hake: eggs, larvae, juveniles, adults
- Whiting: eggs, larvae, juveniles, adults
- Windowpane flounder: eggs, larvae, juveniles
- Winter flounder: eggs, larvae, juveniles, adults
- Witch flounder: eggs, larvae, juveniles, adults
- Yellowtail flounder: eggs, larvae, juveniles, adults
- Skates: juveniles, adults
- Habitat Areas of Particular Concern: None

II. Habitat Impacts from Hurricane Sandy - New Hampshire, Massachusetts, Rhode Island, and Connecticut

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

According to the National Fish and Wildlife Foundation (2012):

- Most of the shoreline along Long Island Sound experienced Low Damage. A few areas generally associated with exposed points and islands such as Hammonasset Point and the Norwalk Island in CT, experienced Moderate Damage. The damage rating was based on damage to the three habitats discussed below: dune/beach, tidal marsh, and maritime forest.

- For beach/dunes in Long Island Sound – 13% experienced no impact, 59% low impact (thinning of beach (<50'), debris deposited), 28% moderate impact (evidence of overwash; loss of dune vegetation; moderate thinning of beach - 50 to 100'), and 0% high impact (new overwash channels opened connecting ocean to bay; major loss of dune vegetation leaving largely barren areas, major thinning or migration of beach - >100'). Hurricane Sandy impact to areas north of Cape Cod were minimal (USACE 2013).

- Beach Dune and Erosion occurred at the following locations (The National Fish and Wildlife Foundation 2012):
    - Milford Point, Milford, CT
    - Sandy Point, Morse Point, West Haven, CT
    - Salt Island, off the coast of Westbrook, CT
    - Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
    - Silver Sands State Park, Milford, CT
    - Pattagansett Marsh Preserve, East Lyme, CT
    - Rocky Neck State Park, East Lyme, CT
    - Hatchetts Point Natural Area, Old Lyme, CT
    - Griswold Point, Old Lyme, CT
    - Woodmont Beach, Milford, CT (Reference for this beach and below: USACE 2013)
    - Gulf Beach, Milford, CT
    - Prospect Beach, West Haven, CT
    - Sherwood Island State Beach, Westport, CT
    - Southport Beach, Fairfield, CT
    - Misquamicut Beach, Westerly, RI
    - Oak Bluffs Town Beach, Oak Bluffs, MA
    - Plum Island Beach, Newbury, MA
    - Revere Beach, Revere, MA
    - North Scituate Beach, Scituate, MA
    - Quincy Shore Beach, Quincy, MA

- Existing Beach/Dune Habitat was moved or new habitat was created at the following locations (The National Fish and Wildlife Foundation 2012; USACE 2013):
  - Long Beach, Stratford, CT
  - Sand Point Island, West Haven, CT
  - Mumford, Cove and Bluff Point State Park, Groton, CT
  - Harkness Memorial State Park, Waterford, CT
  - Griswold Point, Old Lyme, CT
  - Meunketesuck, Salt and Duck Island, Westbrook, CT
  - Hammonasset Beach State Park, Madison, CT
  - Falkner Island, Guilford, CT
  - Morse Point, Milford, CT
  - Pleasure Beach, Bridgeport, CT
  - Cockenone Island, Westport, CT
  - Greater Norwalk Islands, Great Captains Island, Greenwich, CT
  - Sea Bluff Beach, West Haven, CT

Barrier Islands/Inlets

- Falkner Island which is home to rosate and common terns lost approximately 1/3 of its area. (The National Fish and Wildlife Foundation 2012).
- Menunketesuck Island and Duck Island had excessive shoreline erosion (The National Fish and Wildlife Foundation 2012).
- Channel blockage/tidal flow interference occurred at the following locations (The National Fish and Wildlife Foundation 2012):
  - Waterford Town Beach and Pleasure Island – breaches of the barrier dune and beach erosion are causing sand to erode into Alewife Cove which is obstructing the cove's outlet to Long Island Sound.

- At Rocky Neck State Park, accumulated sand prevented flow and proper tidal flushing of the Bride Brook Channel. This is one of the largest alewife runs in CT.
- Harkness Memorial State Park – the outlet of Goshen Cove, an estuarine embayment and tidal creek, is currently blocked by sand and sediment.
- Lynde Point – the storm pushed a dune into the tidal marsh blocking the flow of a tidal creek. Water is accumulating behind this blockage transforming the tidal marsh into freshwater swamp.

Salt / Brackish Marsh

- Coastal salt marshes were impacted to a much lesser degree showing much higher resistance to storm damage (The National Fish and Wildlife Foundation 2012).
- For marsh in Long Island Sound – 28% experienced no impact, 56% low impact (evidence of new wrack and debris deposited), 16% moderate impact (minor erosion/loss of marsh edge; small areas of sand deposited; medium size areas of wrack/debris) and 0% high impact (major erosion/loss of bayward marsh edge; large areas of sand and wrack deposites within marsh proper; rearrangement of tidal creek channels) (The National Fish and Wildlife Foundation 2012).
- Erosion of beaches and dunes left adjacent salt marsh habitat vulnerable to inundation from winter storms and high tides. These areas include (The National Fish and Wildlife Foundation 2012):
    - Waterford Town Beach, Waterford Pleasure Beach, Waterford, CT
    - Pattagansett Marsh Preserve, East Lyme, CT
    - Hattchetts Point Natural Area, Old Lyme, CT
- Lynde Point, Old Saybrook, CT – Storm surge pushed a dune into a tidal marsh and created a dam that which blocked the flow of the tidal creek, preventing it from reaching the adjacent marsh. As a result the area is quickly converting into a freshwater swamp (The National Fish and Wildlife Foundation 2012).
- An earthen berm at Sunken Meadow State Park adjacent to Sunken Meadow Creek in CT was destroyed by the storm. This berm had been scheduled to be removed to restore 100 acres of salt marsh as part of an anadromous fish project. This is considered a positive impact from Hurricane Sandy (The National Fish and Wildlife Foundation 2012).

Maritime Forest

- According to The National Fish and Wildlife Foundation (2012), impacts to the forests in Long Island Sound were as listed:
    - 66% experienced no impact
    - 33% low impact (evidence of a few 5% fallen trees)
    - 1% moderate impact (5-25% trees fallen creating numerous small canopy gaps <1 acre in size)
    - 0% high impact (>25% of trees fallen creating large [>1 acre in size])

Submerged Aquatic Vegetation

- According to The National Fish and Wildlife Foundation (2012), there was significant eelgrass damage at Ninigret Pond, Charlestown, RI.

Rock Reefs

- According to The National Fish and Wildlife Foundation (2012), Penfield Reef in Fairfield, CT "largely washed away" as a result of the storm.

National Park Service Areas

Stewart B. McKinney

- Stewart B. McKinney
    - At Falkner Island, 1/3 of the island was lost as s result of the storm. This area is home to roseate terns and common terns (The National Fish and Wildlife Foundation 2012).
- The following State Parks experienced overwashing of dunes and significant erosion and/or the movement of existing habitat and creation of new habitat from Hurricane Sandy (The National Fish and Wildlife Foundation 2012; USACE 2013).
    - Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
    - Silver Sands State Park, Milford, CT
    - Pattagansett Marsh Preserve, East Lyme, CT
    - Rocky Neck State Park, East Lyme, CT

- Hatchetts Point Natural Area, Old Lyme, CT
- Mumford, Cove and Bluff Point State Park, Groton, CT
- Hammonasset Beach State Park, Madison, CT
- Sherwood Island State Beach, Westport, CT
- Misquamicut Beach, Westerly, RI

Critical/Significant Habitat

- Beaches above that experienced erosion above would have an impact on the species that nest on beaches, including piping plover, least terns, and rosette terns
- Coastal flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013).

Quality

- According to The National Fish and Wildlife Foundation (2012):
    - Ledyard, CT – a backup generator for the Town's treatment plant failed causing officials to pump approximately 60,000 gallons of raw sewage into Set Williams Brook.
    - Branford, East Lyme, Fairfield, Greenwich, New Hartford, and New Haven, CT – Similar problems and releases were reported.
    - Bridgeport, CT – 15 to 20 million gallons of partially treated sewage was discharged into Long Island Sound when the city's two treatment plants were inundated tidal surges.

III. Future Without Action Conditions - Massachusetts

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- According tp EOEEA (2011), increased sea level rise, combined with increased erosion rates, is predicted to threaten Massachusetts' barrier beach and dune systems. Development on the beaches themselves will continue to face challenges associated with erosion and storm damage. Barrier beaches will be more susceptible to erosion and overwash, and in some cases breaching. Such breaching will put at risk extensive areas of developed shoreline located behind these barrier spits and islands, such as the shorelines of Plymouth, Duxbury, and

Kingston. In addition, engineered structures, such as seawalls designed to stabilize shorelines, could be overtopped.

- Low lying coastal areas are expected to be permanently inundated by rising sea level and erosion is expected to be dramatically accelerated particularly on important barrier beaches (Union of Concerned Scientist 2007). Reduction of sediment load to beaches and other coastal habitats will limit the ability of these areas to maintain accretion at a rate that could match sea level rise. These habitats are also expected to face increasingly intense coastal storms, which may cause impacts such as destruction of coastal dunes, breaches in barrier islands, and shoreline erosion. As a result, it is anticipated that important coastal habitats will be lost (EOEEA 2011).

- Large areas of critical coastal and estuarine habitat are at risks they will be unable to adapt and migrate as a result of relative sea level rises (EOEEA 2011). Much of Massachusetts's coastline on the north shore and the Cape and islands could be inundated by 2068; by 2118 almost the entire Plum Island complex, beaches and islands in Boston Harbor, and some of the southern shore of Cape Cod and portions of Martha's Vineyard and Nantucket Island could be inundated by the projected sea level rise.

- It is expected that the beaches at Plum Island in Newbury, Revere Beach in Revere, Salisbury Beach in Salisbury, North Scituate Beach in Scituate, Quincy Shore Beach in Quincy, Winthrop Beach in Winthrop, Wessagusset Beach in Weymouth, Clark Point Beach in New Bedford, and Oak Bluffs Town Beach, in Oak Bluffs, which were all originally constructed as shore protection/beach fill projects by the USACE, would continue to receive sand from the local sponsor to meet their design criteria. Other State and/or Town beaches in Massachusetts may also be expected to maintain their beaches, especially those beaches that are used recreationally. However, continued sea level rise may make this difficult to maintain in the future.

Coastal Wetlands

- An increase in the rate of sea level rise will result in a significant loss of coastal salt marsh habitat. Salt marshes are particularly vulnerable to relative sea level rise, where the normal process of accretion cannot keep pace. As salt marshes become submerged, they migrate inland. This migration is limited as a result of coastal development which has decreased the amount of open space adjacent to the salt marshes. The limitation is exacerbated in locations where man-made structures, such as bulkheads, further interfere with migration (EOEEA 2011).

- In marsh areas where accretion rates cannot keep up with sea-level rise, marsh will eventually revert to unvegetated flats and eventually open water. In some cases where tidal range increased with increased rates of sea-level rise, there may be an overall increase in the acreage of tidal flats. In low energy shores with sediment supplies, where sediments accumulate in shallow waters, flats may become vegetated as low marsh encroaches towards the water, which will increase low marsh at the expense of tidal flats. If sediment inputs are not sufficient, tidal flats will convert to subtidal habitats, which may or may not be vegetated depending on substrate composition and water transparency (US Climate Change Science Program 2009).

- The loss of wetlands would cause wetland dependent species of fish and birds to have reduced population sizes. The National Marine Fisheries Service estimates that approximately 1/3 of commercial fish and shellfish collected in New England are directly dependent on estuaries and salt marshes (EOEEA 2011).

- The flood control benefits of the wetlands in the Charles River Basin that drains to Boston Harbor are estimated to be nearly $40 million/year. These wetlands are likely to be fully inundated by 2118. If this happens, the wetlands will be diminished and will convert to open water or tidal flat.

Submerged Aquatic Vegetation

- Increased water depth and sedimentation from erosion as a result of sea level rise may result in a reduction in light penetration necessary for the growth of SAV.

- Landward edges of SAV beds may migrate inland depending on shore slope and substrate suitability. SAV growth is significantly better in areas where erosion provides sandy substrate, rather than fine-grained or fine organic matter substrates (CCSP 2009).

- Increased storm activity from climate change could negatively impact SAV by increasing erosion resulting in sediment resuspension that can block available sunlight.

Oyster Reefs

- Oysters improve water quality by removing pollutants and nutrients during feeding. If exposd to extreme freshwater events, such as a large storm, oyster will close their shells and isolate themselves from external environmental conditions.

Rock Reefs/Rocky Shorelines

- Rocky shorelines, especially intertidal and shallow water rocky habitat could become inundated and no longer be available as intertidal habitat as a result of sea level rise. Littoral zone biota are likely to respond to changing tide heights by shifting vertically where shoreline topography allows it. However, this type of shoreline would be resistant to erosion and protective of adjacent uplands.

Shallow Bay Habitat/Bay Islands

- The depth of shallow waters of the many harbors, bays, and estuaries and other important shallow water habitat may be expected to increase as the sea rises along with shoreline erosion and the drowning of coastal wetlands and shorelines. Several low-lying islands along the coast of Massachusetts and in particular Boston Harbor would be expected to experience some of flooding of their low lying areas or complete or nearly complete inundation from sea level rise. The large islands of Martha's Vineyard and Nantucket would also experience a loss of low-lying areas by 2118, especially the western and northern coast of Nantucket.

Terrestrial Upland

- Climate change has the potential to dramatically alter the character of the State's forests; particularly the Berkshires' spruce/fir forests.

Floodplains/Riparian

- Floodplains will likely become increasingly vulnerable to flooding without human intervention. In tidal areas, the tidal inundation characteristics of the floodplain may change with the range of tide and associated tidal currents increasing with sea level rise. With this inundation, floodplains will be vulnerable to increased coastal erosion from waves, river and tidal currents, storm-induced flooding, and tidal flooding. Upland floodplain boundaries will be vulnerable to horizontal movement.

Coastal Protected Areas

- Massachusetts has many Federal and State protected areas, from the marine sanctuaries such as the Stellwagen Bank National Marine Sanctuary and the Waquoit Bay National Estuarine Research Reserve, to the Cape Cod National Seashore. Staff from these protected areas has initiated research to determine the extent of climate change on their managed resources. For example, the U.S. Fish and Wildlife Service used the Sea Level Affecting Marshes Model (SLAMM 5.0) to model the fates at five coastal Massachusetts National Wildlife Refuge (NWR) sites, Parker River, Monomoy, Mashpee, Nantucket and Nomans Land Island. In general, the impacts on the various habitats discussed above would also be relevant to these protected areas.

Critical/Significant Habitats

Waterbird Islands

- Low-lying islands such as Ram Island and some of the Boston Harbor islands as well as any barrier beach/bay complexes would be expected to suffer from rising sea levels and increased storms. Inundation of these islands would reduce viable habitat for a variety of birds including birds listed as threatened or endangered under Federal and State laws.

Critical Habitat

- Critical habitat for right whales exists in Cape Cod Bay. Right whales may be affected by climate change by the warming sea temperatures on krill, a key food source . Without dense patches of this zooplankton, female whales can't bulk up to prepare for calving, carry a pregnancy to term or produce enough milk. When the concentration of zooplankton is too low, right whales do not feed; such highly concentrated patches often occur where currents converge or at the boundary of water of different densities. Changes of seawater temperature, winds and water currents can affect patch formation of zooplankton (Leaper et al. 2006).

Atlantic Flyway

- The north shore, greater Boston area, North South Rivers, Duxbury marshes, Barnstable marshes, inner Cape Cod, outer Cape Cod, and Buzzards Bay are Massachusetts waterfowl focus areas. Massachusetts Bay and Buzzards Bay provide sheltered open water that is important for wintering sea ducks and bay ducks such as scoters and scaup as well as fringing salt marshes and mudflats important for dabbling ducks such as mallards. Coastal marshes provide valuable wintering habitat since most inland wetlands freeze during the winter. Mudflats are used by migrating shorebirds. A combination of sea level rise and marsh subsidence could put some of the most important coastal marshes at risk of being lost. There could be a loss or reduction in intertidal habitat.

T&E Species/Species of Concern

Anadromous Fish

- An increase water temperatures resulting from low flows and higher ambient air temperatures would affect growth of cold-water and anadromous fish, their habitat, and migrations. Observations indicate that the timing of the migration of anadromous fish species, such as Atlantic salmon and alewives, has advanced in the last few decades and they are migrating earlier in the season (NECIA 2007). Channels and ponds in Massachusetts salt marshes provide spawning habitat for anadromous fish such as Rainbow smelt. With the inundation of these salt marshes, habitat will be diminished.

Marine Turtles

- These turtles do not nest in Massachusetts and are generally found only during the summer months. With increasing temperatures, it may be possible that these species may be found more frequently in coastal waters for foraging.

Marine mammals

- Whales may not experience a significant effect from sea level rise, but could be affected by a rise in temperature affecting their food source (see above description under critical habitat).

Birds (Nesting)

- Nesting habitat for these birds is likely to diminish with the reduction in available coastal beaches, increased storm activity, and reduction in nesting islands. Erosion control projects will need to recognize the dynamic nature of the habitat to accommodate the birds (Attachment A).

Arthropods

- The Northeastern Beach Tiger Beetle prefers healthy beaches undisturbed by human use. The preference of larval burrows near the high tide line increases the chances of them being washed away by severe storms (Attachment A).

Shellfish/Shellfish beds

- Shellfish which have shells or skeletons made of calcium carbonate may be impacted by ocean acidification. As oceans become more acidic, the dissolution rate calcium carbonate increases. Young larval forms of these species are even more sensitive to acidification than adult forms (www.whoi.edu/main/topic/ocean-acidification).

- Lobsters currently provide the highest dockside value for Massachusetts fishermen. However, the nearshore waters south of Cape Cod are likely to warm by mid-century beyond the range tolerated by lobsters. Lobster habitat in certain shallow, nearshore waters of Massachusetts Bay may also be at risk.

Quality

Water Quality/Impaired Waters

- Changes in hydrologic cycles could have profound impacts on water resources, including increased flooding and polluted overflows from storm water and wastewater systems during high periods of flow, and increased stress on surface and ground drinking waters. Increased intensity of precipitation can create concerns from sewage overflows and hazardous waste leaks (OEEA 2011).

Cultural Resources

- Sea level rise impacts to cultural resources range from increased tidal and wave erosion to inundation. Cultural resources within coastal zones will be subjected to gradual sea level rise impacts exacerbated by event-specific impacts such as high tide events and storms. The frequency and intensity of damage from event-specific impacts is expected to increase as sea level rises (Karl et al. 2009). In addition, high regional subsistence rates are expected to increase rates of sea level rise and associated impacts (Johnson 2000).

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3. Rhode Island: Environmental Existing and Future Conditions

I. Coastal Characterization - Rhode Island

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Beaches/Pebble Shoreline/Beaches

- In Rhode Island there are 245 acres of sand dunes located on the beaches in Washington and Newport counties (http://www.edc.uri.edu/rigis/data/data.aspx?ISO=environment).

- There are approximately 36 linear miles of sandy (coarse and medium-fine grain) beaches across all counties of concern (http://response.restoration.noaa.gov/esi).

- There are approximately 19 linear miles of gravel beaches across the study counties. Mixed sand and gravel beaches comprise 47.6 linear miles of shoreline across all five counties (http://response.restoration.noaa.gov/esi).

Barrier Islands/Inlets

- Number of CBRS Units = 35 (*System Units: 21; Otherwise Protected Areas: 14)*
  - Total Acres = 12,952 (*Upland Acres: 2,816; Associated Aquatic Habitat Acres: 10,136*)
  - Shoreline Miles: 40

(http://www.fws.gov/CBRA/Maps/Locator/RI.pdf)

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

- Approximately 4,110 acres of land in the counties of concern are salt and brackish marshes (http://www.edc.uri.edu/rigis/data/all.aspx).

- Freshwater wetlands are located in Providence, Bristol, Kent, Newport, and Washington counties. There are approximately 88,050 acres of freshwater wetlands in RI (http://www.edc.uri.edu/rigis/data/data.aspx?ISO=biota).

- There are approximately 29 linear miles of tidal mud flats across all study counties (http://response.restoration.noaa.gov/esi).

- In southeastern Massachusetts, Rhode Island, New York, and New Jersey, the barrier island forest vegetation fits into the northeastern oak-pitch pine region. Rhode Island has 6 vegetated islands by forests with a total acreage of 3,660 acres (Bellis 1995).

- There are 156 estuaries in Rhode Island, including the counties of Kent, Newport, Bristol, Providence, and Washington. Narragansett Bay became established as an estuary of national significance under the National Estuary Program in 1987 (.http://water.epa.gov/type/oceb/nep/programs_nb.cfm#summary). Narragansett Bay is 147 square miles in area, but its watershed covers more than 1,600 square miles. 40% of the watershed is in Rhode Island and the other 60% is in Massachusetts. Tourism on Narragansett Bay generates $400 million per year and support 15,000 jobs (http://www.nbep.org/about-theprogram.html).

Submerged Aquatic Vegetation

- In Rhode Island there are 2,218 acres of submerged aquatic vegetation located throughout the coast. These SAV beds surround Block Island, as well as much of the coastline along Washington and Newport counties (http://www.edc.uri.edu/rigis/data/data.aspx?ISO=biota).

Oyster Reefs

- In the summer of 2012, The Nature Conservancy, in partnership with the Rhode Island Department of Environmental Management (R.I. DEM), constructed Rhode Island's first oyster shell reefs in Ninigret Pond. Natural oyster reefs used to be common in Narragansett Bay and Rhode Island's coastal ponds, but these have almost entirely disappeared in recent decades due to overharvesting, disease, siltation, and other environmental changes (Torgen 2012).

Rock Reefs

- The Watch Hill Area Reefs, located just off Westerly Rhode Island, provide anglers with plenty of opportunities from May through November to catch a variety of fish species. Rhode Island is home to many rock reefs, some of which are located in Matunuck in South Kingston and Ruggles Beach in Newport, RI (http://www.fishingchartersri.com/stripedbassfishingtechniques.html).

Rocky Shorelines

- There are approximately 670 acres of rocky shoreline along the coast of the 5 counties of concern (http://www.edc.uri.edu/rigis/data/all.aspx).

Shallow Bay Habitat/ Bay Islands

- Rhode Island boasts 36 islands in the Bay which includes Aquidneck, Whale Island, and Block Island (http://www.edc.uri.edu/rigis/data/data.aspx?ISO=environment).

Terrestrial Upland

- 55% of the RI is forested (371,800 acres). Out of the forested area: 91.8% is timberland and 8.2% is non-commercial or reserved forestland (http://www.edc.uri.edu/rigis/data/data.aspx?ISO=environment).

Floodplain/Riparian

- Riparian zones exist along the shores of Rhode Island's 1,498 linear miles of rivers and 20,917 acres of lakes, and along the 156 square miles of estuarine waters (http://www.edc.uri.edu/rigis/data/data.aspx?ISO=biota).

Coastal Protected Areas

Marine Sanctuaries/Coastal Reserves

- Narragansett Bay National Estuarine Research Reserve: The Narragansett Bay reserve is located on three islands in the geographic center of the Narragansett Bay in Rhode Island. The reserve consists 2,388 acres of upland habitat located on Prudence, Patience and Hope Islands and 1,730 acres of estuarine water adjoining the islands out to a depth of 18 feet MLLW. The islands contain diverse upland, aquatic and estuarine habitats including coastal grassland, coastal shrubland, maritime forests, lowland streams, coastal marshes, cobble and rocky shores and muddy bottoms. About 60 percent of Prudence Island is included in the reserve's boundaries and the reserve is surrounded by a small island community of summer and year round residents. Both Patience and Hope islands are uninhabited; the 91-acre Hope Island component is a major rookery for colonial nesting wading birds (http://www.nbep.org/about-theprogram.html).

National Estuary Program

- Narragansett Bay
  - Area: 147 square miles
  - Watershed: 1,600 square miles (60% MA/40% RI)
  - 2 million people live in watershed in 100 cities and towns
  - 3,500 acres of marshes and wetlands on Narragansett Bay
  - Species of fish and shellfish that feed or spawn in NB: >60
  - Bird species that depend on NB island habitats: > 200
  - 8 million lbs. of quahogs ($6 million) landed in 1997

    - Landed value of NB commercial fish and shellfish is $25 million
    - NB tourism supports 15,000 jobs and generates $400 million/yr.
    - >100,000 people fish on NB/yr.

(http://water.epa.gov/type/oceb/nep/narragansett.cfm)

National Park Service Areas

- Blackstone River Valley National Heritage Corridor: The Blackstone River runs from Worcester, MA to Providence, RI. Its waters powered the Slater Mill in Pawtucket, RI, America's first successful cotton spinning mill (http://www.nps.gov/state/ri/index.htm?program=all).

National Wildlife Refuges

- The Rhode Island National Wildlife Refuge Complex is comprised of five national wildlife refuges. They are the Block Island National Wildlife Refuge on Block Island in the town of New Shoreham; Ninigret National Wildlife Refuge in the town of Charlestown; John H. Chafee National Wildlife Refuge in the towns of South Kingstown and Narragansett; Sachuest Point National Wildlife Refuge in the town of Middletown; and Trustom Pond National Wildlife Refuge in the town of South Kingstown (USFWS 2014).
- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

State/County Parks

- Bristol County
    - Colt State Park on 464 acres
    - Kent County
    - Goddard Memorial State Park
    - Newport County
    - Beavertail State Park
    - Brenton Point State Park
    - Fort Adams State Park
    - Fort Wetherill State Park

- Providence County
  - Haines Memorial State Park
  - Lincoln Woods State Park
  - Snake Den State Park
  - WW II Veteran's State Park
  - East Bay Bike Path
- Washington County
  - Charlestown Breachway
  - East Beach 3 miles of beach shoreline
  - East Matunuck State Beach on 144 acres
  - Misquamicut State Beach on 0.5 miles of beachfront
  - Roger W. Wheeler State Beach
  - Salty Brine State Beach
  - Scarborough North and South State Beach Complex on 26 acres with 2,325 feet of beach front
  - Burlingame State Park and Campground
  - Arcadia Management Area on about 14,000 acres
  - John H. Chafee Nature Preserve

(http://www.riparks.com/#)

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

- The Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. Maschaug, Ninigret, Weekapaug, Moonstone and Briggs Beaches have the highest number of nesting pairs (Attachment A). The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986.

- The New York Bight Distinct Population Segment (NYB DPS) of Atlantic sturgeon was listed as endangered in a final rule on February 6, 2012 by NMFS. Atlantic sturgeon spawn in spring and early summer in freshwater and migrate into estuarine and marine waters where they spend most of their lives (http://www.nmfs.noaa.gov/pr/species/fish/atlanticsturgeon.htm). Dams may impede access to some spawning habitat in the Tauton River (Federal Register vol 77, no. 24, February 6, 2012). Mount Hope Bay is a tidal estuary located at the mouth of the Tauton River which borders the States of Rhode Island and Masschusetts.

- The shortnose sturgeon is an anadromous fish which lives mainly in the slower moving riverine waters or nearshore marine waters before migrating periodically into faster moving freshwater to spawn. Shortnose sturgeons spawn in the coastal rivers along the east coast of North America from Canada to Florida. They were listed as endangered throughout its range on March 11, 1967 under the Endangered Species Act of 1966 (http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm).

- Species of Concern listed by NMFS, and associated area of concern include the anadromous and highly migratory river herring (alewife and blueback herring) found in the Atlantic Ocean from Newfoundland to North Carolina, the pelagic and highly migratory Atlantic bluefin tuna found throughout the the North Atlantic Ocean and adjacent seas, the Atlantic halibut found from Labrador to southern New England in the Northwest Atlantic Ocean, the dusky shark found in the Western Atlantic Ocean, the porbeagle shark found in the Nortwest Atlantic Ocean, the anadromous rainbow smelt found in rivers and coastal areas of eastern North America from Labrador to New Jersey, and the sand tiger shark found in the Western Atlantic Ocean (http://www.nmfs.noaa.gov/pr/species/concern/).

- The American eel was petitioned to be listed as threatened on September 29, 2011 in the Federal Register (vol. 76, no. 189) by the USFWS. Eels spawn in the Sargasso Sea. Juveniles arrive in coastal waters and river systems which are accessible by the oceanic currents of the western North Atlantic Ocean for development. This fish occupies fresh, brackish and marine waters (FR, vol 76. No. 189).

Waterbird Islands

- The offshore islands of Rhode Island provide important refuge for the various colonial nesting bird speces such as terns, egrets, gulls, herons, double crested cormorant, black skimmer, glossy ibis, and American oystercatcher (Attachment A).

- Block Island – A black-crowned night-heron (*Nycticorax nycticorax*) rookery is established on the southern tip of the West Beach area (http://library.fws.gov/pubs5/necas/web_link/28_block.htm).

- A detailed discussion of Waterbird Nesting Colonies can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Essential Fish Habitat (EFH)/Fish

- The area provides EFH for (http://www.nero.noaa.gov/hcd/index2a.htm):
  - Atlantic cod: eggs, larvae, juveniles, adults
  - Atlantic herring: larvae, juveniles, adults
  - Atlantic mackerel: eggs, larvae, juveniles, adults
  - Atlantic salmon: eggs, larvae, juveniles, adults
  - Atlantic sea scallops: eggs, larvae, juveniles, adults
  - Black sea bass: eggs, larvae, juveniles, adults
  - Bluefish: juveniles, adults
  - Butterfish: eggs, larvae, juveniles, adults
  - Haddock: eggs, larvae, juveniles, adults
  - Ilex squid: juveniles, adults
  - Loligo: eggs, juveniles, adults
  - Monkfish: eggs, larvae, juveniles, adults
  - Ocean pout: eggs, larvae, juveniles, adults
  - Ocean quahog: juveniles, adults
  - Offshore hake: eggs, larvae
  - Pollock: juveniles, adults
  - Red hake: eggs, larvae, juveniles, adults
  - Scup: eggs, larvae, juveniles, adults
  - Spiny dogfish: juveniles, adults
  - Summer flounder: eggs, larvae, juveniles, adults
  - Surf clams: juveniles, adults

- Tilefish: eggs, larvae, juveniles, adults
- White hake: eggs, larvae, juveniles, adults
- Whiting: eggs, larvae, juveniles, adults
- Windowpane flounder: eggs, larvae, juveniles
- Winter flounder: eggs, larvae, juveniles, adults
- Witch flounder: juveniles, adults
- Yellowtail flounder: eggs, larvae, juveniles, adults
- Skates: juvenile, adults
- Habitat Areas of Particular Concern: None

II. Habitat Impacts from Hurricane Sandy - New Hampshire, Massachusetts, Rhode Island, and Connecticut

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

According to the National Fish and Wildlife Foundation (2012):

- Most of the shoreline along Long Island Sound experienced Low Damage. A few areas, generally associated with exposed points and islands such as Hammonasset Point and the Norwalk Island in CT, experienced Moderate Damage. The damage rating was based on damage to the three habitats discussed below: dune/beach, tidal marsh, and maritime forest.

- For beach/dunes in Long Island Sound – 13% experienced no impact, 59% low impact (thinning of beach (<50'), debris deposited), 28% moderate impact (evidence of overwash; loss of dune vegetation; moderate thinning of beach - 50 to 100'), and 0% high impact (new overwash channels opened connecting ocean to bay; major loss of dune vegetation leaving largely barren areas, major thinning or migration of beach - >100'). Hurricane Sandy impact to areas north of Cape Cod were minimal (USACE 2013).

- Beach Dune and Erosion occurred at the following locations (The National Fish and Wildlife Foundation 2012):
  - Milford Point, Milford, CT
  - Sandy Point, Morse Point, West Haven, CT

- Salt Island, off the coast of Westbrook, CT
- Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
- Silver Sands State Park, Milford, CT
- Pattagansett Marsh Preserve, East Lyme, CT
- Rocky Neck State Park, East Lyme, CT
- Hatchetts Point Natural Area, Old Lyme, CT
- Griswold Point, Old Lyme, CT
- Woodmont Beach, Milford, CT (Reference for this beach and below: USACE 2013)
- Gulf Beach, Milford, CT
- Prospect Beach, West Haven, CT
- Sherwood Island State Beach, Westport, CT
- Southport Beach, Fairfield, CT
- Misquamicut Beach, Westerly, RI
- Oak Bluffs Town Beach, Oak Bluffs, MA
- Plum Island Beach, Newbury, MA
- Revere Beach, Revere, MA
- North Scituate Beach, Scituate, MA
- Quincy Shore Beach, Quincy, MA

- Existing Beach/Dune Habitat was moved or new habitat was created at the following locations (The National Fish and Wildlife Foundation 2012; USACE 2013):
  - Long Beach, Stratford, CT
  - Sand Point Island, West Haven, CT
  - Mumford, Cove and Bluff Point State Park, Groton, CT

  - Harkness Memorial State Park, Waterford, CT
  - Griswold Point, Old Lyme, CT
  - Meunketesuck, Salt and Duck Island, Westbrook, CT
  - Hammonasset Beach State Park, Madison, CT
  - Falkner Island, Guilford, CT
  - Morse Point, Milford, CT
  - Pleasure Beach, Bridgeport, CT
  - Cockenone Island, Westport, CT
  - Greater Norwalk Islands, Great Captains Island, Greenwich, CT
  - Sea Bluff Beach, West Haven, CT

Barrier Islands/Inlets

- Falkner Island which is home to rosate and common terns lost approximately 1/3 of its area (The National Fish and Wildlife Foundation 2012).
- Menunketesuck Island and Duck Island had excessive shoreline erosion (The National Fish and Wildlife Foundation 2012).
- Channel blockage/tidal flow interference occurred at the following locations (The National Fish and Wildlife Foundation 2012):
  - Waterford Town Beach and Pleasure Island – breaches of the barrier dune and beach erosion are causing sand to erode into Alewife Cove which is obstructing the cove's outlet to Long Island Sound.
  - At Rocky Neck State Park, accumulated sand prevented flow and proper tidal flushing of the Bride Brook Channel. This is one of the largest alewife runs in CT.
  - Harkness Memorial State Park – the outlet of Goshen Cove, an estuarine embayment and tidal creek, is currently blocked by sand and sediment.
  - Lynde Point – the storm pushed a dune into the tidal marsh blocking the flow of a tidal creek. Water is accumulating behind this blockage transforming the tidal marsh into freshwater swamp.

Salt / Brackish Marsh

- Coastal salt marshes were impacted to a much lesser degree showing much higher resistance to storm damage (The National Fish and Wildlife Foundation 2012).

- For marsh in Long Island Sound – 28% experienced no impact, 56% low impact (evidence of new wrack and debris deposited), 16% moderate impact (minor erosion/loss of marsh edge; small areas of sand deposited; medium size areas of wrack/debris) and 0% high impact (major erosion/loss of bayward marsh edge; large areas of sand and wrack deposites within marsh proper; rearrangement of tidal creek channels) (The National Fish and Wildlife Foundation 2012).

- Erosion of beaches and dunes left adjacent salt marsh habitat vulnerable to inundation from winter storms and high tides. These areas include (The National Fish and Wildlife Foundation 2012):

    - Waterford Town Beach, Waterford Pleasure Beach, Waterford, CT

    - Pattagansett Marsh Preserve, East Lyme, CT

    - Hattchetts Point Natural Area, Old Lyme, CT

- Lynde Point, Old Saybrook, CT – Storm surge pushed a dune into a tidal marsh and created a dam that which blocked the flow of the tidal creek, preventing it from reaching the adjacent marsh. As a result the area is quickly converting into a freshwater swamp (The National Fish and Wildlife Foundation 2012).

- An earthen berm at Sunken Meadow State Park adjacent to Sunken Meadow Creek in CT was destroyed by the storm. This berm had been scheduled to be removed to restore 100 acres of salt marsh as part of an anadromous fish project. This is considered a positive impact from Hurricane Sandy (The National Fish and Wildlife Foundation 2012).

Maritime Forest

- According to The National Fish and Wildlife Foundation (2012), impacts to the forests in Long Island Sound were as listed:

    - 66% experienced no impact

    - 33% low impact (evidence of a few 5% fallen trees)

    - 1% moderate impact (5-25% trees fallen creating numerous small canopy gaps <1 acre in size)

    - 0% high impact (>25% of trees fallen creating large [>1 acre in size])

Submerged Aquatic Vegetation

- According to The National Fish and Wildlife Foundation (2012), there was significant eelgrass damage at Ninigret Pond, Charlestown, RI.

Rock Reefs

- According to The National Fish and Wildlife Foundation (2012), Penfield Reef in Fairfield, CT "largely washed away" as a result of the storm.

National Park Service Areas

Stewart B. McKinney

- Stewart B. McKinney
  - At Falkner Island, 1/3 of the island was lost as s result of the storm. This area is home to roseate terns and common terns (The National Fish and Wildlife Foundation 2012).
- The following State Parks experienced overwashing of dunes and significant erosion and/or the movement of existing habitat and creation of new habitat from Hurricane Sandy (The National Fish and Wildlife Foundation 2012; USACE 2013).
  - Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
  - Silver Sands State Park, Milford, CT
  - Pattagansett Marsh Preserve, East Lyme, CT
  - Rocky Neck State Park, East Lyme, CT
  - Hatchetts Point Natural Area, Old Lyme, CT
  - Mumford, Cove and Bluff Point State Park, Groton, CT
  - Hammonasset Beach State Park, Madison, CT
  - Sherwood Island State Beach, Westport, CT
  - Misquamicut Beach, Westerly, RI

Critical/Significant Habitat

- Beaches above that experienced erosion above would have an impact on the species that nest on beaches, including piping plover, least terns, and rosette terns

- Coastal flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013).

Quality

- According to The National Fish and Wildlife Foundation (2012):

    - Ledyard, CT – a backup generator for the Town's treatment plant failed causing officials to pump approximately 60,000 gallons of raw sewage into Set Williams Brook.

    - Branford, East Lyme, Fairfield, Greenwich, New Hartford, and New Haven, CT – Similar problems and releases were reported.

    - Bridgeport, CT – 15 to 20 million gallons of partially treated sewage was discharged into Long Island Sound when the city's two treatment plants were inundated tidal surges.

III. Future Without Action Conditions - Rhode Island

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- Sea level rise is expected to permanently inundate certain low-lying coastal areas and dramatically accelerate erosion, particularly on important barrier beaches such as East Beach and Misquamicut State Beach (Union of Concerned Scientists 2007). However, it is expected that the beaches at Misquamicut Beach in Westerly and Oakland Beach in Warwick, which were both originally constructed as shore protection projects/beach fill by the USACE, would continue to receive sand from the local sponsor to meet their design criteria.

- Other State and/or Town beaches in Rhode Island may also be expected to maintain their beaches, especially those beaches that are used recreationally, although continued sea level rise may make this difficult to maintain in the future.

Coastal Wetlands

- An increase in the rate of sea level rise will result in a significant loss of coastal salt marsh habitat. Salt marshes are particularly vulnerable to relative sea level rise, where the normal process of accretion cannot keep pace. As salt marshes become submerged, they migrate inland. This migration is limited as a result of coastal development which has decreased the amount of open space adjacent to the salt marshes. The limitation is exacerbated in locations where man-made structures, such as bulkheads, further interfere with migration (URI 2012).

- Where tidal marshes become submerged or eroded, the expected overall loss of wetlands would cause wetland dependent species of fish and birds to have reduced population sizes URI 2012).

- In marsh areas where accretion rates cannot keep up with sea-level rise, marsh will eventually revert to unvegetated flats and eventually open water. In some cases where tidal range increased with increased rates of sea-level rise, there may be an overall increase in the acreage of tidal flats. In low energy shores with sediment supplies, where sediments accumulate in shallow waters, flats may become vegetated as low marsh encroaches towards the water, which will increase low marsh at the expense of tidal flats. If sediment inputs are not sufficient, tidal flats will convert to subtidal habitats, which may or may not be vegetated depending on substrate composition and water transparency (US Climate Change Science Program 2009).

- The loss of wetlands would cause wetland dependent species of fish and birds to have reduced population sizes. The National Marine Fisheries Service estimates that approximately 1/3 of commercial fish and shellfish collected in New England are directly dependent on estuaries and salt marshes (Stedman and Hanson 1997).

Submerged Aquatic Vegetation

- Eelgrass beds are predicted to decline in coastal waters of southern New England as a result of warmer water temperatures, decreased light levels from sea level rise, and possibly increased storminess. Eelgrass and other submerged aquatic vegetation (SAV) serve as vital habitat for many commercially important marine species, especially functioning as nursery grounds where juvenile fish can hide from predators. Also, in areas such as the Rhode Island salt ponds, increased breaching events could negatively impact local eelgrass populations by increasing sand sediment in over-wash events in the ponds. As sea level rises, however, the inundation of shorelines could create new SAV habitat (URI 2012).

Oyster Reefs

- Oysters improve water quality by removing pollutants and nutrients during feeding. If exposd to extreme freshwater events, such as a large storm, oyster will close their shells and isolate themselves from external environmental conditions.

Rocky Shorelines

- Rocky shorelines, especially intertidal and shallow water rocky habitat could become inundated and no longer be available as intertidal habitat as a result of sea level rise. Littoral zone biota are likely to respond to changing tide heights by shifting vertically where shoreline topography allows it. However, this type of shoreline would be resistant to erosion and protective of adjacent uplands.

Shallow Bay Habitat/Bay Islands

- Shallow waters of Narragansett Bay may be expected to increase as the sea rises along with shoreline erosion and the drowning of coastal wetlands and shorelines. The fate of the 36 island in the bay would be dependent on the amount of low-lying land on the island. Some islands may become completely submerged. The northern end of Block Island has more low-lying land. Increased storms may increase erosion of the bluffs and cliffs of the island.

Terrestrial Upland

- A variety of potatoes, fruits, and vegetables are produced by growers in Rhode Island from the Blackstone Valley to the fertile soils of the coastal lowlands. By mid-century, it is possible that the winter chilling requirements of blueberries, raspberries, cranberries, and certain varieties of apples would not be met across most of the State (Union of Concerned Scientists 2007).

Floodplains/Riparian

- Floodplains will likely become increasingly vulnerable to flooding without human intervention. In tidal areas, the tidal inundation characteristics of the floodplain may change with the range of tide and associated tidal currents increasing with sea level rise. With this inundation, floodplains will be vulnerable to increased coastal erosion from waves, river and tidal currents, storm-induced flooding, and tidal flooding. Upland floodplain boundaries will be vulnerable to horizontal movement.

Coastal Protected Areas

- Rhode Island has many protected Federal and State areas. Managers at some of these areas have begun assessing the impacts of climate change on their managed resources. For example, the U.S. Fish and Wildlife Service used the Sea Level Affecting Marshes Model (SLAMM) to determine impacts of sea level rise at various levels for the Block Island, Ninigret, Trustom Pond, John H. Chafee, and Sachuest Point National Wildlife Refuges. Proposals for Hurricane Sandy funds include restoration of 200 acres of salt marsh at the John H. Chafee NWR, and replacing an undersized culvert at Sachuest NWR to accommodate natural flows as well as storm surges, flooding and sea level rise. Also, 10 miles of shrub habitat is proposed to be restored and created in salt marsh buffer zones within the Chafee, Sachuest and Ningret NWRs (Attachment A).

Critical/Significant Habitats

Waterbird Islands

- Several islands in Narragansett Bay and portions of Block Island serve as a nesting area for coastal shorebirds. As with other areas described above, low-lying areas would be the most susceptible to sea level rise and storms, in particular Dyer and Spar Islands (Attachment A).

Essential Fish Habitat (EFH)

- Local species that are at or near the southern extent of their range are likely to move north with warming ocean temperatures. This will likely decrease in abundance and/or the extent of time in which these species can be caught by commercial fishers. Atlantic cod, silver hake and winter flounder area commercially valuable species most likely to be impacted this way. On the contrary, species such as Atlantic croaker, black sea bass, blue crab, butterfish, scup and summer flounder that are at or near the northern extent of their range are likely to increase in abundance and/or extent of time in which they can be caught locally (URI 2012).

Atlantic Flyway

- Arnold Neck, Boyd Marsh, Briggs Marsh, the Coastal Ponds on the southwest coast (Galilee Bird Sanctuary, Ningret/Trustom/Potter Ponds, Point Judith Ponds, Quonochontaug Pond, and Winnapaug Pond), Frogland Point, Hamilton Cove, Narragansett Bay Islands, and Pettaquamscutt Cove are all part of the Rhode Island waterfowl focus areas. Narragansett Bay provides sheltered open water that is important for wintering sea ducks and bay ducks such as scoters and scaup as well as fringing salt marshes and mudflats important for dabbling ducks such as mallards (http://www.acjv.org/maps/ri_waterfowl_web_map.pdf).

- Coastal marshes provide valuable wintering habitat since most inland wetlands freeze during the winter. Mudflats are used by migrating shorebirds. A combination of sea level rise and marsh subsidence could put some of the most important coastal marshes at risk of being lost. There could be a loss or reduction in intertidal habitat (URI 2012).

T&E Species/Species of Concern

- Low flows and higher ambient air temperatures would increase water temperatures, which would affect cold-water fisheries, growth, habitat, and salmon and other anadromous fish migrations. Observations indicate that the timing of the migration of anadromous fish species, such as Atlantic salmon and alewives, has advanced in the last few decades and they are migrating earlier in the season. Regionally it has been predicted that with increased warming, the distribution of American shad and alewife will shift north.

Marine Turtles

- Sea turtles generally occur in Rhode Island waters in the warmer months. With increased sea temperatures, it is possible that these species may frequent the coastal waters more often or for a greater period of time. The major impact of global climate change on local sea turtles is that sea level rise will affect nesting areas and feeding grounds on low-lying sand beaches that they typically use in areas south of Rhode Island.

Marine Mammals

- The whales that visit Rhode Island may shift their timing based on the warmer ocean temperatures and availability of prey (URI 2012).

Birds (Nesting)

- Nesting habitat for piping plover, least tern, rosette tern, and red knot is likely to diminish with the reduction in available coastal beaches, increased storm activity, and reduction in nesting islands.

Shellfish/Shellfish Beds

- Shellfish which have shells or skeletons made of calcium carbonate may be impacted by ocean acidification. As oceans become more acidic, the dissolution rate calcium carbonate increases. Young larval forms of these species are even more sensitive to acidification than adult forms.

- Global warming is expected to take a serious toll on the already declining shellfish population. Lobster stocks in Rhode Island's nearshore waters are expected to collapse entirely as the maximum heat-stress threshold for lobsters is consistently exceeded by mid-century.

Quality

Water Quality/Impaired Waters

- More hypoxia events could occur when the water is warmer because warmer water increases metabolic rates of aquatic organisms and their need for more dissolved oxygen. Also, higher water temperatures decrease the solubility of oxygen in water. Higher runoff during wet years leads to stronger density stratification in Narragansett Bay. The long-term trend of increasing precipitation and river runoff is likely to enhance stratification and lead to more severe hypoxia (URI 2012).

Miscellaneous

- Additional exotic species that once found the colder temperatures of Rhode Island inhospitable will be able to reproduce and spread as local and regional waters warm (URI 2012).

Cultural Resources

- Sea level rise impacts to cultural resources range from increased tidal and wave erosion to inundation. Cultural resources within coastal zones will be subjected to gradual sea level rise impacts exacerbated by event-specific impacts such as high tide events and storms. The frequency and intensity of damage from event-specific impacts is expected to increase as sea level rises (Karl et al. 2009). In addition, high regional subsistence rates are expected to increase rates of sea level rise and associated impacts (Johnson 2000).

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4. Connecticut: Environmental Existing and Future Conditions

I. Coastal Characterization - Connecticut

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Beaches/Pebble Shoreline/Beaches

- Coastal barriers, beaches, and dunes along the shoreline of Long Island Sound are formed by a delicate balance of erosion, water currents, and wind currents. Maritime dunes are described by their level of maturity and relative stability.

- The most seaward of the dunes are in constant motion and depend on the establishment of American beachgrass to stabilize them. Plant species like dusty miller, beach pea, sedge (*Carex silicea*), seaside goldenrod (*Solidago sempervirens*), Virginia rose (*Rosa virginiana*), and pasture rose (*Rosa carolina*) are also well adapted to the dry conditions on the dunes and colonize soon after the pioneering beachgrass. Many of these species may also be found in upper dry beach areas where there are no dunes present.

- Dunes occuring more landward are also more stable. Herbaceous species include beach heather (*Hudsonia tomentosa*), seaside goldenrod, bearberry (*Arctostaphylos uva-ursi*), Cyperus (*Cyperus polystachyos var. macrostachyus*), beach pinweed (*Lechea maritima*), poison ivy (*Toxicodendron radicans*), and joint weed (*Polygonella articulata*).

- Species diversity in dune plant communities generally increases as protection from salt spray increases. In Connecticut there is an unusual colony of beach plum known as Graves' beach plum, growing entirely as vegetative clones. This colony has been classified as a separate variety named *Prunus maritima var. gravesii*, and is thought to occur only in that single location. Typical birds associated with the dune community are the gadwall (*Anas strepera*) and short-eared owl (*Asio flammeus*) (Long Island Sound Study 2003).

- Sandy beaches (fine-medium and coarse grain sand) comprise approximately 46 linear miles of shoreline across the counties of concern (http://response.restoration.noaa.gov/esi).

- The coastlines along Fairfield, New Haven, Middlesex, and New London counties are composed of approximately 17 linear miles of gravel beaches. Mixed sand and gravel beaches line the coast of the counties of concern with approximately 20 linear miles of beach being of this type (http://response.restoration.noaa.gov/esi).

Barrier Islands/Inlets

- Number of CBRS Units = 32 (System Units: 25; Otherwise Protected Areas: 7)
  - Total Acres = 9,245 (Upland Acres: 1,130; Associated Aquatic Habitat Acres: 8,115)
  - Shoreline Miles: 22

(http://www.fws.gov/CBRA/Maps/Locator/CT.pdf)

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

- Approximately 16,830 acres of salt and brackish marsh are present in the study counties (http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898).

- There are approximately 77,330 acres of freshwater wetlands (not including ponds and lakes) in the counties of concern.

- In CT, there are approximately 2,660 acres of tidal mud flats along the coast of the counties of concern (http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898).

- Forested Coastal Areas in CT and NY (doesn't separate out maritime forests) in 2006: 356.8 square miles. According to research from the University of Connecticut's Center for Land Use Education and Research (CLEAR), forested land in the late 20th and early 21st century declined by 6 percent in New York and Connecticut from 1985 to 2006. In the coastal area it declined by 9.25 percent. The CLEAR research also indicates that about two-thirds of forested land is fragmented—areas which are compromised by non-forested land (http://longislandsound study.net/2012/06/changes-in-forest-cover-in-ct-ny/).

- Estuaries of national significance in Connecticut include the Long Island Sound, which reaches Fairfield, New Haven, New London, and Middlesex counties (http://www.nbep.org/). The Connecticut River, New England's largest and most celebrated river, winds its way south 410 miles from Vermont and New Hampshire to Long Island Sound. The scenic, historic and ecological value makes the river unique. Its watershed encompasses over seven million acres and is home to countless species, including an estimated eight million humans. The Connecticut River is the largest single contributor of fresh water to the estuary of Long Island Sound (The Connecticut River Gateway Commission 2011).

Submerged Aquatic Vegetation

- Eelgrass: 1616 total acres at 119 sites (high density sites: 453.1 acres at 21 sites; medium density sites: 1011.9 acres at 74 sites; low density sites: 151 acres at 24 sites) (Tiner et al. 2010).

Oyster Reefs

- Connecticut has a 16 million dollar per year shellfish industry, with more than 50 enterprises producing shellfish. The state has been strongly supportive of oyster aquaculture, leasing submerged land, and assisting in planting culch (or clean oyster shell). The value of commercially harvested oysters from Long Island Sound was estimated to be $60 million in 1995 ranking Connecticut first in the nation in the total value of oysters harvested and second in oyster production among all coastal states. Norwalk is considered Connecticut's Oyster Capital based on weight of catch (http://www.lisrc.uconn.edu/coastalaccess/facts.asp).

Rock Reefs

- Penfield Reef is a partially submerged reef that extends a mile into Long Island Sound from the coast of Fairfield, Connecticut (http://www.lighthousefriends.com/light.asp?ID=788).

Rocky Shorelines

- There are approximately 27 linear miles of rocky shoreline in the counties of concern.http://response.restoration.noaa.gov/esi).

Shallow Bay Habitat/ Bay Islands

- There are many small islands located off the coast of Connecticut in Long Island Sound. These islands include: Shea Island and Cockenoe Island in Fairfield County, Charles Island, Exton's Reef Island and the Thimble Islands in New Haven, Menunketesuck Island in Middlesex County, and Pine Island and Sixpenny Island in New London County. Connecticut has almost 200 islands off of its coast (http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898).

Terrestrial Upland

- Forested Coastal Areas in CT and NY (doesn't separate out maritime forests) in 2006: 356.8 square miles. According to research from the University of Connecticut's Center for Land Use Education and Research (CLEAR), forested land in the late 20th and early 21st century declined by 6 percent in New York and Connecticut from 1985 to 2006. In the coastal area it declined by 9.25 percent. The CLEAR research also indicates that about two-thirds of forested land is fragmented—areas which are compromised by non-forested land (http://longislandsoundstudy.net/2012/06/changes-in-forest-cover-in-ct-ny/)

Floodplains/Riparian

- Riparian corridors are generally characterized for land cover and land cover change for both 100 feet and 300 feet to either side of the stream, or shoreline of a water feature. A study by the University of Connecticut looked at land cover for the 100 foot corridor (an area of about 298,250 acres) and the 300 foot corridor (about 849,000 acres) for the state of Connecticut. For the 100 foot corridor, forest accounted for over two-thirds of the area (67.1%), with developed land (14.5%) and the closely associated category of turf/grass (5.1%) being the next most prevalent. For the 300 foot corridor, forest was still the most prevalent land cover (64.1%), with developed land (16.8%) and turf/grass (6.3%) again rounding out the top three (http://clear.uconn.edu/data/interactive.htm).

Coastal Protected Areas

National Estuary Program

- Long Island Sound (including NY) (Yaro et al. 1988)
    - Area: 1,320 square miles
    - Area of drainage basin or watershed: 16,820 square miles
    - Average depth: 63 feet (60 to 120 feet)
    - Length of Coastline: 600 miles
    - Salinity – western end 23 ppt; eastern end 35 ppt
    - Freshwater – 90% from 3 rivers: Thames, Housatonic, and Connecticut
    - Population living within 50 miles: > 23 million people
    - Number of finfish species: > 120
    - Number of species that spawn in the Sound: at least 50
    - Number of tropical species that stray seasonally: 21

National Wildlife Refuges

- Stewart B. McKinney National Wildlife Refuge is located on the Connecticut shore along, and on islands within, Long Island Sound, the second largest estuary in the United States. The Refuge spans 70 miles of the Connecticut Coast and includes diverse barrier beach (141.0 acres), tidal salt marsh (470.6 acres), grassland, shrubland, and near shore woodland habitats. The refuge provides important resting, feeding, and nesting habitat for many species of wading birds, waterfowl, songbirds, shorebirds and terns, including the endangered roseate tern and the threatened piping plover.(USFWS 2014)

- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

National Park Service Areas

- Quinebaug and Shetucket Rivers Valley National Heritage Corridor: This is a special kind of park. It embraces numerous towns, villages and a total population of about 300,000. Quinebaug & Shetucket is not a traditional park. Instead, citizens, businesses, nonprofit cultural and environmental organizations, local and state governments, and the National Park Service work together to preserve and celebrate the region's cultural, historical and natural heritage. The lower portion encompasses New London County (http://www.nps.gov/qush/index.htm).

State/County Parks

- Fairfield County:
    - Sherwood Island State Park on 234 acres
    - Putnam Memorial State Park on 183 acres
    - Squantz Pond State Park on 172 acres
    - Seth Low Pierrepont State Park Reserve on 313 acres
    - Wooster Mountain State Park on 444 acres
    - Collis P. Huntington State Park on 878 acres
    - Indian Well State Park on 153 acres
    - Rocky Glen State Park on 46 acres
    - Bennett’s Pond State Park on 460 acres
    - Mianus River State Park on 527 acres
    - Trout Brook Valley State Park Reserve on 300 acres
    - Centennial Watershed State Forest on 15,300 acres
    - Paugussett State Forest on 2,000 acres
    - Pootatuck State Forest on almost 1,200 acres
- Middlesex County:
    - Brainard Homestead State Park on 25 acres

- Chatfield Hollow State Park on 356 acres
- Connecticut Valley Railroad State Park on 136 acres
- Dart Island State Park on 19 acres
- Devil's Hopyard State Park in East Haddam is 860 acres
- Eagle Landing State Park on 16 acres
- George Dudley Seymour State Park on 334 acres
- Gillette Castle State Park in East Haddam on 184 acres
- Haddam Island State Park in Haddam on 14 acres
- Haddam Meadows State Park on 154 acres
- Higganum Reservoir State Park on 147 acres
- Hurd State Park on 884 acres
- Machimoodus State Park on 300 acres
- Millers Pond State Park on over 200 acres
- River Highlands State Park on 177 acres
- Sunrise Resort State Park on 143 acres
- Tri-Mountain State Park on 157 acres (also located in New Haven county)
- Wadsworth Falls State Park on 285 acres
- Cockaponset State Forest on 16,696 acres
- Meshomasic State Forest, Mountain Block on 6,270 acres
- Mohegan State Forest on over 700 acres
- Salmon River State Forest on nearly 6,000 acres (also located in New London county)

- New Haven County:
    - Farm River State Park on 61 acres

  - Farmington Canal State Park Trail (part of Farmington Canal Trail)
  - George Waldo State Park on 150 acres
  - Hammonasset Beach State Park in Madison, State's largest shoreline park, over 2 miles of beach on 919 acres;
  - Rock Neck State Park in East Lyme on 710 acres;
  - Black Pond State Wildlife Area
  - Naugatuck State Forest on almost 5,000 acres
  - Kettletown State Park on 492 acres
  - Larkin State Park Trail on 110 acres
  - Osborndale State Park on 350 acres
  - Quinnipiac River State Park on 323 acres
  - Silver Sands State Park on 297 acres
  - Sleeping Giant State Park on 1,439 acres
  - Southford Falls State Park on 120 acres
  - West Rock Ridge State Park on 1,533 acres
  - Wharton Brook State Park on 96 acres
  - Whittemore Glen State Park on 242 acres
  - Naugatuck State Forest on up to about 5,000 acres
- New London County:
  - Becket Hill State Park Reserve on 260 acres
  - Bluff Point State Park on 806 acres
  - Day Pond State Park on 180 acres
  - Fort Griswold Battlefield State Park on 16 acres
  - Fort Trumbull State Park on 16 acres

- Gardner Lake State Park on 10 acres
- Haley Farm State Park on 198 acres
- Harkness Memorial State Park on 116 acres
- Hopemead State Park on 60 acres
- Hopeville Pond State Park on 544 acres
- Minnie Island State Park on 1 acre
- Mooween State Park on 577 acres
- Pomeroy State Park on 200 acres
- Rocky Neck State Park on 708 acres
- Salt Rock State Campground on 149 acres
- Selden Neck State Park on 528 acres
- Stoddard Hill State Park on 55 acres
- Nehantic State Forest on 4,222 acres
- Pachaug State Forest on 24,000 acres

(http://www.stateparks.com/connecticut_parks_and_recreation_destinations.html)

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

- The Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986. Piping Plovers nest along many beaches in Connecticut; the most productive nesting beaches are in West Haven, Old Lyme and Groton (Attachment A).

- Roseate tern (*Sterna dougallii*) is a medium-sized, black-capped sea tern about 15 inches long and weighs about four ounces. On November 2, 1987, the USFWS determined the population that nests in the Northeast to be endangered, and the population that nests in the Caribbean to be threatened. Falkner Island, which is part of the Stewart B. McKinney NWR, contains the only roseate tern colony in Connecticut (Attachment A).

- A detailed discussion of Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

- The New York Bight Distinct Population Segment (NYB DPS) of Atlantic sturgeon was listed as endangered in a final rule on February 6, 2012 by NMFS. Atlantic sturgeon spawn in spring and early summer in freshwater and migrate into estuarine and marine waters where they spend most of their lives (http://www.nmfs.noaa.gov/pr/species/fish/atlanticsturgeon.htm). NYB DPS includes all anadromous Atlantic sturgeon that drain into coastal waters including Long Island Sound. Atlantic sturgeons have been documented at the mouth of the Connecticut River and throughout Long Island Sound (Federal Register vol 77, no. 24, February 6, 2012).

- The shortnose sturgeon is an anadromous fish which lives mainly in the slower moving riverine waters or nearshore marine waters before migrating periodically into faster moving freshwater to spawn. Shortnose sturgeons spawn in the coastal rivers along the east coast of North America from Canada to Florida. They are found in the Connecticut River. They were listed as endangered throughout its range on March 11, 1967 under the Endangered Species Act of 1966 (http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm).

- Species of Concern listed by NMFS, and associated area of concern include the anadromous and highly migratory river herring (alewife and blueback herring) found in the Atlantic Ocean from Newfoundland to North Carolina, the pelagic and highly migratory Atlantic bluefin tuna found throughout the the North Atlantic Ocean and adjacent seas, the Atlantic halibut found from Labrador to southern New England in the Northwest Atlantic Ocean, the dusky shark found in the Western Atlantic Ocean, the porbeagle shark found in the Nortwest Atlantic Ocean, the anadromous rainbow smelt found in rivers and coastal areas of eastern North America from Labrador to New Jersey, and the sand tiger shark found in the Western Atlantic Ocean (http://www.nmfs.noaa.gov/pr/species/concern/).

- The American eel was petitioned to be listed as threatened on September 29, 2011 in the Federal Register (vol. 76, no. 189) by the USFWS. Eels spawn in the Sargasso Sea. Juveniles arrive in coastal waters and river systems which are accessible by the oceanic currents of the western North Atlantic Ocean for development. This fish occupies fresh, brackish and marine waters (FR, vol 76. No. 189).

Waterbird Islands

- The Norwalk Islands are of high regional significance for breeding colonial wading birds. These rookeries are mostly dominated by black-crowned night-heron (*Nycticorax nycticorax*), but also include great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), cattle egret (*Bubulcus ibis*), little blue heron (*Egretta caerulea*), yellow-crowned night-heron (*Nyctanassa violacea*), green-backed heron (*Butorides striatus*) and glossy ibis (*Plegadis falcinellus*). The largest colony, numbering over 1000 pairs comprised of eight species, occurs on Chimon Island and tends to move out and utilize the other islands, mainland marshes, and intertidal flats for feeding. The most important wading bird feeding areas in this complex are the tidal flats around some of the islands and on the mainland at Village Creek-Hoyt Island, Norwalk Harbor, Shorehaven-Canfield Island, Saugatuck River mouth and Compo Cove-Sherwood Millpond. Birds from these islands also utilize the mudflats at Great Meadows (Stratford) for feeding. Small nesting colonies of herons and egrets occur on Shea and Grassy Islands and others (http://library.fws.gov/pubs5/necas/web_link/20_norwalk%20island.htm).

- Ram Island, at the mouth of Mystic Harbor, is a tombolo of sandy and cobble beaches connecting two rocky islands and covered with scrub thickets. Mean tidal range in this area is 2.3 feet (0.70 m). Ram Island is an important rookery for several species of colonial wading birds, including black-crowned night-heron (*Nycticorax nycticorax*), snowy egret (*Egretta thula*), glossy ibis (*Plegadis falcinellus*), great egret (*Casmerodius albus*) and little blue heron (*Egretta caerulea*), as well as such problem species as double-crested cormorant (*Phalacrocorax auritus*), great black-backed gull (*Larus marinus*) and herring gull (*Larus argentatus*). These last three species seem to be increasing their numbers and populations everywhere along the coast, often displacing nesting terns and piping plovers (http://library.fws.gov/pubs5/necas/web_link/27_fishers.htm).

- Falkner and Goose Islands – These islands are located in central Long Island Sound approximately 4 miles (6 km) south of Guilford on the central coast of Connecticut. Falkner Island is a glacial moraine island, approximately 5 acres (2 ha) in size, with 16-33 foot (5-10 yards) high bluffs, and consisting of a densely vegetated, grassy interior plateau surrounded by a relatively narrow strip of rocky beach. Goose Island is a one acre island and is comprised of gravel beach and brush upland. This island provides nesting habitat for seagulls, American oystercatchers, and double-breasted cormorants (http://www.fws.gov/refuge/Stewart_B_McKinney/wildlife_and_habitat/islands.html).

- Falkner Island contains the third largest nesting colony of roseate terns (*Sterna dougallii*), a U.S. Endangered species, in North America. Together with Bird Island in Buzzards Bay, Massachusetts, and Great Gull Island off the eastern end of Long Island, New York, these three islands constitute over 90% of the North American breeding population of this species. The number of roseate terns on Falkner Island has averaged about 175 nesting pairs over the past 10 years. Common terns (*Sterna hirundo*) also breed on Falkner Island, though in far greater numbers than roseate terns. The nesting population of common terns is estimated (1989) at over 4,000 pairs on this island. While common terns do a fair amount of feeding along the mainland coast of Connecticut, roseate terns are virtually never observed feeding in this area and, in fact, it has not been established precisely where the roseate terns from Falkner Island actually feed. Goose Island currently has a large and growing breeding population of double-crested cormorants (*Phalacrocorax auritus*), great black-backed gulls (*Larus marinus*) and herring gulls (*Larus argentatus*). Other species of special emphasis using the nearshore waters of this general area, particularly during the winter, are: Atlantic brant (*Branta bernicla*), American black duck (*Anas rubripes*), greater and lesser scaup (*Aythya marila* and *A. affinis*), scoters (*Melanitta* spp.), common and red-throated loans (*Gavia immer* and *G. stellata*, respectively) (http://library.fws.gov/pubs5/ramsar/web_link/sites.htm).

- A detailed discussion on Waterbird Nesting Colonies can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Essential Fish Habitat /Fish

- The area provides EFH for (http://www.nero.noaa.gov/hcd/STATES4/ConnNYNJ.htm):
    - Atlantic herring: larvae, juveniles, adults
    - Atlantic mackerel: eggs, larvae, juveniles, adults
    - Atlantic salmon: eggs, larvae, juveniles, adults
    - Atlantic sea scallops: eggs, larvae, juveniles, adults
    - Black sea bass: eggs, larvae, juveniles, adults
    - Bluefish: juveniles, adults
    - Butterfish: eggs, larvae, juveniles, adults
    - Haddock: larvae, juveniles
    - Ilex squid: juveniles, adults
    - Loligo: eggs, juveniles, adults
    - Monkfish: eggs, larvae, juveniles, adults, spawning adults
    - Ocean pout: eggs, larvae, juveniles, adults, spawning adults
    - Ocean quahog: juveniles, adults
    - Pollock: juveniles, adults
    - Red hake: eggs, larvae, juveniles, adults
    - Scup: eggs, larvae, juveniles, adults
    - Spiny dogfish: juveniles, adults
    - Summer flounder: eggs, larvae, juveniles, adults
    - Surf clams: juveniles, adults

- White hake: eggs, larvae, juveniles, adults
- Whiting: eggs, larvae, juveniles, adults
- Windowpane flounder: eggs, larvae, juveniles, adults
- Winter flounder: eggs, larvae, juveniles, adults
- Yellowtail flounder: eggs, larvae, juveniles, adults
- Skates: juveniles, adults
- Habitat Areas of Particular Concern: None

II. Habitat Impacts from Hurricane Sandy - New Hampshire, Massachusetts, Rhode Island, and Connecticut

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

According to the National Fish and Wildlife Foundation (2012):

- Most of the shoreline along Long Island Sound experienced Low Damage. A few areas generally associated with exposed points and islands such as Hammonasset Point and the Norwalk Island in CT, experienced Moderate Damage. The damage rating was based on damage to the three habitats discussed below: dune/beach, tidal marsh, and maritime forest.

- For beach/dunes in Long Island Sound – 13% experienced no impact, 59% low impact (thinning of beach (<50'), debris deposited), 28% moderate impact (evidence of overwash; loss of dune vegetation; moderate thinning of beach - 50 to 100'), and 0% high impact (new overwash channels opened connecting ocean to bay; major loss of dune vegetation leaving largely barren areas, major thinning or migration of beach - >100'). Hurricane Sandy impact to areas north of Cape Cod were minimal (USACE 2013).

- Beach Dune and Erosion occurred at the following locations (The National Fish and Wildlife Foundation 2012):

  - Milford Point, Milford, CT
  - Sandy Point, Morse Point, West Haven, CT
  - Salt Island, off the coast of Westbrook, CT

- Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
- Silver Sands State Park, Milford, CT
- Pattagansett Marsh Preserve, East Lyme, CT
- Rocky Neck State Park, East Lyme, CT
- Hatchetts Point Natural Area, Old Lyme, CT
- Griswold Point, Old Lyme, CT
- Woodmont Beach, Milford, CT (Reference for this beach and below: USACE 2013)
- Gulf Beach, Milford, CT
- Prospect Beach, West Haven, CT
- Sherwood Island State Beach, Westport, CT
- Southport Beach, Fairfield, CT
- Misquamicut Beach, Westerly, RI
- Oak Bluffs Town Beach, Oak Bluffs, MA
- Plum Island Beach, Newbury, MA
- Revere Beach, Revere, MA
- North Scituate Beach, Scituate, MA
- Quincy Shore Beach, Quincy, MA

- Existing Beach/Dune Habitat was moved or new habitat was created at the following locations (The National Fish and Wildlife Foundation 2012; USACE 2013):
  - Long Beach, Stratford, CT
  - Sand Point Island, West Haven, CT
  - Mumford, Cove and Bluff Point State Park, Groton, CT
  - Harkness Memorial State Park, Waterford, CT

  - Griswold Point, Old Lyme, CT
  - Meunketesuck, Salt and Duck Island, Westbrook, CT
  - Hammonasset Beach State Park, Madison, CT
  - Falkner Island, Guilford, CT
  - Morse Point, Milford, CT
  - Pleasure Beach, Bridgeport, CT
  - Cockenone Island, Westport, CT
  - Greater Norwalk Islands, Great Captains Island, Greenwich, CT
  - Sea Bluff Beach, West Haven, CT

Barrier Islands/Inlets

- Falkner Island which is home to rosate and common terns lost approximately 1/3 of its area (The National Fish and Wildlife Foundation 2012).
- Menunketesuck Island and Duck Island had excessive shoreline erosion (The National Fish and Wildlife Foundation 2012).
- Channel blockage/tidal flow interference occurred at the following locations (The National Fish and Wildlife Foundation 2012):
  - Waterford Town Beach and Pleasure Island – breaches of the barrier dune and beach erosion are causing sand to erode into Alewife Cove which is obstructing the cove's outlet to Long Island Sound.
  - At Rocky Neck State Park, accumulated sand prevented flow and proper tidal flushing of the Bride Brook Channel. This is one of the largest alewife runs in CT.
  - Harkness Memorial State Park – the outlet of Goshen Cove, an estuarine embayment and tidal creek, is currently blocked by sand and sediment.
  - Lynde Point – the storm pushed a dune into the tidal marsh blocking the flow of a tidal creek. Water is accumulating behind this blockage transforming the tidal marsh into freshwater swamp.

Salt / Brackish Marsh

- Coastal salt marshes were impacted to a much lesser degree showing much higher resistance to storm damage (The National Fish and Wildlife Foundation 2012).

- For marsh in Long Island Sound – 28% experienced no impact, 56% low impact (evidence of new wrack and debris deposited), 16% moderate impact (minor erosion/loss of marsh edge; small areas of sand deposited; medium size areas of wrack/debris) and 0% high impact (major erosion/loss of bayward marsh edge; large areas of sand and wrack deposites within marsh proper; rearrangement of tidal creek channels) (The National Fish and Wildlife Foundation 2012).

- Erosion of beaches and dunes left adjacent salt marsh habitat vulnerable to inundation from winter storms and high tides. These areas include (The National Fish and Wildlife Foundation 2012):

    - Waterford Town Beach, Waterford Pleasure Beach, Waterford, CT

    - Pattagansett Marsh Preserve, East Lyme, CT

    - Hattchetts Point Natural Area, Old Lyme, CT

- Lynde Point, Old Saybrook, CT – Storm surge pushed a dune into a tidal marsh and created a dam that which blocked the flow of the tidal creek, preventing it from reaching the adjacent marsh. As a result the area is quickly converting into a freshwater swamp (The National Fish and Wildlife Foundation 2012).

- An earthen berm at Sunken Meadow State Park adjacent to Sunken Meadow Creek in CT was destroyed by the storm. This berm had been scheduled to be removed to restore 100 acres of salt marsh as part of an anadromous fish project. This is considered a positive impact from Hurricane Sandy (The National Fish and Wildlife Foundation 2012).

Maritime Forest

- According to The National Fish and Wildlife Foundation (2012), impacts to the forests in Long Island Sound were as listed:

    - 66% experienced no impact

    - 33% low impact (evidence of a few 5% fallen trees)

    - 1% moderate impact (5-25% trees fallen creating numerous small canopy gaps <1 acre in size)

    - 0% high impact (>25% of trees fallen creating large [>1 acre in size])

Submerged Aquatic Vegetation

- According to The National Fish and Wildlife Foundation (2012), there was significant eelgrass damage at Ninigret Pond, Charlestown, RI.

Rock Reefs

- According to The National Fish and Wildlife Foundation (2012), Penfield Reef in Fairfield, CT "largely washed away" as a result of the storm.

National Park Service Areas

- Stewart B. McKinney
    - At Falkner Island, 1/3 of the island was lost as s result of the storm. This area is home to roseate terns and common terns (The National Fish and Wildlife Foundation 2012).
- The following State Parks experienced overwashing of dunes and significant erosion and/or the movement of existing habitat and creation of new habitat from Hurricane Sandy (The National Fish and Wildlife Foundation 2012; USACE 2013).
    - Harkness Memorial State Park (including William A Niering Natural Area Preserve), Waterford, CT
    - Silver Sands State Park, Milford, CT
    - Pattagansett Marsh Preserve, East Lyme, CT
    - Rocky Neck State Park, East Lyme, CT
    - Hatchetts Point Natural Area, Old Lyme, CT
    - Mumford, Cove and Bluff Point State Park, Groton, CT
    - Hammonasset Beach State Park, Madison, CT
    - Sherwood Island State Beach, Westport, CT
    - Misquamicut Beach, Westerly, RI

Critical/Significant Habitat

- Beaches above that experienced erosion above would have an impact on the species that nest on beaches, including piping plover, least terns, and rosette terns

- Coastal flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013).

Quality

- According to The National Fish and Wildlife Foundation (2012):
  - Ledyard, CT – a backup generator for the Town's treatment plant failed causing officials to pump approximately 60,000 gallons of raw sewage into Set Williams Brook.
  - Branford, East Lyme, Fairfield, Greenwich, New Hartford, and New Haven, CT – Similar problems and releases were reported.
  - Bridgeport, CT – 15 to 20 million gallons of partially treated sewage was discharged into Long Island Sound when the city's two treatment plants were inundated tidal surges.

III. Future Without Action Conditions - Connecticut

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- Given the limited distribution and position of beach and dune habitat along Connecticut's coastal fringe, they are highly susceptible to impacts from sea level rise and storm events. With projected future climatic conditions further loss of this habitat and conversion of supportive dunes to beaches is predicted from ongoing erosion and transport of sediment along the coast. Horseshoe crabs, piping plovers, other migratory shorebirds, terns and other important beach and dunes species will be impacted with the loss of this critical habitat (Adaptation Subcommittee 2010).

- Certain low-lying coastal areas are expected to be permanently inundated and have dramatically accelerate erosion, in particular important barrier beaches such as Bluff Point and Long Beach (Union of Concerned Scientists 2007). However, it is expected that the beaches at Woodmont and Gulf Beaches in Milford, Sea Bluff and Prospect Beaches in West Haven, Sherwood Island State Beach in Westport, and Southport Beach in Fairfield, which were all originally constructed as shore protection/beach fill projects by the USACE, would continue to receive sand from the local sponsor to meet their design criteria. Other State and/or Town beaches in Connecticut may also be expected to maintain their beaches, especially those beaches that are used recreationally. However, continued sea level rise may make this difficult to maintain in the future.

Coastal Wetlands

- Tidal marshes are particularly vulnerable to the higher rise of sea level rise and storm events. The normal process of accretion, the built-up of live and decaying plants and sediments, will not keep pace (Adaptation Subcommittee 2010). As salt marshes become submerged, they migrate inland. Existing development along the coast has decreased the amount of open space adjacent to the salt marshes, limiting their ability to migrate landward. The problem will be exacerbated in locations where bulkheads, causeways and other man-made structures interfere with the migration. Also, if the rate of sea level rise increased dramatically, then the salt marshes may not be able to match the change in vertical elevation. An increase in the rate of sea level rise will result in significant losses of coastal salt marsh habitat.

- Freshwater tidal marshes further upstream on major rivers like the Connecticut River will be lost or converted. This loss will be the result of an increase in salinity as the estuaries move upstream, the lack of suitable adjoining acres to accommodate upland migration, and the alteration in the amplitude and timing of the annual sparing freshets and lower summer flows. The biodiversity with the State of Connecticut and the reduction in the extent and complexity of these highly productive interfaces between land and water will have an impact on the ecological functions of storm buffering, flood storage, fish nurseries, and water filtering (Adaptation Subcommittee 2010).

- In marsh areas where accretion rates cannot keep up with sea-level rise, marsh will eventually revert to unvegetated flats and eventually open water. In some cases where tidal range increased with increased rates of sea-level rise, there may be an overall increase in the acreage of tidal flats. In low energy shores with sediment supplies, where sediments accumulate in shallow waters, flats may become vegetated as low marsh encroaches towards the water, which will increase low marsh at the expense of tidal flats. If sediment inputs are not sufficient, tidal flats will convert to subtidal habitats, which may or may not be vegetated depending on substrate composition and water transparency (US Climate Change Science Program 2009).

- The loss of wetlands would cause wetland dependent species of fish and birds to have reduced population sizes. The National Marine Fisheries Service estimates that approximately 1/3 of commercial fish and shellfish collected in New England are directly dependent on estuaries and salt marshes (Stedman and Hanson 1997).

Submerged Aquatic Vegetation

- Increased water depth and sedimentation from erosion as a result of sea level rise may result in a reduction in light penetration necessary for the growth of SAV.

- Landward edges of SAV beds may migrate inland depending on shore slope and substrate suitability. SAV growth is significantly better in areas where erosion provides sandy substrate, rather than fine-grained or fine organic matter substrates (CCSP 2009).

- Increased storm activity from climate change could negatively impact SAV by increasing erosion resulting in sediment resuspension that can block available sunlight

Oyster Reefs

- Connecticut has a thriving commercial oyster fishery supported by the State. Climate change could affect the shellfish industry in Connecticut by exacerbating exposure to pathogens from increased turbidity runoff and partially treated or untreated sewage overflows from storm events. Also, temperature changes could include changes in predator populations and natural food assemblages which could influence shellfish quality and survival (Adaptation Subcommittee 2010).

Rock Reefs/Rocky Shores

- The functions of a rock reef may not vary much with sea level rise. However, rocky shorelines, especially intertidal and shallow water rocky habitat could become inundated and no longer be available as intertidal habitat. Rocky shores would be expected to be resilient against erosion as sea level rises.

Shallow Bay Habitat/Bay Islands

- Shallow waters in the harbors and Long Island Sound may be expected to increase as the sea rises along with shoreline erosion and the drowning of coastal wetlands and shorelines. Offshore islands would be expected to experience some of flooding of their low lying areas from sea level rise or near or could lead to the complete inundation of some small islands.

Terrestrial Upland

- Increasing sea levels are projected to increase the frequency and severity of damaging storm surges and coastal flooding. This could increase what is now considered a once-in-a-century coastal flood in New London and Groton on the Thames River, to a more a more frequent occurrence as much as once every 17 years (Union of Concerned Scientists 2007).

- Sixty percent of the Connecticut landscape is covered by forests. Forests provide wildlife habitat, protect watersheds and conserve soil among other benefits. The character of the State’s forests has the potential to change dramatically from climate change. For example, Connecticut’s maple/beech/birth forests are projected to disappear by the end of the century or be confined to the northern portion of the State. As certain forest types decline, so will the population of wildlife dependent on them (Union of Concerned Scientists 2007).

Floodplains/Riparian

- Floodplains will likely become increasingly vulnerable to flooding without human intervention. In tidal areas, the tidal inundation characteristics of the floodplain may change with the range of tide and associated tidal currents increasing with sea level rise. With this inundation, floodplains will be vulnerable to increased coastal erosion from waves, river and tidal currents, storm-induced flooding, and tidal flooding. Upland floodplain boundaries will be vulnerable to horizontal movement.

Coastal Protected Areas

- Long Island Sound is part of the National Estuary Program. Changes to fisheries and inundation of beaches, intertidal flats and coastal wetlands will have a profound effect on the amount and type of species observed in Long Island Sound. This is already being seen and will continue into the coming years.

Critical/Significant Habitats

Waterbird Islands

- Several waterbird islands will suffer from the effects of increased erosion and inundation of nesting areas and available habitat for forage species. . Some of the most important waterbird colony islands in Connecticut that are vulnerable to storm damage are Charles Island, Cockenoe Island, Duck Island, Great Captains Island, Ram Island and Tuxis Island. Charles Island for example, has been hit hard by recent storms and as a result, the wading bird colony has declined significantly due to habitat changes (Attachment A).

Essential Fish Habitat (EFH)

- The Long Island Sound finfish community has shifted from one in which cold-adapted species dominate in spring and warm-adapted species dominate in fall, to one in which warm-adapted species are increasingly abundant in both seasons (spring and fall) (Howell and Auster 2012). Cold water species include windowpane, winter flounder, little skate, silver hake and red hake. Warm water species include scup, bluefish, butterfish, American shad, summer flounder, blueback herring and Atlantic menhaden. Temperature shifts can also affect spawning success.

- Increased intensity of precipitation can create concerns from sewage overflows and hazardous waste leaks. Global warming will increase pressures on the historically important Atlantic cod. It is expected that waters south of Cape Cod would be unsuitable for cod by late this century (NECIA 2007)

Atlantic Flyway

- The Connecticut River and Tidal Wetlands complex, the Fishers Island Sound complex, the Lower Thames River complex, the Greater Hammonassset complex, New Haven Harbor, Lower Housatonic River and Great Meadows, and the Norwalk Islands are all part of the Connecticut Waterfowl Focus Area (www.acjv.org). Long Island Sound provides sheltered open water that is important for wintering sea ducks and bay ducks such as scoters and scaup as well as fringing salt marshes and mudflats important for dabbling ducks such as mallards (www.acjv.org/wip/acjv_wip_northeast.pdf).

- Coastal marshes provide valuable wintering habitat since most inland wetlands freeze during the winter. Mudflats are used by migrating shorebirds. A combination of sea level rise and marsh subsidence could put some of the most important coastal marshes at risk of being lost. There could be a loss or reduction in intertidal habitat.

T&E Species/Species of Concern

Fish

- An increase water temperatures resulting from low flows and higher ambient air temperatures would affect growth of cold-water and anadromous fish, their habitat, and migrations. Observations indicate that the timing of the migration of anadromous fish species, such as Atlantic salmon and alewives, has advanced in the last few decades and they are migrating earlier in the season (NECIA 2007).

Marine Turtles

- Sea turtles occur rarely or occasionally in Connecticut waters. The major impact of global climate change on local sea turtles is that sea level rise will affect nesting areas and feeding grounds on low-lying sand beaches that they typically use in areas south of Connecticut.

Marine mammals

- The common large whales of New England (Humpback, Finback, North Atlantic Right, and Minke) are rarely or only occasionally seen in Connecticut waters. .

Birds (Nesting)

- Nesting habitat for piping plover, Least tern, rosette tern, and red knot is likely to diminish with the reduction in available coastal beaches, increased storm activity, and reduction in nesting islands.

Shellfish/Shellfish beds

- The Long Island Sound lobster population has declined nearly 70 percent in recent years, due largely to warmer waters. It is expected to collapse entirely by mid-century as the maximum heat-stress threshold for lobster is consistently exceeded (Union of Concerned Scientists 2007). The Eastern oyster and hard-shelled clam are major species commercially grown in Connecticut that are also found in southern waters. These species should be able to adapt to predicted increases in water temperature; and may in fact actually lead to faster growth. However, diseases prevalence could increase and shellfish larvae and juveniles could be impacted by ocean acidification (Adaptation Subcommittee 2010).

Miscellaneous

- Hypoxia occurs when the dissolved oxygen in the water is reduced to a level that is injurious to coastal and marine organisms. The metabolic rates of aquatic organisms and their need for more dissolved oxygen increases with warmer water. In addition, to increasing oxygen consumption by organisms, higher water temperatures decrease the solubility of oxygen in water. Higher runoff during wet years can lead to stronger density stratification in the western part of Long Island Sound. The long-term trend of increasing precipitation and river runoff will likely enhance stratification and lead to more severe hypoxia (URI 2012).

- More winter rain is expected to drive more high-flow and flooding events during the winter, earlier peak flows in the spring, and extended low-flow periods in the summer months. These changes in hydrologic cycles could have profound impacts on water resources, including increased flooding and polluted overflows from storm water and wastewater systems during high periods of flow, and increased stress on surface and ground drinking waters (EOEEA 2011).

Cultural Resources

- Sea level rise impacts to cultural resources range from increased tidal and wave erosion to inundation. Cultural resources within coastal zones will be subjected to gradual sea level rise impacts exacerbated by event-specific impacts such as high tide events and storms. The frequency and intensity of damage from event-specific impacts is expected to increase as sea level rises (Karl et al. 2009). In addition, high regional subsistence rates are expected to increase rates of sea level rise and associated impacts (Johnson 2000).

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5. New York: Environmental Existing and Future Conditions

I. Coastal Characterization - New York

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Beaches/Pebble Shoreline/Beaches

Atlantic Coast of New York

- The 120-mile coast stretching between Coney Island and Montauk is remarkably diverse in its physical characteristics, use, and development-ranging from heavily developed urbanized barrier islands and recreational beaches to New York State's only federally-designated wilderness area. Long Island's coast contains a variety of shore types (barrier islands and spits, mainland beaches and glacial bluffs) with over 130 miles of sandy beaches and shoreline along the South Shore (Tanski 2007).

- The South Shore can be divided into two distinct physical regions. Stretching almost 100 miles from Coney Island in New York City to Southampton in the east, the shore is composed of narrow, sandy islands and peninsulas separated from the mainland by shallow bays. East of Southampton the headland region directly abuts the ocean all the way to Montauk Point. In the western portion of this 30-mile stretch of coast, sandy beaches separate the ocean from a low-lying plain. To the east, the flat plains are replaced by 40- to 60-foot high bluffs (Tanski 2007).

- Dunes are a common coastal landform along the south shore. In general, the size of the dunes increases from west to east on Long Island. In the urban areas to the west, most of the natural dunes have been heavily impacted by human activities. In some areas, they have been entirely removed or replaced by development along the shoreline (Coney Island, Rockaway, and Jones Island). Most of the dunes found along these heavily used areas have been artificially created or maintained, such as the dune fields on Long Beach in the Town of Hempstead. Further to the east, human manipulation of the dune is still common but there are also places, such as the Wilderness Area on Fire Island, where development is less dense and natural dunes can still be found (Tanski 2007).

- On the Atlantic Ocean side of Montauk Peninsula, the shoreline is dominated in stretches by steep bluffs or large dunes and broad expanses of sparsely vegetated or unvegetated sandy to cobbly beach. Along the stretch of Long Island between Amagansett and Montauk, Nepeague State Park and Hither Hills State Park contain maritime interdunal swales of regional significance (Tanski 2007).

Long Island's South Shore Barrier Island/Back Bay System

- The majority of the back bay beaches are located along the bay side of the barrier islands (approximately 100 miles). The majority of the mainland backbay beaches are bulkheaded with sporadic community beaches.

- The back bay beaches of the south shore provide nesting sites for the northern diamondback terrapin, the endangered roseate tern, and horseshoe crabs.

- Eggs of species that nest on estuarine beaches, such as horseshoe crabs, and abundant invertebrate fauna provide forage for numerous bird species, including migratory shorebirds and species that nest on nearby barrier islands, such as the federally threatened piping plover. Shorebirds feed on all trophic levels of beach invertebrate communities, including herbivorous insects, amphipods, isopods, crabs, and bivalves. Local biologists believe that the large numbers of shorebirds west of Shinnecock Inlet may be due in part to horseshoe crab spawning in the area (Titus and Strange 2008).

North Shore of Long Island and Peconic Estuary

- Barrier beaches are less common in the Long Island Sound, however, some notable undeveloped barrier beaches along the north shore of Long Island include those fronting Hempstead Harbor, the beach-wetland system on Eatons Neck Point, the Port Jefferson Beaches near the Town of Brookhaven, the Nissequogue Inlet Beaches at the mouth of the Nissequogue River in the Town of Smithtown, and Cedar Point Peninsula in the Peconic Estuary (Titus and Strange 2008).

- Non-barrier north shore beaches are predominantly sandy to pebbly, with large (glacial remnant) boulders scattered throughout.

Barrier Islands/Inlets

Atlantic Coast of New York

- Starting from the east and heading west, the South Atlantic edge of Long Island has five barrier islandsConey, Long Beach, Jones, Fire and Westhampton) and two spits (Rockaway and Southampton). Tidal inlets which separate the barriers and connect the bays with the ocean include Rockaway, East Rockaway, Jones, Fire Island, Moriches, Shinnecock Inlets. All of the inlets are artificially stabilized with structures and are dredged to allow for navigation by commercial and recreational boats (Tanski 2007).

- From Rockaway to Long Beach the sandy shorelines are highly developed areas with several erosion control structures, few dunes and sparsely vegetated communities. The area is an important nesting ground for beach nesting shore birds.

- Fire Island to Southampton Islands protect the waters of back bay and the mainland of Long Island, New York. This stretch of barrier islands is rich in marine life, waterfowl, and other wildlife.

- South shore inlets are an especially significant component of the habitat; as a corridor for fish migrations, as a source for the exchange and circulation of bay waters, and as an area where feeding by many fish and wildlife species is concentrated (including adult striped bass and bluefish). Fire Island inlet is also the most important foraging area for roseate terns on western Long Island.

Rockaways

- Breezy Point (part of the Rockaway Barrier Island system) is an undeveloped segment of marine barrier beach habitat. Rare in New York State but diminished by recreational disturbance in a portion of the habitat (NYS DOS Assessment form Breezy Point).

Long Beach

- Long Beach Bay contains a large undisturbed coastal wetland and beach ecosystem, rare in New York State, and eelgrass beds of statewide significance. The Nassau Beach significant habitat consists of approximately 214 acres of maritime beach with scattered dunes through most of the site (NYS DOS Assessment Form Long Beach Bay).

Jones Beach

- Jones Beach East and west are undeveloped marine barrier beachs (rare in New York State, but affected by recreational use (NYS DOS Assessment Form Jones Beach East).

Fire Island

- Fire Island is approximately 32 miles long and averages less than 1 mile in width. The characterof Fire Island is typical of Atlantic barrier islands that grade from a primary dune along the ocean to salt marsh along the bay. The dominant vegetation includes pitch pine (Pinus rigida), beach grass (Ammophilia breviligulata), wax myrtle (Myrica cerifera), bayberry (M. pensylvanica), shadbush (Amelanchier canadensis), and common greenbrier (Smilax rotundifolia) (NPS website).

- The percentages of terrestrial habitats found at Fire Island National Seashore include: 10% forested and 40% wetlands, 25% open (beach, swale and fields), 25% developed either by the National Park Service or the 17 local communities on the island. Of the submerged portion, 80% is in the Great South Bay and 20% is the Atlantic Ocean. All existing habitats within the Seashore are listed as threatened (NPS website).The percentages of terrestrial habitats found at Fire Island National Seashore include: 10% forested and 40% wetlands, 25% open (beach, swale and fields), 25% developed either by the National Park Service or the 17 local communities on the island. Of the submerged portion, 80% is in the Great South Bay and 20%

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Westhampton

- Westhampton Beach and Dunes is approximately a 7.75 mile stretch of barrier beach, extending west to east from the Cupsogue County Park significant habitat border to south of the junction of Post Lane and Dune Road Marsh.

Southampton

- Southampton Beach is located south of Shinnecock Bay and east of Shinnecock Inlet and makes up approximately 285 acres of Southampton Island.

- The fish and wildlife habitat includes open beach and an extensive primary dune zone, including a large dredged material placement area, reaching elevations of 20 to 30 feet. The dredged material area exists within the first 2,500 feet of the land east of the inlet. Moderately heavy growths of beachgrass (*Ammophila breviligulata*) and seaside goldenrod (*Solidago sempervirens*) dominate much of this zone (NYS DOS Assessment Form Southampton Beach).

- Maritime beach and maritime dune communities are pervasive throughout the Southampton Beach landscape. Maritime beach is a sparsely vegetated community dominated by beach grass. Maritime beach occurs on unstable sand, gravel, or cobble ocean shores above mean high tide, where the shore is modified by storm waves and wind erosion (NYS DOS Assessment Form Southampton Beach).

- The community is an important nesting ground for beach nesting shorebirds. The maritime dune community is comprised of grasses and low shrubs in a mosaic of vegetated patches dominated by beach grass, and seaside goldenrod. High and low salt marsh communities exist along the fringes of the bay shoreline. Associations of these communities include smooth cordgrass (*Spartina alterniflora*), salt hay grass (*Spartina patens*), and glasswort species (*Salicornia* spp.) (NYS DOS Assessment Form Southampton Beach).

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries/Bays

Atlantic Coast of New York

- Maritime/Coastal Forest: There are at least 39.5 acres of Maritime/Coastal Forest within the Atlantic Shore of Long Island, including Fire Island. The following table provides a breakdown of the location and vegetation communities. (*Note that the William Floyd Estate and Point Woods, Montauk are not part of the Barrier Island system of Long Island, but contain valuable maritime forest habitat in NY. The William Floyd Estate is recognized as a South Shore Estuary Reserve Bayway*).

- In general, maritime forests play an important role in the barrier island ecosystem by:
    - Stabilizing soil on the barrier island which reduces erosion;
    - Providing hurricane protection;
    - Providing important habitats for wildlife;
    - Protecting and recharging freshwater for wildlife;
    - Conserving ground water by reducing evaporation;
    - Utilizing and recycling scarce nutrients in a relatively sterile environment; and
    - Serving a major part in the overall barrier island ecosystem (Currituck Cooperative Extension).

Maritime and Coastal Forest Communities along the Atlantic Shore of Long Island:

Vegetation Class/Community	Description	Dominant Species
Maritime Holly Forest/Sunken Forest	39.5 acres. Occurs just behind (landward of) the backdune. 200-300 year old forest. Located on Fire Island.	American holly (*Ilex opaca*), shadblow serviceberry (*Amelanchier canadensis*), sassafras, black gum (*Nyssa sylvatica*), black cherry, and pitch pine (*Pinus rigida*)
Old Field Red-Cedar Forest	Found on William Floyd Estate. Individual trees are smaller-crowned and scattered in with hardwoods	Red cedar (*Juniperus virginiana*), autumn olive (*Eleagnus umbellate*), and winged sumac (*Rhus copallina*)

Vegetation Class/Community	Description	Dominant Species
Maritime Post Oak Forest	Limited to the edge of waterways on the William Floyd Estate	Black oak (*Quercus velutina*), post oak (*Quercus stellata*), and northern bayberry (*Myrica pensylvanica*)
Coastal Oak-Heath Forest	Covers a large portion of the William Floyd Estate	Black oak (*Quercus* velutina), white oak (*Quercus alba*), mockernut hickory (*Carya tomentosa*), and lowbush blueberry (*Vaccinium pallidum*)
Acidic Red Maple Basin Swamp Forest	Found on both the William Floyd Estate and Fire Island	Black gum (*Nyssa sylvatica),* red maple (*Acer rubrum*), highbush blueberry, and swamp azalea
Japanese Black Pine Forest	Found in many isolated patches on Fire Island. It is often used to stabilize the fore dune – especially on the eastern end of the island and around human communities.	Japanese black pine (*Pinus thunbergii*), pitch pine (*Pinus rigida*), and switchgrass (*Panicum virgatum*)
Pitch Pine Woodland	Found throughout Fire Island behind the primary dune	Pitch pine (*Pinus rigida*), northern bayberry (*Myrica pensylvanica*), switchgrass (*Panicum virgatum*)
Maritime Deciduous Scrub Forest	Found on the bay side, often behind a large primary dune on wider parts of Fire Island	Mockernut hickory, black oak (Quercus velutina), sassafras (*Sassafras albidum),* northern bayberry (*Myrica pensylvanica*), Pennsylvania sedge (*Carex pennsylvanica*)
Oak, Beech, Mixed Dicot-Holly	Point Woods, Montauk	Northern Red Oak *(Quercus borealis), American Holly (Ilex opaca),* America Beech (*Fagus grandifolia)*
Oak-Holly-Mountain Laurel	Point Woods, Montauk	Northern Red Oak *(Quercus borealis), American Holly (Ilex opaca),* Mountain Laurel *(Kalmia latifolia)*

Sources: Bulletin of the Torrey Botanical Club (1977); Art (1976), USFWS (1997), and USACE (2007)

Long Island's South Shore Barrier Island/Back Bay System

Excerpts from Titus and Strange (2008):

- There are extensive salt marshes to the west of Great South Bay in southern Nassau County. These marshes are particularly notable because much of the historically large area of marsh on the mainland shoreline of southern Nassau County has been lost to development and shoreline armoring, including the mainland marshes of South Oyster Bay and the Hempstead Bay–South Oyster Bay habitat complex.

- To the east of Jones Inlet, there are extensive back-barrier and fringing salt marshes surrounding Great South Bay, Moriches Bay, Shinnecock Bay, and Southampton.

- The salt marshes behind the barrier beaches, especially the large area of marsh behind Hampton and Tiana beaches known as Dune Road Marsh, also support nesting by mallard, Canada Goose, clapper rail (*Rallus longirostris*), sharp-tailed sparrow (*Ammodramus caudacutus*), and seaside sparrow (*Ammodramus maritimus*). The marshes, flats, and shallows in this tidal wetland complex are used extensively for feeding by the birds nesting here, as well as those migrating through, particularly shorebirds. These marshes are also the only area in New York State where black rails are currently found on a regular basis and the only documented breeding location for sora rails on Long Island.

- The northern diamondback terrapin feeds and grows along marsh edges and the nearshore bays of the south shore. Sites on the south shore where terrapins reportedly are found include Captree State Park, east of the Robert Moses State Park on the Fire Island National Seashore, the marshes and ditches of Tobay Sanctuary near Guggenheim Park, and the western section of the Ocean Parkway.

- Of the extensive tidal flats along Long Island's southern shoreline, most are found west of Great South Bay and east of Fire Island Inlet al.ong the bay side of the barrier islands, in the Hempstead Bay–South Oyster Bay complex, and around the Moriches and Shinnecock inlets.

  - These flats are important foraging areas for birds and provide habitat for several edible shellfish species, including soft clam, northern quahog (*Mercenaria mercenaria*), bay scallop (*Argopecten irradians*), and blue mussel (*Mytilus edulis*).

  - Tidal flats and shallow water habitats are heavily used by shorebirds, raptors, and colonial waterbirds in spring and summer and by waterfowl during fall and winter.

  - The John F. Kennedy Bird Sanctuary is a particularly important feeding area for birds in South Oyster Bay. In summer, the state threatened least tern and a variety of herons and egrets forage here, along with the federally endangered roseate tern.

  - The sanctuary also provides overwintering habitat for abundant waterfowl, including American black duck, blue-winged, and greenwinged teal. Shinnecock Bay supports populations of wintering waterfowl of statewide significance.

  - The tidal flats around Moriches and Shinnecock inlets are particularly important foraging areas for migrating shorebirds.

Hempstead/South Oyster Bay

Excerpts from NYS DOS Assessment Forms Hempstead Harbor and South Oyster Bay:

- South Oyster Bay comprises one of the largest, undeveloped, coastal wetland ecosystems in New York.

- The fish and wildlife habitat is the entire bay, which includes extensive areas of undeveloped salt marsh, tidal flats, dredged material islands, and open water.

- It is an integral part of an interconnected marsh complex that also includes the three Hempstead bays. A healthy subsystem of sensitive estuarine intertidal areas exists in the bay. Characteristic communities of the estuarine intertidal subsystem include high and low salt marshes and salt pannes dominated by smooth cordgrass (*Spartina alterniflora*), common glasswort (*Salicornia europea*), salt hay grass (*Spartina patens*), spike grass (*Distichlis spicata*), and perennial salt marsh aster (*Aster tenuifolius*). Water depths in South Oyster Bay are generally less than 6 feet below mean low water, except in Zach's Bay and in portions of some dredged navigation channels.

- Most of South Oyster Bay is owned by the Towns of Hempstead and Oyster Bay, and is managed as a wetland conservation area.

Great South Bay

Excerpt from NYS DOS Assessment Form Great South Bay:

- Great South Bay is one of the largest protected, shallow, coastal bay areas in New York State. Many of the remaining wetland areas along the north shore of Great South Bay are owned by the NYSDEC to protect their natural values. Elsewhere, the bay is bordered by federally owned wetlands (Wertheim National Wildlife Refuge). Cordgrasses (*Spartina alterniflora* and *S. patens*) dominate the low and high salt marsh, respectively. The Great South Bay significant habitat includes (in the east) the wetlands along Fire Island National Seashore, including along Long Cove, Robinson Cove, Whalehouse Point, Molasses Point, and Goose Point.

Moriches Bay

Excerpt from NYS DOS Assessment Form Moriches Bay:

- The Moriches Bay habitat complex includes the entire 9,480-acre aquatic environment of Moriches Bay, Moneybogue Bay, and Quantuck Bay; this includes open water, salt marshes, dredged material islands, and intertidal flats. This habitat complex also includes the tidal creeks and marshes feeding into Moriches Bay from the Long Island mainland and the adjacent uplands of the William Floyd Estate. This boundary encloses regionally significant habitat for fish and shellfish, migrating and wintering waterfowl, colonial nesting waterbirds, beach-nesting birds, migratory shorebirds, raptors, and rare plants.

North Shore of Long Island and Peconic Estuary

Excerpts from Titus and Strange (2008):

- In Westchester County, in the western Long Island Sound, ecologically important tidal wetlands occur in the county owned Marshlands Conservancy property. Tidal wetlands are uncommon along the north shore of Long Island because of the steep uplands and sea cliffs created by the terminal moraine of glaciers, and therefore wetlands are largely confined to former drowned “kettle hole” embayments such as Mount Sinai. There are some notable areas of marsh in and around Stony Brook Harbor and West Meadow, bordering the Nissequogue River, and along the Peconic Estuary. Some marshes around the three large bays western Long Island Sound (Little Neck Bay, Manhasset Bay, and Hempstead Harbor) provide feeding and nesting areas for greenbacked heron, clapper rail, and American black duck, as well as feeding areas for wading birds.

- Shoals along the Long Island shoreline, particularly around Duck Point, Baiting Hollow, and the Port Jefferson area, provide forage for numerous bird species as well as habitat for shellfish. There is hard clam habitat around the northern bays. One of the largest areas of tidal mudflats on the north shore is near Conscience Bay, Little Bay, and Setauket Harbor west of Port Jefferson. Large beds of hard clams, soft clams, American oysters, and ribbed mussels are found in this area.

- Peconic River complex contains regionally rare wetland communities including the Peconic River, coastal plain ponds, and coastal plain Atlantic white cedar swamps, and globally rare upland communities including pitch pine-oak-heath woodland and the dwarf pine plains.

  - These communities support an unusual diversity of rare species with 147 species of special emphasis.The entire Long Island Pine Barrens is important as a complex of relatively undeveloped pine barren forest and wetlands containing regionally rare wetland and upland communities and supporting the highest diversity of rare species in New York State.

  - Focus areas of significance to fish and wildlife resources, unique plant communities, or regional biological diversity include: Peconic River and headwaters and associated coastal plain ponds including the Tarkill Ponds-Lake Panamoka complex; dwarf pine plains; Flanders Bay wetlands and coastal plain pond complex; and Cranberry Bog.

  - There are also three areas on Long Island outside of the core pine barrens area that contain sizable examples of a pitch pine-scrub oak barrens community: Edgewood Oak Brush Plains, Brentwood Oak Brush Plains, and Pinelawn Cemetery (USFWS 1997).

- The Flanders Bay Wetlands-Located along the south shore of Flanders Bay and Great Peconic Bay. The fish and wildlife habitat consists of approximately 820 acres of salt marsh, sand beach, tidal bays, creeks, mudflats and shoals. Flanders Bay Wetlands comprise one of the most undeveloped large coastal wetland ecosystems on Long Island, encompassing the rare sea level fen community and an excellent example of the salt shrub community (NYS DOS Assessment Form Flanders Bay).

Hudson Raritan Estuary

The following regions (Jamaica Bay, Lower Bay, Lower Raritan River, Arthur Kill/Kill van Kull, Hudson River Estuary, Harlem River/East River/Western Long Island Sound and Upper Bay) are delineated by major watersheds and/or major physical features, such as highways or waterways.

Jamaica Bay

- Jamaica Bay, a historically expansive wetlands complex, has been subject to extensive fill and loss of wetlands. About 4,000 acres of the historic wetland habitat remains, a reduction of almost 75%. The region contains Salt marsh, upland islands and sub tidal shallow habitat for a variety of fish and wildlife. Wetland complexes in Jamaica Bay consist of freshwater wetlands and tidal wetlands. Low marsh habitats are dominated by smooth cordgrass (*Spartina alterniflora*). Many high marsh areas and wetlands, which have salinity concentrations less than 18 parts per thousand (ppt) are dominated by common reed (*Phragmites communis*). High marsh is also characterized by herbaceous species such as saltmeadow cordgrass (*Spartina patens*) and shrubs species including beach plum (*Prunus maritima*) and groundsel tree (*Baccharis halimifolia*). Species often found along the upper edge of high marsh include seaside goldenrod (*Solidago sempervirens*) and marsh orach (*Atriplex patula*). In disturbed areas, species such as black cherry (*Prunus serotina*), marsh elder (*Iva frutescens*), and bayberry (*Myrica cerifera*) are often found growing together, among stands of common reed (USACE 2004, 2009).

Arthur Kill/Kill van Kull

- Wetland condition is generally degraded and dominated by monotypic stands of common reed. Natural wetland habitats that remain in the study area include tidal marshes, freshwater marshes and wooded swamps. Tidal and brackish wetlands are dominated by smooth cordgrass (*Spartina alterniflora*) and salt meadow cordgrass (*Spartina patens*), spike rush (*Distichlis spicata*), marsh elder (*Iva frutescens*), common reed, and cattail (*Typha latifolia*). Marshes with more freshwater inputs are characterized by species including pondweed (*Potamogeton* spp.), spatterdock (*Nuphar variegatum*), and pickerelweed (*Pontedaria cordata*). In some places, scrub-shrub wetlands exist adjacent to marshes. Species present in these habitats include dogwoods (*Cornus* spp.), mulberry (*Morus* spp.), alder (*Alnus* spp.), and buttonbush (*Cephalanthus occidentalis*). Tree species present in forested freshwater wetlands include red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), and swamp white oak (*Quercus bicolor*). Understory species present in the forested wetlands include spicebush (*Lindera benzoin*) and skunk cabbage (*Symplocarpus foetidus*). Although natural areas remain, they are highly fragmented due to the intense industrial, residential, and commercial development (USACE 2004, 2009).

- As a result of extensive development, a large portion of the natural shorelines have been hardened or filled by bulkheads or riprap.

Harlem River/East River/Western Long Island Sound

- Many tributaries of the East and Harlem Rivers have been channelized and re-directed through culverts. The upper East River still has bays and creek mouths but with sparse remnants of tidal wetland and upland habitats, however most of the shorelines have been bulkheaded and filled. Portions of the shorelines along Harlem River and East River have been "re-naturalized." In these re-naturalized areas, abandoned waterfront structures have subsided or deteriorated creating coves of littoral habitat (shallow waters and sloping shorelines) where bulkheads and piers once stood (USACE 2004, 2009).

- The Bronx River Watershed includes estuarine and palustrine wetlands. Estuarine wetlands are only located in the southern, Bronx County portion of the watershed. Limited to the tidal portion of the watershed, these wetlands are dominated with native salt grasses such as cord grass (*Spartina alterniflora*), salt meadow grass (*S. patens*), and spike grass (*Distichlis spicata*), as well as invasive common reed (*Phragmites* spp.). Soundview Park located at the delta of the Bronx River, is one of the few remaining estuarine, salt marsh wetlands. Palustrine wetlands are located throughout the Bronx River Watershed. The palustrine system encompasses the majority of vegetated freshwater wetlands, which are divided into three main types: emergent, scrub-shrub, and forested. Emergent wetlands are dominated by herbaceous plants like cattails (*Typha latifolia*) and sedges (*Carex* spp.) that "emerge" from the water and they are often called marshes or wet meadows. Shrub wetlands are dominated by low, woody plants like arrowwood (*Viburnum* spp.), sweet pepperbush (*Clethra alnifolia*) shrubs, and young trees (less than 6 m (20 feet) tall). Forested wetlands, sometimes referred to as swamps or bottomland forests, are dominated by large trees like red maple (*Acer rubrum*), willows (*Salix* spp.), and ashes (*Fraxinus* spp.) more than 20 feet tall (Cowardin et al. 1979, USACE 2010).

- The value of Western Long Island Sound from an ecosystem perspective is primarily as an aquatic habitat due to the highly urbanized nature of the uplands and shorelines. Western Long Island Sound contains second largest expanse of open water habitat in the Estuary. A large proportion of former wetland areas have been filled for urban or industrial land uses such as residential development and landfill (e.g., Pelham Bay Landfill). The wetland systems that remain are predominantly intertidal wetlands that exist along creeks, rivers, and in nearshore areas. Many of the remaining wetlands have been disturbed at some point in time, which has given invasive species, such as common reed the opportunity to become a dominant species. Areas that remain subject to adequate tidal flushing are dominated by smooth cordgrass (*Spartina alterniflora*) and salt meadow cordgrass (*Spartina patens*) remain (USACE 2004, 2009).

Lower Bay

- Lower Bay contains coastal and offshore environments, experiencing loss of dunes and benthic habitat. Lower New York Bay is deeper than neighboring waters and considered more of a marine habitat (USACE 2004, 2009).

- Several small tributaries originate in Staten Island, New York and flow into the Lower Bay. The Hudson, River is considered to have indirect flow in this study area (USACE 2004, 2009).

- A large proportion of wetland and upland areas in the study area have been developed. The remaining undeveloped land is characterized by tidal salt marshes, beaches, dunes, intertidal mudflats, shallow subtidal mudflats, upland forest, forested wetlands, and grass/scrub-shrub uplands. The National Wetlands Inventory mapped over 4,800 acres of intertidal and subtidal sand flats and mudflats off the shorelines of the bays and western Staten Island. In addition, salt marsh and dredge material islands also exist (USACE 2004, 2009).

- Salt marshes in the study area are dominated by cordgrass (*Spartina alterniflora*, *S. patens*), with black grass (*Juncus gerardii*), marsh elder (*Iva frutescens*), and groundsel bush present in the high-tide zone. Common reed (*Phragmites communis*) is an invasive plant found in many of the wetlands in the study area (USACE 2004, 2009).

- Dune habitat is limited in much of the Lower Bay area due to intense development along the shoreline (USACE 2004, 2009).

Hudson River Estuary

- The Hudson River Estuary region of this study (NACCS) from approximately the Upper New York Bay to the Tappan Zee Bridge, is characterized by extensive hardened shorelines and contaminated sediment. This region of the Hudson River is an estuarine environment with moderate to high salinity zones. Turbidity is high which limits phytoplankton production. As a result, the food web is detritus-based. Strong semi-diurnal tides make this portion of the Hudson River one of the few major tidal rivers of the North Atlantic coast (USFWS 1997, USACE 2004, 2009). North of the Tappan Zee Bridge, the Haverstraw Bay Significant Coastal Fish and Wildlife Habitat area extends approximately six miles on the Hudson River, from Stony Point to Croton Point, in the Towns of Stony Point, Haverstraw, and Clarkstown, in Rockland County, and the Town of Cortlandt, in Westchester County (approximately the northern limit of the NYD NACCS boundary). Habitat disturbances, such as dredging, shoreline filling and bulkheading, waste disposal, and pollution and urbanization all exist in the Haverstraw Bay; however, much undeveloped forestland and some natural shoreline habitat also remain.

- Wetlands types present include brackish marsh and intertidal mudflats that transition into shallow, subtidal aquatic beds. Dominant species in these wetland areas include common reed (*Phragmites communis*) and narrow-leaved cattail (*Typha latifolia*). Other species that are present, but not dominant, include smooth cordgrass (*Spartina alterniflora*), spike grass (*Distichlis spicata*), rose-mallow (*Hibiscus moscheutos*) and purple loosestrife (*Lythrum* *salicaria*). Common reed dominates many wetland areas. Other shallow-water habitat, like shoal and inter-pier areas, may be important foraging sites for young fish before they move into deeper Harbor waters (USACE 2004, 2009).

- Haverstraw Bay contains extensive shallow areas (less than 15 feet deep at mean low water) that deepen to a navigation channel (which is dredged to maintain a depth of about 35 feet) in the western half of the area. During much of the year, this area is the place where freshwater from the upper river mixes with salt water from the Atlantic Ocean to produce a predominantly brackish water habitat with salinities varying from 0-10 ppt. Iona Island is located in Bear Mountain State Park on the east side of Route 9W in the Town of Stony Point in Rockland County, six miles south of West Point. Iona Island is a bedrock island in the midst of the Hudson Highlands, bordered to the west and the southwest by Salisbury and Ring Meadows, two large tidal marshes, the mouth of Doodletown Bight, an expanse of shallows and mudflats. A separate Island, Round Island, was attached to the south end of Iona Island with fill in the early 20th century. The marshes and shallows occupy one mile between Iona Island and the west shore. The area of Iona Island is comprised of brackish intertidal mudflats, brackish tidal marsh, freshwater tidal marsh and deciduous forested uplands. Doodletown Brook is the principal tributary to the site, draining approximately 2.9 square miles.

Upper Bay

- Most of the wetlands and upland areas in the study area have been filled to accommodate commercial, residential, and industrial development. The entire New York shoreline of the Upper Bay has been hardened with bulkheads or riprap (USACE 2004, 2009).

- Sandy shallows within the Bay Ridge Flats that have been significantly reduced in size over time by dredging are located along the eastern edge of the Bay. These flats provide some habitat to many species of young fishes. Shallow sheltered areas and littoral habitats are almost non-existent, and heavy commercial boat traffic erodes unprotected shorelines (USACE 2004, 2009).

- The majority of remaining, undeveloped wetland habitats in the Upper Bay study area have been disturbed at one time or another. As a result invasive, non-native species have colonized these disturbed habitats. The few remaining salt marshes in the study area are dominated by cordgrass (*Spartina alterniflora, S. patens*), with black grass (*Juncus gerardii*), marsh elder (*Iva frutescens*), and groundsel bush (*Baccharis halimifolia*) present in the high-tide zone. Common reed (*Phragmites communis*) is invasive along many of the wetlands in the study area (USACE 2004, 2009).

Submerged Aquatic Vegetation

Long Island's South Shore Barrier Island/Back Bay System

- Seagrass beds occur along much of the southern shoreline of Long Island.

South Oyster Bay

- South Oyster Bay consists of over 2,544 acres of submerged rooted aquatic vegetation beds, accounting for approximately 33% of the entire habitat area. These beds consist of rooted plants, primarily by eelgrass (*Zostera marina*) with some widgeon grass (*Ruppia maritima*), as well as unattached macrophytes, growing in shallow, quiet waters below the spring low tide level (NYS DOS Assessment Form South Oyster Bay).

Great South Bay

- Great South Bay encompasses 3,713 acres of submerged rooted aquatic vegetation beds. These beds are dominated primarily by eelgrass (*Zostera marina*) with some widgeon grass (*Ruppia maritima*). The western portion of Great South Bay has over 10,818 acres of submerged rooted aquatic vegetation beds. These beds are dominated primarily by eelgrass with some widgeon grass (*Ruppia maritima*). Submerged aquatic vegetation beds are most prevalent along the south shore of the bay along Fire Island and along the north shore in Bellport Bay (NYS DOS Assessment Form Great South Bay).

Moriches Bay

- Moriches Bay encompasses 1,903 acres of submerged rooted aquatic vegetation beds, accounting for approximately 21% of the entire habitat area. These beds are dominated primarily by eelgrass (*Zostera marina*) with some widgeon grass (*Ruppia maritima*) (NYS DOS Assessment Form Moriches Bay).

Shinnecock Bay

- Shinnecock Bay encompasses 969 acres of submerged rooted aquatic vegetation beds, accounting for approximately 11% of the entire habitat area. These beds are dominated primarily by eelgrass (*Zostera marina*) with some widgeon grass (*Ruppia maritima*) (NYS DOS Assessment Form Shinnecock Bay).

North Shore of Long Island and Peconic Estuary

- Eelgrass distribution in the New York Portion of the Long Island Sound is limited to the eastern most regions, primarily around Fishers Island with some smaller meadows long the north shore of Long Island just west of Orient Point (USFWS 2003).
- -The U.S. Fish and Wildlife Service reports that eelgrass beds of statewide significance in the Peconic Estuary are in Orient Bay and Cedar Point/Hedges Bank Shallows.
- Once abundant throughout the Peconic estuary, eelgrass beds are now limited to waters near Shelter Island and other eastern most waters. 2005 data estimated 1,550 acres of eelgrass beds; this number is not expanding (USEPA 2007a).

- Eelgrass meadows heavily influenced by anthropogenic impacts and have been declining over the last three decades. A combination of stressors, including increased porewater sulfide concentrations, eutrophic shading, increased temperature, and habitat modification have been implicated as causes for extensive seagrass loss here as well as world-wide (http://www.dec.ny.gov/docs/fish_marine_pdf/finalseagrassreport.pdf)

Hudson Raritan Estuary

- Haverstraw Bay contains extensive shallow areas and several submerged aquatic vegetation beds, dominated by water celery (*Vallisneria americana*).

Oyster Reefs

Long Island's South Shore Barrier Island/Back Bay System

- The entire Great South Bay area is inhabited by concentrations of hard clams along with local concentrations of American oyster. Today, most of the bay waters are certified for shellfishing, with approximately 2,130 acres of permanently closed and 2,300 acres of seasonally closed waters, resulting in a commercial and recreational harvest of statewide significance (NYS DOS Assessment Form Great South Bay).

North Shore of Long Island and Peconic Estuary

- Oyster Bay, NY – is a highly productive area for marine finfish and shellfish. Includes New York's only remaining commercial oyster farm, which produces up to 90% of New York's oyster harvest (USFWS 1997).

Rocky Shorelines

North Shore of Long Island and Peconic Estuary

- Sandy to pebbly beaches and spits occur along the north shore of Long Island to Montauk Point, the Block Island Sound side of the peninsula and in the vicinity of Napeague Harbor USFWS 1997).

- Several offshore islands in western Long Island Sound are significant for their colonial wading bird rookeries (Huckleberry Island, Great Captain Island, North Brother Island, South Brother Island, and Pelican Island). The rocky shorelines of these islands provide habitat for species such as shellfish, sea stars, and barnacles (USFWS 1997).

- Rocky reefs are sporadic along the north shore of Long Island. Fishers Island Coastline in Southold, NY contains significant rocky reef habitat (USFWS 1997).

Hudson Raritan Estuary

- Pelham Bay is regionally distinct, pairing rocky outcroppings of the New England rocky coast with intertidal mudflats that are exposed during low tide (USACE 2004, 2009).

Shallow Bay Habitat/ Bay Islands

Long Island's South Shore Barrier Island/Back Bay System

- The large back-barrier bays of the south shore contain 173 square miles of shallow bays behind them. They include, from west to east, Hempstead Bay, South Oyster Bay, Great South Bay, Moriches Bay, and Shinnecock Bay. These bays contain regionally significant habitats for fish, shellfish, and birds. A great deal is known about their ecology and habitat needs.

- South shore Estuaries (Hempstead Bay, South Oyster Bay, Great South Bay, Moriches Bay and Shinnecock Bay) contains 173 square miles of shallow bays behind them.

- The salt marsh and dredged material islands in the south shore estuaries support significant nesting colonies of terns, gulls, and wading birds. Great South Bay includes Lanes Island and the Warner Islands support large colonies of common terns (*Sterna hirundo*), and two of only a limited number of roseate tern colonies on the East Coast. Black skimmer (*Rynchops niger*), herring gull (*Larus argentatus*), and great black-backed gull (*Larus marinus*) also occur on these islands. Common tern also occur, or have recently occurred, at several other islands in the bay including Shinnecock Bay Islands – Sedge Island, Greater Greenbacks Island, and Lesser Greenbacks Island. Ponquogue Spoil Island, a dredged material island near the Ponquogue Bridge in Shinnecock and East and West Inlet Islands, Carters Island, and New Made Island in Moriches Bay are important to a variety of waders, including black-crowned night-heron (*Nycticorax nycticorax*), great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), glossy ibis (*Plegadis falcinellus*), and little blue heron (*Egretta caerulea*), as well as to great black-backed and herring gulls. American oystercatcher (*Haematopus palliatus*) nest in small numbers at several islands in the bay (USFWS 1997).

  From NYS DOS Assessment Forms:

  - South Oyster Bay - One of the largest, undeveloped, coastal wetlands ecosystems in New York State.
    - Common tern nesting.
    - One of the most important waterfowl hunting areas on Long Island.
    - Wintering brant concentrations of statewide significance. One of three locations with nesting Forster's tern on Long Island.
  - Great South Bay (east and west)

- *East* - The largest protected, shallow, coastal bay in New York State Piping plover least tern, and common tern nesting and feeding areas.
  - Commercial hard clam industry of statewide significance; sportfishing of statewide significance; waterfowl hunting of county-wide significance.
  - This area supports one of the largest concentrations of wintering waterfowl in New York State, and population levels of diving ducks are unusual in the northeastern U.S.
- West - One of the largest shallow coastal wetland ecosystems in New York State.
  - Roseate tern, common tern, northern harrier, osprey, and black skimmer. Black rail nest in area, but not well documented.
  - Sportfishing of statewide significance, waterfowl hunting of regional significance and shellfish hatcheries of local significance.
  - This area supports some of the largest concentrations of wintering waterfowl, nesting northern harriers, estuarine fish, and the only population of black rails in New York State.

- Moriches Bay - One of the largest, protected, shallow, coastal bays in New York State.
  - Roseate tern, least tern, common tern, osprey, and black skimmer (SC) nesting and feeding areas. Recreational fishing, shellfishing, and waterfowl hunting in the area are significant to residents from throughout Long Island.
  - Concentrations of wintering waterfowl are of statewide significance.
- Shinnecock Bay - Large, protected, shallow, coastal bay; rare in New York State.
  - Osprey (SC) nesting grounds.
  - Recreational fishing and shellfishing in the area are significant to residents from throughout Long Island.
  - Commercial fishing in the area of regional significance.
  - Concentrations of wintering waterfowl and harbor seals are of statewide significance.

North Shore of Long Island and Peconic Estuary

- The Peconic Bay Estuary system is located in the eastern end of Long Island, between the North and South Forks made up of a series of shallow, interconnected bays fed by groundwater, creeks and rivers. The estuary contains 340 miles of shoreline and contains more than 100 distinct harbors, embayments and tributaries (EPA 2007).

- The Peconic estuary includes several smaller bays such as Flanders Bay, Great Peconic Bay, Little Peconic Bay, Shelter Island Sound, and Gardiners Bay; islands include Peconic Bay includes: Shelter, Gardiners, Robbins Islands.

- Fishers Island is located at the eastern end of the Long Island Sound.

East Hampton

- Napeague. Large, undeveloped, coastal bay and wetlands ecosystem; rare on Long Island outside of the major bays on the south shore.

- Napeague Harbor is a large undeveloped coastal bay and wetland ecosystem located on the north shore of the south fork of Long Island. The fish and wildlife habitat includes the entire harbor, Napeague Meadows, and Hicks Island, most of which are within the undeveloped Napeague State Park. This ~ 1,300 acre area contains relatively shallow open water (less than 10 feet deep at mean low water), eelgrass beds, a large expanse of salt marsh, upland meadows, and sparsely vegetated sand and pebble peninsulas. The rare sea level fen plant community is found at this site. Locally significant concentrations of wintering waterfowl occur in open water portions of the harbor (NYS DOS Assessment Form Napeague Harbor).

- Napeague Harbor is a highly productive area for marine finfish, shellfish, and other wildlife. Sandy upland areas around Napeague Harbor provide suitable habitat for eastern hognose snake. The wetlands around the Harbor support a large spotted turtle population, and eastern spadefoot toad breed in the area. This area may provide important breeding habitat for horseshoe crab, but additional documentation is required. The harbor serves as a nursery and feeding area for winter flounder, summer flounder, bluefish, striped bass, and scup, providing an excellent sport fishery for local residents. Healthy eelgrass beds are present along the eastern shore of Napeague Harbor, and south and southeast of Goff Point and Hick’s Island, respectively. The hard clam population in Napeague Harbor is the largest in East Hampton Town. Soft clams are also abundant in the harbor, and both species are important in Suffolk County for recreational and commercial shellfishing. The once-abundant bay scallop population has undergone substantial decline (NYS DOS Assessment Form Napeague Harbor).

Montauk Point

- The nearshore open waters surrounding Montauk Point provide regionally significant and critical wintering waterfowl habitat and concentration areas and contain extensive beds of blue mussel (*Mytilis edulis*) and kelp (*Laminaria agardhii*). Found here in significant numbers, particularly in winter, are several species of special emphasis in the region, such as common loon (*Gavia immer*), common eider (*Somateria mollissima*), white-winged scoter (*Melanitta fusca*), surf scoter (*Melanitta perspicillata*), black scoter (*Melanitta nigra*), bufflehead (*Bucephala albeola*), common goldeneye (*Bucephala clangula*), great cormorant (*Phalacrocorax carbo*) and red-breasted merganser (*Mergus serrator*). Also occurring here regularly during the winter are harlequin duck (*Histrionicus*) and king eider (*Somateria spectabilis*) (USFWS undated).

Shelter Island Sound:

- Mashomack Preserve is located between the north and south forks of Long Island in the Town of Shelter Island, Suffolk County. The habitat includes eelgrass beds, coastal marshes, freshwater wetlands, ponds, beaches, dunes, bluffs, and a large relatively undisturbed forest, including excellent examples of coastal oak-beech, coastal oak-hickory, and maritime post oak communities. The extensive tidal, freshwater, and brackish wetlands, as well as the high quality upland habitats, support many species of wildlife. The shallows to the east of Mashomack support important eelgrass beds (NYS DOS Assessment Form Mashomack Preserve).

- The Shelter Island Eastern Shallows are located off the eastern shore of Shelter Island. The habitat consists of marine shallows and submerged aquatic vegetation (SAV) on muddy and gravelly sand substrates approximately within the twelve foot bathymetric contour. The Shelter Island Eastern Shallows habitat is one of only a few remaining eelgrass meadows in the State of New York. Providing provide critical habitat for a variety of aquatic species, including the important bay scallop (NYS DOS Assessment Form Shelter Island Eastern Shallows).

Gardiners Bay

- Gardiners Island is situated in Gardiners Bay between the north and south forks of Long Island. The approximate 3,300 acre island is located in the Town of East Hampton, Suffolk County. Gardiners Island is a large, nearly undeveloped, marine island with tidal and freshwater wetlands, beaches, dunes, bluffs, woodlands, pine barrens, brushland, and meadows. Cartwright Island and Cartwright Shoals at the southern end of Gardiners Island are included in this habitat. The eelgrass beds fringing the shores of Gardiners Island on the eastern and southeastern sides are included in this habitat. Gardiners Island is an extremely rare ecosystem because of its nearly pristine condition. The diversity of the habitats present makes Gardiners Island especially valuable as a coastal wildlife refuge (NYS DOS Assessment Form Gardiners Bay).

- The eelgrass meadows fringing the island contribute to the nearshore habitat value of the island for juvenile fish and shellfish species (NYS DOS Assessment Form Gardiners Bay).

Terrestrial Upland

North Shore of Long Island and Peconic Estuary

- The entire Long Island Pine Barrens is important as a complex of relatively undeveloped pine barrens forest and wetlands containing regionally rare wetland and upland communities and supporting the highest diversity of rare species in New York State (USFWS 1997).

- The Peconic River complex contains globally rare upland communities including pitch pine-oak-heath woodland and the dwarf pine plains. There are also three areas on Long Island outside of the core pine barrens area that contain sizable examples of a pitch pine-scrub oak barrens community: Edgewood Oak Brush Plains, Brentwood Oak Brush Plains, and Pinelawn Cemetery One of the largest undeveloped tracts of coastal uplands, dominated by deciduous forest, on Long Island (NYS DOS Assessment Form Hither Hills Uplands).

- Mashomack Preserve is a rare and outstanding example of undeveloped marine coastal ecosystems in New York. Large tracts of undisturbed habitat such as the Mashomack Preserve are essential for the survival of many species of wildlife. The large forested area (predominantly oak, hickory, and beech), approximately 1,200 acres, is significant for its size alone. Such areas of mature deciduous forest are rare on Long Island (NYS DOS Assessment Form Mashomack Preserve).

Hudson Raritan Estuary

Lower Bay

- Upland forests in the study area are comprised of species such as black cherry (*Prunus serotina*), oaks (*Quercus* spp.), hickory (*Carya* sp.), and tree-of-heaven (*Ailanthus altisima*). The understory of these forests usually includes the following species: mountain laurel (*Kalmia latifolia*), and arrowwood (*Viburnum* spp.). Forested wetlands are dominated by sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*). Many of the forested habitats in the region have been fragmented by human development (USACE 2004, 2009).

Hudson River Estuary

- Disturbed habitats exist in the Haverstraw Bay; however, much undeveloped forestland and some natural shoreline habitat also remain.

- North of the George Washington Bridge is the Palisades, which reaches over 800 feet above the river at its highest point (Beczak 2003, USACE 2004, 2009).

- Iona Island is located in Bear Mountain State Park, contains deciduous forested uplands.

Upper Bay

- Most of the upland areas in the study area have been filled to accommodate commercial, residential, and industrial development and have been disturbed at one time or another. As a result invasive, non-native species have colonized these disturbed habitats (USACE 2004, 2009).

- Remaining upland habitat consists of old field and scrub-shrub/woodland habitats. Frequently, disturbed old-field habitats are dominated by common mugwort (*Artemisa vulgaris*). In other places, old-field habitats are characterized by mixed forbs and grasses such as goldenrod (*Solidago* spp,), aster (*Aster* spp.), and switch grass (*Panicum virgatum*). Scrub-shrub/woodland habitats are characterized by species such as black cherry (*Prunus serotina*), bayberry (*Myrica cerifera*), sumac (*Rhus* spp.), black locust (*Robinia pseudoacacia*), tree-of-heaven (*Ailanthus altissima*), and common mugwort. Many of these upland communities exist on former wetlands that were filled with material that is contaminated. Other upland communities have grown on abandoned or vacant properties that are former developed sites (USACE 2004, 2009).

Floodplains/Riparian

Hudson Raritan Estuary

Harlem River/East River/Western Long Island Sound

- In many areas along the Bronx River where natural shoreline remains, native vegetation has been replaced by invasive species such as common reed (*Phragmites communis*) and purple loosestrife (*Lythrum salicaria*) (USACE 2004, 2009).

Hudson River Estuary

- Disturbed habitats exist in the Haverstraw Bay; however, much undeveloped forestland and some natural shoreline habitat also remain.

Coastal Protected Areas

Marine Sanctuaries/Coastal Reserves

North Shore of Long Island and Peconic Estuary

- Oyster Bay National Wildlife Refuge – The Oyster Bay NWR on the north shore of Long Island consists of high quality marine habitats that support a variety of aquatic-dependent wildlife. The Oyster Bay NWR is managed primarily for use by migratory waterfowl and other waterbirds (www.fws.gov/northeast/oysterbay).

- Target Rock National Wildlife Refuge – The Target Rock National Wildlife Refuge is located on the north shore of Long Island, 25 miles east of New York City. This 80-acre refuge is composed of mature oak-hickory forest, a half-mile rocky beach, a brackish pond, and several vernal ponds. The refuge is managed to provide habitat for migratory songbirds, shorebirds, waterfowl and other wildlife (www.fws.gov/refuge/target_rock).

National Estuary Program

- New Jersey Harbor & Estuary
    - The NY-NJ Harbor Estuary is an estuary of national significance (1988) and home to incredible natural diversity. This estuary is also one of the most vibrant and populated metropolitan areas in the country and the world, presenting unique opportunities and challenges.
- Long Island Sound
    - Long Island Sound is an estuary of national significance (1987) it is one of the most significant coastal areas in the nation, with a watershed that includes an area of more than 16,000 mi^2 and that traverses all of Connecticut and parts of New York, Massachusetts, New Hampshire, Rhode Island, and Vermont. More than 170 species of finfish can be found in the Sound, including at least 50 species that spawn in the Sound and 21 tropical species that stray into this region on a seasonal basis (USEPA 2007b).
- Peconic Bays
    - Peconic Bay is an estuary of national significance (1992). It exhibits a rich mosaic of coastal and underwater habitats that support diverse communities and 140 globally and locally rare species. The distinctive ecology of the Peconic Estuary can be attributed to its unique fresh groundwater source and the restriction of flow out of the estuary by Shelter Island.

National Wildlife Refuges

From USFWS 2014

- Morton NWR separates Little Peconic Bay from Noyack Bay. The north-south axis of the peninsula between Long Island's two forks also makes the refuge an important migration corridor for a variety of birds.
- This small refuge is a 60-acre mix of woodlands, grasslands and saltmarsh. Wading birds and osprey are common on the refuge during the spring and summer.
- Amagansett National Wildlife Refuge is located in Amagansett on the south shore of eastern Long Island. This 36-acre refuge consists of barrier beach, dunes and scrub oak habitats.

- Seatuck National Wildlife Refuge is a 196-acre refuge consisting of grasslands, woodlands, and salt and freshwater marshes bordering Champlain Creek and Great South Bay, in Islip, New York.

- The Oyster Bay NWR on the north shore of Long Island consists of high quality marine habitats that support a variety of aquatic-dependent wildlife. The refuge's waters and marshes surround Sagamore Hill National Historic Site.

- The Target Rock National Wildlife Refuge is located on the north shore of Long Island, 25 miles east of New York City. This 80-acre refuge is composed of mature oak-hickory forest, a half-mile rocky beach, a brackish pond, and several vernal ponds.

- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

National Park Service Areas /Coastal Protected Areas

Long Island’s South Shore Barrier Island/Back Bay System

- The Long Island South Shore Estuary Reserve encompasses one of New York State's most diverse estuaries and its 326 square mile watershed in Nassau and Suffolk Counties. The Reserve extends from the Queens/Nassau County line eastward about 75 miles to the Village of Southampton in Suffolk County. The reserve includes the interconnected bays, rivers, streams, wetlands and small islands located along Long Island's south shore between the mainland and the barrier islands. Reynolds Channel, West Bay, Middle Bay, East Bay, South Oyster Bay, Great South Bay, Patchogue Bay, Moriches Bay and Shinnecock Bay (NYS DEC South Shore Estuary Reserve webpage).

Areas covered under Coastal Barrier Resource Act (CBRA)

Rockaways

- Breezy Point, which is part of the Rockaway Barrier Island system, is identified by the USFWS as a Significant Habitat/Habitat Complex (note that Jamaica Bay is included in this designation). Breezy Point includes an area of approximately 200 acres. The location of Breezy Point and the rich food resources found there make it a regionally important fish, wildlife, and plant habitat complex (USFWS 1997).

Jones Beach

- Jones Beach East (Bay Shore West, NY and West Gilgo Beach, NY) contains significant coastal fish and wildlife habitat. Undeveloped marine barrier beach habitat, such as Jones Beach East, are becoming less common on Long Island and are rare in New York State. This ecosystem type is rare on Long Island and only occurs at a limited number of locations along the south shore, although development and use of the adjacent recreation facilities has resulted in some degradation of the habitat (NYS DOS Assessment Forms Jones Beach East).

- Jones Beach West (southeast of Jones Inlet, extending east along the coastline for approximately 3 miles to the Jones Beach Causeway). Relatively undeveloped barrier island habitats and the maritime dune community which dominates the landscape in Jones Beach West are rare in NYS. However, development and use of the adjacent recreation facilities have resulted in some degradation of the habitat (NYSDOS Assessment Forms Jones Beach West).

Fire Island

- Fire Island National Seashore – Fire Island National Seashore (FIIS) was established on September 11, 1964, "for the purpose of conserving and preserving for the use of future generations relatively unspoiled and undeveloped beaches, dunes and other natural features…." (http://www.nps.gov/fiis/naturescience/index.htm).

- In 1980 a 7-mile stretch from Smith Point West to Watch Hill was designated by Congress as wilderness, the only area in New York State to be honored in this manner (www.npca.org).

- The Otis Pike Fire Island High Dune Wilderness contains a variety of barrier island ecosystems in a relatively natural condition. It is the only federally designated wilderness area in the State of New York and is 1,380 acres (www.nps.gov/fiis).

- The Sunken Forest is a very rare ecological community; it is a 39 acre maritime oak-holly forest occurring behind the secondary dune, one of only a few mature maritime forests in the New York area and the northernmost holly-dominated maritime forest on the Atlantic barrier island chain. In 2001 the New York Natural Heritage Program ranked this maritime holly forest as "globally rare" meaning there are few remaining occurrences of this assemblage of plants throughout the world (National Park Service/Fire Island/Sunken Forest webpage). Both federal and New York State endangered species either breed or germinate in the park, along with eleven other species of concern.(www.nps.gov/fiis).

- The William Floyd Estate, located across Great South Bay on the Long Island mainland, is quite different from the Seashore's barrier island habitat. The William Floyd Estate is 65% forested, 25% wetlands including salt marsh, 5% open space and 5% developed around the estate house area. Species found at the Estate include great blue herons, great and snowy egrets, willets, and diamond-backed terrapins (www.nps.gov/fiis).

Southampton

- Southampton Beach is an important segment of undeveloped barrier beach on Long Island. Most of this area has been designated as part of the National Coastal Barrier Resources System, one of only twelve such areas on Long Island.

New York - Federal Parks

- Ellis Island National Monument
- Saint Paul's Church National Historic Site
- Sagamore Hill National Historic Site
- Morton National Wildlife Refuge
- Amagansett National Wildlife Refuge
- Target Rock National Wildlife Refuge
- Oyster Bay National Wildlife Refuge
- Wertheim National Wildlife Refuge
- Seatuck National Wildlife Refuge
- Fire Island National Seashore
- Lido Beach National Wildlife Management Area
- Gateway National Recreation Area

New York - State Parks

- Middle Island State Environmental Education Center
- State Boat Launch
- Rocky Point State Pine Barrens Preserve
- State Pine Barrens Preserve
- David A Sarnoff Pine State Barrens Preserve
- David A Sarnoff State Pine Barrens Preserve
- Manorville State Pine Barrens Preserve
- Long Island State Pine Barrens Preserve

- Edgewood Oak Brush Plains State Preserve
- Belmont Lake State Park
- Empire Fulton Ferry State Park
- Hempstead Lake State Park
- Valley Stream State Park
- Captree State Park
- Robert Moses State Park
- Orient Beach State Park
- Haverstraw Beach State Park
- Hook Mountain and Rockland Lake State Parks
- Montauk Point State Park
- Rockefeller State Park Preserve
- Montauk Downs State Park
- Blauvelt State Park (undeveloped)
- Hither Hills State Park
- Brookhaven State Park (undeveloped)
- Caumsett State Park
- Sunken Meadow State Park
- Planting Fields Arboretum State Park
- Caleb Smith State Park
- Roberto Clemente State Park
- Riverbank State Park

- Connetquot River State Park
- Tallman Mountain State Park
- Napeague State Park (undeveloped)
- Hartsbrook State Park Nature Preserve and Arboretum
- Palisades State Park
- Wildwood State Park
- Harriman State Park
- Rockwood Hall State Park
- Nyack Beach State Park
- Hudson Highlands State Park
- Franklin D Roosevelt State Park
- Gilgo State Park (undeveloped)
- Jones Beach State Park
- Bayswater State Park
- Clay Pit Ponds State Park Preserve
- Pepperidge Hall Marsh State Tidal Wetlands
- Timber Point State Tidal Wetlands
- H J Isbrandtsen State Tidal Wetlands
- Babylon Marsh State Tidal Wetlands
- Petteanger Island State Tidal Wetlands
- State Tidal Wetland
- Lido Beach State Tidal Wetlands

- State Tidal Wetlands
- Sawmill Creek State Wetland
- Havens Point State Tidal Wetlands
- Moneyboque Bay State Tidal Wetlands
- Fireplace Neck State Tidal Wetlands
- Bellport Bay State Tidal Wetlands
- Johns Neck State Tidal Wetlands
- Lymans Marsh State Tidal Wetlands
- Stillman Creek State Tidal Wetlands
- Barcelona Neck State Natural Resource Management Area
- Rocky Point State Natural Resource Management Area
- Kings Park State Natural Resource Management Area
- John Jay Homestead State Historic Site
- Stony Point Battlefield State Historic Site
- Bayard Cutting Arboretum State Park
- Bethpage State Park
- Heckscher State Park
- Bear Mountain State Park
- High Tor State Park
- State Open Space
- Fox Point State Tidal Wetlands
- Acabonack Harbor State Tidal Wetlands

- North Haven State Tidal Wetlands
- Northwest Harbor State Tidal Wetlands
- Piermont Marsh State Tidal Wetlands
- Oregon Marsh State Tidal Wetlands
- Napeague Harbor State Tidal Wetlands
- Little Northwest Creek State Tidal Wetlands
- Turtle Cove State Tidal Wetlands
- Flax Pond State Tidal Wetlands
- Baiting Hollow State Tidal Wetlands
- Conscience Bay Little Bay State Tidal Wetlands
- Davis Island State Tidal Wetlands
- Titus Mill Pond State Tidal Wetland
- Shinnecock Bay State Tidal Wetlands
- State Reforestation Area
- Minisceongo State Tidal Wetlands
- Long Beach State Tidal Wetlands
- Currans Road Pond State Wildlife Management Area
- Harbor Hurons State Wildlife Management Area
- Arden Heights Woods State Wildlife Management Area
- Ludlows Creek State Tidal Wetlands
- Namkee Creek State Tidal Wetlands
- Connetquot River State Tidal Wetlands

- Browns River State Tidal Wetlands
- Croton Gorge State Unique Area
- Mount Loretto State Unique Area
- State Unique Area New York - County Parks
- Froehlich County Farm
- Riverside County Nature Preserve
- County Nature Preserve (undeveloped)
- Muttontown County Preserve
- Leeds Pond County Preserve
- Islip Greenbelt County Preserve
- William Cullen Bryant County Preserve
- Grist Mill Pond County Preserve
- Bishops Tract County Preserve
- Orowoc Creek County Nature Preserve (undeveloped)
- Islip Meadows County Nature Preserve
- Massapequa County Preserve
- Tackapausha County Preserve
- Merrick County Preserve
- Mohansic County Park
- Muscoot Farm County Park
- Ward Pound Ridge County Park
- Georges Island County Park

- Oscawana County Park (undeveloped)
- Kitchawan County Park
- Croton Gorge County Park
- Mountain Lakes Camp (County Park)
- Lasdon County Park
- Blue Mountain Reservation (County Park)
- Cedar Point County Park
- Clausland Mountain County Park
- Cedar Beach County Park
- Tarrytown Lakes South County Park (undeveloped)
- Silver Lake Preserve (County Park)
- Northwest Harbor County Park (undeveloped)
- Ridge Road County Park
- V Everit Macy County Park
- Noyac Hills County Park (undeveloped)
- Mcallister County Park (undeveloped)
- Edith G Read Natural Park and Wildlife Sanctuary (County Park)
- Lenoir Preserve (County Park)
- Poxabogue County Park
- Playland County Park
- Saxon Woods County Park
- Sprain Ridge County Park

- Marshlands Conservancy (County Park)
- Malcolm Wilson County Park
- Mildred S Lasdon Bird And Nature Sanctuary
- Clam Island County Nature Preserve
- Suffolk County Bird Sanctuary (undeveloped)
- Cordwood Landing County Nature Preserve
- Cranberry Bog County Nature Preserve
- Makamah County Nature Preserve
- South Setauket County Nature Preserve (undeveloped)
- Mill Neck County Preserve
- Coindre Hall County Estate
- Welwyn County Preserve
- Dwarf Pine Plains County Nature Preserve (undeveloped)
- Garvies Point County Preserve
- Tiffany Creek County Preserve
- Indian Island County Park
- Twin Lakes County Park (undeveloped)
- Hubbard County Park
- Nature Study Woods County Park
- Peconic Bog County Park
- Tibbetts Brook County Park
- Peconic Hills County Park

- Birch Creek Owl Pond County Park
- Wilson Woods County Park
- Sears Bellows County Park
- Maple Swamp County Park
- Arthur H Kunz County Park
- Robert Cushman Murphy County Park
- Bailey Arboretum County Park
- Cathedral Pines County Park
- Prosser Pines County Park
- Glen Island County Park
- RC Murphy County Park
- Shinnecock County Park East
- Sands Point County Park
- Suffolk County Park
- Smithtown Greenbelt County Park
- Shinnecock County Park West
- Blydenburg County Park
- Southaven County Park
- Berkeley Jackson County Park
- Stillwell Woods County Park
- Hempstead Harbor County Park
- Hempstead Harbor County Beach

- Baxter Pond County Park (undeveloped)
- Cupsoque County Park
- Manhasset Valley County Park
- Lake Ronkonkoma County Park
- Terrel River County Park
- Lakeland County Park
- Flower Hill County Park
- Washington Terrace County Park
- West Hills County Park
- Morley County Park
- Whitney Pond County Park
- Bohemia County Park
- Old Bethpage Village Restoration County Park
- Cantiague County Park
- Battle Row County Park
- Smith Point County Park North (undeveloped)
- Smith Point County Park
- Eisenhower County Park
- Sans Souci County Park
- Meadowbrook County Park (undeveloped)
- Mitchel County Park
- Gardiners County Park

- Washington Ave County Park
- Halls Pond County Park
- Roosevelt County Park
- Bergen Point County Park
- Roosevelt Preserve County Park
- Centennial Ave County Park
- Millpond County Park
- Indian Island County Park (undeveloped)
- Tanglewood County Preserve
- Cedar Creek County Park
- Wantagh County Park
- Lofts Pond County Park
- Cammanns Pond County Park
- Silver Lake County Park
- Milburn Pond County Park
- Milburn Creek County Park
- North Woodmere County Park
- Grant County Park
- Cow Meadow County Park
- Bay County Park
- Inwood County Park
- Nassau Beach County Park

- Silver Point County Park
- County Park
- Paradise Island County Park (undeveloped)
- Croton Point County Park
- Orient Point County Park
- South Mountain County Park
- Gurnee County Park
- Mount Ivy County Park
- Kennedy Dells County Park
- Datar Mountain Nature County Park
- Wampus Pond County Park
- Demarest Kill County Park
- Kakiat County Park
- Dutch Gardens (County Park)
- Inlet Pond County Park
- Pocantico Lake County Park
- Graham Hills County Park
- Montauk County Park
- Ram Island County Park (undeveloped)
- Monsey Glen County Park
- Mountainview Nature County Park
- Peconic Dunes County Park

- Kingsland Point County Park
- Buttermilk Falls County Park
- Cranberry Lake Preserve (County Park)
- Goldsmiths Inlet County Park
- Kensico Dam Plaza County Park

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

- The Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986.
- Roseate tern (*Sterna dougallii*) is a medium-sized, black-capped sea tern about 15 inches long and weighs about four ounces. On November 2, 1987, the USFWS determined the population that nests in the Northeast to be endangered, and the population that nests in the Caribbean to be threatened.
- Seabeach amaranth (family Amaranthaceae) is an annual plant native to the barrier island beaches of the Atlantic Coast, from Massachusetts (MA) to South Carolina (SC). The original range of this species extended from Cape Cod, MA, to central SC, a stretch of coast about 994 miles. In New York, the range of seabeach amaranth is also characterized by islands developed by high wave energy, low tidal energy, frequent overwash, and breaching by hurricanes with resulting formation of new inlets (Weakley and Bucher 1992).
- The Red Knot (*Calidris canutus*) (Proposed) is a medium sized shorebird which in the State of New York, utilizes barrier beaches, bay shorelines, tidal flats, and wetland margins as foraging areas primarily along the south shore of on Long Island.
- The Gulf of Maine Destinct Population Segment (GOM DPS) for Atlantic salmon was listed as endangered in a final rule on November 17, 2000 by the National Marine Fisheries Service (NMFS) and the USFWS (collectively “the Services”). Atlantic salmon return to rivers from the sea and migrate to their natal stream beginning in the spring in New England and continues into the fall to spawn (Federal Register vol. 74, no. 117, June 19, 2009).
- The GOM DPS for Atlantic sturgeon was listed as threatened and the New York Bight (NYB) DPS listed as endangered in a final rule on February 6, 2012 by NMFS. Atlantic sturgeon spawn in spring and early summer in freshwater and migrate into estuarine and marine waters where

they spend most of their lives (http://www.nmfs.noaa.gov/pr/species/fish/atlanticsturgeon.htm). Atlantic sturgeons have been documented in the Merrimack River. Dams may impede access to some spawning habitat in the Tauton River and at the site of the Holyoke Dam on the Connecticut River in Massachusetts (Federal Register vol 77, no. 24, February 6, 2012).

- The shortnose sturgeon is an anadromous fish which lives mainly in the slower moving riverine waters or nearshore marine waters before migrating periodically into faster moving freshwater to spawn. Shortnose sturgeon can be found in the lower Merrimack River. They were listed as endangered throughout its range on March 11, 1967 under the Endangered Species Act of 1966 (http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm).

- Species of Concern listed by NMFS, and associated area of concern include the anadromous and highly migratory river herring (alewife and blueback herring) found in the Atlantic Ocean from Newfoundland to North Carolina, the pelagic and highly migratory Atlantic bluefin tuna found throughout the the North Atlantic Ocean and adjacent seas, the Atlantic halibut found from Labrador to southern New England in the Northwest Atlantic Ocean, the dusky shark found in the Western Atlantic Ocean, the porbeagle shark found in the Nortwest Atlantic Ocean, the anadromous rainbow smelt found in rivers and coastal areas of eastern North America from Labrador to New Jersey, and the sand tiger shark found in the Western Atlantic Ocean (http://www.nmfs.noaa.gov/pr/species/concern/).

- The American eel was petitioned to be listed as threatened on September 29, 2011 in the Federal Register (vol. 76, no. 189) by the USFWS. Eels spawn in the Sargasso Sea. Juveniles arrive in coastal waters and river systems which are accessible by the oceanic currents of the western North Atlantic Ocean for development. This fish occupies fresh, brackish and marine waters (FR, vol 76. No. 189).

- A detailed discussion of USFWS managed Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Waterbird Islands/Waterfowl

- A detailed discussion on Waterbird Nesting Colonies can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Long Island's South Shore Barrier Island/Back Bay System

Hempstead Bay

- The Hempstead Bay – South Oyster Bay complex includes a network of salt marsh and dredge spoil islands that are important for nesting by herons, egrets, and ibises. Hempstead Bay is the primary nesting area in Long Island for yellow crowned night-herons. Waterfowl such as brant and American black duck feed and rest in the shallow waters around the islands and tidal flats of the complex (Titus and Strange 2008).

South Oyster Bay

- South Oyster Bay complex is a productive estuary that is especially notable for its regionally significant concentrations of waterbird nesting colonies. South Oyster Bay and the Hempstead Bays are an important component of the Atlantic Flyway for migrating and wintering waterfowl, with an average of nearly 25,000 waterfowl counted on mid-winter aerial surveys. Thousands of brant (*Branta bernicla*) and American black duck (*Anas rubripes*) congregate to feed and rest in the shallow waters around salt marsh islands and tidal flats. Notable islands and those that include nesting tern habitat include: The Line Island Group, Black Banks Island, Goose Island, Neds Island, and several unnamed marsh islands in the eastern end of the area (USFWS 1997).

- South Oyster Bay is an important nesting area and feeding ground for a variety of colonial wading birds, including snowy egret, great egret, black-crowned night heron, tri-colored heron, glossy ibis, and green-backed heron. Other species nesting in the area include herring gull, great black-backed gull, American oystercatcher, black skimmer, and least tern (NYS DOS Assessment Form South Oyster Bay).

Great South Bay

- Several rookeries have been located on islands within Great South Bay - West, including Gilgo Island, Sexton Island, Seganus Thatch, Ox Island, Pipe Island, Nazeras Island, the Cedar Island Group, and an unnamed dredged material island southwest of Nazeras Island. Species nesting in these areas include great egret, snowy egret, yellow-crowned night heron, black-crowned night heron, green-backed heron, little blue heron, tri-colored heron, and glossy ibis. These birds use a network of islands in the bays, with shifts in island use from year to year (NYS DOS Assessment Form Great South Bay).

- Great South Bay is also one of the most important waterfowl wintering areas (November - March) on Long Island, especially for diving ducks. Dominant concentrations of waterfowl for the aforementioned period included scaup, red-breasted merganser, American black duck, brant, common goldeneye, and Canada goose. The Captree Island vicinity is recognized as an Important Bird Area by the National Audubon Society of New York State, and serves as foraging habitat for peregrine falcon and other migrating raptors. A tremendous diversity of fish and wildlife species occur in this vast wetland area. Many species of migratory birds nest among the salt marshes and dredged material islands (NYS DOS Assessment Form Great South Bay).

Moriches Bay

- Moriches Bay is one of the most important waterfowl wintering areas (November - March) on Long Island. Diving ducks are distributed throughout Moriches Bay, and are concentrated in the bay between Forge Point and Tuthill Point, Tuthill Cove, Hart Cove, Seatuck Cove, and the area behind Cupsogue and Westhampton Beach extending out into the bay. Based on surveys, Moriches Bay supports wintering waterfowl concentrations of statewide significance and

Carter's Island has supported nesting by the state endangered least tern (NYS DOS Assessment Form Moriches Bay).

Shinnecock Bay

- Shinnecock Bay is one of the most important waterfowl wintering areas on Long Island. Lanes Island and Warner Island in Shinnecock Bay support colonies of the state listed common tern and the federally endangered roseate tern (NYS DOS Assessment Form Shinnecock Bay).

North Shore of Long Island and Peconic Estuary

- Several offshore islands in western Long Island Sound are significant for their colonial wading bird rookeries. The most important are Huckleberry Island, Great Captain Island, North Brother Island, South Brother Island, and Pelican Island. These islands are rocky and mostly covered by deciduous forest; their rocky shorelines provide habitat for species such as shellfish, sea stars, and barnacles (Titus and Strange 2008).

- North and South Brother islands have the largest black crowned night heron colony in New York State, along with snowy egret, great egret, cattle egret, and glossy ibis.

- The Long Island Sound Study considers Plum Island, Little Gull Island, and Great Gull Island off Orient Point "exemplary" colonial waterbird habitat, with sites "of national, if not international, significance.

- Gardiners Island, Robins Island, and Cow Neck in Little Peconic Bay, in private ownership, provide habitats for many rare species such as roseate tern, common tern, least tern, northern harrier, red-tailed hawk, eastern mud turtle, and diamondback terrapin.

- Specific North Shore Areas include - *From Long Island Sound Study Stewardship Area Atlas website (http://longislandsoundstudy.net/issues-actions/stewardship/stewardship-areas-atlas/):*

    - Alley Pond Park and Fort Totten are important winter waterfowl area.

    - Hempstead Harbor - North Hempstead, Oyster Bay and Glen Cove, NY is designated by Audubon New York as an Important Bird Area.

    - Huckleberry & Davids Islands - New Rochelle, NY - Anchor Sites: Huckleberry and Davids Islands. Is the largest colonial waterbird rookery in western Long Island Sound.

    - Lloyd Neck - Huntington, NY – Includes a site designated as a Bird Conservation Area.

    - Manhasset Bay - North Hempstead, NY. A major waterfowl wintering area. Provides significant nursery and feeding habitat for striped bass, winter flounder, menhaden and other forage species.

- Marshlands - Rye, NY – Provides nesting and feeding habitat for native shorebirds and rare birds, including the wood sandpiper, black rail, little gull, sedge wren and yellow-headed blackbird.

- Mt. Sinai - Port Jefferson Harbor - Brookhaven, NY – Provides habitat for wading birds, waterfowl, and commercially and recreationally important shellfish (e.g., hard and soft clams) and finfish (e.g., winter flounder). Areas designated as part of the National Coastal Barrier Resources System.

- Nissequogue River - Smithtown, NY – Supports a sea-run fishery for brown trout. Includes a 100-acre site designated as a Bird Conservation Area.

- Oyster Bay (Mill Neck) - Oyster Bay, NY – Provides critical habitat for wintering waterfowl.

- Pelham Bay - Bronx, NY – Provides productive nursery and feeding habitats for a variety of marine finfish and shellfish, including striped bass, bluefish, silversides, menhaden, winter flounder, hard clams, oyster, and horseshoe crabs

- Plum, Little and Great Gull Islands - Southold, NY – Identified by the USFWS as a Significant Coastal Habitat. Exemplary colonial waterbird habitat, including sites that are of national, if not international, significance.

- Stony Brook Harbor - Brookhaven/Smithtown, NY – Includes a site designated as a Bird Conservation Area. Provides habitat for diverse species of colonial waterbirds. Provides important spawning sites for horseshoe crabs.

- Specific Peconic Bay Areas Include:

  - Plum, Little and Great Gull Islands - Southold, NY - Anchor Sites: Plum and Great Gull Islands. Small rocky islets dominated by grassy and herbaceous vegetation.

  - Shoreham - Baiting Hollow - Riverhead, NY - Anchor Sites: Wildwood State Park and Wading River Tidal Wetlands. Relatively undisturbed salt marsh and maritime beach complex that is rare on the north shore of Long Island in Suffolk County. Includes over 15 acres of barrier beach. Exemplary bluff habitat supports a globally-rare maritime beech forest. Sand shoal habitat supports sandlance which is a food source for tern populations.

  - Stony Brook Harbor - Brookhaven/Smithtown, NY - Anchor Sites: Flax Pond State Tidal Wetlands and Long Beach. Over a 1,000 acres of diverse tidal wetlands.

Hudson Raritan Estuary

- *The following regions (Jamaica Bay, Lower Bay, Lower Raritan River, Arthur Kill/Kill van Kull, Hudson River Estuary, Harlem River/East River/Western Long Island Sound and Upper Bay) are delineated by major watersheds and/or major physical features, such as highways or waterways.*

Jamaica Bay

- Jamaica Bay is situated at a turning point along the mid-Atlantic coast and acts as a funnel concentrating migratory marine and estuarine species moving between the New York Bight portion of the North Atlantic and the Hudson-Raritan Estuary. Migrating shorebirds, raptors, land birds, waterfowl, and insects often concentrate in the terrestrial and open water habitats of the Jamaica Bay study area because of the Bay's position along the Atlantic Flyway. The USFWS estimates nearly 20% of North America's bird species migrate through or breed in the study area annually. Salt marsh habitat and upland islands provide nesting habitat for waterfowl, wading birds, terns, and gulls. These habitats also provide roosting and foraging habitat for shorebirds and waterbirds as well as nesting and foraging habitat for grassland birds. Jamaica Bay GNRA is also known nesting habitat for diamond-backed terrapins (USACE 2004, 2009).

Arthur Kill/Kill van Kull

- Shooter's Island, Prall's Island, and Isle of Meadows are upland islands comprised primarily of dredged material and fill. Collectively referred to as the "Harbor Herons Complex", these islands form the largest heronry in New York State. They also account for 25 percent of the wading birds that breed in coastal New Jersey, New York, and Connecticut (USFWS 1997). Nine species of wading birds including black-crowned night herons (*Nycticorax nycticorax*), snowy egrets (*Egretta thula*), great egrets (*Ardea alba*), cattle egrets (*Bulbulcus ibis*), glossy ibis (*Plagidis facinellus*), and yellow-crowned night heron (*Nyctanassa violacea*) nest in the Harbor Herons Complex; however, in recent years breeding populations on the islands have declined. The wading birds are thought to be abandoning the islands because tree-of-heaven, a non-native and invasive species, is replacing native tree species that were once dominant (HEP 2001). Native species, particularly gray birch (*Betula lenta*), are the preferred nesting substrate of wading birds (HEP 2001). Islands in the study area also provide nesting habitat for gulls and terns, which generally nest on the ground in open areas characterized by sparse, low-growing vegetation (Baicich and Harrison 1997, USACE 2004, 2009).

Harlem River/East River/Western Long Island Sound

- The "re-naturalized" urban shallow waters and sloping shorelines that have returned in these areas provide limited nursery habitat for fish and foraging habitat for waterfowl and long-legged wading birds (USACE 1997, 2004, 2009)

- Several undeveloped or uninhabited rocky islands exist within the East River, the largest and most significant being North and South Brother Islands. Once developed, these islands are now of ecological importance because they are important breeding grounds for colonial waterbirds. In addition to the natural regrowth, deteriorated structures and piers on the islands provide nesting habitat for double-crested cormorants (*Phalacrocorax auritus*), black-crowned night herons (*Nycticorax nycticorax*), snowy egrets (*Egretta thula*), great egrets (*Ardea alba*), cattle egrets (*Bulbulcus ibis*), and glossy ibis (*Plagidis facinellus*). These islands are home to the largest black-crowned night heron colony in New York State (USACE 2004, 2009).

- Avian species within the Bronx River Basin vary considerably with habitat and season, with generalist species, such as house sparrow (*Passer domesticus*) and northern mockingbird (*Mimus polyglottos*), as well as species with more specific habitat requirements, such as belted kingfisher (*Ceryle alcyon*) and black crowned night heron (*Nycticorax nycitcorax*) having been observed within the Bronx River Basin. This basin is part of the Atlantic Migratory Flyway (USACE 2010).

- Despite the degradation within the study area, the wetlands and/or sand beaches that remain in areas including those found in Western Long Island Sound – Little Neck Bay, Manhasset Bay, and Hempstead Harbor serve as important waterfowl wintering areas in the Estuary, especially for scaup (*Aythya marila, A. affinis*), canvasback (*Aythya valisineria*), and American black duck (*Anas rubripes*).

- Rocky offshore islands in the Western Long Island Sound support colonial waterbird colonies of regional significance (USFWS 1997, USACE 2004, 2009)

Lower Bay

- The Lower Bay region provides significant wintering and migratory habitat for waterfowl species including greater scaup (*Aythya* spp.), Canada goose (*Branta candensis*), American black duck (*Anas rupripes*), brant (*Branta bernicla*), and long-tailed duck (*Clangula hyemalis*). Breeding waterbirds include American black duck, mallard (*Anas platyrhynchos*), clapper rail (*Rallus longirostris*), marsh wren (*Cistothorus palustris*), and willet (*Cataptrophours semipalmatus*) (USACE 2004, 2009).

Hudson River Estuary

- Wetlands and open water habitats in the lower Hudson support diverse bird communities. Concentrations of shorebirds, herons, and waterfowl use the shallow water habitats and mudflats as staging areas during migration. Breeding birds found in wetlands of the study area include Virginia rail (*Rallus limicola*), marsh wren (*Cistothorus palustris*), wood duck (*Aix sponsa*), and least bittern (*Ixobrychus exilis*).

Upper Bay

- The few remaining salt marshes in the study area support a variety of waterbirds. Great blue herons (*Ardea herodias*), great egrets (*Casmerodius albus*), snowy egrets (*Egretta thula*), black-crowned night herons (*Nycticorax nycticorax*) and double-crested cormorants (*Phalacrocorax auritus*) commonly forage in the area (USACE 2004, 2009).

- Waterfowl species that use the study area include American black duck (*Anas rubripes*), Canada goose (*Branta Canadensis*), mallard (*Anas platyrhynchos*), and gadwall (*Anas strepera*) (USACE 2004, 2009).

Essential Fish Habitat (EFH)/Fish

Atlantic Coast of New York

- The Atlantic Coast of New York provides EFH for the following species: American plaice (*Hippoglossoides platessoides*), Atlantic butterfish (*Peprilus triacanthus*), Atlantic cod (*Gadus morhua*), Atlantic mackerel (*Scomber scombrus*), Atlantic salmon (*Salmo salar*), Atlantic sea herring (*Clupea harengus*), Atlantic sea scallop (*Placopecten magellanicus*), basking shark (*Cetorhinus maximus*), black sea bass (*Centropristis striata*), blue shark (*Prionace glauca*), bluefin tuna (*Thunnus thynnus*), bluefish (*Pomatomus saltatrix*), clearnose skate (*Raja eglanteria*), cobia (*Rachycentron canadum*), common thresher shark (*Alopias vulpinus*), dusky shark (*Carcharhinus obscurus*), haddock (*Melanogrammus aeglefinus*), king mackerel (*Scomberomorus cavalla*), little skate (*Raja erinacea*), long finned squid (*Loligo pealeii*), monkfish (*Lophius americanus*), ocean pout (*Macrozoarces americanus*), ocean quahog (*Artica islandica*), pollock (*Pollachius virens*), red hake (*Urophycis chuss*), redfish (*Sebastes fasciatus*), sand tiger shark (*Carcharias taurus*), sandbar shark (*Carcharhinus plumbeus*), scup (*Stenotomus chrysops*), short finned squid (*Illex illecebrosus*), shortfin mako shark (*Isurus oxyrinchus*), skipjack tuna (*Katsuwonus pelamis*), Spanish mackerel (*Scomberomorus maculatus*), spiny dogfish (*Squalus acanthias*), summer flounder (*Paralichthys dentatus*), surf clam (*Spisula solidissima*), tiger shark (*Galeocerdo cuvieri*), tilefish (*Lopholatilus chamaeleonticeps*), white shark (*Carcharodon carcharias*), whiting (*Merluccius bilinearis*), windowpane flounder (*Scophthalmus aquosus*), winter flounder (*Pseudopleuronectes americanus*), winter skate (*Leucoraja ocellata*), witch flounder (*Glyptocephalus cynoglossus*), yellowfin tuna (*Thunnus albacares*), yellowtail flounder (*Limanda ferruginea*).

Long Island's South Shore Barrier Island/ Back Bay System

- Shinnecock Bay serves as a nursery and feeding area (April - November, generally) for bluefish, winter flounder, summer flounder, scup, weakfish, tomcod, and blue crab. Forage fish species are also present, including Atlantic silversides, Atlantic menhaden, striped killifish, pipefish, American sandlance (the primary food source of the endangered roseate tern), American eel, alewife, blueback herring, Atlantic sturgeon, and sticklebacks. Halsey Lane Pond, a freshwater pond draining into Heady Creek, contains a significant population (at least 1,000 individuals) of alewife.

North Shore of Long Island and Peconic Estuary

- The North Shore area of Long Island Sound provides EFH for the following species: Atlantic salmon (*Salmo salar*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), whiting (*Merluccius bilinearis*), offshore hake (*Merluccius albidus*), red hake (*Urophycis chuss*), witch flounder (*Glyptocephalus cynoglossus*), winter flounder (*Pleuronectes americanus*), yellowtail flounder (*Pleuronectes ferruginea*), windowpane (*Scopthalmus aquosus*), American plaice (*Hippoglossoides platessoides*), ocean pout (*Macrozoarces americanus*), Atlantic sea scallop (*Placopecten magellanicus*) , Atlantic sea herring (*Clupea harengus*), monkfish (*Lophius americanus*), bluefish (*Pomatomus saltatrix*), long finned squid (*Loligo pealei*), short finned squid (*Illex illecebrosus*), Atlantic butterfish (*Peprilus triacanthus*), Atlantic mackerel (*Scomber scombrus*), summer flounder (*Paralicthys dentatus*), scup (*Stenotomus chrysops*), black sea bass (*Centropristus striata*), surf clam (*Spisula solidissima*), ocean quahog (*Artica islandica*), spiny dogfish (*Squalus acanthias*), tilefish (*Lopholatilus chamaeleonticeps*), king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*Scomberomorus maculatus*), cobia (*Rachycentron canadum*), sand tiger shark (*Odontaspis taurus*), blue shark (*Prionace glauca*), dusky shark (*Charcharinus obscurus*), sandbar shark (*Charcharinus plumbeus*), tiger shark (*Galeocerdo cuvieri*), Winter skate (*Leucoraja ocellata)*, Little Skate (*Leucoraja erinacea)*, Clearnose skate (*Raja eglanteria*).

Hudson Raritan Estuary

- The Hudson Raritan Estuary provides EFH for the following species: Atlantic butterfish (*Peprilus triacanthus*), Atlantic mackerel (*Scomber scombrus*), Atlantic sea herring (*Clupea harengus*)black sea bass (*Centropristis striata*), bluefish (*Pomatomus saltatrix*), clearnose skate (*Raja eglanteria*), cobia (*Rachycentron canadum*), dusky shark (*Carcharhinus obscurus*), king mackerel (*Scomberomorus cavalla*), little skate (*Raja erinacea*), long finned squid (*Loligo pealeii*), monkfish (*Lophius americanus*), ocean quahog (*Artica islandica*), red hake (*Urophycis chuss*), redfish (*Sebastes fasciatus*), sand tiger shark (*Carcharias taurus*), sandbar shark (*Carcharhinus plumbeus*), scup (*Stenotomus chrysops*), short finned squid (*Illex illecebrosus*), Spanish mackerel (*Scomberomorus maculatus*), spiny dogfish (*Squalus acanthias*), summer flounder (*Paralichthys dentatus*), surf clam (*Spisula solidissima*), whiting (*Merluccius bilinearis*), windowpane flounder (*Scophthalmus aquosus*), winter flounder (*Pseudopleuronectes americanus*), winter skate (*Leucoraja ocellata).*

Habitat Areas of Particular Concern (HAPC)

- Summer Flounder (*Paralichthys dentatus*) All native species of macroalgae, seagrasses and freshwater and tidal macrophytes in any size bed as well as loose aggregations, within adult and juvenile EFH (http://www.nero.noaa.gov/hcd/efhtables.pdf).

- Tilefish are shelter-seeking and habitat limited, HAPC is substrate between the 76 and 365m isobath, from U.S. / Canadian Boundary to the Virginia / North Carolina boundary within statistical areas 616 and 537 (intersection of isobaths east of Cape May, NJ and south of Provincetown, MA) (http://www.nero.noaa.gov/hcd/efhtables.pdf).

Critical Habitat/Species

Long Island's South Shore Barrier Island/Back Bay System

Rockaw*ays*

- Breezy Point supports seasonal or year-round populations of 214 species of special emphasis and listed species, incorporating 48 species of fish and 120 species of birds. Breezy Point supports some of the highest concentrations of beach-nesting birds in NYS and in the entire NY Bight coastal region. Breezy Point consistently supports one of the largest piping plover nesting sites, concentrations of least terns and black skimmer colonies in NYS and in the New York Bight region in recent years. Small numbers of roseate terns began nesting at Breezy Point in 1993. Other notable nesting waterbirds include common tern, great black-backed gull (*Larus marinus),* herring gull *(Larus argentatus*), *willet (Catoptrophorus semipalmatus*), and American oystercatcher (*Haematopus palliatus) (USFWS 1*997).

- *Breezy Point is a concentration area for other migratory shorebirds, raptors, waterfowl, and land birds, especially during the summer and fall migrations. The most numerous species sighted were American kestrel* (*Falco sparverius*) and sharp-shinned hawk (*Accipiter striatus*). Other species consistently sighted include Cooper's hawk, northern harrier, osprey, peregrine falcon, and merlin (*Falco columbarius*). The federally listed endangered peregrine falcon nest on the Marine Parkway bridge and feed throughout the bay (USFWS 1997).

- Breezy Point supports three species of rare plants, including the federally listed threatened and globally rare seabeach amaranth and globally rare seabeach knotweed (*Polygonum glaucum*) along the ocean beach and dune, and state-listed rare Schweinitz's flatsedge on the bay side of the barrier (USFWS 1997).

- Also included in the Breezy Point unit are the portions of ocean beach extending east to Jacob Riis Park, presently used by beach-nesting birds and rare plant species (USFWS 1997).

Long Beach

- Nassau Beach is located approximately one half mile west of Point Lookout, on the Long Beach Island barrier island on Long Island's south shore. The Nassau Beach significant habitat includes Lido Beach, and the adjoining beach to its east, including Nassau Beach County Park, and the westernmost beach area of Malibu Beach Town Park (Jones Inlet, N.Y.). The Nassau Beach significant habitat consists of approximately 214 acres of maritime beach with scattered dunes through most of the site (USFWS 1997).

Jones Beach

- Jones Beach East significant habitat supports one of the best piping plover-tern nesting colonies on Long Island. Tern breeding colonies may contain several hundred to several thousand birds, including roseate, least, common, and gull-billed terns, along with black skimmer. Additionally, thousands of seabeach knotweed (*Polygonum glaucum*) plants can be found on a broad section of barrier beach that contains a series of salt water ponds covering 10 acres within the Jones Beach East habitat. Seabeach knotweed is rare in New York State with fewer than 35 occurrences, and only 21 to 100 plants occur globally. Seabeach amaranth (*Amaranthus pumilus*), commonly associated with piping plovers has also been observed at this site. The population included within the Jones Beach East significant habitat is one of the best global populations. Seabeach amaranth has been eliminated from two-thirds of its historic global range with typically fewer than five occurrences in NYS (NYS DOS Assessment Form Jones Beach East).

- Jones Beach West serves as an important site for several beach nesting shorebirds, including the least, roseate, common, and gull-billed terns, along with black skimmer. Piping plover also are commonly found nesting in association with least tern. Hundreds of seabeach knotweed plants can be found in a highly disturbed area within the Jones Beach West habitat. Seabeach knotweed is rare in New York State with fewer than 35 occurrences, and only 21 to 100 plants occur globally. Marsh straw sedge (*Carex hormathodes*), another rare plant species is also found within the Jones Beach West significant habitat. According to current documentation, less than 20 site occurrences exist for marsh straw sedge in New York State. Seaside bulrush (*Bolboschoenus maritimus* ssp. *Paludosus*) is found within the brackish interdunal swales of Jones Beach West. Seaside bulrush is restricted in New York State to the south and eastern shores of Long Island with typically 5 or fewer occurrences (NYS DOS Assessment Form Jones Beach West).

Fire Island

From the USFWS Fire Island/Threatened and Endangered Species webpage (http://www.nps.gov/fiis/naturescience/threatened-and-endangered-species.htm):

- The follow threatened and endangered species exist on the Fire Island National Seashore Piping plover (*Charadrius melodus*) – Federally threatened; state endangered
    - Roseate tern (*Sterna dougallii*) – Federally endangered; state endangered.
    - Least Tern (*Sternula antillarum*) – state threatened
    - Common tern (*Sterna hirundo*) – state threatened
    - Black skimmer (*Rhynchops niger*) – state species of special concern
    - Osprey (*Pandion haliaetus*) – species of special concern
    - Bald eagle (*Haliaeetus leucocephalus*) – officially removed from the federally threatened list on August 8, 2007. Eagles continue to be protected by the 1940 *Bald and Golden Eagle Protection Act* and the 1918 *Migratory Bird Treaty Act*. Bald eagles are occasionally sighted in the national seashore

- Of more than 30 species of reptiles and amphibians known to live within or visit Fire Island National Seashore, five are listed as New York State endangered species or species of special concern and may be found in/around the maritime forest community:
  - Eastern Mud Turtle (historically common; now uncommon) - state endangered
  - Spotted Turtle (historically common; now uncommon) - state species of special concern
  - Eastern Box Turtle (common) - state species of special concern
  - Eastern Hog-nosed Snake - state species of special concern
  - Southern Leopard Frog (historically abundant; now extirpated) - state species of special concern
- There are two T&E plant species that may be found on the Fire Island National Seashore:
  - Seabeach amaranth (*Amaranthus pumilus*) - Federally threatened annual plant species
  - Seabeach knotweed (*Polygonum glaucum*) - state rare plant

Southampton

From NYS DOS Assessment Form- Southhampton:

- Southampton Beach is an important segment of undeveloped barrier beach on Long Island. Most of this area has been designated as part of the National Coastal Barrier Resources System, one of only twelve such areas on Long Island.
- While this ecosystem type is generally rare in New York State, portions of Southampton Beach have been degraded by dredged material placement, heavy recreational use, and residential development at the eastern end. Nevertheless, this area is a valuable habitat for a number of migratory bird species.
- Shorebird species present include the piping plover and least tern, and have used the beach to nest. Seabeach (*Amaranthus pumilus*), has also been observed at this site. Seabeach amaranth has been eliminated from two-thirds of its historic global range with typically fewer than five occurrences in New York State.
- Fish and Barrier beach dunelands such as those found on Southampton Beach are essential resting and feeding areas for migrating raptors, which move south through a very narrow corridor along the south shore.
- The wetland areas on Southampton Beach are valuable feeding areas for a variety of shorebirds and waterfowl throughout the year, and contribute to the biological productivity of Shinnecock.

- Shorebird species present include the piping plover and least tern, and utilize the beach for nesting. Least tern typically nest in association with black skimmer and other tern species in large colonies located in sand, gravel, shells, and seaweed above the high tide mark. Piping plovers nest in association with least tern, but well above the high tide mark in generally grassless sand beaches. The horned lark and seaside sparrow are species of concern that may be found in the area.

Westhampton

- The fish and wildlife habitat includes well developed dunes (over 20 feet high at their maximum elevation) on the west end of the beach and open beach throughout. Seabeach amaranth (*Amaranthus pumilus*) has been observed at this site. Seabeach amaranth has been eliminated from two-thirds of its historic global range with typically fewer than 5 occurrences in New York State. Seabeach knotweed (*Polygonum glaucum*) has also been observed at this site. Seabeach knotweed is rare in New York State with fewer than 35 occurrences and globally it is rare and restricted throughout its range with between 21 and 100 occurrences.

- Undeveloped barrier beach ecosystems of this size are rare in New York State. Westhampton Beach and Dunes are a critical foraging and nesting habitat for shorebird species including piping plover and least tern. Westhampton Beach and Dunes supports piping plover and least tern populations of statewide significance. Least tern breeding colonies may contain several hundred birds, including roseate, common, and gull-billed terns, along with black skimmer .Westhampton Island contains the largest concentration of piping plover and least tern on Long Island and is of statewide significance. Habitat includes Piping plover and least tern foraging and nesting grounds. Least tern breeding colonies may contain several hundred birds, including roseate and common terns.

- Seabeach amaranth (*Amaranthus pumilus*), commonly associated with piping plover, has been observed at this site. Seabeach knotweed (*Polygonum glaucum*) has also been observed at this site.

Montauk and East Hampton

- The M*ontauk Peninsula C*omplex has been identified by the US Fish and Wildlife Service as a Significant Coastal Habitat. The complex *extends from Nape*ague Harbor, including Napeague Pond and Meadows and adjacent shorelands along the western edge, eastward to Montauk Point, and is approximately 12 miles (USFWS 1997).

- There are five ecological/geographical subcomplexes of sites that can be identified within the greater complex as being of particular regional significance to fish, wildlife, plants or biological diversity: 1) Napeague Harbor (including Goff Point, Hicks Island, Napeague Pond and Napeague Meadows); 2) Hither Hills (including the Walking Dunes); 3) Montauk Moorlands (including Culloden Point, Ditch Plains, Montauk Downs and Montauk Point); 4) Embayed Aquatic Habitats (including Lake Montauk, Oyster Pond, Big and Little Reed Ponds and Fort Pond; and 5) Nearshore Open Water Aquatic Habitats (USFWS 1997).

- Napeague Harbor is one of the least developed of several large coastal bays in eastern Long Island. A portion of the habitat has been designated as part of the national Coastal Barrier Resources System, one of 67 such areas on Long Island. This area is a high quality and productive estuarine ecosystem, supporting a diversity of fish and wildlife species that is rare on Long Island, outside of the major coastal bays on the south shore. Napeague Harbor is an important nesting and feeding area for many migratory bird species. Osprey have historically nested in Napeague Meadows (NYS DOS Assessment Form Napeague Harbor). Hicks Island and Goff Point are important nesting areas for piping plover, least tern, roseate tern, common tern, black skimmer, herring gull, great black-backed gull and horned lark (NYS DOS Assessment Form Napeague Harbor).

- The maritime moorlands and forest communities of the Montauk Peninsula are regionally significant and noteworthy not only for their uniqueness and restricted geographical occurrence, but also for their relatively pristine condition. These communities, which are in themselves rare, provide essential habitat for a number of regionally and globally rare plant species, including sandplain gerardia (*Agalinis acuta*), a U.S. Endangered species found here in maritime grasslands, Nantucket serviceberry (*Amelanchier nantucketensis*) and New England blazing-star (*Liatris borealis*), both candidates for listing under the U.S. Endangered Species Act, and bushy rockrose (*Helianthemum dumosum*) (USFWS 1997).

- Some upland areas on the Montauk Peninsula, especially on Hither Hills, contain some of the largest undeveloped tracts of maritime deciduous forests in the region, including stands of the globally rare maritime oak-holly forest. This forest type is restricted in the New York Bight region to undeveloped barrier beaches of Long Island and New Jersey and the eastern end of Long Island. The complex of undeveloped maritime communities on the Montauk peninsula supports an unusual diversity of rare plants and animals, and the nearshore waters supports important concentrations of marine species (USFWS 1997).

South Oyster Bay

- The salt marshes, intertidal flats, and shallows in this area (especially the Line Islands) provide invertebrate-rich feeding grounds for birds nesting here and for many migratory shorebirds, including sanderling, dowitchers, red knot, ruddy turnstone, marbled godwit, plovers, American oystercatchers, and sandpipers. The Hempstead South Oyster Bay complex supports one of the largest wintering concentrations of brant in the Atlantic Flyway region, representing 8% of the total population. South Oyster Bay alone represents 11% of the state’s total brant population (USFWS 1997).

- South Oyster Bay is a productive area for marine finfish, shellfish, and other wildlife. The bay serves as critical pre-migratory habitat for yearling striped bass and bluefish. It is also an important spawning ground for winter flounder and Atlantic menhaden, as well as forage fish species including Atlantic silverside, bay anchovy, and killifish. Harvest records from South Oyster Bay include winter and summer flounder, weakfish, grey snapper, and kingfish (NYS DOS Assessment Form South Oyster Bay).

Great South Bay

- The Great South Bay significant habitat includes (in the east) the wetlands along Fire Island National Seashore, including along Long Cove, Robinson Cove, Whalehouse Point, Molasses Point, and Goose Point. This broad expanse of open water is highly productive, and supports a tremendous diversity of fish and wildlife species. Great South Bay is the only bay on Long Island's south shore that has major riverine input (from the Carmans and Connetquot Rivers). In addition, the bay is unique because it receives possibly as much as 11% of freshwater input directly through its floor. The nature of the habitat is highly influenced by three fundamental conditions: freshwater input from ground water, salt water input from the ocean through the Great South Bay inlets, and protection provided by the barrier island (NYS DOS Assessment Form Great South Bay).

- The salt marshes, intertidal flats, and shallows in this area provide valuable feeding areas for birds throughout the year, including species nesting in the area and large concentrations of shorebirds during migration. These include green-backed heron, black-crowned night heron, snowy egret, American bittern, Canada goose, mallard, American black duck, gadwall, northern harrier, osprey, piping plover, least tern, common tern, herring gull, willet, horned lark, fish crow, marsh wren, red-winged blackbird, sharp-tailed sparrow, and seaside sparrow (NYS DOS Assessment Form Great South Bay).

- Great South Bay is an extremely productive area for marine finfish, shellfish, and other wildlife. Much of this productivity is directly attributable to the salt marshes and tidal flats found throughout Great South Bay. Great South Bay-East and its connected freshwater tributaries serve as a major spawning, nursery, migratory, and foraging area (April - November, generally) for winter flounder, northern kingfish, bluefish, blue crab, and forage fish species, such as Atlantic silverside (abundant throughout the bay), striped killifish, mummichog, northern pipefish, weakfish, striped bass, sticklebacks (NYS DOS Assessment Form Great South Bay).

Moriches Bay

- Moriches Bay is one of the major protected, shallow, coastal bay areas on the south shore of Long Island, and constitutes one of the largest estuarine ecosystems in New York State. Moriches Bay is a regionally significant habitat for fish and shellfish, migrating and wintering waterfowl, colonial nesting waterbirds, beach-nesting birds, migratory shorebirds, raptors, and rare plants (NYS DOS Assessment Form Moriches Bay).

- Other bird species nesting in the area include American black duck, mallard, gadwall, American oystercatcher, snowy egret, great egret, glossy ibis, great black-backed gull, laughing gull, herring gull, willet, clapper rail, fish crow, sharp-tailed sparrow, seaside sparrow. The salt marshes are used extensively as feeding areas by birds nesting in the area, and by a variety of herons, egrets (NYS DOS Assessment Form Moriches Bay).

- Moriches Bay serves as a nursery and feeding area for bluefish, winter flounder, summer flounder, American shad, tomcod, American eel, striped bass, weakfish, American sandlance (the primary food source of the endangered roseate tern), blue crab, and forage fish species, such as Atlantic silverside, striped killifish, pipefish, and sticklebacks (NYS DOS Assessment Form Moriches Bay).

Shinnecock Bay

- Shinnecock Bay is one of three major protected, shallow, coastal bay areas on the south shore of Long Island, and represents one of the largest estuarine ecosystems in New York State. This highly productive bay is important to a variety of fish and wildlife species throughout the year. Much of the productivity of marine finfish and shellfish is directly attributable to the salt marshes and tidal flats which border the bay (NYS DOS Assessment Form Shinnecock Bay).

- Shinnecock Bay serves as a nursery and feeding area American eel, alewife, blueback herring, Atlantic sturgeon, and sticklebacks. Halsey Lane Pond, a freshwater pond draining into Heady Creek, contains a significant population of alewife (NYS DOS Assessment Form Shinnecock Bay).

- Wildlife species which feed extensively on fishery resources near the inlet and on the islands within the bay include gray seal and harbor seal. Exposed sand shoals near the inlet provide an important haul out area which seals use for resting and sunning. This location is one of five major haulouts around Long Island, serving as a focal point for seals feeding in the bay. Other marine mammals using the habitat area include mink whale and bottle-nosed dolphin. In the summer months juvenile loggerhead sea turtles and green sea turtles come to feed in Shinnecock Bay (NYS DOS Assessment Form Shinnecock Bay).

North Shore of Long Island and Peconic Estuary

- North Shore Areas that are designated as NYS Significant Coastal Fish and Wildlife Habitat include :
  - Fishers Island Coastline, Southold; Hempstead Harbor – North Hempstead, Oyster Bay and Glen Cove, Lloyd Neck, Huntington, Crab Meadow, Huntington; Huckleberry & Davids Islands – New Rochelle; Jamesport State Park – Mattituck Inlet – Southold; Manhasset Bay – North Hempstead; Mt. Sinai – Port Jefferson Harbor – Brookhaven; Nissequogue River – Smithtown; Oyster Bay (Mill Neck) – Oyster Bay; Shoreham – Baiting Hollow – Riverhead; Stony Brook Harbor – Brookhaven/Smithtown

- Specific North Shore areas include the following Anchor Sites highlighted in the Long Island Sound Study Stewardship Area Atlas website (http://longislandsoundstudy.net/issues-actions/stewardship/stewardship-areas-atlas/):
  - Alley Pond - Queens, NY - Anchor Sites: Alley Pond Park and Fort Totten. Contains over 635 acres of forested hills, ponds, meadows, salt marshes, tidal flats and freshwater wetlands, habitats that are unusual in the northern Queens County and East River area. One of the few remaining natural resource areas in northern Queens.

- Crab Meadow - Huntington, NY - Anchor Sites: Crab Meadow Wetlands and Beach and Eatons Neck Point. Contains one of the few large areas (approximately 300 acres) of undeveloped salt marsh ecosystems remaining on the north shore of Long Island. Area also includes undeveloped barrier beach and wetland ecosystems that are rare on Long Island.

- Fishers Island Coastline - Southold, NY - Anchor Site: Fishers Island Submerged Aquatic Vegetation Beds. Contains exemplary submerged aquatic vegetation habitat and rocky reef habitat. Includes 98% of the eelgrass meadows in NY waters of Long Island Sound.

- Hempstead Harbor - North Hempstead, Oyster Bay and Glen Cove, NY - Anchor Sites: Hempstead Harbor and Sands Point Preserve. Contains recently restored wetlands at Bar Beach and native plants on the Garvies Point bluff.

- Jamesport State Park - Mattituck Inlet - Southold, NY - Anchor Sites: Jamesport State Park and Preserve and Mattituck State Tidal Wetlands. Includes a variety of freshwater wetland types that are not typical on the north shore of Long Island.

- Lloyd Neck - Huntington, NY - Anchor Sites: Caumsett State Park and Target Rock National Wildlife Refuge. Largest and most diverse coastal forest on the north shore of Long Island, including coastal oak-hickory forest, oak-tulip tree forest, tidal mudflats, a maritime beach, mature woodlands, a freshwater pond, bluffs and open fields.

- Manhasset Bay - North Hempstead, NY - Anchor Sites: Manhasset Bay and Mitchells Creek. Is an exemplary embayment area and includes an undeveloped stream/wetland community.

- Marshlands - Rye, NY - Anchor Sites: Marshlands Conservancy, Edith Read Sanctuary and Rye Playland Park. One of the largest contiguous areas of undeveloped coastal land and the largest tidal marsh system in Westchester County.

- Mt. Sinai - Port Jefferson Harbor - Brookhaven, NY - Anchor Sites: Mt. Sinai and Port Jefferson Harbors. Contains large area of undeveloped coastal wetlands and barrier beach.

- Nissequogue River - Smithtown, NY - Anchor Sites: Nissequogue River State Park and Sunken Meadow State Park. Provides exemplary riverine habitat – the only major tidal river draining into Long Island Sound where the coastal portion remains in relatively undisturbed condition. One of the largest coastal wetlands on the north shore. Includes diverse habitats, including intertidal mudflats, brackish tidal wetlands, freshwater wetlands, a rare red maple-black gum swamp and coastal forests.

  - Oyster Bay (Mill Neck) - Oyster Bay, NY - Anchor Sites: Oyster Bay National Wildlife Refuge and Shu Swamp Nature Preserve are exemplary embayment areas and include red maple – black gum swamp habitat.

  - Pelham Bay - Bronx, NY - Anchor Sites: Pelham Bay Park and Orchard Beach. Contains almost 500 acres of relatively undisturbed tidal wetlands – one of the few undisturbed wetland areas remaining in the Bronx.

- Peconic Bay – Over 90 separate areas have been designated as significant coastal fish and wildlife habitat by NYSDOS. The estuary provides feeding habitat and spawning ground to a wide variety of aquatic and terrestrial species.

  - The most notable species of finfish in Peconic bay include – bay anchovy, Atlantic silverside, scup, summer flounder, winter flounder, windowpane flounder, weakfish and black fish (USEPA 2007a).

  - Flanders Bay – This diverse area is one of the most valuable fish and wildlife habitats in the Peconic Bays section of Long Island. The Flanders Bay Wetlands are within the "Peconic Bays/Flanders Bay" Important Bird Area, one of 127 such sites identified in New York by the National Audubon Society.

Hudson Raritan Estuary

Jamaica Bay

- The sub tidal shallows and wetland of Jamaica Bay are important habitat for benthic invertebrates, fish, and birds. The substrate is significant nursery ground for commercially and recreationally important fish such as the winter flounder (*Pleuronectes americanus*) and striped bass (*Morone saxatilis*). Other fish species commonly found in Jamaica Bay include Atlantic silverside (*Menidia menidia*), bay anchovy (*Anchoa mitchilli*), mummichog (*Fundulus heteroclitus*), and striped killifish (*F. majalis*). These species are important forage for predatory fish and birds that breed, migrate through, or winter in the study area. Other common species found in the study area include bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), and sea robin (*Prionotus* spp.). Under the conditions of the Magnusson-Stevenson Act Jamaica Bay has been designated by the NMFS as Essential Fish Habitat for numerous species and life stages of commercially or ecologically important fish (USACE 2004, 2009, 2011).

- Mudflats in the study area, such as those found in the Plumb Beach area, are important habitat for horseshoe crabs (*Limulus polyphemus*) and shorebirds. Each spring, horseshoe crabs congregate on these mudflats to breed. Migratory shorebirds that winter in the Geotropic and breed in the Arctic stop here during their migration to rest and feed on the horseshoe crab eggs. This phenomenon has been occurring for eons and species such as ruddy turnstones (*Arenaria interpres*) and red knots (*Calidris canutus*) rely on the horseshoe crabs for their survival. Islands characterized by a variety of habitats including salt marshes, intertidal mud flats, and uplands also exist within the region. These islands provide important habitat for colonial nesting waterbirds such as herons, egrets, gulls, and terns (USACE 2004, 2009).

- Anadromous species that use Jamaica Bay include Atlantic sturgeon (*Accipenser oxyrhynchos*), alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), and striped bass (*Morone saxatilis*) (USACE 2004, 2009).

- Breezy Point on the western tip of the Rockaway Barrier Beach sustains large populations of beach-nesting birds, and consistently supports one of the largest nesting colonies of piping plovers in the New York Bight coastal region (USFWS 1997, USACE 2009).

- Additionally roseate tern, the piping plover, seabeach amaranth, peregrine falcon, and northern harrier. Four different species of protected marine turtles have been found in the bay as well as marine mammals.

Arthur Kill/Kill van Kull

- The Arthur Kill/Kill Van Kull complex has been designated as a Significant Habitat Complex of the New York Bight Watershed by the USFWS (USFWS 1997, USACE 2009).

- With 7 tributaries (notably Fresh Kills Creek), this region offers much needed backwater habitat for important marine and estuarine fish species, such as winter flounder, black sea bass, and red hake (RPA 2003). This region also contains deepwater habitats in which over 60 migratory and resident fish species have been collected (USACE 2004).

- Remnant patches of undisturbed wetland and upland habitat include regionally-rare vegetative communities that include southern and coastal plant species like native persimmon (*Diospyros virginiana*), blackjack oak (*Quercus marilandica*), sweet bay (*Magnolia virginiana*), and a population of southern leopard frogs (*Rana sphenocephala*). These patches are important for landbirds, including neotropical migrant songbirds because they provide small areas of natural habitat for resting, foraging, and breeding in an otherwise urbanized landscape. Although these habitat patches can be important to many species of wildlife, their small size and isolation from one another reduces their habitat value for some groups of species, such as forest-nesting birds. (USACE 2004, 2009)

- The freshwater tributaries have the potential to provide spawning habitat for anadromous fish such as striped bass (*Morone saxitilis*) and alewife (*Alosa pseudoharengus*). However, in many cases, debris dams, tidegates, and other structures block fish passage.

Harlem River/East River/Western Long Island Sound

- The Western Long Island Sound provides important habitat for migratory and resident fish. Wetlands and sand beaches in this region provide significant wildlife habitat. A few of the more ecologically significant areas within Western Long Island Sound include Little Neck Bay, Manhasset Bay, Hempstead Harbor, and Pelham Bay (USACE 2004, 2009).

- The bays also are important nursery and foraging habitat for marine finfish, including striped bass (*Morone saxatilis*), scup (*Stenotomus chrysops*), bluefish (*Pomatomus saltatrix*), and winter flounder (*Pleuronectes americanus*) (USACE 2004, 2009).

- The Harlem and East Rivers are important migratory pathways for fish because they connect Long Island Sound and the Hudson River. However, many of these fish populations, like American eel, winter flounder and especially the Atlantic and shortnose sturgeons, are fractions of their historic population levels. The quality of habitat for fish in these waterbodies is degraded because the majority of the shorelines have been straightened, bulkheaded, and/or filled. The piping of tributaries to the Harlem and East Rivers has resulted in culvert outfalls as opposed to natural confluences. The piping of the freshwater tributaries has also led to a significant loss of potential spawning habitat for anadromous fish in the study area (USACE 2004, 2009).

- River herring (alewife and blueback herring) have been found in the lower portion of the Bronx River, but are absent from middle and upper portions due to dams and flow impediments (USACE 2010).

- The Bronx River Basin: bog turtle (*Clemmys muhlenbergii*) is a federally listed threatened species known to occur within Westchester County. State listed animals and plants include multiple amphibian, reptile, and bird species as well as the stiff leaf goldenrod (*Solidago rigida*) (USACE 2010).

- There are a limited number of beaches in the Western Long Island Sound. Although the existing beaches are small in size, they provide important nesting habitat for piping plovers (*Charadrius melodus*), least tern (*Sterna antillarum*), and northern diamondback terrapin (*Malaclemys terrapin terrapin*). Rocky offshore islands also exist in the study area. These islands support colonial waterbird colonies of regional significance .(USFWS 1997, USACE 2004, 2009)

Lower Bay

- The Lower Bay contains significant habitat for shellfish and marine, estuarine, and anadramous fish. Open water habitats are important for wintering and migratory waterfowl. Wetlands and uplands in the study area provide important nursery habitat for fish, foraging habitat for waterbirds and shorebirds, nesting habitat for diamond-backed terrapins, and migratory and wintering stopovers for songbirds, raptors, and shorebirds (USACE 2004, 2009).

- Over 90 species of fish have been reported in the Lower Bay. Resident species include mummichog (*Fundulus heteroclitus*), white perch (*Morone americana*), and hogchoker (*Trinectes macalatus*). Fish species of recreational importance include, but are not limited to, bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*) weakfish (*Cynoscion regalis*), and winter flounder (*Pleuronectes americanus*). The area is also an important stopover for migratory landbirds and shorebirds. During spring and fall migration sanderling (*Calidris alba*), ruddy turnstone (*Arenaria interpres*), and semipalmated sandpiper (*Calidris pusilla*) forage in the mudflats and subtidal shallows along the south shores of Staten Island (USACE 2004, 2009).

- Although the fish community in the Lower Bay study area is diverse, habitat quality for some species (particularly those that swim upstream to spawn) has been reduced as a result of human alteration of the landscape.

- The Lower Bay region also provides habitat for marine mammals and sea turtles.

Hudson River Estuary

- This region is located within a USFWS designated Significant Habitat Complex of the New York Bight Watershed (USFWS 1997).

- The regions wetlands also support a diverse community of reptiles such as northern water snake (*Nerodia sipedon sipedon*), diamond-backed terrapin (*Malaclemys terrapin terrapin*), and snapping turtle (*Cheldrya serpentine*) (USACE 2004, 2009).

- The Lower Hudson River includes a wide range of riverine and estuarine habitats that function as overwintering habitat and significant nursery areas for many fish and invertebrate species. Twenty-three fish species are common in the study area with bay anchovy (*Anchoa mitchilli*), winter flounder (*Pleuronectes americanus*), American shad (*Aalosa sapidissima*), Atlantic tomcod (*Microgadus tomcod*), and alewife (*Alosa pseudoharengus*) being the dominant species. The area is also extremely important nursery and wintering habitat for striped bass (*Morone saxitilis*). The conditions prevalent in pier, shoal, and inter-pier areas may be particularly important foraging and overwintering areas for juvenile fish as they move from nursery habitat upstream, to the more saline waters of the Estuary (USACE 2004, 2009)

- Haverstraw Bay Significant Coastal Fish and Wildlife Habitat area is a critical habitat for most estuarine-dependent fisheries originating from the Hudson River. This area contributes directly to the production of in-river and ocean populations of food, game, and forage fish species. Consequently, commercial and recreational fisheries throughout the Atlantic Coast depend on, or benefit from, these biological inputs from the Hudson River estuary. Haverstraw Bay is a major nursery and feeding area for certain marine species, most notably bay anchovy (*Anchoa mitchilli*), Atlantic menhaden (*Brevoortia tyrannus*) and Atlantic blue crab (*Callinectes sapidus*). Atlantic tomcod (*Microgadus tomcod*), bluefish (*Pomatomus saltatrix*), fourspine stickleback (*Apeltes quadracus*), Hogchoker (*Trinectes maculatus*), killifish (*Fundulus* spp.), rainbow smelt (*Osmerus mordax*), silversides (*Menidia menidia*), summer flounder (*Paralichthys dentatus*), threespine stickleback (*Gasterosteus aculeatus*), white perch (*Morone americana*), common carp (*Cyprinus carpio*), American eel (*Anguilla rostrata*) and white catfish (*Ameiurus catus*) are also found in this area.

- Haverstraw Bay regularly comprises a substantial part of the nursery area for striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), white perch (*Morone americana*), Atlantic tomcod (*Microgadus tomcod*), and Atlantic sturgeon (*Acipenser oxyrhynchus*). Other anadromous species, such as blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*), spawn in upstream freshwater areas, but move south and concentrate in this area before leaving the river in the fall. Depending on location of the salt front, a majority of the spawning and wintering populations of Atlantic sturgeon (*Acipenser oxyrhynchus*) in the Hudson may reside in Haverstraw Bay. Shortnose sturgeon (*Acipenser brevirostrum*) usually winter in this area as well. Croton Point is a place where common loons (*Gavia immer*) overwinter. Harbor seals (*Phoca vitulina*) use the surface waters of this habitat during winter months.

- Many acres of river habitat around the southern Rockland-Westchester County border have been designated "significant coastal fish and wildlife habitat" by the New York State Department of Environmental Conservation (NYSDEC) and the New York Department of State. The NYSDEC New York Natural Heritage Program has identified numerous sites where rare plant and animal species and exemplary natural communities occur in this area.

- This area provides habitat for several threatened and endangered species including the p*eregrine falcon (Falco pregrinus*), *shortnose sturgeon* (*Acipenser brevirostrum*), and Atlantic sturgeon (*A. oxyrhynchus*) (USACE 2004, 2009).

Upper Bay

- Many marine and estuarine finfish species, like bluefish, scup, striped bass, and winter flounder use the Upper Bay as nursery, foraging areas and overwintering habitat (USACE 2004a). It is considered a critical component of the HRE because it serves as a migratory pathway for many species of fish. Bay Ridge Flats (although severely reduced in size due to dredging) provide some habitat to many species of young fishes (USACE 2004, 2009).

- Diamond-backed terrapins (*Malaclemys terrapin terrapin*) are found in the study area (USACE 2004, 2009)

- The contamination of both marine sediments by chemical pollutants and heavy metals and the resulting spread of those materials through aquatic and terrestrial food chains have been recognized as key environmental problems. Numerous studies of the contaminant problems throughout the HRE region have been undertaken by various organizations and agencies, including the Environmental Protection Agency, the National Oceanic and Atmospheric Administration (NOAA), the USACE, and the States of New York and New Jersey, which have focused on the relationship between sediment contaminant levels and benthic habitat quality (USACE 2004, 2009)

II. Habitat Impacts from Hurricane Sandy - New York

- Sandy turned to the north-northwest and made landfall as a post-tropical cyclone on 29 October 2012 near Atlantic City, NJ with winds of 90 mph, causing extensive flooding, beach erosion, and coastal damage along the shorelines of Delaware, New Jersey, and New York. As Sandy approached landfall, it generated intense onshore winds, waves, and a storm surge that was augmented by astronomical spring tides associated with the full moon of 29 October.

- Within the New York and northern New Jersey area, Sandy had a larger effect on areas close to the Atlantic Ocean—Jamaica Bay, Sandy Hook, and Staten Island. Areas located farther upriver from the harbor saw little damage from flooding, although winds were still a factor. Areas around the harbor saw heavy flooding, carrying with it high volumes of sand, Phragmites wrack, and trash, which then further impacted inshore communities by covering understory plants in thick layers of debris. Farther north, reports from the Bronx River, the Hudson River and the Catskills all indicated little to no damage to the waterways. Flooding was reported from the banks of the Hudson only, and does not appear to have been as great as that seen in New York City. There was minimal damage to the shorelines.

In general, most observed damage was above the tide lines, and was primarily due to winds or flooding from the tide.

Coastal and Marine Habitats

Beaches and Dunes

- The erosion impacts and data described by the resource managers demonstrate that more than 50% of the beach and dune habitat in the Hudson/Raritan Jamaica Bay region and Long Island Sound suffered a similar fate (ALS 2012).

Hudson Raritan Estuary–NY/NJ Harbor Region (HRE)

- Storm surge level at Battery Park on the south tip of Manhattan topped out nearly 4 feet higher than the previous record set by Hurricane Donna in 1960. Similar to many areas of the Northeast, the peak surge associated with the storm hit within a half an hour of high tide that was already made higher than normal by the full moon.

- Staten Island, NY – In some places, the local topography was affected by the storm. For example, one bluff at Great Kills, reaching 10 to 12 feet high, was flattened into a gradual slope. The bluff served as nesting habitat for belted kingfisher (*Megaceryle alcyon)*, bank swallow, (*Riparia riparia*) and cliff swallow (*Petrochelidon pyrrhonota)* (HRF 2012).

- Oakwood Beach, Staten Island, NY – Contrast between areas that were protected by dunes and areas that were not is not clear. Impacted species include: Shorebirds, wading birds and invertebrates.

- Westchester Count , Manursing Lake, Edith Reade Sanctuary, Rye NY – The dunes and vegetation that stood between the Sound and the lake have been destroyed, leaving nothing but 200 feet of field and road to prevent further inundation to the salt marsh and lake (ALS 2012).

Long Island General

- Storm surge from Sandy created new habitat by adding sand to beaches and existing barrier and spoil islands, and moved other habitat by pushing sand and dunes westward. Dunes throughout Long Island were breached, flattened, washed away or pushed westward, leaving the beaches and marshes they protect vulnerable to impacts from future storms and surges.

However, without them, the damage would have been much worse and, in many areas, dunes were credited with major saves.

- Storm surge and resultant beach and dune erosion created problems by lowering the elevation of beaches throughout the project area.

- The force of the wind and storm surge caused numerous overwashes and resulted in three breaches on barrier islands along the south shore of Long Island. Two of those three breaches were on Fire Island and within the boundaries of Fire Island National Seashore: one at Old Inlet (within the Otis Pike Fire Island High Dune Wilderness Area), Smith Point County Park and the third in Cupsogue County Park (same as the 1980 Breach Location which will negatively impact the existing navigation channel at Moriches Inlet)

- The breaches at Smith Point County Park and Cupsogue County Park were closed in November 2012.

- The breach within the Otis Pike Fire Island High Dune Wilderness Area, the National Park Service is to determine if the breach will close naturally. That initial monitoring period passed at the end of December 2012. The breach remains dynamic, but by September 2013 no monitoring data has triggered the immediate closure of the breach.

North Shore of Long Island, NY – Long Island Sound Coast

- Elevation of nesting areas has been lowered, vulnerable to repeated flooding, overwash, and high or neap flooding, as well as, storm surges and wave action from future storms. Impacts species: Piping plover, American oystercatcher, least tern and common tern that breed and nest, migratory shorebirds such as sanderling, semipalmated sandpiper, ruddy turnstone, black-bellied plover and red knot.

- This low elevation problem was specifically observed at beaches along the North Shore, at Great Gull Island and Manursing Lake in New York.

- Along the north shore, storm created habitat for beach nesting shorebirds and other shore and migratory species, but also created new problems. Much of the new habitat is in areas heavily accessed by humans. If habitat is not known to municipalities and others, habitat can be damaged or lost in recovery efforts. This issue has been noted as a potential problem at the following locations: Orient Beach State Park, Orient, NY; Prospect Point and Half Moon Beach, North Hempstead, NY.

- Shoreline along Long Island Sound experienced Low Damage with a few areas of Moderate Damage associated with exposed points and islands: Hammonasset Point and inlets such as Oyster Bay and Northport Bay, in New York.

- Dune and/or beach erosion problems have occurred at the following areas along the north shore: Orient Beach State Park, Orient, NY; Prospect Point and Half Moon Beach, North Hempstead, NY.

- Great Gull Island located in New York off the Eastern End of Long Island Sound; Great Gull Island was completely breached in two locations by the storm. Additional large sections of beach along the edges of the island, including at both the north and south shores, where washed away. The significant erosion will impact this important habitat, which provides nesting sites for approximately 1600 pairs of federally endangered roseate tern, the largest colony in the Western Hemisphere, as well as 9500 pairs of common tern, a species listed as threatened in New York State.

- Asharoken Beach, NY – Asharoken has incurred major losses due to coastal erosion and flooding, while storms have accelerated shoreline erosion and inundated highly developed areas. The western section of Asharoken Avenue, in the proximity of the seawall had been exposed to erosive wave attack causing damage to the seawall and the roadway.

- North Fork, NY – The stormwater culverts, too few and too small, placed in and around the North Fork of Long Island were overwhelmed by the storm surge, causing massive inland flooding in this area.

South Shore (Atlantic Coast) of Long Island, NY

- Most extensive damages are along the South Shore of Long Island.

- Dune and/or beach erosion problems have occurred in Jones Beach, Wantagh, NY.

- Field Observations and Measurements of Coastal Change - Fire Island, New York:

  - The impacts to the island were extensive. The majority of oceanfront homes in the communities within Fire Island National Seashore were damaged or destroyed. Enormous volumes of sand were carried from the beach and dunes to the central portion of the island, forming large overwash deposits, and the island was breached in 3 locations. With few exceptions, lower-relief dunes were overwashed and flattened. High dunes, which are more commonly found within undeveloped portions of the island, experienced severe erosion and overwash. The elevation of the beach was lowered and the dunes form vertical scarps where they survived. Oceanfront homes were destroyed in the community of Davis Park. More damage of oceanfront houses along western Fire Island. Dunes were severely eroded and the beach elevation lowered during the storm.

  - Some key findings of the field data collection effort indicate that:

    - 50% of the dunes on Fire Island were overwashed during the storm, carrying large volumes of material to the interior portion of the island

        - In locations where the dunes remained intact, they eroded an average of 22m in cross-beach position

    - Three breaches of the barrier island occurred on the south shore of Long Island: Two of those three breaches were on Fire Island and within the boundaries of Fire Island National Seashore (FIIS): one (which is presently still open) in the area of Old Inlet (within the Otis G. Pike High Dune Wilderness Area) and another in Smith Point County Park. The third breach was at Moriches Inlet (Cupsogue County Park).

    - Resource managers familiar with the area (especially Fire Island National Seashore) consider the breach an opportunity for species recovery, including for hard clams, eelgrass, bay scallops, American eel and associated fish and waterfowl. Presently, breaches in New York's barrier islands are subject to closure pursuant to the Breach Contingency Plan prepared by the U.S. Army Corps of Engineers in partnership with the New York Department of Environmental Conservation. The breach at the "Old Inlet" is being evaluated by NPS to create a baseline from which to measure changes in the breach. At this time, no closure activities have been initiated and remain to be seen if documentation regarding the positive effects of the breach at Otis Pike will exclude it from closure operations.

- Seagate and Coney Island Public Beach, NY - Village of Seagate – The 0.6 mile shoreline experienced heavier wave damage than the public beach due to existing narrow beach and a lower berm height. This community experienced heavier storm damage and inland flooding due to a general low ground elevation and lower, narrower berm width. Beach erosion volume losses include reduced berm elevation and shoreline retreat. The waterfront bulkhead and first row residential building were severely damaged by storm waves.

    - Coney Island Public Beach - Based on the initial storm data and visual inspection, it was evident that the entire inspected area has been subject to general beach erosion resulting in shoreline retreat and lowering of berm elevations; storm surge induced inundation of the entire inland area; storm wave induced runup, overtopping, overwash, and damages to the waterfront structures including boardwalk, concrete wall, residential building, roads, and infrastructures.

    - Public Beach, Corbin Place west to W 37th Street - The entire area was inundated by storm surge. The ocean front shoreline retreated and berm elevation was reduced by storm waves. A portion of beach sand was carried landward by surging waves and overtopping waves.

- Atlantic Coast of New York City East Rockaway Inlet to Rockaway Inlet and Jamaica Bay, NY – The surveyed area encompasses approximately 6.2 miles of shoreline in the Borough of Queens, NY, a highly urbanized area of the south shore. Rockaway is a long, narrow peninsula bordered by East Rockaway Inlet to the east and Rockaway Inlet to the west. The Atlantic Ocean shoreline has been sub-divided into six study reaches in the current reformulations study. General issues included:

- Severe beach erosion resulting in shoreline retreat and lowering of dune and berm elevations
- Storm surge induced inundation of the entire inland area, up to approximately 4 to 5 feet above ground
- Storm wave induced runup, overtopping, overwash, and damages to the waterfront structures including boardwalk, concrete walls, residential buildings, roads, and other infrastructure

- Reach 1: Breezy Point to Beach 193rd Street, 2.2 miles - The entire area was inundated by storm surge from both ocean and bay. The ocean front shoreline retreated and there is evidence of dune wash-over by storm waves. The residential buildings were inundated, in addition to flooded basements and floors, outdoor decks; pavements were damaged by flood water and waves.

- Reach 2: Beach 193rd Street to Beach 149th Street, 2.0 miles - This reach includes Fort Tilden and Jacob Riis Park. Ocean front shoreline retreated and the berm elevation was reduced. The aerial photo indicates wave wash-over of dunes and damage to waterfront buildings. Flood water level exceeded the top deck of boardwalk and the interior of the park building were damaged by flood water and waves.

- Reach 3: Beach 149th Street to Beach 109th Street, 1.8 miles - This stretch of shoreline has experienced heavy erosion, wave damage, and flood inundation. The average shoreline retreat is approximately 100 ft. and the berm has lowered 4 to 5 ft. In addition to beach erosion, the first row buildings, concrete walls, and infrastructure were damaged by waves riding on storm surge.

- Reach 4: Beach 109th Street to Beach 86th Street, 1.0 miles - Similar to Reach 3, this reach experienced heavy storm wave erosion, building damage, and shoreline retreat. The observed shoreline retreat is up to 100 ft. with up to 5 ft. berm lowering. Sand dune under boardwalk was washed on street and all timber decks were destroyed.

- Reach 5: Beach 86th Street to Beach 42nd Street, 2.3 miles - This reach experienced relatively lower storm damage. Average shoreline retreat was less than 50 ft. and the average berm lowering was 2 to 3 ft., possibly due to protection of the rock groin field. The timber deck on one boardwalk was destroyed and the shoreward ends of timber groins were exposed.

- Reach 6: Beach 42nd Street to Beach 19th Street, 1.0 miles - Both shoreline retreat and beach berm lowering are evident in this reach. The mean high water shoreline has retreated near the boardwalk. Timber deck on boardwalk is destroyed with remaining concrete pier. Average shoreline retreat is 100 ft. with lowered berm elevation.

- Atlantic Coast of Long Island, Fire Island Inlet and Shores Westerly to Jones Inlet, Long Island, NY – Site visit observations post-storm (11/15/12) showed a general drop in elevation of the sand berm along the entire barrier island, resulting in a post-storm profile that is low and flat.

Observations show drop in elevation on the order of 2-5 feet with greater loss at dunes. Established dunes showed vertical scarping generally along the ocean face of the dune. Berm lowering was also evidenced by exposed piles on buildings, and exposure of previously buried building remnants at the old Coast Guard Station, as well as ponding on the berm face at Oak Beach. Overwash of water and sand onto the roadway was widespread over the entire Project area.

- The Fire Island Inlet to Montauk Point (FIMP), NY, including Moriches to Shinnecock Reach – A distance of approximately 83 miles. The primary impact to the project is loss of beachfill material within the project dune and berm cross-section. Storm impacts to the beach cross-section consist of lowering and flattening of the berm above water, reduction of berm width, and damage to the dune cross-section. Lowering and flattening of the berm occurred over the entire project length (Groin 7 through to the Park Facility at Cupsogue) with an estimated average drop in beach elevation of 5-8 feet. Berm widths decreased in along the entire project shoreline. The primary dune, initially constructed in 1996, located most landward, suffered at least 50% to almost 80% volume loss for 4,100 feet, out of 10,000 ft. of dune Groin 15 to the western limit of the project within Cupsogue Park. Secondary lower dunes, more ocean-ward were destroyed along 9,300 feet of the project length. Within the groin field from groin 7 through groin 15, the beaches lowered and receded, and there were significant impacts to the most ocean-ward dunes. There was evidence of wave runup over the primary landward dune and overwash of ocean water in some project locations. Overwash of sand over the existing dune occurred at Pike Beach. Beach and dune profiles show the extreme loss of protective berm and dune and berm due to the effects of Hurricane Sandy.

Barrier Islands/Inlets

Inlets

- Highly dynamic barrier feature, critical to migrant shorebirds, critical to nesting shorebirds, important for nesting of some seabirds and were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).
    - Vast areas of inlet, beach, and overwash habitats have been created on the New York and New Jersey coasts. These areas may provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013a).

Barrier Islands

- Critical to nesting seabirds and shorebirds, critical to migrant and wintering shorebirds for feeding and roosting, important to migrant and wintering seabirds and were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).
    - Barrier sand beach systems are critical to obligate beach-nesting shorebirds and seabirds, migrant shorebirds and seabirds, and important feeding areas for some

species of wading birds and were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).

- Possibly impacted spp: American Bittern, American Black Duck, American Oystercatcher, Atlantic Brant, Black-bellied Plover, Black-crowned Night-Heron, Black Rail, Black Skimmer, Black Tern, Canvasback, Caspian Tern, Common Tern, Dowitcher species, Forster's Tern, Great Black-backed Gull, Great Blue Heron, Great Egret, Greater Yellowlegs, Green Heron, Gull-billed Tern, King Rail, Least Bittern, Least Tern, Little Blue Heron, Laughing Gull, Marsh Wren, Northern Pintail, Piping Plover, Ruddy Turnstone, Red Knot, Roseate Tern, Sanderling, Saltmarsh Sharp-tailed Sparrow, Seaside Sparrow, Semipalmated Sandpiper, Snowy Egret, Tricolored Heron, Willet, Whimbrel, Yellow-crowned Night-Heron, Yellowlegs species.

Wetlands (Coastal and Freshwater)

- Inundation of tidal marshes and intertidal sediment/substrate was prevalent throughout the coastal area.

Coastal Marshes

- Hurricane Sandy moved massive amounts of coastal sediments with the extreme power of storm-driven water, changing barrier landscapes, eroding important bird nesting islands, and blowing out dikes of impoundments managed specifically for breeding, migrating, and wintering shorebirds, seabirds, wading birds, and waterfowl. Important habitats for high priority species like Piping Plover, Red Knot, American Black Duck, Tri-colored Heron, Least Bittern, and American Oystercatcher have been altered by this storm (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).
  - Potentially Impacted Species:
    - American Oystercatcher
    - Black Skimmer
    - Gull-billed Tern
    - Least Tern
    - Piping Plover
    - Roseate Tern
    - Red Knot
    - Ruddy Turnstone

- Saltmarsh Systems – including marsh hammocks are critical to saltmarsh obligate breeders, important to feeding nesting and roosting wading birds and migrant shorebirds (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).
    - Potentially impacted saltmarsh species:
        - American Black Duck
        - Atlantic Brant
        - Black-bellied Plover
        - Black Rail
        - Black Tern
        - Forster's Tern
        - Greater Yellowlegs
        - Little Blue Heron
        - Marsh Wren
        - Nelson's Sparrow
        - Saltmarsh Sparrow
        - Seaside Sparrow
        - Tricolored Heron
        - Whimbrel
        - Willet
- Managed coastal salt marsh – important for shorebirds and wading birds.

Hudson Raritan Estuary - Coastal

- Coastal salt marshes were impacted to a much lesser degree showing much higher resistance to storm surge. Raritan-Bay marshes experienced some moderate damage but mainly low levels of damage. Bulk of the issues lay with the associated marsh communities. The small mammal population has been reportedly "wiped out" in many areas, creating a food shortage for the northern harriers that prey upon them. The impacts and implications of the storm to invertebrates has been described as a “big unknown” but could be devastating to the long-legged wading birds that prey upon this community, including great blue heron, blackcrowned night heron, yellow crowned night heron, snowy egret, great egret, American bittern, least bittern, glossy ibis and white ibis. The need to further assess the impacts to these communities and to the species that depend upon them as a food source was noted as an important source of concern by resource managers throughout the study area (ALS 2012).

  - Wrack deposits were visible in many back-bay marsh areas, often at the marsh/upland forest edge. Soundview Park, Bronx River Forest, Bronx, NY – Recent salt marsh restoration area intact (ALS 2012).

- Staten Island, NY – Of the areas discussed in the surveys, the east side of Staten Island was the most affected by Sandy. That area experienced the full force of both the winds and the tidal swelling. Human structures up and down the coast were destroyed and there is evidence that much of the coastal habitats were greatly affected as well. Sand was pushed inland up to 60 feet from the shore, in one spot, up to about 150 feet inland,and much of the nearshore understory was covered up to three inches deep in sand (HRF 2012). Mats of *Phragmites australis* were also washed inwards, smothering understory plants up to 300 to 400 feet from the shore, and were even found in tree branches 10 feet up (HRF 2012). Impacted species include: shorebirds, invertebrates small mammals, belted kingfishers, bank swallows, cliff swallows (HRF 2012).

- The west side of Staten Island, NY also experienced flooding damage, but relatively little wind damage. The shores showed some erosion, with sizable sections of shoreline carved out by water in locations (HRF 2012).

- Wrack deposits were visible in many back-bay marsh areas, often at the marsh/upland forest edge. This was especially evident in Jamaica Bay. The analysis may underestimate the amount of wrack deposit, especially where obscured by dense *Phragmites* reed stands or maritime shrubs and scrub (ALS 2012).

- Five marsh islands restored by the U.S. Army Corps of Engineers within Jamaica Bay from dredged material obtained from the NY/NJ Harbor Deepening Project showed significant amounts of debris, but no damage to existing plantings and no significant shift in sand placement on the islands, including to the two most recently established sand-only islands. A resource manager involved in the project noted that the islands “did exactly what they were supposed to do” by absorbing the energy of the waves and storm surge. (ALS 2012)

Freshwater Wetlands

- Outerbridge Crossing - It is currently unknown whether flooding and saltwater inundation in this area impacted the habitat of a new species of Leopard Frog discovered in Staten Island in 2009 (ALS 2012).

- Staten Island, NY – Freshwater Brown's Pond surrounded by dead fish mostly carp, most likely due to saltwater inundation. Impacted species include: Carp, other fish, ducks, and freshwater dependent shorebirds.

- Westchester County NY - Manursing Lake, Edith Reade Sanctuary, Rye NY – Manursing Lake was the subject of a major two-part restoration project completed in 2011. The first part replaced an outdated, manually operated tidal gate with a more effective, electronically controlled gate that improved tidal flow in and out of the lake and improved its connection to Long Island Sound. The second part restored and created coastal habitat, including a tidal creek, salt marshes and the lake's southern shoreline. Impacts to this area from Sandy are significant. The dunes and vegetation that stood between the Sound and the lake have been destroyed, leaving nothing but 200 feet of field and road to prevent further inundation to the salt marsh and lake. Enormous amounts of sand and rock have been pushed onto the fields and access roads, and sections of the salt marsh have been buried by sand and debris. Portions of the lake shore have eroded, and some cliffs at the north end of the beach have eroded significantly.

Tidal Marsh

- Inundation of tidal marshes and intertidal sediment/substrate was prevalent throughout the coastal area, with some reportedly under water for more than five days. The small mammal population has been reportedly "wiped out" in many areas, creating a food shortage for northern harriers and other species that prey upon them. The impacts and implications to the invertebrates has been described as a "big unknown" but could be devastating to the long-legged wading birds that prey upon this community, including great blue heron, black crowned night heron, yellow crowned night heron, snowy egret, great egret, American bittern, least bittern, glossy ibis and white ibis (ALS 2012).

Critical/Significant Habitats

Water Birds Islands/Shorebirds

- Coastal Flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013a).

Hudson Raritan Estuary

- Pralls Island, located in the Arthur Kill off of Staten Island, NY – Prall's Island was once the source of the area's largest heron and egret colonies. The island suffered from a complete overwash from the storm surge, as well as damage to trees and other plants from the both the surge and high winds. Debris that was previously scattered along the island's edges is now piled in the middle and deer fencing established to protect heron nesting areas has been knocked down. In addition, the salt marshes on the island were covered with oil from the spills in the Arthur Kill. Several oil-covered birds were brought to a rehabilitation facility on Staten Island by volunteers (ALS 2012).

- Impacts to Prall's island, particularly the marshes, threaten the long-legged wading birds that inhabit them, including glossy ibis, blackcrowned night heron, little blue heron, snowy egret, cattle egret, and great egret (ALS 2012).

Coastal and Maritime

- Damage to maritime or coastal zone forests was more difficult to assess, but a number of locations did show blow-down of trees and canopy gaps. However, a comparatively smaller percentage of the area was assessed at Moderate Damage NY Harbor and Long Island Sound study areas respectively, and Low Damage for NY Harbor and Long Island Sound study areas respectively.

Hudson Raritan Estuary

- Soundview Park, Bronx River Forest, Bronx, NY Soundview Park in the Bronx River Forest, NY– The surrounding area suffered wind damage; loss of trees opened holes in Bronx River Forest canopy. Tree branches create habitat in river for American eels. Opportunity for invasive species (ALS 2012).

- New York Botanical Gardens, NY – More than 200 trees were downed.

North Shore of Long Island, NY

- Transition of Native Tree Habitat, North Fork, Long Island NY – The storm felled many large trees along the roadways and in the suburban neighborhoods of the North Fork area. As with other storms, homeowners and government entities are replacing the felled trees, which are typically large native species such as pines, oaks, elms, sycamores, and beech trees, with smaller ornamentals. This tree replacement process has become a disturbing and continuous trend, and, over time, is completely changing the ecology of the area. Non-native ornamentals drastically reduce the carrying capacity of native insect herbivores and the animals that depend on them.5 Since 96% of terrestrial North American birds raise their young on a diet of insect protein, more native trees in a given area means more food and more birds. In addition, the planting of ornamentals changes the overall canopy height, affecting the nesting habitat potential for large birds, including owls, hawks and bald eagles which have recently been recolonizing in the North Fork (ALS 2012).

Quality

HTRW

Hudson Raritan Estuary

- Significant contamination to waterways occurred during the storm from the flooding of industrial facilities located adjacent to waterways and from antiquated and inoperable sewage treatment plants. Some notable contamination events include the following:

- Oil Spill Contamination – Arthur Kill waterway, marshes and tributaries – As the storm surge flooded the banks of the Arthur Kill, several bulk fuel tanks were damaged, releasing nearly 378,000 gallons of diesel fuel into the water. Oil contamination from this and two smaller oil spills in the area was far reaching, and oil coated the marshes along the shores of Staten Island and New Jersey. Impacted species include: Fish, invertebrates, small mammals, wading birds (ALS 2012).

- Oil Spill Contamination – Affected the birds and marshes of Prall's Island and the birds, marshes and grasslands of the Outerbridge Crossing area- the known habitat of a recently discovered new species of Leopard Frog Impacted species include: Glossy ibis, blackcrowned night heron, little blue heron, snowy egret, cattle egret, great egret, invertebrates, small mammals (ALS 2012).

- Sewage – Flooded by the storm surge and rendered inoperable due to power outages, several major sewage treatment plants released raw or partially treated sewage into local waterways. State officials issued advisories for the waters of the Hudson, Newark and Raritan Bays and the Arthur Kill and the Kill van Kull. Impacted species include: Fish, invertebrates, small mammals, wading birds, Leopard Frog (ALS 2012).

- Oyster habitat – Runoff from Hurricane Sandy is laden with sediment, contaminants and debris all pose a significant threat to the health of oyster reefs and shellfish beds along the Atlantic Coast.

III. Future Without Action Conditions - New York

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem- Coastal Sand Dunes/Sandy Shorelines/Beaches/Pebble Shoreline/Beaches

Atlantic Coast of New York

- The South Shore of Long Island has a long history of inlet and beach management activities within its bays and estuaries, and along its barrier beaches. Over years, impacts to littoral ecosystems, including sediment transport processes, significant weather events, and human interference have resulted in sediment-related problems for the shorelines and coastal watersheds of the Atlantic Coast of Long Island. As Tanski points out in his 2007 report on Long Island's Dynamic South Shore, short-term changes in sea level caused by storms are much larger than those associated with the long-term trends as the frequency and intensity of the storms and the supply of sand in the system available for building the beaches play a far bigger role in shaping the coast.

- From a planning perspective up to 50 years, the biggest impact of an increased rate of relative sea level rise will be the submergence of the flat, low lying areas around the bays on the south shore. Communities in these areas could be subject to increased flooding and erosion if there is not room for migration (Tanski 2007). Threats to communities from flooding are especially evident in the highly urbanized western portion of the Atlantic Coast (Coney, Rockaway and Jones Islands) while erosion threatens the sandy beaches, dunes and glacial bluffs in the headlands region east of Southampton (Titus and Strange 2008; LISHRI 2003).

- Within the USACE-New York District Area of Responsibility, beach erosion control and storm damage reduction projects extend continuously along the entire Atlantic Coast of Long Island from Coney Island to Montauk Point. These projects all include beach nourishment/re-nourishment for 50 years after initial construction, with some additional features for some areas, such as dunes, berms, jetties and groins. Additionally, the NY District has executed a Breach Contingency Plan to expedite the Corps response time to implement emergency measures in cases where the formation of permanent breaches or new inlets change bay hydrodynamics causing damage to communities and built environment. The following beach erosion control and storm damage reduction projects cover the Atlantic Coast of Long Island: Rockaway Beach, Long Beach, Point Lookout/ Jones Inlet / Gilgo Beach, Fire Island to Montauk Point (FIMP), Coney Island and Montauk Point. Additionally, some of these areas are monitored and maintained under National Parks Service.

- Coastal storm risk management measures such as nourishing and widening eroding beaches along the Atlantic Coast of Long Island can provide many benefits, such as habitat for threatened and endangered plants (seabeach amaranth, seabeach knotweed); creation and protection of back bay habitat as well as habitat behind dunes or next to beaches; creation or restoration of habitat lost through erosion, for shorebirds and other beach organisms (including protected species such as the piping plover, black skimmer, least tern and roseate tern); and create new nesting areas for protected species (piping plovers) and spawning grounds for other species. However, artificial disruptions to natural process such as closure of breaches can disrupt the natural process of beach migration, bay flushing, wetland formation and barrier island replenishment.

Long Island’s South Shore Barrier Island/Back Bay System

- The back bays of the south shore include, from west to east, Hempstead Bay, South Oyster Bay, Great South Bay, Moriches Bay and Shinnecock Bay. These bays have been designated significant habitat complexes by the US Fish and Wildlife Service (USFWS 1997). The back bays and inlets of Long Island have a long history of inlet and beach management activities and the majority of the mainland back bay beaches are hardened with sporadic recreational community beaches.

- The shorelines of Long Islands back bay system will likely have a varying response to sea level rise. In areas with adequate sediment supply and no artificial or natural barriers, shoreline habitat will be able to migrate landward. However, at increased rates of SLR and in cases of inadequate sediment supplies, the effects are difficult to assess and will likely include more significant loss of habitat, accelerated erosion and limited landward migration of beach dune systems (NYS SLR Task Force 2010).

- Within the managed South Shore Barrier Island/Back Bay System, as sea levels rise, many beaches will erode to the point in front of shoreline protection structures and would be eventually lost without continual beach nourishment. Because the Back Bay System contains regionally significant habitats for fish, shellfish and birds, loss or reduction of this habitat could have a significant negative impact on species such as the diamondback terrapin, roseate tern, the federally listed piping plover and a large number of shore birds that rely on horseshoe crab spawing areas during spring migration (Titus and Strange 2008).

- The eastern bays (Great South Bay, Moriches, Shinnecock) are within the USACE Fire Island to Montauk Point (FIMP) study authority. The purpose of this study is to identify, evaluate and recommend long-term solutions for hurricane and storm damage reduction for homes and businesses within the floodplain extending along 83-miles of ocean and bay shorelines from Fire Island Inlet to Montauk Point. The study team is developing long-term, comprehensive plans for storm damage reduction, which maintains, preserves or enhances the natural resources through advancing five key physical processes that need to be sustained, restored, or enhanced to re-establish protective features. These processes include longshore sediment transport, cross-shore sediment transport, dune growth and evolution, bayside shoreline processes and circulation. In response to these concerns, the project proposes natural protective features including wetland restoration and creation of overwash features that may help to mitigate existing issues such as water quality, loss of back bay beaches and potentially fortify the back bays from storms. Resource Agencies have commented that FIMP will preclude the occurrence of severe overwash and breaching.

North Shore of Long Island

- There are several major rivers, embayments, maritime beaches and dune systems along the north shore of Long Island that sustain a diversity of species. These embayments and harbor complexes contain abundant invertebrate fauna and provide foraging, habitat and nesting sites for many species of migrating and rare shorebirds, horseshoe crabs and nesting diamondback terrapins. Notable undeveloped barrier beaches along the north shore of Long Island include the sandy beach barrier system fronting Hempstead Harbor (a typical example of this areas beach systems), the beach-wetland system on Eatons Neck Point, the Port Jefferson Beaches near the Town of Brookhaven, the Nissequogue Inlet Beaches at the mouth of the Nissequogue River in the Town of Smithtown (Titus and Anderson 2009; Titus and Strange 2008).

- The north shore of Long Island is generally characterized by high bluffs of glacial origin, making this area less susceptible to problems associated with increased sea level (Titus and Anderson 2009). However, barrier beaches may be at risk because sea level rise will accelerate headland erosion, which is the dominant type of beach development process along the Sound's Long Island shoreline (LISHRI 2003, Titus and Strange 2008). Additionally, since Long Island Sound is densely populated and highly developed, it is likely that the majority of the shoreline will be hardened as a response to SLR, disrupting the movement of sand and the formation of beaches (Titus and Anderson 2009).

- There are currently no authorized long term USACE storm damage reduction projects along the majority of the north shore of Long Island. Maintenance dredging from Corp navigation project such as Mattituck Inlet is providing sand nourishment to adjacent erosion prone areas; and New York State projects at Sunken Meadow State Park may help absorb storm impacts although there is not a lot of dune habitat particularly in the area of Huntington Harbor to Cedar Beach (Titus and Strange 2008). However, over time the resources along this shoreline will likely experience loss of sand and erosion of bluffs, beaches and wetlands due to natural processes.

The Peconic Estuary

- Cedar Point Peninsula in the Peconic Estuary contains a notable undeveloped barrier beaches. Barrier beaches are less common than tidal wetlands in the Peconic Estuary study area, but beaches may risk because sea level rise will accelerate shoreline erosion (Titus and Strange 2008).
- There are currently no authorized long term USACE storm damage reduction projects within the Peconic Estuary.

Hudson Raritan Estuary

- The Hudson Raritan Estuary (HRE) is a system of bays and tidal rivers where the Hudson, Hackensack, Passaic, Rahway, and Raritan rivers meet the Atlantic Ocean (National Geographic website). The HRE is within the boundaries of the Port District of New York and New Jersey, and is situated within a 25 mile radius of the Statue of Liberty National Monument. The following HRE sections throughout the document refer to the regions that lie within New York State.

- The HRE within New York State contains regionally significant fish and wildlife habitat interspersed with some of the most heavily urbanized areas in the country. Most shorelines in this region are modified and planners indicate that the remaining shorelines will likely be modified in the future. Where modifications occur, New York City's Waterfront Revitalization Program (WRP) requires the use of natural/nature based alternatives such as beach nourishment, dune construction, and vegetation wherever possible. There are relatively few areas of beach remaining in the New York City Metropolitan Area and beach nourishment is planned or under way for most of them.

- Jamaica Bay has been designated and mapped as a protected beach unit pursuant to the federal coastal barriers resource act. Several islands in Jamaica Bay contain dredged sand, so they now have sandy beaches. Sandy beach also exists from Breezy Point tip to Fort Tilden (at Flatbush Avenue). Floyd Bennett Field is entirely on top of former saltmarsh and estuarine beach; this artificial island now has sandy beach along more than half of its shoreline, although portions have a bulkhead farther inland. Because of the importance of beach species (invertebrates, horseshoe crabs) for estuarine food webs, along with the critical habitat these beaches provide for shorebirds, diamond back terrapins and rare species, scientists have raised concerns about the ecological implications of the loss of estuarine beaches. Continued loss of the few remaining sandy habitats in the study region would be particularly serious for diamondback terrapin, which only nest in these habitats. Because so few beaches remain, local planners indicate that beach nourishment in the face of sea level rise is required to maintain most remaining beach habitat in this area (Titus and Strange 2008).

South Shore of Staten Island

- USACE currently has an authorized storm damage reduction study along the south shore of Staten Island. The study area covers approximately 13 miles of coast on Staten Island, extending along lower New York Bay and Raritan Bay from Fort Wadsworth to Oakwood Beach. The area has a long history of storm damage. The shoreline experienced major erosion and storm damage from the Northeaster of December 1992, the March 1993 storm and most recently, Hurricane Sandy in October 2012. These storms caused evacuation in several communities, damage to hundreds of structures from flooding and loss of over hundreds of structures from erosion. The loss of beachfront now leaves the area increasingly vulnerable to severe damages even from moderate storms. The storm damage reduction study includes the optimization and selection of structural line of protection (seawalls, revetments and levees) and interior drainage improvement plans, from Fort Wadsworth to Oakwood Beach. This USACE plan of action links to Staten Island Bluebelt (see wetlands section below).

- A second phase of the project, currently in study phase, proposes beach fill along the future structure from Fort Wadsworth to Oakwood Beach portion of Staten Island. Without continual nourishment of sand this area, the South Shore of Staten Island will be subject to increased degradation and erosion of remaining habitats fronting the structure. Sandy beaches are common along the shores of Staten Island from Tottenville to Ft. Wadsworth and the second phase of this project (study phase) includes some nourishment and storm protection measures along the western portion of the Staten Island shoreline from Tottenville to Annadale. From Annadale west the shoreline has a higher elevation due to natural cliffs and bluffs which provide protection from storms but are subject to erosion.

Western Long Island Sound

- Orchard Beach is located in Pelham Bay Park on the northeast shore of the Borough of the Bronx, New York, at the western end of Long Island Sound. It is an artificial beach constructed by the City of New York between 1935 and 1937. Erosion of the shoreline had reduced the size of the recreational beach and a USACE storm damage reduction beach nourishment project was completed in 2011. While this project was built to protect the structures behind the beach it provides secondary benefits of protecting critical habitat within the park.

New York City

- In June 2013, NYC Department of City Planning released the ‘Special Initiative for Rebuilding and Resiliency Report (SIRR). The measures which range from beach nourishment and creation of habitat to hard structures will, at full build, form the city's comprehensive coastal protection system. While some measures can begin immediately, many are in the initial planning phase and will require partnerships and concurrence with other governmental entities.

- The City's plan for coastal protection focuses on the below listed coastal protection strategies. The report highlights 37 specific initiatives to implement these strategies (see report: NYC Department of City Planning. June 2013. Special Initiative for Rebuilding and Resiliency Report, for selected locations of each initiative):

    - Increase coastal edge elevations - To address this risk, the City plans to increase the height of vulnerable coastal edges with various structural methods, including beach nourishment, over time. This adaptive strategy allows for ongoing monitoring of sea level rise and investment as and where needs arise.

    - Minimize upland wave zones- To address this risk, the City plans to work to provide significant attenuation of waves both off and onshore, before they reach neighborhoods, with a combination of traditional to nature/natural based engineering solutions. This approach will reduce potential damage to structures, reduce erosive forces on the shoreline, and protect infrastructure.

    - Protect against storm surge- To do this, the City plans to use flood protection structures, such as floodwalls, levees, and local storm surge barriers built, where possible, to the 100-year flood elevation with an additional allowance for future sea level rise. Generally, the City seeks to implement measures that minimize damage if overtopped.

- To ensure the successful implementation of the strategies outlined above, the City also plans to make improvements to the design and governance of coastal areas. Specifically, the City has plans to study how natural areas and open space can be used to protect adjacent neighborhoods and maintain neighborhood quality of life, and will work to manage its own waterfront assets more effectively, while also developing partnerships to improve permitting and study innovative coastal protections.

Jamaica Bay

- Much of the bay's shoreline has been hardened with seawalls and bulkheads, so estuarine sandy beach habitat is now uncommon. Remaining estuarine beaches occur off Belt Parkway (e.g., Plumb Beach) and on the bay islands. Several islands in Jamaica Bay contain mountains of dredged sand (on top of salt marshes), so they now have sandy beaches. Sandy beach also exists from Breezy Point tip to Fort Tilden (at Flatbush Avenue). Floyd Bennett Field is entirely on top of former saltmarsh and estuarine beach; this artificial island now has sandy beach along more than half of its shoreline, although portions have a bulkhead farther inland. It is assumed that the these beaches will disappear without nourishment due to the highly urbanized area of Rockaway peninsula, the degraded condition of the bay and the Rockaway Inlet to East Rockaway storm damage reduction project.

Jamaica Bay Sea Level Rise

- The USACE New York District East Rockaway Inlet to Rockaway Inlet (Rockaway Beach) flood control project covers the area along the shoreline of the Rockaway Peninsula within the Borough of Queens, New York City. The objective of this study is to find a long term, cost-effective solution to the effects of continued erosion on the Rockaway peninsula. Beach nourishment is currently underway and involves the placement of more than 3.5 million cubic yards of sand stretching from Beach 19th Street to Beach 149th Street to repair and restore the Rockaway coastline which was severely damaged by Hurricane Sandy.

Barrier Islands/Inlets

Atlantic Coast of New York

- Long Island's South Shore Barrier Islands protect the coast from severe storms and support unique ecological communities. Many of the bays and estuaries enclosed by barrier islands on the south shore of Long Island are designated as Significant Coastal Fish and Wildlife Habitat Areas by the New York State Department of State (NYS SLR task force 2010).

- In response to sea level rise, barrier islands migrate landward as sand is transported across the island from the ocean to the bay. This process occurs at varying rates along the south shore of Long Island. There are three primary ways that sand can be transported across a barrier island: inlet formation, overwash processes and eolian (or wind) transport (Tanski 2007).

- Short-term changes in sea level caused by storms are much larger than those associated with long-term trends such as relative sea level rise, therefore the greatest impact to barrier islands over 30-50 year planning periods can be expected from storms and disruption of sediment transport by human activity (Tanski 2007, NYS SLR task force 2010). Over longer planning time frames, an increasing sea level means we will be faced with erosion problems for the foreseeable future (Tanski 2007). High rates of projected sea level rise may lead to increased overwash, breaching of new inlets, and the eventual disappearance of barrier islands altogether if the system cannot supply a sufficient amount of sand (Tanski 2007, NYS SLR task force 2010).

- Within the USACE-New York District Area of Responsibility, beach erosion control and storm damage reduction projects extend continuously along the entire Atlantic Coast of Long Island (see above discussion on Atlantic Coast of New York Ocean Beach and Dune Ecosystems, for a list of projects). Additionally, all inlets and navigation channels along the Atlantic Coast of Long Island are periodically maintained to their authorized depths through dredging for navigation purposes with nearby beneficial placement of dredge material. These include Rockaway Inlet, East Rockaway Inlet, Jones Inlet, Fire Island Inlet, Moriches Inlet and Shinnecock Inlet. While these measures protect and stabilize the shorelines and inlets, they also alter the naturally dynamic nature that allows barrier islands to persist.

Coastal Wetlands- Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries/Bays

Long Island's South Shore Barrier Island/ Back Bay System

- There are extensive wetlands, including vegetated marsh islands and non-vegetated tidal flats present along the Back Bays and South Shore of Long Island throughout Hempstead Bay, South Oyster Bay, Great South Bay, Moriches Bay, Shinnecock Bay and along Southampton. These wetlands provide nesting and feeding habitat for a variety of shorebirds, wading birds and waterfowl and support rare bird and plant species. The Back Bay waters have been designated as Significant Coastal Fish and Wildlife Habitat by the New York State Department of State (NYSDOS); and as Significant Habitat and Complexes of the New York Bight Watershed by the US Fish and Wildlife Service (USFWS).

- Remaining Back Bay marshes are particularly notable because much of the historically large area of marsh on the mainland shoreline has been lost to development and shoreline armoring (Titus and Strange2008). Although many wetlands areas in the Back Bay waters are under public ownership and therefore not likely to be developed the areas are subject to significant disturbances including recreational usage, increasing mainland development and fisheries disturbances that may pose a threat to wildlife species dependent on these areas (USFWS 1997).

- The historical trend of wetland losses is dominant in the Back Bay waters, however, the exact cause and pattern of wetland gains and losses is difficult to establish. A tidal wetland trend analysis conducted by the NY State Department of Environmental Conservation (NYSDEC) determined that wetlands have increased in some areas of Shinnecock and Moriches Bays by 250 acres due to landward migration, but losses have also been detected in other areas of these particular bays (NYS DEC http://www.dec.ny.gov/lands/4940.html).

- Marshes may be able to further migrate landward in some areas of the Back Bays if there is room to retreat. Development and shoreline protection are widespread and permitted outside this buffer. Further, Titus and Strange (2008) point out that these opportunities may be limited as much of the mainland shoreline in southern Nassau County is bulkheaded, and the rural areas that remain in eastern Suffolk County are likely to be developed in the future.

- If sea level in the back bays rises faster than sediments can be supplied to marshes, they could eventually be flooded and replaced by open water (Tanski 2007). Changing the hydrology and causing local populations to move elsewhere in search of suitable habitat (Titus and Strange 2008).

- The extensive shallow water habitat and tidal flats along Long Island's southern shoreline are a diverse and productive ecosystem that are heavily used as nursery and foraging habitat by many species of estuarine fin fish, shorebirds, raptors, colonial waterbirds and waterfowl as well as several edible shellfish species. If shoreline waters become too deep for foraging on these flats, migrating shorebirds could have insufficient foraging areas to support their long-distance migrations (Titus and Strange 2008) and USFWS scientists have asserted that loss or degradation of key sites could devastate shorebird populations as populations utilize few areas during migration (Titus and Strange 2008).

- The eastern bays of Long Island's south shore (Great South Bay, Moriches, Shinnecock) are covered by the USACE FIMP study which aims to preserve the natural habitat through advancing these five key physical processes that need to be sustained, restored, or enhanced to re-establish protective features- Longshore sediment transport, cross-shore sediment transport, dune growth and evolution, bayside shoreline processes and circulation. Additionally, the project proposes habitat restoration in the bays including wetland restoration and creation of sand spit. This may help to mitigate existing issues such as water quality and potentially provide protection to the western marsh complex through re-establishing natural processes and fortifying the barrier island against breaches.

North Shore of Long Island

- In general tidal wetlands along the north shore are limited; the glacial terminal moraine resulted in steep uplands and bluffs and more kettle-hole wetlands, such as Mount Sinai, along the eastern portion (LISHRI 2003). On the north shore of Long Island the primary areas of marsh are found in and around Stony Brook Harbor and West Meadow and bordering the Nissequogue River (Titus and Anderson 2009).

- There are locations in the study area with naturally steep shorelines that will interfere to varying degrees with marine transgression of tidal wetlands in response to rising seas (Titus and Strange 2008). In the eastern portion there has already been a significant loss of the historical area of vegetated tidal wetlands, which some scientists partially attribute to sea-level rise (Titus and Anderson 2009). The loss of vegetated low marsh reduces habitat for several rare birds, small resident and transient fishes and Diamondback terrapins. Along the North Shore of Long Island, some wetlands will be allowed to respond naturally to sea level rise where migration is possible. Accroding to (Titus and Strange 2008), local planners expect that coastal lands designated for preservation, conservation, or recreation in northern Suffolk County will not be designated for hardened shorelines.

- Along the North Shore of Long Island, some of the largest areas of tidal mudflats occur near Conscience Bay, Little Bay and Setauket Harbor west of Port Jefferson (NYS DOS). Large beds of hard clams, soft clams, American oyster and ribbed mussels are found along these flats (NYS DOS). The physical process of longshore drift, which carries material eroding from bluffs and deposits it to form flats, barrier spits and shoals takes place along these flats (LISHRI 2003). These areas may be susceptible as sea level rise has the potential to change this habitat into subtidal area.

- There are currently no authorized long term USACE projects affecting wetlands within this area.

Peconic Estuary

- Flanders Bay Wetlands in the Peconic Estuary comprise one of the most undeveloped large coastal wetland ecosystems on Long Island. This diverse area is one of the most valuable fish and wildlife habitats in the Peconic Bays section of Long Island (NYS DOS). Flanders Bay contains a sea level fen community that may be susceptible to SLR due to intrusion of tidal flooding and salinity.

- Some wetlands in the Peconic Estuary may be allowed to respond naturally to sea-level rise, where migration is possible some preservation is possible. Accroding to (Titus and Strange 2008) local planners believe that Peconic Estuary shorelines around Shelter Island, Robins Island, the Conscience Point National Wildlife Reserve, the E.A. Morton National Wildlife Reserve, Novack, Sag Harbor, Orient Point and Orient Beach, and Napeague Bay will be allowed to respond naturally to sea level rise. However, it is likely that shore protection will occur along the shorelines of Flanders Bay, threatening the Flanders Bay wetlands.

- Currently, an Estuary Act of 2000 restoration project focused on invasive species removal is taking place at Cedar Beach Creek, within the Peconic Estuary. There are no authorized long term USACE projects affecting wetlands within this area.

Hudson Raritan Estuary

- The remaining significant marsh resources in this area provide valuable ecological and socioeconomic benefits, still, shorelines and inland reaches of this highly urbanized area continue to be developed and armored. Although New York City's Waterfront Revitalization Program (WRP) requires the use of nonstructural alternatives such as beach nourishment, dune construction, and vegetation, planners expect that the only sizeable areas in the New York City metropolitan area that are unlikely to be protected are portions of the three Special Natural Waterfront Areas (SNWAs) designated by the city: Northwest Staten Island/Harbor Heron SNWA; East River–Long Island Sound SNWA; and Jamaica Bay SNWA (Titus and Strange 2008). Remaining wetlands in the HRE complexes include:

Staten Island

- Example of natural wetland can still be found in the estuarine marsh habitat of the Arthur Kill wetland complex, the intertidal and subtidal sand flats and mudflats off the shorelines of western Staten Island and the freshwater marsh habitat along the south Shore of Staten Island. The Northwest Staten Island SNWA including the Harbor Herons Complex includes three island heronries of regional significance, including Shooters Island, Pralls Island, and Isle of Meadows and several tidal emergent, salt, brackish, and fresh water marshes. The Fresh Kills wetland system is one of the largest tidal wetland systems in the region, covering an estimated ha (1,000 acres). Local planners expect that these wetlands will probably be allowed to respond naturally to sea level rise, but migration may not be possible because of the relatively steep slopes that have formed near the shore as a result of landfilling activities (Titus and Strange 2008).

- Along the South Shore of Staten Island NYCDEP has a plan to amend the drainage plans for three watersheds within the Mid-Island (South Shore) area of Staten Island. The proposed project, called the Staten Island Bluebelt, covers the Oakwood Beach, New Creek, and South Beach watersheds, an area approximately 5,000 acres in size. Each of these watersheds has surface water features such as streams, ponds and wetlands that would be utilized with the objective of protecting and enhancing these resources through the preservation and improvement of existing streams and wetlands. The objective of the project is to provide comprehensive stormwater management and address chronic flooding of streets and properties in Mid-Island while preserving and enhancing existing wetlands. This NYCDEP project represents the preservation of a large freshwater and estuarine wetland complex along the south shore of Staten Island and is complimentary to the USACE Fort Wadsworth to Oakwood Beach structural line of protections project (see ocean beach and dune section above).

Western Long Island Sound

- Wetlands in the New York State portion of the Sound exist along the shores of Westchester and Bronx counties. In Westchester County, ecologically important tidal wetlands occur in the county owned Marshlands Conservancy property (Titus and Strange 2008). While the USACE has many New York City restoration projects in the study phase there are currently no long term USACE projects in this are that may protect marsh habitat. As a result it is likely that these resources will continue to decline due to urbanization and loss and conversion of habitat.

Jamaica Bay

- The Marsh Islands Complex is an integral part of the Jamaica Bay Ecosystem and has been targeted for restoration over the last several years. Left alone, the marshes were projected to vanish by 2025, destroying wildlife habitat and threatening the bay's shorelines. To date, there is no consensus among ecological experts on the cause of the erosion of the marsh islands, which range from rising sea levels and warmer temperatures to nitrogen input from stormwater run-off (Titus and Strange 2008). In a 2006 response to these losses, the U.S. Army Corps of Engineers', via its Continuing Authorities Program (CAP), the New York City Department of Environmental Protection (NYCDEP) and the New York State Department of Environmental Conservation (NYSDEC) requested assistance in implementing one or more marsh island restoration projects. To date the following Marsh Islands have been constructed:
    - Elders East, approximately 40 acres
    - Elders West, approximately 40 acres
    - Yellow Bar Hassock, approximately 44 acres
    - Black Wall, approximately 20 acres
    - Rulers Bar, approximately 10 acres

- While these restoration measures support the healthy function of the Jamaica Bay ecosystem, currently there is no authority for future marsh islands construction.

Lower Hudson

- Remaining wetlands in the Hudson River include a brackish marsh at the mouth of the Croton River, in Piermont Marsh, and in a network of marshes behind Grassy Point near Haverstraw Bay. In the northern portion of the Hudson River, significant marsh complexes include Constitution Marsh, Cold Spring and Tivoli Bay. Although these marshes may be able to keep pace in the short term, space is limited by urbanization and steep slopes and they are likely to be gradually reduced in size due to inundation from rising water. Without these natural barriers, storm surges and waves are more likely to erode banks and flood waterfront areas (Titus and Strange 2008).

- The primary impacts of sea level rise on wetlands within the HRE are the direct loss of land and habitat from inundation and the migration of coastal landforms inland. In urbanized areas such as the NYC metropolitan area, the likelihood of this process taking place is severely restricted as a result of centuries of shoreline development and re-alignment (Titus et al. 2009). An additional impact of climate change and sea level rise in the HRE is the effect of increased salinity in the upper reaches of the estuary, ultimately resulting in the conversion of freshwater tidal wetlands to brackish salt marshes.

- Tidal range is also a factor that will play into the response of coastal wetlands to sea level rise. Meso-tidal estuaries, such as the Hudson Raritan Estuary, are likely to exhibit a moderate degree of resilience in comparison to micro or macrotidal systems (Needelman et al. 2012).

- Within the HRE, it is anticipated that regional variation in response to sea level rise will be apparent. For example Jamaica Bay, a back-barrier system with limited sediment sources, will likely continue to experience rapid erosion and/or subsidence of wetlands in the face of rising sea level. In contrast, wetlands associated with a continuous source of alluvial sediments from extensive riverine drainage basins (e.g., Raritan River wetlands) may persist for a much longer duration before reaching disturbance thresholds. Anthropogenic activities within estuaries or along coastlines (e.g., dredging, channelization, hydrologic modifications) exacerbate or accelerate disturbance response times, mainly by altering patterns of sediment distribution (Needelman et al. 2012). In areas where wetlands are bordered by natural uplands, they will be able to migrate inland, as uplands are eventually converted to intertidal habitats. However, in developed urban areas, natural shorelines landward of coastal marshes are rare, and marshes are unable to migrate (Titus et al. 2009). Existing low-elevation marsh areas will convert to mud or sand flats. While the idea of promoting or enhancing the opportunity for coastal wetlands to migrate or retreat in the face of advancing sea level rise is appealing, very few opportunities exist within the HRE to abandon land to accommodate this process without loss of valuable infrastructure or public services (e.g. rail or road infrastructure), and the current predicted sea level rise rates for the HRE region are likely to exceed the time frame in which meaningful coastal landform migration can take place (Needelman et al. 2012).

Submerged Aquatic Vegetation

- The global importance of seagrasses as essential habitat for fish and invertebrates has been established for decades (Heck et al. 1997). Their ecosystem contributions include nutrient cycling, reductions in flow regimes and particulate removal, sediment stabilization and reduced erosion, and dissipation of storm energy to coastal communities.

- Seagrass distribution within the NY District area of responsibility is limited to areas of the South Shore Estuaries of Long Island, the Long Island Sound, the Peconic Estuary and the Hudson River. This limited distribution is due to both natural and anthropogenic conditions that characterize this highly urban environment. Currently, seagrass populations in New York State are declining due to threats associated with excess nitrogen (affecting water quality), persistent and sustained algal blooms, and fishing and shellfishing gear impacts (NYS seagrass task force 2009). Sea level rise may pose significant threats to remaining populations due to potential implications of increased water depth such as increased water temperatures and limited light penetration. Additionally, hardened shoreline exacerbate the effects of sea level rise ,on seagrass beds by preventing landward migration and causing scour and decreased availability of suitable habitat (NYS seagrass task force 2009).

Long Island's South Shore Barrier Island/ Back Bay System

- Seagrass beds occur along the South Shore Estuaries of Long Island from Great South Bay to Shinnecock Bay (Titus and Strange 2008). The South Shore Estuary is the shallowest area where seagrasses are found in New York State and populations in this area are susceptible to sea level rise, and increased water temperatures from climate change. The proliferation of docks and hardened shorelines in response to sea level rise will decrease seagrass coverage further by preventing migration and shading seagrass habitat (NYS Seagrass Task Force 2009).

- Potential coverage for SAV may occur in the future if the restoration and water quality goals of the FIMP project are realized.

North Shore of Long Island

- Seagrass in Long Island Sound is limited to the shallow margins of the Sound; with only 236 acres of seagrass coverage remain on the New York side, predominantly in the eastern portion of the sound (2006 LIS report). Although most of the eelgrass found in LIS is in waters less than 3m depth, there is eelgrass growing at depths of 8m around Fishers Island (NYS Seagrass Task Force 2009), where 98% of New York's LIS seagrass is found.

- Long Island Sound seagrass is most susceptible to climate change, particularly rising water temperatures in shallow water areas and embayments (NYS Seagrass Task Force 2009).

- There are currently no authorized long term USACE projects affecting seagrass within this area.

Peconic Estuary

- Shallow water habitats are a major ecological feature in and around the Peconic Estuary, however, eelgrass populations are limited to the eastern portion of the estuary, mainly east of Shelter Island, with an annual population in Bullhead Bay (NYS Seagrass Task Force 2009). New York State recognizes the Cedar Point/Hedges Bank Shallows habitat as one of only a few remaining eelgrass meadows in the State of New York.

- Migration of beds in the Peconic Estuary are at risk from hardened shorelines and construction of private docks, steep shores, erosion and water turbidity in front of shoreline protection structures. In their 2008 study Titus and Strange indicate that local planners believe that shorelines around Shelter Island, Robins Island, the Conscience Point National Wildlife Reserve, the E.A. Morton National Wildlife Reserve, Novack, Sag Harbor, Orient Point and Orient Beach, and Napeague Bay will be allowed to respond naturally to sea level rise. However, other shorelines of the Peconic Estuary are considered "likely" or "almost certain" to be protected, and if these shorelines are hardened, SAV will be unable to migrate in response to sea level rise. Additionally, sea level rise and increasing development pressures may spark increased hardening. Peconic seagrass is also susceptible to increased water temperatures brought about by climate change (Titus and Strange 2008, NYS Seagrass Task Force 2009).

Hudson Raritan Estuary

- SAV occurs in various locations throughout the Hudson River from Hastings on Hudson to the northern limit of the NACCS study boundary. There is extensive shallow water habitat and high biological productivity in the part of the Hudson River from Stony Point south to Piermont Marsh. This wide, shallow area is where the estuary’s seasonal (and annual) salt front occurs, which is the area of greatest mixing of ocean and freshwater. This part of the Hudson is a major habitat area for numerous fish and bird species and contains a portion of the areas SAV, dominated by water celery, sago pondweed, and horned pondweed (Titus and Strange 2008). Water celery is the most common native SAV in the Hudson River and provides spawning habitat for fish populations. Water celery populations are susceptible to impacts from coastal storms and flooding- Tropical Storms Irene and Lee scoured water celery beds severe population declines and absences the following season (http://www.dec.ny.gov/lands/87648.html).

- Sea level rise may alter abiotic conditions such as temperature and salinity in the Hudson River which affecting vegetation and associated fauna (Titus and Strange 2008). Anthropogenic alterations in response to sea level rise, such as hardened shorelines along with maintenance of the federal navigation channel may also negatively impact SAV populations through loss of shallow water habitat.

- There are currently no authorized long term USACE projects affecting seagrass within this area.

Shallow Bay Habitat/ Bay Islands

Long Island's South Shore Barrier Island/ Back Bay System

- In general, the maintenance of channels into the south shore bays and the elimination of natural island breaches due to development have created a more stagnant system than would naturally occur associated with barrier island beach-lagoon systems. While each of the back bays has a unique set of ecological characteristics and varying amounts of human development, they are all subjected to anthropogenic impacts. The severe loss of wetlands, hardening of shorelines from bulkheads, increased nutrient inputs from various sources, and overharvesting of natural resources such as clams and oysters has led to a generalized decline in water quality (Titus and Strange 2008).

- Due to the urban backdrop of the south shore estuaries, it is unlikely that natural landward migration will occur in the event of accelerated sea level increase. At the highest rates of sea level rise, barrier retreat may not be pace inundation, significantly increasing overwash and breaching of new inlets and potentially changing the physical and environmental characteristics of the bays such as, lagoon flushing rates, salinity, light penetration and nutrient dynamics (NYS SLR task force 2010).

- Local planners have indicated that eroding marsh islands throughout the South Shore Estuaries may need to be artificially protected to maintain the vegetated wetlands which support significant wildlife habitat that they provide. For example, the network of salt marsh and dredge material islands in the Hempstead Bay–South Oyster Bay complex are important for nesting by herons, egrets, and ibises; Lanes Island and Warner Island in Shinnecock Bay support colonies of the state listed common tern and the federally endangered roseate tern; and erosion on Warner Island is reducing nesting habitat and increasing flooding risk during nesting season (Titus and Strange 2008).

- The eastern bays (Great South Bay, Moriches, Shinnecock) are within the boundaries of USACE FIMP study area which is developing a long-term comprehensive plan for storm damage reduction, which maintains, preserves or enhances the natural resource. Additionally, the project proposes natural protective features including wetland restoration and creation of overwash fans. This may help to mitigate existing issues such as degraded water quality and potentially provide protection to the western marsh complex by re-establishing natural processes and fortifying the barrier island against breaches.

- Erosion on Warner Island is reducing nesting habitat for roseate tern and increasing flooding risk during nesting. The Hempstead Bay–South Oyster Bay complex includes a network of salt marsh and dredge spoil islands that are important for nesting by herons, egrets, and ibises. Lanes Island and Warner Island in Shinnecock Bay support colonies of the state listed common tern and the federally endangered roseate tern. Carter's Island has supported nesting by the state endangered least tern. Local planners have indicated that eroding marsh islands such as those in Great South Bay may need to be artificially protected to maintain the vegetated wetlands (Strange 2008).

North Shore of Long Island

- The Long Island Sound Study considers Plum Island, Little Gull Island, and Great Gull Island off Orient Point "exemplary" colonial waterbird habitat, with sites "of national—if not international—significance." The islands are relatively small and covered with grassy and herbaceous vegetation (Titus and Strange 2008).

Peconic Estuary

- Gardiners Island, Robins Island, and Cow Neck in Little Peconic Bay provide habitats for many rare species such as roseate tern, common tern, least tern, northern harrier, red-tailed hawk, eastern mud turtle, and diamondback terrapin.

- In their 2008 review, Titus and Strange identify that Suffolk County Department of Planning believe that because these properties are in private ownership they will be left in a natural state. Even if some protection of the islands' shorelines does occur, it seems likely that it will involve vegetation-based approaches rather than shoreline hardening to help preserve these valuable habitats (Titus and Strange 2008).

Hudson Raritan Estuary

- Within the Hudson Raritan Estuary many off shore islands provide roosting, nesting and foraging habitat for regionally significant bird colonies and contain rich rocky shoreline habitat. In their 2008 paper, Titus and Strange have reported that the Jamaica Bay Wildlife Refuge regularly supports large populations of nesting, state threatened common terns; the heronry on Canarsie Pol supports nesting by great black-backed gull, herring gull, and American oystercatcher; East High Meadow, Silver Hole Marsh, Jo Co Marsh, and West Hempstead Bay support the only colonies of laughing gull in New York State; and several offshore islands in western Long Island Sound (eg. Huckleberry Island and North and South Brother Islands) and in the Arthur Kill and Kill van Kull (Shooter's Island, Prall's Island and Isle of Meadows) support regionally significant bird colonies. Loss of island area with sea level rise could eliminate nesting sites, having significant impacts on the populations of these and other species associated with this island habitat (eg. Diamondback terrapins).

Floodplains/Riparian

Hudson Raritan Estuary

- Within the HRE area many urban and residential center are within the floodplain. Where river systems exist, there is little riparian buffer to accommodate floodplain migration. It is likely that State and Municipalities in the in affected urban areas will take measures to reduce the impacts of flooding. The resources in the following areas would likely be vulnerable to gradual flooding, habitat change and degradation:
    - The northern portion of the Hudson River where natural shorelines remain.

- The Bronx River where natural shoreline remains, native vegetation has been replaced by invasive species such as common reed (*Phragmites comm*unis) and purple loosestrife (Lythrum salicaria).

- Riparian forests of the Atlantic Highlands line the freshwater tributaries that feed into Sandy Hook Bay, the Navesink and Shrewsbury Rivers.

- Haverstraw Bay however contains some undeveloped forestland and some natural shoreline habitat.

- The Lower Raritan River contains some regionally important floral and faunal assemblages.

Cultural and Historic Resources

- As sea level continues to rise and inland marshes and barrier islands erode or subside, cultural resources existing on them or behind them could be exposed to the elements or inundated, putting them at a greater risk of damage or destruction. Resources could also be adversely impacted over time by an increased risk of storm damage. Cultural resources would continue to be affected in coastal areas where there is no protection against storm events. Areas in the New York District which have not received storm damage reduction measures include the North Shore of Long Island, the West Shore of Long Island, Staten Island, and select areas in the Raritan Bay in New Jersey.

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6. New Jersey: Environmental Existing and Future Conditions

I. Coastal Characterization - New Jersey

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Beaches/Pebble Shoreline/Beaches

Atlantic Coast

- The general coastal environment is typical of coastal barrier island and trapped bay conditions (barrier spit complex). This type of complex is a common feature along coastal plains with a gentle slope and a tidal range of less than 13 feet. The islands are fronted with sandy beaches and upland dunes, which help to shield the barrier island complex (USACE 2001, 2002a).

- Natural dunes or remnants of ones are present along the coast, especially at Corson's Inlet State Park, Strathmere State Natural Area and Island Beach State Park.

    - In typical natural beach profiles along New Jersey's Coast, more than one dune may exist. The primary dune is the first dune or sometimes the only dune landward from the beach.

    - The secondary dunes lie landward of the primary dunes, and tend to be more stable resulting from the protection provided by the primary dunes.

    - Along undeveloped portions of the study area such as Corson's Inlet State Park and Strathmere Natural Area, the primary and secondary dunes grade into a zone of shrubby vegetation. These zones are typically located on the barrier flats of the barrier beaches.

    - The upper beach or supralittoral zone typically lies below the primary dune and above the intertidal zone.

    - The intertidal zone contains more intensive biological activity than the other zones. Shifting sand and pounding surf dominate a habitat, which is inhabited by a specialized fauna.

    - New Jersey Atlantic nearshore waters provide a dynamic environment heavily influenced by the tidal flows and long-shore currents. The nearshore and offshore waters of the New Jersey Coast contain a wide assemblage of invertebrate species inhabiting the benthic substrate and open water. Invertebrate Phyla existing along the coast are represented by Cnidaria (corals, anemones, and jellyfish), Annelida (Polychaetes, Oligochaetes), Platyhelminthes (flatworms), Nemertinea (ribbon worms), Nematoda (roundworms), Bryozoa, Mollusca (chitons, clams, mussels, etc.), Echinodermata (sea urchins, sea cucumbers, sand dollars, starfish), Arthropoda (Crustaceans), and the Urochordata (tunicates) (USACE 2001, 2002a).

Sandy Hook to Manasquan Inlet

From GNRA webpage and Burlas et al. 2001

- This shoreline is composed of approximately 29 miles of exposed, high-energy beaches extending northward from Manasquan Inlet to Highland Beach. From Highland Beach north, Sandy Hook Gateway National Recreation Area (GNRA) extends an additional 6.5 miles.

- Sandy Hook GNRA is backed by vegetated dunes, providing habitat for nesting shorebirds and other terrestrial wildlife. Back dune thickets and forests create a diversity of habitats not known anywhere else along the New Jersey coast. On the bay side of Sandy Hook are salt marshes and other estuarine habitats that provide calmer and more stable conditions than the ocean side.

- Barrier peninsula Beach occupy a barrier peninsula, the northern terminus of which is Sandy Hook, a unit of the Gateway National Recreation Area (6.5 mile long barrier beach). The barrier peninsula, including the ocean beach, separates Shrewsbury River, which has a Federal navigation project, from the Atlantic Ocean. The barrier peninsula is relatively narrow.

- Ocean Beach and Dune – 12-mile length of ocean frontage (not including Sandy Hook) has been highly modified as a result of intensive human development and concomitant measures to control erosion forces. In the barrier portion of the project the beach, if present, is backed by a seawall. Further south variations of riprap construction and bulkheads protect the bluffs and adjacent shoreline development. In addition, a wide variety of stone and timber groins have been constructed all along the project shore.

- The National Guard Encampment, between Sea Girt and Manasquan, is the only area not associated with immediate human development between Asbury and Manasquan. The Encampment contains a small isolated dune system.

Delaware Bay

- Characterized by a narrow beach, mostly natural dunes, and shallow offshore waters, including an area of sand flats that are exposed at low tide.

- Dune habitat

    - The existing dunes have varying value for wildlife depending if they have been developed or are still relatively undisturbed. Some of the valuable dune areas occur where they are adjacent to wetlands such as just north of the Cape May Canal, at the mouth of Cox Hall Creek, at the mouth of Fishing Creek, and at Sunray Beach. undeveloped dunes are especially important to the millions of migrating birds that pass through Cape May County each fall (USACE 1999).

- Estuarine intertidal sandflats, a special aquatic site, extends bayward about 1,000 to 1,500 feet from the mean low water line.

Barrier Islands/Inlets

- On the Atlantic coast, the general coastal environment is typical of coastal barrier island and trapped bay conditions (barrier spit complex). This type of complex is a common feature along coastal plains with a gentle slope and a tidal range of less than 13 feet. The islands are fronted with sandy beaches and upland dunes, which help to shield the barrier island complex.
    - Atlantic Coast Barrier islands (north to south): Sandy Hook, Long Beach Island, Pullen Island, Brigantine Island, Absecon Island, Ludlam Island, Seven Mile Island (Avalon and Stone Harbor), Five Mile Island (North Wildwood, Wildwood, Wildwood Crest, Lower Township).
    - Atlantic Coast Inlets (north to south) – Manasquan Inlet, Barnegat Inlet, Little Egg Inlet, Brigantine Inlet, Absecon Inlet, Great Egg Harbor Inlet, Corsons Inlet, Townsend Inlet, Hereford Inlet, and Cape May Inlet (USACE 2002a).

Coastal Wetlands

- On 20 May 1992, over 126,000 acres of Delaware Bay wetlands were designated as Wetlands of International Importance and added to the Ramsar List.

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

Atlantic Coast

- The low marsh zone is typically dominated by saltmarsh cordgrass (*Spartina alterniflora*). Tidal flats are areas that are muddy or sandy areas covered with water at high tide and exposed at low tide (USACE 2001, 2002a).

Delaware Bay

- Freshwater tidal wetlands are found upstream of the Delaware Memorial Bridge, especially near Trenton.

- Vast expanses of saltmarsh are found throughout the Delaware Bay.

- The bayshore area of Cape May County is characterized by low bluffs fronted by a low, narrow beach, and drained by small tidal streams. To the north, marshlands front on the Delaware Bay and are subject to normal tidal flooding. Mud flats, submerged during high-tide, front the small patches of sand beach that are scattered along the bayshore narrow beach, mostly natural dunes, and shallow offshore waters, including an area of sand flats that are exposed at low tide (USACE 1999).

Hudson Raritan Estuary

- The following regions (Lower Bay, Lower Raritan River, Arthur Kill/Kill van Kull, Newark Bay/Hackensack River/Passaic River, Hudson River Estuary, and Upper Bay) are delineated by major watersheds and/or major physical features, such as highways or waterways.

Arthur Kill/Kill van Kull

- Wetland condition is generally degraded and dominated by monotypic stands of common reed. Natural wetland habitats that remain in the study area include tidal marshes, freshwater marshes and wooded swamps. Tidal and brackish wetlands are dominated by smooth cordgrass (*Spartina alterniflora*) and salt meadow cordgrass (*Spartina patens*), spike rush (*Distichlis spicata*), marsh elder (*Iva frutescens*), common reed, and cattail (*Typha latifolia*). Marshes with more freshwater inputs are characterized by species including pondweed (*Potamogeton* spp.), spatterdock (*Nuphar variegatum*), and pickerelweed (*Pontedaria cordata*). In some places, scrub-shrub wetlands exist adjacent to marshes. Species present in these habitats include dogwoods (*Cornus* spp.), mulberry (*Morus* spp.), alder (*Alnus* spp.), and buttonbush (*Cephalanthus occidentalis*). Tree species present in forested freshwater wetlands include red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), and swamp white oak (*Quercus bicolor*). Understory species present in the forested wetlands include spicebush (*Lindera benzoin*) and skunk cabbage (*Symplocarpus foetidus*). Although natural areas remain, they are highly fragmented due to the intense industrial, residential, and commercial development (USACE 2004, 2009).

- As a result of extensive development, a large portion of the natural shorelines have been hardened or filled by bulkheads or riprap. Areas where natural conditions remain are still generally characterized as tidal wetlands; however, in the New Jersey portion of the Arthur Kill/Kill van Kull study area, only about 4 percent of the land remains as wetlands (Hatch Mott MacDonald 2003,USACE 2004, 2009).

Lower Bay

- Lower Bay contains coastal and offshore environments, experiencing loss of dunes and benthic habitat. Raritan Bay and Sandy Hook Bay have relatively shallow subtidal areas. There are approximately 24 miles of beaches along the southern shore of the Raritan Bay in Monmouth County, NJ, and several private beaches located along these same shorelines (USACE 2004, 2009).

- Major tributaries to the Lower Bay include the Raritan, Navesink, and Shrewsbury Rivers in New Jersey. The Passaic and Hackensack Rivers are considered to have indirect flow in this study area (USACE 2004, 2009).

- A large proportion of wetland and upland areas in the study area have been developed. The remaining undeveloped land is characterized by tidal salt marshes, beaches, dunes, intertidal mudflats, shallow subtidal mudflats, upland forest, forested wetlands, and grass/scrub-shrub uplands. In addition, salt marsh and dredge material islands also exist (USACE 2004, 2009).

- Salt marshes in the study area are dominated by cordgrass (*Spartina alterniflora*, *S. patens*), with black grass (*Juncus gerardii*), marsh elder (*Iva frutescens*), and groundsel bush present in the high-tide zone. Common reed (*Phragmites communis*) is an invasive plant found in many of the wetlands in the study area (USACE 2004, 2009).

- Sandy Hook is a sand spit comprised of several unique habitats in the study area. This sand spit extends north from the New Jersey mainland into New York Harbor and divides the open ocean to the east from the Sandy Hook, Raritan, and Lower New York Bays to the west. On the ocean side, the southern shoreline is reinforced by a seawall and groin field. Despite these reinforcements, erosion is a continual problem. Deposition of sands and sediments is occurring at the northern end of the spit where extensive foredune and backdune areas are present. Foredunes are vegetated with beach grass (*Ammophila breviligulata*). Backdune areas are dominated by winged sumac (*Rhus copallina*), bayberry (*Myrica pennsylvanic*), and beach plum (*Prunus martima*). Dune habitat is limited elsewhere in the Lower Bay area due to intense development along the shoreline (USACE 2004, 2009).

- Remnant patches of rare maritime forest, a once common community, exist on Sandy Hook. Maritime forests are dominated by American holly (*Llex opaca*), black cherry, serviceberry (*Amelanchier canadensis*), greenbriar (*Smilax rotundifolia*), and poison ivy (*Toxicodendron radicans*) (USACE 2004, 2009).

Hudson River Estuary

- The Hudson River Estuary region of this study (NACCS) from approximately the Upper New York Bay to the Tappan Zee Bridge, is characterized by extensive hardened shorelines and contaminated sediment. This region of the Hudson River is an estuarine environment with moderate to high salinity zones. Turbidity is high which limits phytoplankton production. As a result, the food web is detritus-based. Strong semi-diurnal tides make this portion of the Hudson River one of the few major tidal rivers of the North Atlantic coast (USFWS 1997, USACE 2004, 2009). North of the Tappan Zee Bridge, the Haverstraw Bay Significant Coastal Fish and Wildlife Habitat area extends approximately six miles on the Hudson River, from Stony Point to Croton Point, in the Towns of Stony Point, Haverstraw, and Clarkstown, in Rockland County, and the Town of Cortlandt, in Westchester County (approximately the northern limit of the NYD NACCS boundary). Habitat disturbances, such as dredging, shoreline filling and bulkheading, waste disposal, and pollution and urbanization all exist in the Haverstraw Bay; however, much undeveloped forestland and some natural shoreline habitat also remain.

- Wetlands types present include brackish marsh and intertidal mudflats that transition into shallow, subtidal aquatic beds. Dominant species in these wetland areas include common reed (*Phragmites communis*) and narrow-leaved cattail (*Typha latifolia*). Other species that are present, but not dominant, include smooth cordgrass (*Spartina alterniflora*), spike grass (*Distichlis spicata*), rose-mallow (*Hibiscus moscheutos*) and purple loosestrife (*Lythrum* *salicaria*). Common reed dominates many wetland areas. For example, common reed covers approximately 70% of Piermont Marsh (largest wetland complex in this region). Other shallow-water habitat, like shoal and inter-pier areas, may be important foraging sites for young fish before they move into deeper Harbor waters (USACE 2004, 2009).

- Piermont Marsh encompasses 1,017 acres and lies at the southern edge of the village of Piermont, four miles south of Nyack in Rockland County. The Piermont Marsh is on the western shore of the Tappan Zee. The site occupies two miles of shoreline south of the mile-long Erie Pier and includes the mouth of Sparkill Creek and extensive tidal shallows. Piermont marsh habitats include brackish tidal marsh, shallows and intertidal flats. The Sparkill Creek drains 11.1 square miles of watershed. Species reported to be present in the shallow subtidal area near Piermont Marsh supports include (SAV) water celery (*Vallisneria americana*), sago pondweed (*Potomogeton pectinatus*), and horned pondweed (*Zannichellia palustris*) (USACE 2004, 2009).

- Haverstraw Bay contains extensive shallow areas (less than 15 feet deep at mean low water) that deepen to a navigation channel (which is dredged to maintain a depth of about 35 feet) in the western half of the area. During much of the year, this area is the place where freshwater from the upper river mixes with salt water from the Atlantic Ocean to produce a predominantly brackish water habitat with salinities varying from 0-10 ppt.

Lower Raritan

- Many wetlands that remain have been degraded and invaded by non-native species such as common reed (*Phragmites communis*). Approximately 93% of all wetlands in the Lower Raritan River Basin have been converted to urban land uses (New Jersey Water Supply Authority 2002). A significant wetland system is located in Edison Township, near the Raritan Center. This wetland system is nearly 1,000-acres in size and consists of a complex of habitat types including emergent wetlands, freshwater ponds, and tidal creeks (USACE 2004, 2009).

Newark Bay/Hackensack River/Passaic River

- In the lower Passaic River basin, the majority of wetland areas have been filled and many streams have been converted to storm sewer drains (USACE 2004, 2009).

- Intertidal wetlands characterized by an intermittent flooding regime and dominated by common reed are the most common type of wetland present in the New Jersey Meadowlands. Other wetland types still present in this habitat complex include tidal bays/mudflats, low salt marsh, high marsh, brackish impoundments, freshwater impoundments, and remnant palustrine forest (USACE 2004, 2009).

Upper Bay

- Most of the wetlands and upland areas in the study area have been filled to accommodate commercial, residential, and industrial development. With the exception of small areas in

Bayonne adjacent to the U.S. Military Ocean Terminal (MOTBY) and at Caven Point, the entire shoreline of the Upper Bay has been hardened with bulkheads or riprap (USACE 2004, 2009).

- Shoreline habitat can be found in the form of wetlands on the west side of Liberty Island. Remnant mudflats are located along the New Jersey coastline (USACE 2000, USACE 1999). Shallow sheltered areas and littoral habitats are almost non-existent, and heavy commercial boat traffic erodes unprotected shorelines (USACE 2004a, 2009).

- The majority of remaining, undeveloped wetland habitats in the Upper Bay study area have been disturbed at one time or another. As a result invasive, non-native species have colonized these disturbed habitats. The few remaining salt marshes in the study area are dominated by cordgrass (*Spartina alterniflora, S. patens*), with black grass (*Juncus gerardii*), marsh elder (*Iva frutescens*), and groundsel bush (*Baccharis halimifolia*) present in the high-tide zone. Common reed (*Phragmites communis*) is invasive along many of the wetlands in the study area (USACE 2004, 2009).

Submerged Aquatic Vegetation

Atlantic Coast

- Backbay vegetation in open water is primarily composed of algal species like sea lettuce (*Ulva lactuca*), which is dominant in backbays, and SAV's (submerged aquatic vegetation) such as eelgrass (*Zostera marina*). Eelgrass is a common SAV in the Atlantic back bays, which can form extensive beds important for fish, shellfish and other wildlife species (USACE 2001, 2002).

Delaware Bay

- There are some freshwater SAVs are in the Delaware River.

- High suspended sediments appear to be the reason why there are no significant areas of submerged aquatic vegetation in the Delaware Bay.

Hudson Raritan Estuary

- Haverstraw Bay contains extensive shallow areas and several submerged aquatic vegetation beds, dominated by water celery (*Vallisneria americana*).

- Species reported to be present in the shallow subtidal area near Piermont Marsh supports include (SAV) water celery (*Valisneria americana*), sago pondweed (*Potomogeton pectinatus*), and horned pondweed (*Zannichellia palustris*) (USACE 2004, 2009).

Oyster Reefs

Delaware Bay

- Oyster seed beds are located north of Fortescue while most of the leasing grounds and tonging areas occur south of Fortescue.
    - The oyster fishery ranges from the mouth of the Maurice River and shoals on the New Jersey side to the Smyrna and Cohansey rivers These low salinity areas provide a refuge for young oysters to grow, free from predation and competition that limits survival in higher salinity, downbay water (USACE 2009).

Barnegat Bay

- Sixty-six acres are leased for commercial harvesting of oysters Rock Reefs/ Rocky Shorelines.

- Naturally occurring rocky intertidal zones are absent from the area; however, man-made structures such as seawalls, jetties, and groins are present and provide suitable habitats for aquatic and avian species.

- Man-made structures within the study area such as groins and jetties add more habitat diversity within the study area for finfish. Juvenile and larval finfish such as black sea bass (*Centropristis striata*), summer flounder (*Paralichthys dentatus*), winter flounder (*Pseudoharengus dentatus*) and striped bass (*Morone saxatilis*) utilize these areas for feeding, protection from predators, and nursery habitat.

- Artificial reefs located approximately 4 miles east of Manasquan Inlet and 2.5 miles east of Mantoloking offshore shoal areas, also called “lumps” are sandy areas in the offshore zone that are generally 30 feet or less in depth surrounded by deeper, flatter areas. These areas are believed to attract higher numbers of finfish species and are frequently targeted by recreational fishermen.

Mullica River/Great Bay

- There is a naturally occurring oyster population located in the Mullica River/Great Bay.

- The NJDEP is trying to restore the population in the Mullica River and the area is open to recreational harvest during certain parts of the year.

Shallow Bay Habitat/ Bay Islands

Atlantic Coast

- The shallow marsh habitat and dredged material disposal islands in backbay areas provide habitat for a variety of wading birds including: cattle egret (*Bubulcus ibis*), great egret

(*Casmerodius albus*), little blue heron (*Egretta caerulea), s*nowy egret (*Egretta thula*),tricolored heron (*Egretta tricolor*), yellow-crowned night-heron (*Nyctanassa violacea*), and black-crowned night-heron (*Nycticorax nycticorax*). Heron rookeries and galleries have been sited on marsh islands, although not as numerous as in regions immediately to the north and south of Townsends Inlet (USACE 2001).

- Back bay/coastal marsh complexes – comprised of open water, a low marsh zone, tidal flats, a high marsh zone, and a transition zone including: Great Egg Harbor Bay, Peck Bay, Ludlam Bay and Townsends Sound, all located on the landward side of the barrier islands (USACE 2001).

- Behind Sea Isle City, the tidal salt marsh system that encompasses Townsends Sound is interspersed with shallow bays, forested fringe wetlands and music uplands to the west.

- Many of the islands in Barnegat Bay (Clam and Sedge Islands), and the isolated or undeveloped marshes and beaches on Long Beach Island and the mainland, provide nesting ground for a wide variety of migratory shorebirds including: glossy ibis (*Plegadis falcinellus*), green-backed heron (*Butorides striatus*), little blue heron (*Egretta caerulea*), snowy egret (*Egretta thula*), great egret (*Casmerodius albus)*, black-crowned night heron (*Nycticorax nyticorax*), yellow-crowned night heron (*Nyctanassa violacea*), great black-backed gull (*Larus marinus*), herring gull (*Larus argentatus*), laughing gull (*Larus atricilla*), least tern (*Sterna antillarum*), black skimmer (*Rynchops niger*) and common tern (*Sterna hirundo*) (USACE 2002).

- The backbays are comprised of open water, a low marsh zone, tidal flats, a high marsh zone, and a transition zone.

Terrestrial Upland

Hudson Raritan Estuary

Lower Bay

- Upland forests in the study area are comprised of species such as black cherry (*Prunus serotina*), oaks (*Quercus* spp.), hickory (*Carya* sp.), and tree-of-heaven (*Ailanthus altisima*). The understory of these forests usually includes the following species: mountain laurel (*Kalmia latifolia*), and arrowwood (*Viburnum* spp.). Forested wetlands are dominated by sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*). Many of the forested habitats in the region have been fragmented by human development (USACE 2004, 2009).

Hudson River Estuary

- Disturbed habitats exist in the Haverstraw Bay; however, much undeveloped forestland and some natural shoreline habitat also remain.

Lower Raritan

- The study area is densely populated and few natural forests remain. In some portions of the upper study area, abandoned or fallow farmland, characterized by old-field communities, remains. These are comprised primarily of abandoned or fallow farm fields. Species commonly found in old-field communities include eastern red cedar (*Juniperus virginiana*), gray birch (*Betula lenta*), black locust (*Robinia pseudoacacia*), common mullein (*Verbascum thapsus*), orchard grass (*Dactylis glomerata*), and Canada thistle (*Cirsium arvense*) (USACE 2004, 2009).

Newark Bay/Hackensack River/Passaic River

- Grassland, shrubland, and early successional forest exist on undeveloped upland fill areas that are scattered throughout the study area (USACE 2004, 2009).

Upper Bay

- Most of the upland areas in the study area have been filled to accommodate commercial, residential, and industrial development and have been disturbed at one time or another. As a result invasive, non-native species have colonized these disturbed habitats (USACE 2004, 2009).

- Remaining upland habitat consists of old field and scrub-shrub/woodland habitats. Frequently, disturbed old-field habitats are dominated by common mugwort (*Artemisa vulgaris*). In other places, old-field habitats are characterized by mixed forbs and grasses such as goldenrod (*Solidago* spp,), aster (*Aster* spp.), and switch grass (*Panicum virgatum*). Scrub-shrub/woodland habitats are characterized by species such as black cherry (*Prunus serotina*), bayberry (*Myrica cerifera*), sumac (*Rhus* spp.), black locust (*Robinia pseudoacacia*), tree-of-heaven (*Ailanthus altissima),* and common mugwort. Many of these upland communities exist on former wetlands that were filled with material that is contaminated. Other upland communities have grown on abandoned or vacant properties that are former developed sites (USACE 2004, 2009).

Floodplains/Riparian

Delaware Bay/ Delaware River

- The Lower Delaware Watershed contains fragmented and degraded wetlands and riparian corridors along the Delaware River and its tributaries. Aquatic ecosystems have been impaired in multiple ways in association with impacts of urbanization, industry and port activity. Natural shoreline habitats have largely been destroyed and tidal marshes have been filled to make more usable land and bulkheads or riprap have been installed for stabilization, eliminating the shoreline fringe in the tidal portion of the Delaware River (USACE 1999).

- The Maurice River Watershed in New Jersey as well as other smaller sub-watersheds along the Delaware Bay are characterized by relatively flat coastal plain topography, extensive salt marshes, and small tidal streams (USACE 1999).

Hudson Raritan Estuary

Lower Bay

- Riparian forests of the Atlantic Highlands line the freshwater tributaries that feed into Sandy Hook Bay, the Navesink and Shrewsbury Rivers (USACE 2004, 2009).

Hudson River Estuary

- Disturbed habitat exists in the Haverstraw Bay; however, much undeveloped forestland and some natural shoreline habitat also remain.

Lower Raritan

- This tidally influenced river features some regionally important floral and faunal assemblages.

Newark Bay/Hackensack River/Passaic River

- Lower stretches of the Passaic and Hackensack Rivers provide habitat for marine and estuarine fish and invertebrates, while further upstream, the rivers support a mix of estuarine and freshwater species. The shorelines of Newark Bay, the Hackensack River, and the Passaic River are highly modified by bulkheads and riprap. The once forested floodplain of the Hackensack and Passaic Rivers has been replaced by expansive urban development. In some areas, the banks remain vegetated by species such as American Sycamore (*Platanus occidentalis*) and black cherry (*Prunis serotina*). However, these vegetated buffers are often very narrow and highly fragmented and little natural vegetation or shoreline features remain. In the most urbanized portions of the study area, it is highly unlikely that the remaining natural areas are able to provide ecological functions such as flood attenuation and filtering of runoff, let al.one support the diversity and abundance of resources historically present (USACE 2004, 2009).

- Substrate of the Hackensack and Passaic Rivers vary from sand to mud to bare concrete bed. Some portions of the rivers have rocky substrate ranging from large rocks to small pebbles. In other portions of the rivers, contaminated bottom sediments reduce habitat quality for fish and other aquatic organisms (USACE 2004, 2009).

Coastal Protected Areas

National Park Service Areas

- Sandy Hook GNRA is the terminal 6 miles of barrier spit that stretches northward from coastal headland portion of Monmouth Beach. The Gateway National Recreation Area is managed as a unit of the National Park Service for natural resource management and recreational purposes.

State Parks

- Corson's Inlet State Park/Strathmere Natural Area, Cape May Wetlands Wildlife Management Area, Island Beach State Park, Barnegat State Park, Brigantine New Jersey Wildlife Refuge, Great Bay Boulevard State Wildlife Management Area, Manahawkin Wildlife Management Area, Brigantine Natural Area.

National Estuary Program

- The Barnegat Bay-Little Egg Harbor estuary is an estuary of national significance, covers over 42 miles of shoreline from the Point Pleasant Canal south to Little Egg Harbor Inlet, and is composed of three shallow, micro-tidal bays: Barnegat Bay, Manahawkin Bay, and Little Egg Harbor. The flow of fresh water into the bay produces ideal habitat for fish, shellfish, birds, and other wildlife (http://bbp.ocean.edu/pages/114.asp). Barnegat Bay is an important estuary fed by the Metedeconk River, Toms River and ground water seepage from the Pine Barrens. This estuary provides over-wintering habitat for 35% of the total Atlantic flyway's population of black duck (Anas rubripes), as well as 70% of the flyway's American brant (Branta bernicla) population. Furthermore, the bay itself provides important nesting, feeding, and migratory habitat for 287 other species of waterfowl and birds (USACE 2002a).

Estuary of National Significance

- The NY-NJ Harbor Estuary is an estuary of national significance (1988) and home to incredible natural diversity. This estuary is also one of the most vibrant and populated metropolitan areas in the country and the world, presenting unique opportunities and challenges.

National Wildlife Refuges

- The Edwin B. Forsythe National Wildlife Refuge protects more than 47,000 acres of southern New Jersey coastal habitats which is actively managed for migratory birds. The refuge's location in one of the Atlantic Flyway's most active flight paths makes it an important link in seasonal bird migration. Its value for the protection of water birds and their habitat continues to increase as people develop the New Jersey shore for our own use (www.fws.gov/refuges/Edwin_B_Forsythe).

- Cape May National Wildlife Refuge encompasses 11,500 acres within the Cape May Peninsula. Habitats such as grasslands, saltmarshes, bogs, maritime forests, and beachfront are home to a variety of wildlife including State and Federally threatened and endangered species. Cape May Peninsula's unique configuration and location concentrates songbirds, raptors, wading birds, and shorebirds on their annual migrations (http://www.fws.gov/northeast/capemay/).

- Supawna Meadows National Wildlife Refuge encompasses approximately 3,000 acres along the Delaware River estuary just north of the Salem River in Salem County, in Pennsville, NJ. The tidal marshes that comprise nearly 80 percent of the refuge provide waterfowl with an important feeding and resting area, particularly during the fall and spring migrations. The refuge supports visiting populations of black ducks, mallards and northern pintails during winter. Sandpipers and other shorebirds use the refuge marshes as a feeding area in summer and throughout seasonal migratory travel. Warblers, sparrows and other migratory birds use the upland areas of the refuge as resting and feeding areas during migration and for nesting during the summer. Thousands of tree swallows forage on the refuge in the late summer. Ospreys, bald eagle, northern harrier, short-eared owl and barn owls also nest on the refuge (http://www.fws.gov/supawnameadows/).

- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

Federally Listed Species

- The Federally-listed threatened piping plover *(Charadrius melodus)* historically (up to 1987) nested immediately north of the Cape May Canal (USACE 1999). Piping plovers nest on sandy beaches above the high tide line on mainland coastal beaches, sand flats, and barrier island coastal beaches. The nesting sites are typically located on gently sloping foredunes, blowout areas behind primary dunes, washover areas cut into or between dunes, ends of sandspits, and on sites with deposits of suitable dredged or pumped sand.
    - Piping plover breeding also occurred at Cape May Point, Higbee Beach and North Cape May near the ferry dock (USACE 1999)), Mantoloking, and occasionally along the beach at Island Beach State Park (USACE 2002a).
- There are several known occurrences of the Federally-listed threatened plant, swamp pink *(Helonias bullata*) along the Delaware Bay coast (USACE 1999). Swamp pink typically occurs in forested wetlands, although occurrence in scrub-shrub wetlands is known.
- Seabeach amaranth (family Amaranthaceae) is an annual plant native to the barrier island beaches of the Atlantic Coast, from Massachusetts (MA) to South Carolina (SC). The original range of this species extended from Cape Cod, MA, to central SC, a stretch of coast about 994 miles (mi).
- The endangered peregrine falcon (*Falco peregrinus*) is likely to occur in New Jersey as a transient, during migration (USACE 1999).
    - A pair of peregrine falcons (*Falco peregrinus*) (Federally threatened, state endangered) nest in a nesting box behind Sea Isle City. There is another pair that nests on the marshes of the Tuckahoe River.

- The New York Bight Distinct Population Segment of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) and shortnose sturgeon are present in the area and are a federally listed endangered species;

- Several species of sea turtles may occur in the inshore waters of New Jersey from late spring to mid-fall including the Federally endangered Kemp's Ridley *(Lepidochelys kempii),* and green *(Chelonia mydas),* as well as the threatened loggerhead *(Caretta caretta).* In addition, the endangered leatherback *(Dermochelys coriacea)* sea turtle occupies the coastal waters of New Jersey during the summer months, foraging for jellyfish (USACE 1999).

- Endangered right whales *(Eubalaena glacialis)* and humpback whales *(Megaptera novaeangaliae)* are present in the mid-Atlantic waters off the coast of New Jersey in late winter through early spring. Endangered finback whales *(Balaenoptera physalus)* which are the most likely species to be in the coastal waters of New Jersey are present throughout the year. The endangered sperm whale (*Physeter catodon*), humpback whale (*Megaptera novaeangliae*), blue whale (*Balaenoptera musculus*), sei whale (*Balaenoptera borealis*) and black right whale (*Balaena glacialis*) may occasionally be encountered in nearshore waters within the study area during their migrations (USACE 1999, USACE 2001, USACE 2002a).

- Atlantic coast bottlenose dolphin (*Tursiops turncatus*), common dolphin (*Delphinus delphis*), common porpoise (*Phocoena phocoena*), short-finned pilot whale (*Globiocephala sieboldii macrorhyncus*) and fin whale (*Balaenoptera physalus*). The project area is within the range of the harbor seal (*Phoca vitulina*) (USACE 1999, USACE 2001, USACE 2002a).

- The harbor porpoise *(Phocoena phocoena),* has been proposed for listing as threatened under the Endangered Species Act. While mid-Atlantic waters are the southern extreme of their distribution, stranding data indicate a strong presence of harbor porpoise off the coast of New Jersey, predominately during spring (USACE 2001, USACE 2002a).

- The Red Knot (*Calidris canutus*) (Proposed) is a medium sized shorebird which utilizes barrier beaches, bay shorelines, tidal flats, and wetland margins as foraging areas. Small numbers of red knots may occur in New Jersey year-round, while large numbers of birds rely on New Jersey's coastal stopover *habitats during* the spring (mid-May through early June) and fall (late-July through November) migration periods. Smaller numbers of knots may spend all or part of the winter in New Jersey

- The GOM DPS for Atlantic sturgeon was listed as threatened and the New York Bight (NYB) DPS listed as endangered in a final rule on February 6, 2012 by NMFS. Atlantic sturgeon spawn in spring and early summer in freshwater and migrate into estuarine and marine waters where they spend most of their lives (http://www.nmfs.noaa.gov/pr/species/fish/atlanticsturgeon.htm). Atlantic sturgeons have been documented in the Merrimack River. Dams may impede access to some spawning habitat in the Tauton River and at the site of the Holyoke Dam on the Connecticut River in Massachusetts (Federal Register vol 77, no. 24, February 6, 2012).

- The shortnose sturgeon is an anadromous fish which lives mainly in the slower moving riverine waters or nearshore marine waters before migrating periodically into faster moving freshwater to spawn. Shortnose sturgeon can be found in the lower Merrimack River. They were listed as endangered throughout its range on March 11, 1967 under the Endangered Species Act of 1966 (http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm).

- Species of Concern listed by NMFS, and associated area of concern include the anadromous and highly migratory river herring (alewife and blueback herring) found in the Atlantic Ocean from Newfoundland to North Carolina, the pelagic and highly migratory Atlantic bluefin tuna found throughout the the North Atlantic Ocean and adjacent seas, the Atlantic halibut found from Labrador to southern New England in the Northwest Atlantic Ocean, the dusky shark found in the Western Atlantic Ocean, the porbeagle shark found in the Nortwest Atlantic Ocean, the anadromous rainbow smelt found in rivers and coastal areas of eastern North America from Labrador to New Jersey, and the sand tiger shark found in the Western Atlantic Ocean (http://www.nmfs.noaa.gov/pr/species/concern/).

- The American eel was petitioned to be listed as threatened on September 29, 2011 in the Federal Register (vol. 76, no. 189) by the USFWS. Eels spawn in the Sargasso Sea. Juveniles arrive in coastal waters and river systems which are accessible by the oceanic currents of the western North Atlantic Ocean for development. This fish occupies fresh, brackish and marine waters (FR, vol 76. No. 189).

- A detailed discussion of USFWS managed Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Appendix P, Attachment A).

State Listed Species

- A variety of State-listed endangered and threatened species inhabit the beaches and marshes of the Villas area. Several birds-of-prey occur in the vicinity of the project area including the State-listed endangered Cooper's hawk, and the State-listed threatened northern goshawk *(Accipiter gentilis),* red-shouldered hawk, barred owl *(Strix varia),* and longeared owl *(Asia otus)* (USACE 1999).

- Nesting populations of the State listed endangered northern harrier (*Circus cyaneus*) and black rail (*Laterallus jamaicensis*) nest in high emergent marshes. The State-listed endangered short-eared owl (*Asio flammeus*), and sedge wren (*Cistothorus latensis*) previously nested in Delaware bayshore marshes; however, their current breeding status in the project area is unknown. The State-listed threatened osprey (*Pandion haliaetus*) currently nests on trees, nesting platforms, and other structures within the project area. Nesting populations of the State-listed endangered sedge wren *(Cistothorus platens is)* occur in high emergent marshes.

- The State-listed threatened black rail *(Lateralus jamaicensis)* nests in emergent tidal marshes in the project area (USACE 1999).

- The State-listed endangered least tern and black skimmer, and State-listed threatened great blue heron (*Ardea herodias*) and yellow-crowned night heron utilize coastline habitats.
    - Large colonies of State threatened least tern (*Sterna dougallii*), common tern (*Sterna hirundo*), and black skimmer (*Rynchops niger*) use the Atlantic coast area along with any associated dunes, including Island Beach State Park (USACE 2002a).
- The largest colony of black skimmer recorded in this area inhabits the Strathmere Natural Area at Corson Inlet (USACE 2002a).
- Several osprey (Pandion haliaetus) pairs (state threatened) that nest mostly on artificial structures in this region (USACE 2002a).
- Birds/Waterbird Islands
- A detailed discussion on Waterbird Nesting Colonies can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Atlantic Coast

- One hundred and twenty-nine bird species are believed to utilize dune areas at the south end of Peck Beach Island, in the region of Corson's Inlet State Park.
- The shallow marsh habitat and dredged material disposal islands in backbay areas provide habitat for a variety of wading birds including: cattle egret (*Bubulcus ibis*), great egret (*Casmerodius albus*), little blue heron (*Egretta caerulea*), snowy egret (*Egretta thula*),tricolored heron (Egretta tricolor), yellow-crowned night-heron (*Nyctanassa violacea*), and black-crowned night-heron (*Nycticorax nycticorax*). Heron rookeries and gulleries have been sighted on marsh islands, although not as numerous as in regions immediately to the north and south of Townsends Inlet.
- Many of the islands in Barnegat Bay (Clam and Sedge Islands), and the isolated or undeveloped marshes and beaches on Long Beach Island and the mainland, provide nesting ground for a wide variety of migratory shorebirds including: glossy ibis (*Plegadis falcinellus*), green-backed heron (*Butorides striatus), little blue heron (Egretta caerulea), snowy egret (Egretta* thula), great egret (*Casmerodius albus*), black-crowned night heron (*Nycticorax nyticorax*), yellow-crowned night heron (*Nyctanassa violacea*), great black-backed gull (*Larus marinus*), herring gull (*Larus argentatus*), laughing gull (*Larus atricilla*), least tern (*Sterna antillarum*), black skimmer (*Rynchops niger*) and common tern (*Sterna hirundo*).

Hudson Raritan Estuary

Lower Bay

- The Lower Bay region provides significant wintering and migratory habitat for waterfowl species including greater scaup (*Aythya* spp.), Canada goose (*Branta candensis*), American black duck (*Anas ruripes*), brant (*Branta bernicla*), and long-tailed duck (*Clangula hyemalis*). Breeding waterbirds include American black duck, mallard (*Anas platyrhynchos*), clapper rail (*Rallus longirostris*), marsh wren (*Cistothorus palustris*), and willet (*Cataptrophours semipalmatus*) (USACE 2004, 2009).

Hudson River Estuary

- Wetlands and open water habitats in the lower Hudson support diverse bird communities. Concentrations of shorebirds, herons, and waterfowl use the shallow water habitats and mudflats as staging areas during migration. Breeding birds found in wetlands of the study area include Virginia rail (*Rallus limicola*), marsh wren (*Cistothorus palustris*), wood duck (*Aix sponsa*), and least bittern (*Ixobrychus exilis*).

Lower Raritan

- Edison wetland complex provides important habitat for waterfowl, shorebirds, and colonial waterbirds (USACE 2004, 2009).

Upper Bay

- The few remaining salt marshes in the study area support a variety of waterbirds. Great blue herons (*Ardea herodias*), great egrets (*Casmerodius albus*), snowy egrets (*Egretta thula*), black-crowned night herons (*Nycticorax nycticorax*) and double-crested cormorants (*Phalacrocorax auritus*) commonly forage in the area (USACE 2004, 2009).

- Waterfowl species that use the study area include American black duck (*Anas rubripes*), Canada goose (*Branta Canadensis*), mallard (*Anas platyrhynchos*), and gadwall (*Anas strepera*) (USACE 2004, 2009).

Newark Bay/Hackensack River/Passaic River

- The Passaic River is tidal from the mouth at Newark Bay to Dundee Dam, Anadromous fish runs have been eliminated from all reaches of the watershed above the Dundee Dam. The species that make annual spawning runs up the 17-mile tidal stretch of the Passaic River to the Dundee Dam include American shad, blueback herring (*Alosa aestivalis*), and alewife (*Alosa pseudoharengus*). Man-made dams and debris block fish passage in portions of the rivers and their tributaries. Similarly, a number of obstacles block or inhibit passage of these species along the Hackensack River with the Oradell Reservoir Dam blocking upstream passage and preventing most of the freshwater flow from the Hackensack River from reaching the New

Jersey Meadowlands. Catadromous species, like American eel, may also be negatively affected by these impediments (USACE 2004, 2009).

Critical Habitat/Atlantic Flyway

Delaware Bay

- Delaware Bay ranks as the largest spring staging site for shorebirds in eastern North America. Staging sites, such as the study area, serve to link wintering areas with breeding grounds, and are critical to the survival of hundreds of thousands of migrating shorebirds (USACE 1999).

    - The most common species are the sanderling *(Calidris alba),* semipalmated sandpiper *(Calidris pusilla),* ruddy turnstone *(Arenaria interpres),* and red knot *(Calidris canutus)* (Niles~ Undated). Other common species include yellowlegs *(Totanus spp.),* dowitcher *(Limnodromus spp.),* dunlin *(Calidris alpina),* and least sandpiper *(Calidris minutilla).*

    - The birds arrive at the shores of the bay in early May from the coast of Brazil, Patagonia, Tierra del Fuego, Chile, Peru, Surinam, Venezuela, and the Guyanas. They reach the bay depleted of their energy reserves after several days of nonstop flight, traveling up to 5,000 miles. On the beaches, the birds feast on horseshoe crab eggs for an estimated 15 days to fuel their northward migration from the bay to their Arctic nesting grounds. The Western Hemisphere Shorebird Reserve Network (WSHRN) was created in 1985 by the International Association of Fish and Wildlife Agencies.

    - The lower 25 miles of the Delaware Bay shore of New Jersey and Delaware has been established as a "Sister Reserve" through a joint resolution by then Governors Thomas H. Kean of New Jersey and Michael M. Castle of Delaware. The objective of the joint resolution is to recognize and protect the critical migrating and feeding habitat for over one million shorebirds which utilize the Delaware Bay during spring migration between April and June (USACE 1999).

- A variety of raptors use habitats along the Delaware Bay coastline for migrations and overwintering. Migratory raptors concentrate along the southern tip of New Jersey prior to crossing the Delaware Bay (USACE 1999).

    - The most numerous species encountered during these migrations are the sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk (*A. cooperii*), red-tailed hawk (*Buteo jamaicensis*), red-shouldered hawk, broad-winged hawk, American kestrel (*Falco sparverius*), and merlin. Owls, which undertake a similar migration, include the barn owl (*Tyto alba*), northern saw-whet owl (*Aegolills acadicus*), and long-eared owl (*Asio otus*) (U.S. Fish and Wildlife Service).

    - Migratory raptor surveys conducted each fall at Cape May Point by the Cape May Bird Observatory have shown a dramatic increase in observations of bald eagle and peregrine falcons since 1976. Peregrine nest towers have been placed in Delaware Bay coastline marshes at Heislerville and Egg Island Wildlife Management Areas.

- The area of the Fortescue, Glades and the nearby Maurice River marshes appear to support the highest wintering eagle concentrations of any Delaware Bay coastline marsh.

- The beaches and adjacent sand flats are especially important nesting, feeding, and migratory habitat for many species of waterfowl and birds.

- A detailed discussion on the importance of the Delaware Bay as a migratory shorebird stopover can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Atlantic Coast

- The Cape May peninsula is very important for a variety of fish and wildlife resources. Millions of migratory birds pass through the area, a critical stopover point along the Atlantic Flyway, in spring and fall migrations.

- Almost any species that migrates along the east coast of North America can be found in Cape May County during migration. Other birds that would be expected to use dune/beach/sand flat habitat include the great egret *(Casmerodius a/bus),* snowy egret *(Egretta thula),* great black-backed gull *(Larus marinus),* herring gull *(Larus argentatus),* ring-billed gull *(Larus delawarensis),* laughing gull *(Larus atricilla),* least tern *(Sterna antillarum),* black skimmer *(Rynchops niger),* common tern *(Sterna hirundo)* eastern willet *(Catoptrophorus semipalmatus),* black-bellied plover *(Squatarola squatarola),* and mallard duck *(Anas platyrhynchos)* (USACE 1999).

Hudson Raritan Estuary

Arthur Kill/Kill van Kull

- The Arthur Kill/Kill Van Kull complex has been designated as a Significant Habitat Complex of the New York Bight Watershed by the USFWS (USFWS 1997, USACE 2009).

- With 9 tributaries (notably Rahway and Elizabeth Rivers), this region offers much needed backwater habitat for important marine and estuarine fish species, such as winter flounder, black sea bass, and red hake (RPA 2003). This region also contains deepwater habitats in which over 60 migratory and resident fish species have been collected (USACE 2004).

- Remnant patches of undisturbed wetland and upland habitat include regionally-rare vegetative communities that include southern and coastal plant species like native persimmon (*Diospyros virginiana*), blackjack oak (*Quercus marilandica*), sweet bay (*Magnolia virginiana*), and a population of southern leopard frogs (*Rana sphenocephala*). These patches are important for landbirds, including Neotropical migrant songbirds because they provide small areas of natural habitat for resting, foraging, and breeding in an otherwise urbanized landscape. Although these habitat patches can be important to many species of wildlife, their small size and isolation from one another reduces their habitat value for some groups of species, such as forest-nesting birds (USACE 2004, 2009).

- The freshwater tributaries have the potential to provide spawning habitat for anadromous fish such as striped bass (*Morone saxitilis*) and alewife (*Alosa pseudoharengus*). However, in many cases, debris dams, tidegates, and other structures block fish passage.

Lower Bay

- The Raritan – Sandy Hook Bay complex (NJ) is one of the USFWS Significant Habitats and Habitat Complexes of the New York Bight Watershed. This region is ecologically significant because of its geographic location and the presence of a variety of habitat types, including several rare ecological communities and plant species. The Sandy Hook Peninsula separates the Atlantic Ocean from the southern portion of the Estuary. Sandy Hook and Sandy Hook Bay are located at the junction between the east-west oriented coastline of New England and the north-south oriented coastline of the mid-Atlantic study area. This configuration concentrates fish and wildlife species migrating to and from New England and the mid-Atlantic coast. Development in the surrounding upland areas further concentrates migratory species into the remaining undeveloped open space (both upland and wetland) and open water areas in the Lower Bay (USACE 2004, 2009).

- The Lower Bay contains significant habitat for shellfish and marine, estuarine, and anadramous fish. Open water habitats are important for wintering and migratory waterfowl. Wetlands and uplands in the study area provide important nursery habitat for fish, foraging habitat for waterbirds and shorebirds, nesting habitat for diamond-backed terrapins, and migratory and wintering stopovers for songbirds, raptors, and shorebirds (USACE 2004, 2009).

- Over 90 species of fish have been reported in the Lower Bay. Resident species include mummichog (*Fundulus heteroclitus*), white perch (*Morone americana*), and hogchoker (*Trinectes macalatus*). Fish species of recreational importance include, but are not limited to, bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*) weakfish (*Cynoscion regalis*), and winter flounder (*Pleuronectes americanus*). The Lower Bay, particularly around Raritan and Sandy Hook Bays, support important commercial fisheries for American shad (*Alosa sapidissima*), American eel (*Anguilla rostrata*), and American lobster (*Homarus americanus*). Blue crab (*Callinectes sapidus*) and horseshoe crab (*Limulus polyphemus*) are also harvested (USACE 2004, 2009). The area is also an important stopover for migratory landbirds and shorebirds. During spring and fall migration sanderling (*Calidris alba*), ruddy turnstone (*Arenaria interpres*), and semipalmated sandpiper (*Calidris pusilla*) forage in the mudflats and subtidal shallows along the south shores of Monmouth County (USACE 2004, 2009).

- Although the fish community in the Lower Bay study area is diverse, habitat quality for some species (particularly those that swim upstream to spawn) has been reduced as a result of human alteration of the landscape. For example, dams on the Swimming River and the Shadow Lake branch of the Navesink River prevent anadromous fish from reaching upstream areas to spawn. Species that have been confirmed at the base of these dams include alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*).

- The Lower Bay region also provides habitat for marine mammals and sea turtles. Harbor seals (*Phoca vitulina vitulina*), ringed seals (*Phoca hispida*), and harp seals (*Phoca groenlandica*) are commonly seen off of Sandy Hook Peninsula. Loggerhead sea turtles (*Caretta caretta*) and Atlantic Ridley sea turtles (*Lepidochelys kempii*) are often seen feeding in the offshore waters of Sandy Hook Bay (USACE 2004, 2009).

- Sandy Hook (GNRA) sustains large populations of beach-nesting birds, and consistently supports a large population of nesting colonies of piping plovers (USFWS 1997, USACE 2009).

Hudson River Estuary

- This region is located within a USFWS designated Significant Habitat Complex of the New York Bight Watershed (USFWS 1997).

- The regions wetlands also support a diverse community of reptiles such as northern water snake (*Nerodia sipedon sipedon*), diamond-backed terrapin (*Malaclemys terrapin terrapin*), and snapping turtle (*Cheldrya serpentine*) (USACE 2004, 2009).

- Areas of SAV in Piermont Marsh (large wetland complex in the region) provide cover and nursery habitat for fish. Water celery and other aquatic plants are important food resources for canvasback ducks (*Aythya valisineria*) (USACE 2004, 2009).

- The Lower Hudson River includes a wide range of riverine and estuarine habitats that function as overwintering habitat and significant nursery areas for many fish and invertebrate species. Twenty-three fish species are common in the study area with bay anchovy (*Anchoa mitchilli*), winter flounder (*Pleuronectes americanus*), American shad (*Aalosa sapidissima*), Atlantic tomcod (*Microgadus tomcod*), and alewife (*Alosa pseudoharengus*) being the dominant species. The area is also extremely important nursery and wintering habitat for striped bass (*Morone saxitilis*). The conditions prevalent in pier, shoal, and inter-pier areas may be particularly important foraging and overwintering areas for juvenile fish as they move from nursery habitat upstream, to the more saline waters of the Estuary (USACE 2004, 2009).

- Haverstraw Bay Significant Coastal Fish and Wildlife Habitat area is a critical habitat for most estuarine-dependent fisheries originating from the Hudson River. This area contributes directly to the production of in-river and ocean populations of food, game, and forage fish species. Consequently, commercial and recreational fisheries throughout the Atlantic Coast depend on, or benefit from, these biological inputs from the Hudson River estuary. Haverstraw Bay is a major nursery and feeding area for certain marine species, most notably bay anchovy (*Anchoa mitchilli*), Atlantic menhaden (*Brevoortia tyrannus*) and Atlantic blue crab (*Callinectes sapidus*). Atlantic tomcod (*Microgadus tomcod*), bluefish (*Pomatomus saltatrix*), fourspine stickleback

(Apeltes quadracus), Hogchoker (*Trinectes maculatus*), killifish (*Fundulus* spp.), rainbow smelt (*Osmerus mordax*), silversides (*Menidia menidia*), summer flounder (*Paralichthys dentatus*), threespine stickleback (*Gasterosteus aculeatus*), white perch (*Morone americana*), common carp (*Cyprinus carpio*), American eel (*Anguilla rostrata*) and white catfish (*Ameiurus catus*) are also found in this area.

- Haverstraw Bay regularly comprises a substantial part of the nursery area for striped bass (*Morone saxatilis*), American shad (*Alosa sapidissima*), white perch (*Morone americana*), Atlantic tomcod (*Microgadus tomcod*), and Atlantic sturgeon (*Acipenser oxyrhynchus*). Other anadromous species, such as blueback herring (*Alosa aestivalis*) and alewife (*Alosa pseudoharengus*), spawn in upstream freshwater areas, but move south and concentrate in this area before leaving the river in the fall. Depending on location of the salt front, a majority of the spawning and wintering populations of Atlantic sturgeon (*Acipenser oxyrhynchus*) in the Hudson may reside in Haverstraw Bay. Shortnose sturgeon (*Acipenser brevirostrum*) usually winter in this area as well. Croton Point is a place where common loons (*Gavia immer*) overwinter. Harbor seals (*Phoca vitulina*) use the surface waters of this habitat during winter months.

- This area provides habitat for several threatened and endangered species including the p*eregrine falcon (Falco pregrinus*), *shortnose sturgeon* (*Acipenser brevirostrum), and Atlantic* sturgeon (*A. oxyrhynchus*) (USACE 2004, 2009).

Lower Raritan

- Edison wetland complex provides important habitat for waterfowl, shorebirds, colonial waterbirds, mammals, and anadromous fish in an otherwise highly urbanized environment (USACE 2004, 2009).

- Forested and old-field habitats that remain are important to a variety of species because these fragments of habitat provide nesting and migratory stopover sites for a variety of landbirds including warblers and sparrows. Additionally, remaining wetland habitats provide foraging habitat for wading birds such great blue herons (*Ardea herodias*) and great egrets (*Casmerodius albus*) (USACE 2004, 2009).

Upper Bay

- Many marine and estuarine finfish species, like bluefish, scup, striped bass, and winter flounder use the Upper Bay as nursery, foraging areas and overwintering habitat (USACE 2004a). It is considered a critical component of the HRE because it serves as a migratory pathway for many species of fish (USACE 2004, 2009).

- Diamond-backed terrapins (*Malaclemys terrapin terrapin*) are found in the study area (USACE 2004, 2009).

- The contamination of both marine sediments by chemical pollutants and heavy metals and the resulting spread of those materials through aquatic and terrestrial food chains have been recognized as key environmental problems. Numerous studies of the contaminant problems throughout the HRE region have been undertaken by various organizations and agencies, including the Environmental Protection Agency, the National Oceanic and Atmospheric Administration (NOAA), the USACE and the States of New York and New Jersey, which have focused on the relationship between sediment contaminant levels and benthic habitat quality (USACE 2004, 2009).

Newark Bay/Hackensack River/Passaic River

- The Hackensack River is of moderate salinity from the mouth upstream to Cromakill Creek. In this mesohaline reach, a combination of marine and estuarine invertebrates, fish, and turtles can be found. Upstream of Cromakill Creek, the Hackensack River is of low salinity and supports both estuarine and freshwater species (USACE 2004, 2009).

- Two large habitat complexes of regional importance and ecological value in this region are the New Jersey Hackensack Meadowlands and a portion of the Central Basin Wetlands. The largest remaining brackish wetland complex in the HRE study area, the Hackensack Meadowlands District, measures approximately 8,400 acres (USACE 2004b). Originally a large, 21,000 acres marshland complex, the Meadowlands have diverse habitat types and over 100 species of nesting birds, fish and shellfish, many of which are State – or Federally-protected (RPA 2003). Near the Watchung Mountains, the Central Basin Wetlands support large swamp areas and forested wetlands that are fed by several important tributaries (USACE 2004, 2009).

- The Raritan River is the largest watershed completely within New Jersey that supports migratory fish species. The American Shad (*Alosa sapidissima)* was once the most plentiful anadromous fish to swim up the river. Dams, located on the Lower Raritan River and its tributaries impede the movement of diadromous fish that travel upriver or downriver to spawn. The removals of the Calco and Robert Street dams as well as the planned removal of the Nevius Street dam have opened up 35 river and tributary miles of spawning habitat.

Horseshoe crabs

- The largest population of spawning horseshoe crabs in the world is found in the Delaware Bay (USFWS 1995a, USACE 1999).

    - Horseshoe crab eggs provide a critical food source for the thousands of shorebirds that migrate through Delaware Bay each spring. Each spring adult horseshoe crabs migrate from deep water in the Delaware Bay and the Atlantic continental shelf to spawn on Delaware Bay beaches.

    - The uniform morphology of Delaware Bay's lower shoreline facilitates movement of horseshoe crabs along the shoreline and enables them to find suitable spawning beaches. Spawning generally occurs from April to July, with the peak spawning activity occurring on full moon high tides in May and June. The average width of the intertidal area used by horseshoe crabs for spawning is about 45 feet on Delaware Bay beaches.

- In addition to the intertidal zone used for spawning, horseshoe crabs also use shallow water areas (less than two fathom depths) such as intertidal flats and shoal water as nursery habitat for juvenile life stages. Adult horseshoe crabs forage in deep water habitat during most of the year, except during the breeding season when they move into shallow and intertidal water.

- Spawning horseshoe crabs may congregate on mud flats to wait for full moon high tides, because these areas provide protection from wave energy.

- Horseshoe crab habitat is being lost throughout the Delaware Bay. The populations of many bird species depend on the reproductive success of the horseshoe crab. A detailed discussion on the importance of horshoe crabs in the Delaware Bay can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Fish/Essential Fish Habitat (EFH)

- New York Bight Distinct Population Segment of Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) and shortnose sturgeon are present in the area and are a federally listed endangered species;

- There are Habitat Areas of Particular Concern (HAPC) for Sandbar shark (*Charcharinus plumbeus*) in parts of New Jersey, including Ocean City, and Cape May, SAV beds are HAPCs for summer flounder in parts of New Jersey.

Delaware Bay

- Delaware Bay estuary, contiguous streams, and adjacent wetlands provide nursery grounds for many coastal fish populations, and support recreational and commercial fisheries for fin and shellfish.

  - The Delaware Bay is borne to over 100 species of finfish, many of which are commercially or recreationally important. This great diversity is the result of the overlap between northern and southern species in the mid-Atlantic coastal region. Many species use the bay as a breeding ground and nursery area for their young. Abundant finfish species include: red hake (*Urophycis chuss),* northern sea robin *(Prionotus carolinus),* spot *(Leiostomus xanthurus),* windowpane flounder *(Scopthalmus aquosus),* silver hake *(Merluccuns bilinear* is), clearnose skate *(Raja eglanteria),* bogchoker *(Trinectes maculatus),* and weakfish *(Cynocion regalis)* (USACE 1999).

- In terms of its abundance and value to the recreational and commercial fisheries, the weakfish ranks as one of the most important species in Delaware Bay. It is a seasonal resident from April through October.

- The bayshore area is also used by commercial gill netters for American shad *(Alosa sapidissima),* bluefish *(Pomatomus saltatrix),* and menhaden *(Brevoortia tyrannus),* with recreational use increasing, particularly for striped bass *(Marone saxatilis)* (USACE 1999).

Atlantic Coast

- The proximity of several embayments allows the coastal waters of New Jersey to have a productive fishery. Many species utilize the estuaries behind Ludlam Island and Peck Beach for forage and nursery grounds. The finfish found along the Atlantic Coast of New Jersey are principally seasonal migrants. Winter is a time of low abundance and diversity as most species leave the area for warmer waters offshore and southward. During the spring, increasing numbers of fish are attracted to the New Jersey Coast, because of its proximity to several estuaries, which are utilized by these fish for spawning and nurseries (USACE 2002a).

- The Atlantic Coast of New Jersey provides EFH for:
    - Atlantic cod (*Gadus morhua*)
    - Whiting (*Merluccius bilinearis*)
    - Red hake (*Urophycis chuss*)
    - Redfish (*Sebastes fasciatus*)
    - Witch flounder (*Glyptocephalus cynoglossus*)
    - Winter flounder (*Pleuronectes americanus*)
    - Windowpane flounder (*Scopthalmus aquosus*)
    - Yellowtail flounder (*Pleuronectes ferruginea*)
    - Atlantic sea herring (*Clupea harengus*)
    - Monkfish (*Lophius americanus*)
    - Bluefish (*Pomatomus saltatrix*)
    - Long finned squid (*Loligo pealei*)
    - Short finned squid (*Illex ilecebrosus*)
    - Atlantic butterfish (*Peprilus tricanthus*)
    - Summer flounder (*Paralicthys dentatus*)

  - Scup (*Stenotomus chrysops*)
  - Black sea bass (*Centropristus striata*)
  - Surfclam (*Spisula solidissima*)
  - Ocean quahog (*Artica islandica*)
  - Spiny dogfish (*Squalus acanthias*)
  - King mackerel (*Scomberomorus cavalla*)
  - Spanish mackerel (*Scomberomorus maculatus*)
  - Cobia (*Rachycentron canadum*)
  - Sand tiger shark (*Odontaspis taurus*)
  - Atlantic angel shark (*Squatina dumerili*)
  - Dusky shark (*Charcharinus obscurus*)
  - Sandbar shark (*Charcharinus plumbeus*)
  - Tiger shark (*Galeocerdo cuvieri*)
  - Atl. Sharpnose shark (*Rhizopriondon terraenovae*)
  - Ocean pout (*Macrozoarces americanus*)
  - Atlantic sea herring (*Clupea harengus*)
  - Long finned squid (*Loligo pealei*)
  - Short finned squid (*Illex ilecebrosus*)
  - Atlantic butterfish (*Peprilus tricanthus*)

- Recreational fishing in southern New Jersey consists of scup (*Stenotomus chrysops*), black sea bass (*Centropristis striata*), summer flounder (*Paralichtys dentatus*), weakfish (*Cynoscion regalis*), bluefish (*Pomatomus saltatrix*), red hake (*Urophycis chuss*), white hake (*Urophycis tenuis*), silver hake (*Merluccius bilinearis*), Atlantic mackerel (*Scomber scombrus*), chub mackerel (*S. japonicus*), Atlantic cod (*Gadus morhua*), northern *kingfish (Menticirrhus saxatilis*), and tautog (*Tautoga onitiss*). Northern puffer (*Sphaeroides maculatus*), spot (*Leiostomus* *xanthurus*), red drum (*Sciaenops ocellatus*), pollock (*Pollachius virens*), and Atlantic bonito (*Sarda sarda*) may also be taken occasionally (USACE 2002a).

- Commercially important species include menhaden (*Brevoortia tyrannus*), winter flounder, weakfish, bluefish, scup, mackerel, silver hake, red hake, yellow flounder, black sea bass, butterfish (*Perpilus triacanthus*), and shad (*Alosa mediocris*) (USACE 2002a).

- Delaware Bay estuary, contiguous streams, and adjacent wetlands provide nursery grounds for many coastal fish populations, and support recreational and commercial fisheries for fin and shellfish (USACE 1999).

    - The Delaware Bay is borne to over 100 species of finfish, many of which are commercially or recreationally important. This great diversity is the result of the overlap between northern and southern species in the mid-Atlantic coastal region. Many species use the bay as a breeding ground and nursery area for their young. Abundant finfish species include: red hake (*Urophycis chuss),* northern sea robin *(Prionotus carolinus),* spot *(Leiostomus xanthurus),* windowpane flounder *(Scopthalmus aquosus),* silver hake *(Merluccuns bilinear* is), clearnose skate *(Raja eglanteria),* bogchoker *(Trinectes maculatus),* and weakfish *(Cynocion regalis).*

    - In terms of its abundance and value to the recreational and commercial fisheries, the weakfish ranks as one of the most important species in Delaware Bay. It is a seasonal resident from April through October.

    - The bayshore area is also used by commercial gill netters for American shad *(Alosa sapidissima),* bluefish *(Pomatomus saltatrix),* and menhaden *(Brevoortia tyrannus),* with recreational use increasing, particularly for striped bass *(Marone saxatilis)* (McDowell. 1995).

Hudson Raritan Estuary

- Atlantic butterfish (*Peprilus triacanthus*), Atlantic mackerel (*Scomber scombrus*), Atlantic sea herring (*Clupea harengus*), black sea bass (*Centropristis striata*), bluefish (*Pomatomus saltatrix*), clearnose skate (*Raja eglanteria*), cobia (*Rachycentron canadum*), dusky shark (*Carcharhinus obscurus*), king mackerel (*Scomberomorus cavalla*), little skate (*Raja erinacea*), long finned squid (*Loligo pealeii*), monkfish (*Lophius americanus*), ocean quahog (*Artica islandica*), red hake (*Urophycis chuss*), redfish (*Sebastes fasciatus*), sand tiger shark (*Carcharias taurus*), sandbar shark (*Carcharhinus plumbeus*), scup (*Stenotomus chrysops*), short finned squid (*Illex illecebrosus*), Spanish mackerel (*Scomberomorus maculatus*), spiny dogfish (*Squalus acanthias*), summer flounder (*Paralichthys dentatus*), surf clam (*Spisula solidissima*), whiting (*Merluccius bilinearis*), windowpane flounder (*Scophthalmus aquosus*), winter flounder (*Pseudopleuronectes americanus*), winter skate (*Leucoraja ocellata*).

Habitat Areas of Particular Concern (HAPC)

- Summer Flounder (Paralichthys dentatus) All native species of macroalgae, seagrasses and freshwater and tidal macrophytes in any size bed as well as loose aggregations, within adult and juvenile EFH (http://www.nero.noaa.gov/hcd/efhtables.pdf).

- Tilefish are shelter-seeking and habitat limited, HAPC is substrate between the 76 and 365m isobath, from U.S. / Canadian Boundary to the Virginia / North Carolina boundary within statistical areas 616 and 537 (intersection of isobaths east of Cape May, NJ and south of Provincetown, MA) (http://www.nero.noaa.gov/hcd/efhtables.pdf).

Shellfish

Delaware Bay

- Extensive shellfish beds, which fluctuate in quality and productivity, are found in the back bays and shallow ocean waters of the study area. Atlantic surfclams *(Spisula solidissima*), hard clams (*Mercenaria mercenaria*), blue mussels (*Mytilus edulis*) and blue crabs (*Callinectes sapidus*) are common commercial and recreational shellfish within the coastal waters of the study area. The blue crab and the hard clam are two of the most important invertebrates of recreational and commercial value along the New Jersey Coast, and are common in backbays and inlets (USACE 1999).

- The blue crab *(Callinectes sapidus)* is widely distributed in Delaware Bay and is an important component of the commercial fishery. The bay's blue crab population is considered healthy and sustainable despite annual fluctuations in catch. Over two million pounds a year are commercially harvested by dredge in the fall (USACE 1999).

- Delaware Bay – Oyster seed beds are located north of Fortescue while most of the leasing grounds and tonging areas occur south of Fortescue.
  - The oyster fishery ranges from the mouth of the Maurice River and shoals on the New Jersey side to the Smyrna and Cohansey rivers These low salinity areas provide a refuge for young oysters to grow, free from predation and competition that limits survival in higher salinity, downbay water.

Atlantic Coast

- Surf clams are the largest bivalve community found off the Atlantic coast from the Gulf of Saint Lawrence, Canada to North Carolina (USACE 2001).
  - Surfclams most commonly inhabit substrates composed of medium to coarse sand and gravel in turbulent marine waters just beyond the breaker zone (USACE 2001).

  - The surfclam fishery supports the largest molluscan fishery in New Jersey, accounting for, by weight, 67% of the State's total molluscan commercial landing in 1999. Surfclam resources in Cape May County (ie. below Great Egg Harbor Inlet) have contributed 14.4% to the total harvest in the 1999-2000 season, and had been as high as 24.8% in the 1998-1999 season.

  - NJDEP has established surfclam conservation zones along the NJ coast, which prohibits harvest in these areas.

- Hard-shell clam harvest in the northern half of Barnegat Bay earns high commercial fishery revenues (USACE 2001).

  - The hard clam is the most economically important shellfish of the back bays, supporting both commercial and recreational fisheries (USACE 2001). Although data on exact locations and densities of adult hard clams within the project area is limited, they are known to be found in the intertidal and subtidal zones of bays and lower estuaries.

  - Barnegat Bay – Sixty-six acres are leased in for commercial harvesting of oysters and hard shelled clams Soft clams (*Mya arenaria*) and blue mussels are primarily harvested for recreation, but occasionally commercial densities are present (USACE 2001).

II. Habitat Impacts from Hurricane Sandy - New Jersey

Sandy turned to the north-northwest and made landfall as a post-tropical cyclone on 29 October 2012 near Atlantic City, NJ with winds of 90 mph, causing extensive flooding, beach erosion, and coastal damage along the shorelines of Delaware, New Jersey, and New York. As Sandy approached landfall, it generated intense onshore winds, waves, and a storm surge that was augmented by astronomical spring tides associated with the full moon of 29 October 2012.

Within the New York and northern New Jersey area, Sandy had a larger effect on areas close to the Atlantic Ocean—Jamaica Bay, Sandy Hook, and Staten Island. Areas located farther upriver from the harbor saw little damage from flooding, although winds were still a factor. Areas around the harbor saw heavy flooding, carrying with it high volumes of sand, Phragmites wrack, and trash, which then further impacted inshore communities by covering understory plants in thick layers of debris. Farther north, reports from the Bronx River, the Hudson River and the Catskills all indicated little to no damage to the waterways. Flooding was reported from the banks of the Hudson only and does not appear to have been as great as that seen in New York City. There was minimal damage to the shorelines.

In general, most observed damage was above the tide lines, and was primarily due to winds or flooding from the tide.

Coastal and Marine Habitats

Beaches and Dunes

- The erosion impacts described by the resource managers that more than 50% of the beach and dune habitat in the Hudson/Raritan Jamaica Bay region and Long Island Sound suffered a similar fate (ALS 2012).

- The U.S. Army Corps' of Engineer's Lower Cape May Meadows ecological restoration project at TNC's South Cape May Meadows Preserve and Cape May Point State Park saw minimal impacts to the dunes from the storm, but this area was not as directly impacted by the storm as other parts of the New Jersey coast.

Hudson Raritan Estuary–NY/NJ Harbor Region (HRE)

- Raritan Bay – The primary impact to the 2.7 mile shoreline in Keansburg, East Keansburg, and Laurence Harbor, NJ was loss of beach fill. Storm impacts to the beach cross-section consisted of lowering and flattening of the berm above water, plus reduction of berm width. Lowering and flattening of the berm occurred over the entire project length. Shoreline recession averaged 26 feet and 7 feet in Laurence Harbor and Keansburg/East Keansburg, respectively. Some locations that had dunes prior to the storm lost 100% or near 100% of existing dunes, plus any established dune vegetation. Significant overwash of sand into landside streets occurred, and several homes were destroyed within the protected area. In addition to the sand loss there was significant damage to the closure levees in Keansburg. Two wingwalls at the tide gate structure in Keansburg moved by nearly four inches. Impacted species include: This area is important nursery habitat for fish, foraging habitat for waterbirds and shorebirds, nesting habitat for diamond-backed terrapins, and migratory and wintering stopovers for songbirds, raptors, and shorebirds (USACE 2012).

Atlantic Coast

- Beach and dune habitat along the New Jersey Atlantic coastline was particularly hard hit with approximately 65% experiencing Moderate Damage and a few areas showing High Damage (ALS 2012).

- The towns of Stone Harbor, Avalon, and the north end of Corson's Inlet State Park near Ocean City. Dunes were flattened and sand was lost causing the elevation of these beaches to be lowered. The lower elevations render the already compromised beaches vulnerable to additional impacts by exposing them to high or neap tide flooding as well as storm surges and wave action from winter storms. This has the potential to further erode nesting habitat for shorebirds such as the piping plover, and to subject the nests in the remaining habitat to flooding (ALS 2012).

    - There was significant beach erosion caused by the extreme storm surge and wave action associated with Sandy north end of Corson's Inlet State Park near Ocean City, New Jersey, where the ocean breached a section of dunes flooding the interior and significantly damaging the already seriously eroded piping plover habitat (ALS 2012).

- Stone Harbor Point in Cape May County, with its low profile and lack of dunes, experienced extensive overwash (ALS 2012).
  - The immense storm surge and resultant beach and dune erosion created another problem by lowering the elevation of beaches throughout the area. The lower elevations have rendered the already compromised beaches vulnerable to additional impacts from high or neap tide flooding as well as from storm surges and wave action that will inevitably come with winter storms. Additional nesting habitat for shorebirds, such as the Piping Plover will be lost, and the nests that are established in the remaining habitat will be subjected to flooding. This low elevation problem was specifically observed at beaches at Stone Harbor and Avalon in New Jersey (ALS 2012).

- Sea Bright to Manasquan Inlet, NJ – The primary impact along the 21 mile stretch of shoreline from Sea Bright to the Manasquan Inlet, NJ was loss of beach fill. Storm impacts to the beach cross-section consist of lowering and flattening of the berm above water, plus reduction of berm width. Lowering and flattening of the berm occurred over the entire project length (Sea Bright to Manasquan Inlet) with an estimated average drop in beach elevation of 5-10 feet. Berm widths decreased generally, however berm widths did increase in some locations. Locations which had dunes prior to the storm lost 100% or near 100% of existing dunes, plus any established dune vegetation. Significant overwash of sand into landside streets occurred. This area is critical to nesting seabirds and shorebirds, migrant and wintering shorebirds for feeding and roosting, important to migrant and wintering seabirds (USACE NAN 2012).

- Sandy Hook, NJ, was exposed to the full power of the tidal surge and the worst of the storm's winds. The shore profile was completely changed and sand dunes along the peninsula were pushed up to several hundred feet west. Many dunes were completely flattened, likely causing great amounts of damage to the beach grass normally found on them and to the bird species that use them for breeding. The holly, *Illex opaca,* and red cedar, *Juniperus virginiana*, forests in the area held up well through the storm, while the marshes in Navesink and Shrewsbury Rivers to the south had a significant amount of debris and many of the shore areas in towns in the area were covered in sand. Atlantic Highlands, west of Sandy Hook was also reportedly damaged but no facts about the damage were available (HRF 2012).

- Breached Berm at Wreck Pond Outfall, Spring Lake, NJ. The sand berm broke through at Wreck Pond, allowing flow of sea water directly into and out of the pond overland. Prior to the storm water exchange between pond and ocean was via an 84" diameter reinforced concrete cylinder pipe (RCCP) buried beneath the berm. Impacted species include: American Shad and River herring Creates early successional habitat for plovers, tern, seabeach amaranth (USACE NAN 2012).

- In some cases, natural dune systems provided a strong defense against the ocean storm surge and significantly limited damage to property and infrastructure.

- Seven Presidents Oceanfront Park in Long Branch, NJ – The combination of a wide beach, well-established dune system and a substantial bluff protected the boardwalk and pavilion behind them while other beach and dune areas wiped out. Positively impacted species include: Piping plover, least tern (ALS 2012).

- Bayshore Waterfront Park, Monmouth Marina, NJ – Area experienced a 7 foot tidal surge, the recently reconstructed dune between the upland portion of the park and Sandy Hook Bay protected the historic Cedric Wilson House. The unprotected Monmouth Marina adjacent to the park was completely destroyed by the surge and may be abandoned rather than rebuilt (ALS 2012).

- Natural dune systems, such as those at Barnegat Light, NJ, provided a strong defense against the ocean storm surge and significantly limited damage to property and infrastructure (ALS 2012).

- The “natural” beaches of Little Beach and Holgate, part of the Forsythe National Wildlife Refuge, experienced extensive overwash and erosion resulting in significant landward migration (ALS 2012).

- Avalon Dunes, which have a natural beach, in part because they are managed for nesting shorebirds, and utilize a less intensive beach maintenance regimen (i.e., less mechanical beach raking and sand transfers), appear to have been more resilient than nearby or adjacent beaches that were subject to more heavy maintenance activities (ALS 2012).

- The beach of Longport, NJ (north of Ocean City, NJ), is New Jersey’s only significant Black skimmers (state endangered) nesting colony with 200 + utilizing the habitat. It was impacted and should be assessed (ALS 2012).

Delaware Bay Coast of New Jersey

- A rapid response survey in the Reeds Beach area found horseshoe crab spawning habitat had decreased significantly post-Hurricane Sandy. The loss of horseshoe crabspawning habitat would lead to a loss of horseshoe crab eggs, the “lifeblood” of many migrating shorebirds in the Atlantic. The cascading effects would be that migrating shorebirds will not gain enough fat for their trip to Arctic breeding grounds and without significant weight gain, shorebirds won’t lay eggs to produce fledglings. The effects of Hurricane Sandy could significantly decrease the carrying capacity for horseshoe crabs and shorebirds (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).

- A loss of 2 to 3 feet of sand was reported on many of the Delaware Bay, NJ beaches and the force of the storm placed most of this sand well above the normal high tide line and out of reach of spawning horseshoe crabs. The remaining portions of the beaches were covered with debris, including chunks of asphalt and bricks strewn throughout the substrate, which can impact the horseshoe crab's ability to dig in to lay eggs. In addition, larger debris such as concrete pipes, slabs, and pilings created impingement hazards and may further hamper or prevent spawning. These beaches also serve as habitat for a number of other shorebirds, including ruddy turnstone, sanderling, sandpiper, dunlin, and shortbilled dowitcher (ALS 2012).

Barrier Islands/Inlets

Inlets

- The inlets that create openings to the line of barrier islands between the Atlantic Ocean and New Jersey's bays provide some of the most important nesting shorebird habitat in the project area. Many of these inlets, including Hereford Inlet, Townsend's Inlet, Corson's Inlet, Great Egg Harbor Inlet and Brigantine Inlet, suffered significant damage. The berms and dunes in these areas were flattened and vulnerable to flooding, decreasing the suitability of this nesting habitat. It is unlikely thatthese impacted inlets could still support the large least tern colonies that have utilized them in recent years. Other species that could be impacted by this loss of habitat include piping plover, American oystercatcher, least tern, black skimmer and common tern (ALS 2012).

- Highly dynamic barrier features, critical to migrant and nesting shorebirds, and important for nesting seabirds were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).

- Vast areas of inlet, beach, and overwash habitats have been created on the New York and New Jersey coasts. These areas may provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013a).

Barrier islands

- Barrier islands are critical to nesting seabirds and shorebirds, critical to migrant and wintering shorebirds for feeding and roosting, important to migrant and wintering seabirds and were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).
    - Barrier sand beach systems are critical to obligate beach-nesting shorebirds and seabirds, migrant shorebirds and seabirds, and important feeding areas for some species of wading birds and were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).
    - Possibly impacted spp: American Bittern, American Black Duck, American Oystercatcher, Atlantic Brant, Black-bellied Plover, Black-crowned Night-Heron, Black Rail, Black Skimmer, Black Tern, Canvasback, Caspian Tern, Common Tern, Dowitcher species, Forster's Tern, Great Black-backed Gull, Great Blue Heron, Great Egret, Greater Yellowlegs, Green Heron, Gull-billed Tern, King Rail, Least Bittern, Least Tern, Little Blue Heron, Laughing Gull, Marsh Wren, Northern Pintail, Piping Plover, Ruddy Turnstone, Red Knot, Roseate Tern, Sanderling, Saltmarsh Sharp-tailed Sparrow,

Seaside Sparrow, Semipalmated Sandpiper, Snowy Egret, Tricolored Heron, Willet, Whimbrel, Yellow-crowned Night-Heron, Yellowlegs species.

- Dunes washed to the backside of the barrier islands at Forsythe National Wildlife Refuge, Galloway, NJ, potentially creating new piping plover nesting habitat, but there are also several areas where sea water is now able to cross the islands at high tide. Debris, including possible hazardous add the strong potential for gross contamination to concerns that the tidal marsh under the debris will be killed (ALS 2012).

Wetlands (Coastal and Freshwater)

- Inundation of tidal marshes and intertidal sediment/substrate was prevalent throughout the coastal area.

Coastal Marshes

- Hurricane Sandy moved massive amounts of coastal sediments with the extreme power of storm-driven water, changing barrier landscapes, eroding important bird nesting islands, and blowing out dikes of impoundments managed specifically for breeding, migrating, and wintering shorebirds, seabirds, wading birds, and waterfowl. Important habitats for high priority species like Piping Plover, Red Knot, American Black Duck, Tri-colored Heron, Least Bittern, and American Oystercatcher have been altered by this storm (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).
    - Potentially Impacted Species:
        - American Oystercatcher
        - Black Skimmer
        - Gull-billed Tern
        - Least Tern
        - Piping Plover
        - Roseate Tern
        - Red Knot
        - Ruddy Turnstone
- Saltmarsh Systems – including marsh hammocks are critical to saltmarsh obligate breeders, important to feeding nesting and roosting wading birds and migrant shorebirds (Atlantic Flyway

Shorebird Business Strategy Planning Team 2013b). Managed coastal salt marsh is also important for shorebirds and wading birds.

- Potentially impacted saltmarsh species:
  - American Black Duck
  - Atlantic Brant
  - Black-bellied Plover
  - Black Rail
  - Black Tern
  - Forster’s Tern
  - Greater Yellowlegs
  - Little Blue Heron
  - Marsh Wren
  - Nelson’s Sparrow
  - Saltmarsh Sparrow
  - Seaside Sparrow
  - Tricolored Heron
  - Whimbrel
  - Willet

- Salt marsh islands in Forsythe National Wildlife Refuge and the Tuckerton Wildlife Management Area located west of Brigantine and Little Egg Harbor Inlet were hotspots of High impact (ALS 2012b).
- The wetlands in the Barnegat Bay behind Mantoloking were impacted by the breached island and resulting sediment influx.
- Wetlands at Island Beach State Park eroded during the storm.

- The wetlands in the Barnegat Bay behind Mantoloking were impacted by the breached island and the subsequent sediment influx.

- Wetlands at Island Beach State Park eroded during the storm.

- Managed coastal salt marsh – important for shorebirds and wading birds.

Tuckahoe Wildlife Management Area, Tuckahoe, NJ

- Extensive marsh overwash, water control structures damaged, proposal to restore and restabilize the 5 miles of dike that create the 6 impoundments at the Tuckahoe Wildlife Management Area, repair/replace damaged water control structures (Hurricane Sandy Rapid Assessment, Final Report, Atlantic Flyway Shorebird Business Strategy Planning Team 2013).

  Storm surge inundated and left debris in marsh areas, potentially destroying nesting habitat, especially in intercoastal waterways of NJ, e.g., Great Egg Harbor, Little Egg Harbor, Barnegat Bay, potentially impacting the following species (ALS 2012):

  - Common tern, forsters
  - tern, black skimmer,
  - American
  - oystercatcher, laughing
  - gull, little blue heron,
  - snowy egret, great
  - egret, tricolored heron,
  - glossy ibis

Delaware Bay Coast of New Jersey

- Post-Sandy wetland monitoring has shown sediment compaction from flooding, widening of creeks, and 1-5 yards of edge retreat. In areas where living shoreline projects were implemented, such as Matt's Landing along the Maurice River, there was significantly less erosion than nearby unprotected areas, which eroded 5-10 yards, or areas protected by hardened measures, such as bulkheads, which were damaged (D. Kreeger, Science Director, Partnership for the Delaware Estuary, personal communication August 8, 2013).

- The area near Nantuxent Creek along the Delaware Bay was impacted by sand overwash that fragmented wetlands. This overwash built up elevation, but left the marsh shoreline vulnerable

(D. Kreeger, Science Director, Partnership for the Delaware Estuary, personal communication August 8, 2013).

Hudson Raritan Estuary - Coastal

- Coastal salt marshes were impacted to a much lesser degree showing much higher resistance to storm surge. Raritan-Bay marshes experienced some moderate damage but mainly low levels of damage. Bulk of the issues lay with the associated marsh communities. The small mammal population has been reportedly “wiped out” in many areas, creating a food shortage for the northern harriers that prey upon them. The impacts and implications of the storm to invertebrates has been described as a “big unknown” but could be devastating to the long-legged wading birds that prey upon this community, including great blue heron, blackcrowned night heron, yellow crowned night heron, snowy egret, great egret, American bittern, least bittern, glossy ibis and white ibis. The need to further assess the impacts to these communities and to the species that depend upon them as a food source was noted as an important source of concern by resource managers throughout the study area (ALS 2012).

- Wrack deposits were visible in many back-bay marsh areas, often at the marsh/upland forest edge. The analysis may underestimate the amount of wrack deposit, especially where obscured by dense *Phragmites* reed stands or maritime shrubs and scrub (ALS 2012).

    - In Cheesequake State Park, NJ, located adjacent to the Raritan Bay, there is a 4 to 6 foot deep layer of organic tidal debris in the marshes comprised mostly of reeds and other vegetation, combined with tires, duck blinds and other man-made structures. Estimated at approximately 100,000 tons, this debris layer will stunt the growth of vegetation impacting not only the crabs that dwell there, but the kingfishers, herons and gulls that feed upon them (ALS 2012).

    - In Jersey City, New Jersey, Lincoln Park covers 270 acres of recreation fields and natural areas and was the site of a major restoration project that began in 2010 and was recently completed. The projected restored 42 acres of wetland, stream and salt marsh habitat on the Hackensack River to create new habitat for birds and fish and to provide coastline support against climate change. According to resource managers who visited the site after Sandy, the area experienced “zero damage” (ALS 2012).

Freshwater Wetlands

- Forsythe National Wildlife Refuge, Galloway, NJ – Dikes were damaged, allowing saltwater to enter the freshwater impoundments, potentially impacting species that use the area (ALS 2012).

- Cheesequake State Park, NJ – The tremendous tidal surge in this area caused significant saltwater intrusion into the cedar swamp populated by Atlantic white cedars. Impacted species include: Oak trees, Atlantic White Cedar, woodpeckers, screech owls, voles and moles, crabs, Kingfishers, gulls, herons and Osprey (ALS 2012).

- Hook Lake - Cheesequake State Park, NJ – There was significant saltwater intrusion into Hooks Creek Lake, a freshwater lake that is habitat for a variety of fish that were killed off by the high salinity levels. The saltwater intrusion at the freshwater lake at Cheesequake State Park is exacerbated by the fact that the dam at the lake area with a culvert underneath has been compromised by the storm and the outflow pipe is broken. In addition, the inflow pipe from Landing Creek to Perrine Pond was damaged. Hook Lake impacted species include: American eel, mummichog Bass, catfish, sunfish, carp, crappie (ALS 2012).

- Meadowlands – It is currently unknown whether flooding and saltwater inundation in this area impacted the habitat of a new species of Leopard Frog (ALS 2012).

- Flooding occurred in areas throughout the Meadowlands. Definitive damages from the storm are few but a number of suspected impacts could be significant. A 76-acre marsh appeared to have been completely flooded leaving about seven areas covered in two feet of wrack.

- Kearney Marsh – an important breeding site for least bittern, *Ixobrychus exilis* – had floating islands of Phragmites pushed inland. The Hackensack River in some areas reported that numerous carp had washed up on the shores. Data collected by the Meadowlands Environmental Research Institute showed a sharp increase in salinity in various areas of the Meadowlands as the storm hit (MERI website), supporting the hypothesis that this caused the fish kills.

Tidal Marsh

- Inundation of tidal marshes and intertidal sediment/substrate was prevalent throughout the coastal area, with some reportedly under water for more than five days. The small mammal population has been reportedly “wiped out” in many areas, creating a food shortage for northern harriers and other species that prey upon them. The impacts and implications to the invertebrates has been described as a “big unknown” but could be devastating to the long-legged wading birds that prey upon this community, including great blue heron, black crowned night heron, yellow crowned night heron, snowy egret, great egret, American bittern, least bittern, glossy ibis and white ibis (ALS 2012).

Back bays

- Storm surge inundated and left debris in back bay marsh areas in coastal New Jersey, potentially wiping out invertebrates that serve as important food source for shore birds and breeding water birds, potentially impacting the following species: Semipalmated sandpiper, short-billed dowitcher, lesser yellowlegs, dunlin, greater yellowlegs, black-bellied plover, semipalmated plover, spotted sandpiper, willet, clapper rail, black rail, American black duck (ALS 2012).

Critical/Significant Habitats

Water Birds Islands/Shorebirds

- Coastal Flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013a).

Coastal and Maritime

- Damage to maritime or coastal zone forests was more difficult to assess, but a number of locations did show blow-down of trees and canopy gaps. However, a comparatively smaller percentage of the area was assessed at Moderate and Low Damage for the New Jersey shore.

Hudson Raritan Estuary

- Cheesequake State Park, NJ – Damage was reported to maritime or coastal zone forests from blow-down of trees and canopy gaps. More than 300 trees were lost, including 100-year old oaks and numerous Atlantic White Cedars (ALS 2012).

- Cheesequake State Park, NJ – Several vernal pools in the lowland forest were destroyed by the storm surge. Impacted species include: frogs, toads and salamanders (ALS 2012).

Horseshoe Crabs

Delaware Bay

- A comparison of pre and post-storm aerial photography of the Delaware Bay in New Jersey, estimated that there was a 70% decrease in optimal horseshoe crab nesting habitat and greater than 20% decrease in suitable and less suitable habitat categories (Conserve Wildlife Foundation of NJ and NJ Audubon, February 2013). There were complementary increases in Avoided and Disturbed Habitats and habitat suitability declines were attributed to the loss of sand from the upper intertidal areas. Extensive evidence of overwash was noted and it appeared that sand was transported from the intertidal areas into the marshes, leaving the intertidal area devoid of sand. It appeared that some sand was moved offshore, and some sand moved northward along the shoreface. In many areas, the effects of the storm has resulted in a net lowering of the beach elevation so that at high tide, water now covers all sand to the vegetation line and/or exposed peat; in these areas there is no sand in which horseshoe crabs can lay eggs successfully (Conserve Wildlife Foundation of NJ and NJ Audubon, February 2013).

- The suitability for horseshoe crab nesting on the Reed’s Beach to Pierce’s Point section and the area south of Pierce’s Point south to Villas of the New Jersey bayshore was substantially reduced. This area is the heart of the NJ shorebird stopover, especially for red knots, ruddy turnstones, and sanderlings. In addition, the storm caused substantial damage to the upper bay, particularly around Moore’s Beach, Fortescue, and the areas north of Fortescue including and northwest of Gandy’s beach (Conserve Wildlife Foundation of NJ and NJ Audubon, February 2013, ALS 2012).

- Another horseshoe crab nesting beach, Thomson’s Beach, was repaired by NJ Fish and Wildlife staff (Conserve Wildlife Foundation of NJ and NJ Audubon, February 2013).

- Initial observations have shown that there was a positive response to these restoration projects, as horseshoe crab nesting rates seemed better than previous years at Moore’s Beach. Monitoring was conducted and the data will be released after it is finalized (J. Lynch, Stewardship Project Director-South Region, New Jersey Audubon Society, personal communication August 20, 2013).

- Pierce’s Point Beach, Cooks Beach, and Reeds Beach were also replenished with sand to cover the exposed peat layer and make the habitat more favorable for horseshoe crab nesting (J. Lynch, Stewardship Project Director-South Region, New Jersey Audubon Society, personal communication August 20, 2013).

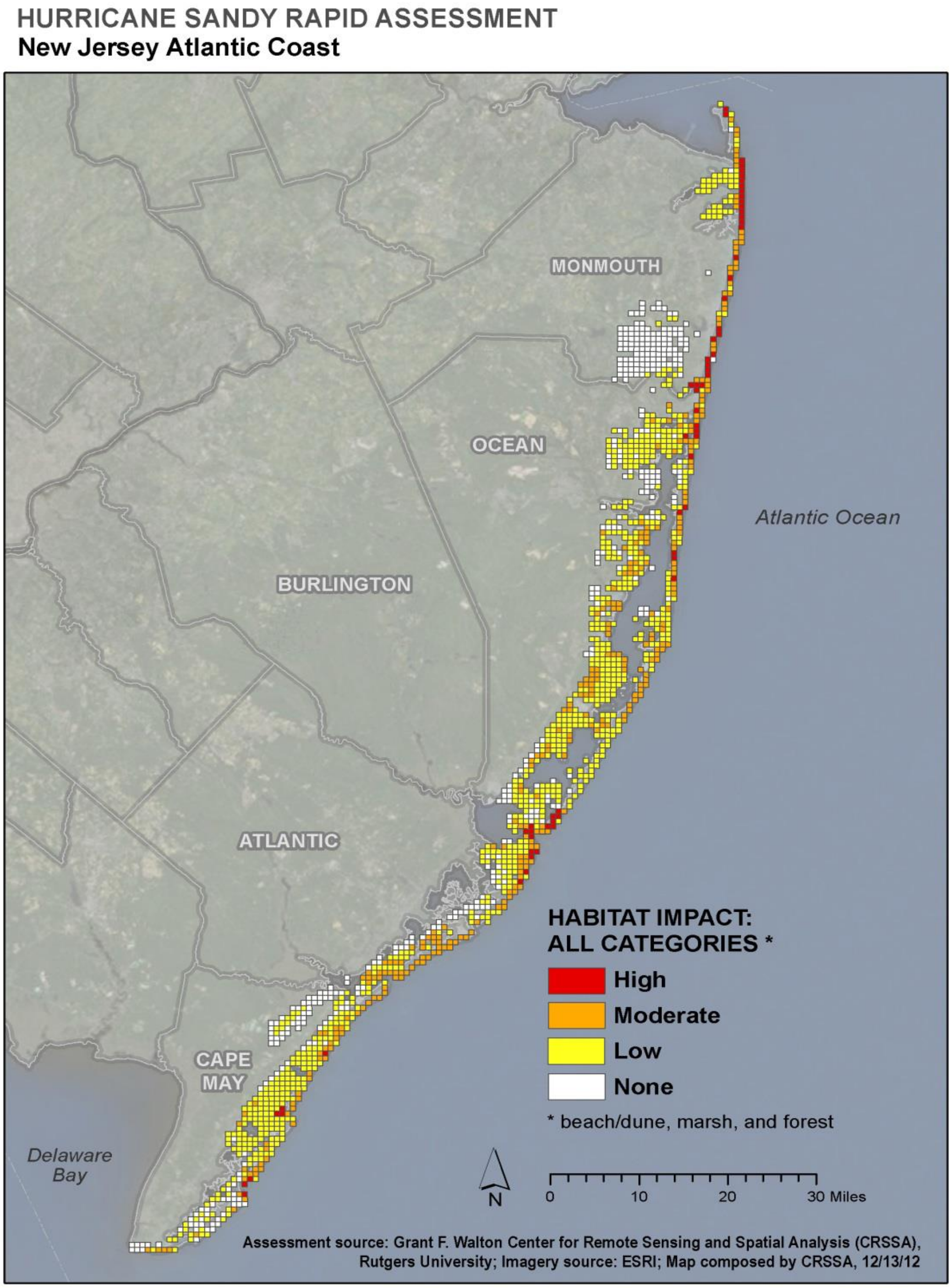

Figure 6-1 Hurricane Sandy Habitat Impacts

Quality

HTRW

Hudson Raritan Estuary

- Significant contamination to waterways occurred during the storm from the flooding of industrial facilities located adjacent to waterways and from antiquated and inoperable sewage treatment plants. Some notable contamination events include the following:

    - Oil Spill Contamination – Arthur Kill waterway, marshes and tributaries – As the storm surge flooded the banks of the Arthur Kill, several bulk fuel tanks were damaged, releasing nearly 378,000 gallons of diesel fuel into the water. Oil contamination from this and two smaller oil spills in the area was far reaching, and oil coated the marshes along the shores of Staten Island and New Jersey. Impacted species include: Fish, invertebrates, small mammals, wading birds (ALS 2012).

    - Oil Spill Contamination – Affected the birds, marshes and grasslands of the Meadowlands, NJ - the known habitat of a recently discovered new species of Leopard Frog - and the marshes and waters of various creeks and tributaries, including Woodbridge Creek, Smith Creek Inlet, and Rum Creek in New Jersey. Impacted species include: Glossy ibis, blackcrowned night heron, little blue heron, snowy egret, cattle egret, great egret, invertebrates, small mammals (ALS 2012).

    - Sewage – Flooded by the storm surge and rendered inoperable due to power outages, several major sewage treatment plants released raw or partially treated sewage into local waterways. The Passaic Valley Sewerage Commission (NJ) treatment plant released an estimated 400 to 500 million gallons of untreated wastewater into the Newark Bay for several days, with the total amount discharged estimated to be in the billions of gallons. The Middlesex County (NJ) Utilities Authority treatment plant in Sayreville, New Jersey released about 300 million gallons per day into the Raritan River for an unknown period of days. State officials issued advisories for the waters of the Raritan, Passaic and Hackensack Rivers, Newark and Raritan Bays and the Arthur Kill and the Kill van Kull. Impacted species include: Fish, invertebrates, small mammals, wading birds, Leopard Frog (ALS 2012).

Atlantic Coast

- Oyster habitat – Runoff from Hurricane Sandy is laden with sediment, contaminants and debris all pose a significant threat to the health of oyster reefs and shellfish beds along the Atlantic Coast.

III. Future Without Action Conditions - New Jersey

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- If the natural inland migration of New Jersey's beaches and wetlands are not accommodated by future policies, these systems may be highly impacted by sea level rise and the ecological, economic, and social benefits they provide will be lost (Cooper et. al 2005).

- Sand beaches and vegetated dunes provide an important buffer between coastal waters and human development and adjacent development may compromise some of the habitat value and other natural functions of the beach and inhibit future movement or migration of these features (Lathrop and Love 2007):

    - Lathrop and Love (2007) examined the entire coastline and reported 48% of the beach and dune habitats are within 100m of developed areas and when only Atlantic and Raritan Bayshore beaches and dunes are considered, this figure increases to 60%.

    - It was also reported that comparatively short stretches of Atlantic coastal beach/dune systems are relatively undisturbed by adjacent development (e.g., Sandy Hook, Island Beach, Holgate and Pullen Island and some isolated sections of Avalon, Stone Harbor and the Wildwoods).

- Sea level rise could cause erosion and inundation of sandy habitat on estuarine beaches, , eliminating habitat for billions of invertebrates that are found within or on the sandy substrate or beach wrack along the tide line. This would decrease the availability of a rich and abundant food source for several bird species (Strange 2008). Many of these estuarine beaches are being protected with beach nourishment in developed portions of the Ocean County shore, while bulkheading continues to be used on the bayside shores of Ocean County (Strange 2008).

- Beach erosion control and storm damage reduction projects extend continuously along the Atlantic Coast of New Jersey from Sea Bright to Manasquan. These projects all include beach nourishment/re-nourishment for 50 years after initial construction, with some additional features for some areas, such as berms, groins, seawalls (existing), as well as other stormwater management and interior drainage features (outfall pipes). Historically, erosion has seriously reduced the width of most of these beaches, resulting in increased exposure of the shore to storm damages from storm erosion, wave attack and flooding). Storms in 1962 and 1963 resulted in millions of dollars in damages to shorefront property, public roads and utilities.

- Nourishing and widening eroding beaches along the Atlantic Coast of NJ provide many benefits, such as: protect threatened and endangered plants (seabeach amaranth, knotweed); protect habitat behind dunes or next to beaches; create or restore habitat, lost through erosion, for shorebirds and other beach organisms (including protected species such as the piping plover, black skimmer, least tern and roseate tern); and creating new nesting areas for protected species (piping plovers) and spawning grounds for other species.

Delaware Bay

- The sandy beaches of southern New Jersey play a vital role in the lifecycle of the horseshoe crab (Limulus polyphemus) and millions of migratory birds and are highly susceptible to sea level rise (Cooper et al. 2005), if there is no room for inland migration.

- The loss of horseshoe crab eggs as a result of beach erosion or beach nourishment could have important implications for the 1.5 million migratory shorebirds that stop over on New Jersey's shores to feed on these eggs during their annual migrations (Strange 2008).

- Many Delaware Bay beaches have a relatively thin layer of sand which is enough to protect the marshes immediately inland from wave action, but there is some question about whether some beaches would survive accelerated sea level rise without shoreline armoring (Kreeger and Titus 2008).

- The loss of Delaware Bay's beaches would harm horseshoe crabs, migratory birds, and other wildlife (Kreeger and Titus 2008).

Raritan Bay

- The shoreline in Raritan Bay is susceptible to storm damages, as evidenced by Hurricane Sandy and the widespread flooding, coastal erosion, wave attack and subsequent power outages, and damage to infrastructure, businesses and residents. Projects in Port Monmouth, Keansburg and Union Beach are designed to reduce storm damages through shoreline protection measures. Features of each project include: sand nourishment/re-nourishment for 50 years after initial construction; dune construction and maintenance; and/or construction and maintenance of levees, floodwalls, and storm gates.

    - These projects will provide protection to low-lying residential and commercial structures in the areas surrounding small creeks, bayshore beachfront, and salt and freshwater marshes that have historically experienced tidal inundation during severe storms. This problem has progressively worsened in recent years due to loss of protective beaches and increased urbanization in the area with structures susceptible to flooding from rainfall and coastal storm surges, erosion and wave attack, combined with restrictions to channel flow in the tidal creeks.

    - There is a strip of native coastal shrub vegetation that provides nesting and cover for approximately 80 species of migratory birds in the Port Monmouth project area. Construction and maintenance of the dune along this area will provide some protection for this unique habitat. Although the habitat is elevated on the beach side (it slopes down as you go away from the shore), beach erosion and sea level rise may harm this ecosystem by changing or eliminating this habitat for wildlife.

- In addition to the projects identified, there are other areas along Raritan Bay that provide valuable wildlife habitat, contribute to improved water quality, store carbon, reduce floods and provide recreational benefits. Without protection, these areas may be altered or eliminated:

    - Cheesequake State Park lies in a transition zone between two different ecosystems, and is characterized by open fields, saltwater and freshwater marshes, white cedar swamp, Pine Barrens, and northeastern hardwood forest.

    - There are a series of parks and beaches along the shoreline from South Amboy to Morgan, and Laurence Harbor to Keyport, which are adjacent to heavily urbanized areas. Without sufficient sand volume, a wide beach and protective dunes, these areas risk damage from hurricanes and coastal storms. Protecting the shore may also help restore valuable ecosystems that may be lost to storm events, such as beaches, wetlands, and habitat for fish and wildlife, including protected species such as terns (least and roseate) and osprey.

Raritan Bay Sea Level Rise:

- A local marine biologist with the National Marine Fisheries Service reports that there are small areas of estuarine beach all along the shorelines of this region where there is no shoreline hardening or marsh, except in low current areas where mud flats predominate. Hardened shores are common on the New Jersey side of Raritan Bay including portions of the estuarine beaches of Sandy Hook which are bulkheaded or armored. The southern shoreline of Raritan Bay includes a number of beaches along Sandy Hook Peninsula and from the Highlands to South Amboy. There are also beaches on the Perth Amboy side. Other beaches are found on some of the shorelines around small islands within the Shrewsbury-Navesink River system. All of these areas show inundation on the 50 year high sea level rise projections.

- The estuarine beaches in the region are extremely important habitat for horseshoe crabs, nesting terrapins and many other coastal birds such as terns, gulls and skimmers.

- Beaches are also important foraging grounds for birds, especially migrating shorebirds such as sanderlings, yellowlegs, and oystercatchers looking for clams and other invertebrates. Red knots, ruddy turnstones, and laughing gulls feed on horseshoe crab eggs in the sand of area beaches. Mud snails are common on estuarine beaches, and beach wrack contains insects, isopods, and amphipods. The abundance of shorebird species is positively correlated with the abundance of beach wrack and associated invertebrates. Recent research indicates that beach wrack traps horseshoe crab eggs, making them more available for shorebirds.

- Local planners anticipate that most of the shoreline along the beach/dune systems of Raritan Bay and Sandy Hook are almost certain to be protected as sea level rises. However, it is uncertain whether beach nourishment or shoreline armoring will be more common. If the beaches are armored, beaches will erode and sediments will not be available for natural replenishment of sand in areas that are not supplemented with beach nourishment projects (mentioned above). In many areas this will eliminate the beach nesting areas of terrapins and horseshoe crabs and the forage provided to birds by small beach organisms. The loss of horseshoe crab eggs will be especially critical for red knot, which feed almost exclusively on crab eggs during their spring migration.

- If beaches are nourished, their geomorphic characteristics may be altered in ways that some scientists believe are unsuitable for many beach invertebrates, including horseshoe crabs. Sandy Hook is considered almost certain to be protected using approaches that retain natural shores. The Park Service is currently planning to build a sand bypass system to replenish a narrow section of the spit (Titus and Strange 2008).

Barrier Islands/Inlets

- Barrier islands may be degraded or lost by flooding as a result of sea level rise (Wenzel et al. 2013)

- The Federally-listed seabeach amaranth (Amaranthus pumilus), a plant found in the foredunes of New Jersey's barrier beaches, is highly susceptible to the effects of sea level rise and could be irreversibly damaged (Cooper et al. 2005).

- New Jersey's sandy barrier beaches are dynamic features that, in a natural state, migrate landward by storm overwash as the shoreline retreats due to erosion (Lathrop and Love 2007).

- Lathrop and Love (2007) simulated a 100-year (3m) storm tidal surge and found that this would inundate all of New Jersey's barrier island communities, as well as significant sections of the Barnegat, Delaware and Raritan Bays, 16% of which is primarily residential developed land, and 79% of which is natural land cover, primarily tidal salt marshes and freshwater wetlands, and the remaining 6% is agricultural.

- Strange (2008) reported that narrow fringing salt marshes along protected shorelines north of Barnegat Inlet could be lost even with a 2 mm/yr acceleration in rate of sea level rise; but, below Barnegat Inlet, natural shorelines are likely to remain because the sea would have to rise many feet before it would reach US Highway 9.

Coastal Wetlands

- New Jersey's coastal wetlands are highly susceptible to the effects of sea level rise. Coastal wetlands can adapt and keep pace with sea level rise through vertical accretion and inland migration but must remain at the same elevation relative to the tidal range and have a stable source of sediment. Cooper et al. (2005) reported that coastal wetlands in New Jersey will generally be unable to accrete at a pace greater or equal to relative sea level rise (3.53 mm/year) and are extremely susceptible to permanent inundation.

- Strange (2008) reported that New Jersey's tidal salt marshes are keeping pace with current local rates of sea level rise of 4 mm/yr, but will become marginal with a 2 mm/yr acceleration, and will be lost with a 7 mm/yr acceleration except where they are near local sources of sediments (e.g., rivers such as the Mullica and Great Harbor rivers in Atlantic County).Coastal wetlands are forced to migrate inland due to a combination of sea level rise and vertical accretion forcing the saline marshes on the coastline to drown or erode and the upslope transitional brackish wetlands to convert to saline marshes. A significant portion of New Jersey's coastal wetlands are adjacent to human development or seawalls that block natural wetland migration paths and increase the likelihood of wetland loss from inundation (Cooper et al. 2005).

- The vulnerability of tidal marshes in the Delaware Estuary to sea level rise can be exacerbated by the presence of excess nutrient loadings,that promote greater aboveground plant production at the expense of belowground production, leading to diminished peat formation and vertical accretion (Kreeger et al. 2010).

- Tidal wetlands may be degraded or lost by flooding due to sea level rise (Wenzel et al. 2013).

- Marsh vegetation can only tolerate tidal flooding to a certain physiological limit, so increases in tidal range associated with rising seas may affect plant productivity, which reduces the ability to accumulate organic matter and grow vertically (Kreeger et al. 2010). This loss of elevation makes the marsh community more susceptible to storm surge erosion that accompanies storm events (Kreeger et al. 2010).

- Wetlands that are not able to naturally keep up with increased rates of sea level rise through accretion of sediment and organic matter may be able to migrate landward, given proper soil and hydrological conditions and lack of barriers (NOAA 2010).

- Lathrop and Love (2007) reported that a vast majority (over 75%) of New Jersey's coastal shoreline is made up of bay, lagoon and tidal creek shorelines bordered by salt marsh or other vegetation and approximately 17% of the mapped shoreline has been altered due to bulkheading, rip-rap or other coastal protection structures, leaving this habitat vulnerable to sea level rise.

- Tidal salt marshes fring the back side of the barrier islands and the mainland of New Jersey's coastal bays (Lathrop and Love 2007). Tidal salt marsh surfaces can rise in relation to sea level through the process of vertical accretion of sediment and organic matter. New Jersey's salt marshes appear to have been able to keep pace with historical rates of sea level rise but if sea level rises faster than marsh accretion, tidal marshes could eventually be drowned and replaced by open water (Lathrop and Love 2007).

- Tidal marshes can also retreat landward through migration if there is only a gradual rise in elevation, the adjacent uplands will be periodically flooded by rising tidal inundation and the more sensitive upland vegetation will be replaced by salt-tolerant emergent marsh vegetation (Lathrop and Love 2007). However, in most areas, the slope above the coastal marsh is steeper than the marsh; so a rise in sea level will cause a net loss of marsh acreage (Lathrop and Love 2007).

- Lathrop and Love (2007) modeled buffer areas within 500 meters up-gradient of existing tidal marshes and to elevations of 3 meters or less that could potentially serve as retreat zones as sea levels rise and limited salt marsh retreat is limited by existing developed features, including major roads and found that approximately 29% of potential tidal marsh retreat area is presently limited by developed features and roads. It was also found tha tidal marshes along Raritan Bay, northern/central Barnegat Bay and the backsides of the barrier islands have limited retreat zones. However, extensive areas in southern Barnegat Bay/Little Egg Harbor, Great Bay, Reed Bay, Great Egg Harbor have comparatively unrestricted retreat zones due to the extensive amounts of federal and state wildlife refuge and management lands that protect both the coastal wetlands and the adjacent uplands.

Delaware Bay

- Unlike other estuaries in the mid-Atlantic, the tidal range of the Delaware Bay estuary is greater than the ocean tidal range, generally about two meters. Bay shoreline and tidal marshes appear to be at the low end of their potential elevation range, which increases their vulnerability to sea level rise (Kearney et al. 2002).

- Lathrop and Love (2007) modeled buffer areas within 500 meters up-gradient of existing tidal marshes and to elevations of 3 meters or less that could potentially serve as retreat zones as sea levels rise and limited salt marsh retreat is limited by existing developed features, including major roads and found that extensive areas in Delaware Bay have comparatively unrestricted retreat zones due to the extensive amounts of federal and state wildlife refuge and management lands that protect both the coastal wetlands and adjacent uplands.

- In much of Delaware Bay, tidal marshes appear to be at the low end of their potential elevation range, increasing their vulnerability to sea-level rise and research indicates that 50 to 60 percent of Delaware Bay's tidal marsh has been degraded, primarily because the surface of the marshes is not rising as fast as the sea (Kreeger and Titus 2008, Titus et al. 2009). In addition, the tidal marshes of Delaware Bay grow upward primarily through the accretion of organic matter, not sediment (Kreeger and Titus 2008).

Raritan Bay

- There are a series of wetlands (riverine, freshwater emergent, freshwater forested/shrub wetland, estuarine and marine) in the western portion of the Raritan Bay- Raritan River Waterfront Park, Conaskonk Point, from Flat Creek to Thorn's Creek, Cheesequake State Park, and in Keyport. There are less extensive wetlands on the eastern side of Raritan Bay in Leonardo, Highlands, and Atlantic Highlands. If beaches cannot provide a protective buffer, these wetland areas may be at risk from sediment overwash, salt water inundation, and erosion.

- Raritan Bay Sea Level Rise:
    - The shorelines of Raritan Bay have the most natural estuarine and saline fringing marsh remaining in the region. The southern portion of Raritan Bay includes large tracts of

fringing salt marsh (mentioned above). Local planners expect that much of the region's shoreline will be protected from sea level rise; in developed areas, bulkheading is already common. Therefore, migration of brackish and saline fringing marsh will not be possible along most, if not all, of the shoreline. Given these scenarios and considering 50 year high sea level rise projections, these resources will likely be lost or converted in these long term time frames, depending on height of flooding.

- These marshes are critical for numerous nesting and migrating bird species. The salt marsh at Conaskonk Point provides breeding areas for green heron, clapper rail, willet, American oystercatcher, marsh wren, seaside sparrow, and saltmarsh sharp-tailed sparrow, as well as feeding areas for herons, egrets, common tern, least tern, and black skimmer. In late May and early June, sanderlings, ruddy turnstones, semipalmated sandpipers, and red knots feed on horseshoe crab eggs near the mouth of Chingarora Creek. Diamondback terrapin feed in the marshes and creeks in this area.

- Saltmarsh along the backside of the Sandy Hook spit is dominated by low marsh cordgrass. These areas provide habitat for many important invertebrates and resident fish species. The young of a number of marine fish species find forage and protection in low marsh, including winter flounder, Atlantic menhaden, bluefish, and striped bass. Characteristic bird species of the low marsh also inhabit the area, including clapper rail, willet, and marsh wren.

- The area's flats are known foraging grounds for numerous bird species, diamondback terrapin, and horseshoe crabs. The thousands of birds that pass through or reside in and around Raritan and Sandy Hook bays depend on intertidal invertebrate food resources as well as the many small adult and juvenile fishes that feed in these areas. These species would potentially be displaced if tidal flats were not able to keep up with sea level rise (Titus and Strange 2008).

Raritan River

- The Raritan River and its tributaries are prone to flooding from South Amboy west to New Brunswick and south to Old Bridge, as evidenced most recently by the storm surge created by Hurricane Sandy. There is one flood damage reduction project along the South River, which is the first major tributary of the Raritan River (USACE 2002b). The river is tidally controlled and prone to imminent and severe flooding from hurricanes and other storms in the towns of South River and Sayreville, with significant flood events occurring in March 1962, May 1968, August and September 1971, April 1984, December 1992, March 1993. The project identified flooding problems associated with storm events and developed a plan to minimize damages. The plan consists of a storm surge barrier, levees/floodwalls, and interior drainage facilities [i.e., pump station, outlets, etc.]. There was an ecosystem restoration component that would return 379 acres of Common Reed [*Phragmites sp.*] wetlands to wetland forest, upland forest, low emergent marsh, mudflat, and open water; however, this portion of the project was eliminated. Restoration of the wetland would have improved habitat for many protected species (black skimmer, northern harrier, peregrine falcon, yellow-crowned night heron, osprey, black-crowned night heron, and American bittern). However, there are some wetland (tidal and freshwater) and forested areas in and around the project area that are suitable for Great Blue heron, Northern harrier, yellow-crowned night heron, and Fowler's toad.

- Outside of the project area, and as evidenced by Hurricane Sandy, flooding occurred along the river in Raritan Center (Edison, NJ), portions of South Amboy, Old Bridge, and to a lesser extent in Piscataway and New Brunswick. Without future projects in these areas, flooding would continue and potentially worsen (sea level rise), leading to a reduction and potential loss of wetland habitat (estuarine and marine, freshwater emergent, pond, freshwater forested/shrub). Much of the area surrounding these wetlands is developed, leaving little space for migration. Loss of wetlands would lead to shrinking habitat for many fish and wildlife species, and loss of flood control and water quality improvement functions.

- Raritan River Sea Level Rise:

  - Tidal marshes in this region are mostly estuarine marsh or saline fringing marsh, with small areas of freshwater tidal marsh along South River and Raritan River. According to a panel of accretion experts, the dominant accretionary processes in these marshes are peat accumulation and inputs of river sediments, both of which they anticipate will increase in the future depending on marsh type and local conditions. As a result of the high productivity and the potential for peat accumulation of tidal freshwater marshes in the region, the accretion panel believes that freshwater tidal marshes along the South and Raritan rivers will accumulate sufficient sediment to accrete and even expand as sea level rise increases, even with a 7 mm/yr increase in the current rate.

  - However, the accretion panel anticipates that peat accumulation in estuarine and saline fringe marsh will increase only up to a threshold level, which is currently unknown. The panel projects that beyond that threshold these marshes will become marginal if the rate of sea level rise increases by 2 mm/yr, and will not survive if the rate increases by 7 mm/yr. Even at the modest rate of increase of 2 mm/yr and 50 year high sea level rise projections these marshes will be lost if hardened shorelines prevent migration or the marshes are degraded by human activities (Titus and Strange 2008).

Hackensack Meadowlands

- New Jersey's Hackensack Meadowlands, in Hudson and Bergen counties, are renowned for containing the largest single tract of estuarine tidal wetland in the New York/New Jersey Harbor Estuary. The Meadowlands have been dramatically altered by a variety of human activities.

- The New Jersey Meadowlands Commission (NJMC) is the regional planning authority for a 32 square mile district located less than 3 miles from New York City. Although the New York District USACE has completed some modeling studies and restoration planning in the region, there are no flood control or restoration projects currently underway. The local municipalities and the NJMC may potentially design and construct flood control solutions in the future.

- The Hackensack Meadowlands contains many miles of tide gates, ditches and berms on public and private property. Some built in recent years by experts informed by FEMA flood-level data, and some built in the 1920s by Bergen County's Mosquito Commission. The average height of the berms is five feet, which was built to accommodate the three and a half feet the waters usually rise during high tide. During a rare storm of Sandy's magnitude these structures will experience flooding under pressure from tidal surge, flooding the surrounding towns.

- Experts at the MERI do not believe that proposals to re-enforce the berms or install a movable flood barrier in Newark Bay, would keep out water during a storm of Sandy's magnitude — at least not without a substantial financial investment (S.P. Sullivan, NJ.com 2013).

- Hackensack Meadowlands Sea Level Rise:

    - The tidal marshes that remain provide regionally significant habitat for a number of federally or state-listed species. Diamondback terrapin, a federal species of concern, is common in the Sawmill Wildlife Management Area. The state-listed endangered least tern, black skimmer, and pied-billed grebe use Kearney Marsh as a feeding area.

    - Much of the tidal marsh of the Meadowlands is dominated by the invasive common reed (*Phragmites*), a species found in degraded wetlands with decreased tidal flow. As a result of recent restoration activities, parts of Harrier Meadow and the Riverbend Wetlands Preserve now support a mixture of open water and native high saltmarsh vegetation. Although 50 year high sea level rise modeling shows inundation of the Hackensack Meadowlands, the result may be conversion of some *Phragmites* dominated marshes into salt marshes dominated by the native cordgrass, *Spartina alterniflora*. This may benefit some bird species, because the dense physical structure of *Phragmites* limits access to the marsh surface by foraging shorebirds, waders, waterfowl, and other taxa (Titus and Strange 2008). Due to urbanization along Meadowlands marsh complex, it does not appear that the marsh will have much room to migrate beyond its present boundaries if the height of flooding is very high.

Salt/Brackish Marsh

- In the Delaware Estuary, landward migration of salt marshes is impeded in many areas due to coastal development and hard structures. Ultimately, tidal flooding limits plant survival and marsh areas will convert to open water or intertidal mud flats (Kreeger et al. 2010).

- Kreeger et al. (2010) report that the greatest vulnerabilities of salt and brackish marsh to sea level rise are predicted to be: the inability to keep pace with rising sea levels through vertical accretion, the inability to migrate landward, shifts in species composition, loss of suitable marsh area, increased seaward edge erosion, increased susceptibility to storm surge, an expected increase in tidal range, and a change in the ratio of marsh edge to interior area.

  - Cooper et al. (2005) reported that a 0.61 m rise in sea level could permanently inundate approximately 15 % of the saline marshes in New Jersey, while a 1.22 m rise in sea level could inundate about 30 % of saline marshes.

Freshwater Marsh

- Coastal freshwater wetlands are particularly sensitive to extreme high tides resulting from an increase in storm frequency or magnitude; these high tides can carry salts inland to salt-intolerant vegetation and soils, and could lead to the displacement of freshwater flora and fauna by salt-tolerant species (Combes 2003). These coastal freshwater wetland communities could be destroyed if they cannot shift inland due to development or dikes (Combes 2003).

- Cooper et al. (2005) reported that a 0.61 m rise in sea level could permanently inundate approximately 7% of freshwater tidal marshes in New Jersey and a 1.22 m rise in sea level could inundate about 27 % of freshwater tidal marshes.

- Freshwater coastal ponds in Cape May Meadows are within a few hundred feet of the shoreline and could easily be inundated as seas rise. This ecologically important area is being protected by dunes and bulkheading and is vulnerable to breaching due to sea level rise. The ponds provide critical foraging and resting habitat for a variety of bird species, primarily migrating shorebirds, including rare birds such as buff-breasted sandpipers, arctic tern, roseate tern, whiskered tern, Wilson's phalarope, black rail, king rail, Hudsonian godwit, and black-necked stilt (Strange 2008).

Tidal Mud Flat

- Strange (2008) reported that inundation of tidal flats as a result of rising seas would eliminate critical foraging opportunities for hundreds of species of shorebirds, passerines, raptors, and waterfowl, as the tidal flats of New Jersey's back-barrier bays, including the flats of Great Bay Boulevard Wildlife Management Area, North Brigantine Natural Area, and the Brigantine Unit of the Forsythe Refuge . In addition, as tidal flat area declines, increased crowding in remaining areas could lead to exclusion and mortality of many foraging birds. Some formerly tidal flat areas may become potential sea grass restoration sites, but as the feasibility of restoring these eelgrass areas will depend on their location, acreage, and sediment type (Strange 2008).

Delaware Bay

- Galbraith et al. (2002) ran sea level rise scenarios and reported that one of the scenarios for the Delaware Bay predicted losing 60 percent or more of intertidal shorebird feeding habitats, such as exposed sand and mud flats by 2100 due to coastal changes and sea level rise.

- Lathrop and Love (2007) reported that under more extreme sea level rise and assuming that coastal protection structures do not constrain shoreline migration, Delaware Bay may actually have a net gain of intertidal flats as the coastline migrates further inland converting marsh or upland to intertidal habitat.

Kreeger and Titus (2008) reported that areas of exposed tidal flats in Delaware Bay occur between mean sea level (MSL) and mean low water (MLW), extend primarily along the bay's shorelines, and are vulnerable to sea level rise. The greatest loss of mud flats generally occurs where migration is prevented by the presence of shore protection structures. These intertidal flats are known to be important foraging areas for finfish as well as migrating shorebirds, including red knot, ruddy turnstone, sanderling, and semipalmated sandpiper (Kreeger and Titus 2008).

Maritime Forest

- Cooper et al. (2005) reported that the loss of vulnerable coastal dune forests, of which less than 12 km² remain in New Jersey, would endanger the threatened black-crowned night heron (*Nycticorax nycticorx).*

Estuaries

- The Delaware Estuary has the largest freshwater tidal prism in the world, the freshwater tidal region extends about 70 river miles, with a gradual change in salinity andincreasing sea level could result in larger tidal volumes that bring more salt water further up the estuary, further increasing the tidal range (Kreeger et al. 2010) There is a large array of ecosystem services supplied to human and natural communities, including a rich diversity of marsh types, tied to the extended salinity gradient which could be at risk due to sea level rise (Kreeger et al. 2010).

Submerged Aquatic Vegetation

- Seagrass beds, beaches, tidal wetlands and barrier islands may be degraded or lost by flooding as a result of sea level rise (Wenzel et al. 2013).

- Strange (2008) ran a sea level rise simulation and reported that sea level rise can reduce productivity and functional values of eelgrass (SAV) beds- a 50 cm (19.7 in.) increase in water depth as a result of sea level rise could reduce the light available for eelgrass photosynthesis by 50 percent, resulting in a 30–40 percent reduction in seagrass growth. In Barnegat Estuary, particularly on sandy shoals along the backside of Long Beach Island and Island Beach, and around Barnegat Inlet, Manahawkin Bay, and Little Egg Inlet, eelgrass beds provide habitat for invertebrates, birds, and fish that use the submerged vegetation for spawning, nursery, and feeding habitat and this could be impacted by sea level rise (Strange 2008).

Oyster Reefs

- Kreeger et al. (2010) reported that the partly narrow geographic configuration of the Delaware Estuary means that, while the oyster resource can migrate up estuary in response to increased salinity, the total population of oysters could decline due to loss of area. The potential for lateral expansion of the estuary due to sea level rise would not be sufficient to provide equivalent areas for reef expansion (Kreeger et al. 2010). Since oyster reefs are an important habitat type for the

Delaware Estuary, cascading ecological effects would likely follow if substantial loss of reefs occurred in part of the bay (Kreeger et al. 2010).

Delaware Bay

- Salinity increases would also impact the natural oyster beds managed by the oyster industry to provide seed oysters for planting in leased growing areas in more seaward, saline areas of the bay (DVRPC 2004).

Rock Reefs/Rocky Shorelines

- There are artificial rock groins that currently represent an artificial rocky intertidal zone in parts of the Atlantic Coast of New Jersey. It is assumed that this habitat will be further submerged with rising sea levels and species intolerant to this change in depth, temperature, and light penetration will no longer use the habitat.

Shallow Bay Habitat/ Bay Islands

- Lathrop and Love (2007) modeled buffer areas within 500 meters up-gradient of existing tidal marshes and to elevations of 3 meters or less that could potentially serve as retreat zones as sea levels rise and limited salt marsh retreat is limited by existing developed features, including major roads and found that extensive areas in southern Barnegat Bay/Little Egg Harbor, Great Bay, Reed Bay, Great Egg Harbor and Delaware Bay have comparatively unrestricted retreat zones due to the extensive amounts of federal and state wildlife refuge and management lands that have protect both the coastal wetlands as well as the adjacent uplands.

- Strange (2008) reported that ontinued sea level rise could disrupt natural sedimentary processes and lead to “drowning” of marshes, thus promoting the conversion of typical back-bay areas to lakes

- Titus and Strange (2009) reported that wetlands along the back-barrier bays of New Jersey’s Atlantic coast are likely to have some room to migrate inland, because they are adjacent to large areas of non-tidal wetlands.

- Although the direct effect of sea level rise will be to deepen waters, shallow water habitat may increase if wetlands convert to open water and it is difficult to determine cannot currently say whether this type of habitat will increase or decrease in the Delaware Bay (Kreeger and Titus 2008). Species that use this shallow habitat area and could be impacted are: blue crab, Callinectes sapidus and the eastern oyster, Crassostrea virginica, bay anchovy, alewife, Atlantic menhaden, striped bass, hogchoker, and Atlantic croaker, blueback herring, mummichog, banded killifish, silverside, and white perch (Kreeger and Titus 2008).

Terrestrial Upland

- Dikes were built in southern New Jersey along the southern portion of the Delaware River to convert tidal marshes to agricultural land and prevent tidal inundation of farmland. Titus et al. (2009) reported that rising sea level and land subsidence have left this land barely above low tide, and many lands drain too slowly to completely drain during low tide and farmland has converted to non-tidal wetland. They estimated that over longer periods of time, increases in salinity of the Delaware River resulting from rising sea level and reduced river flows during droughts could enable salt water to invade these fresh marshes, which would convert them to open water ponds (Titus et al. 2009).

Floodplains/Riparian

- As marshes along protected shorelines experience increased tidal flooding, tidal creeks become wider, deeper, and more abundant (Strange 2008).

- Along the industrial and commercial docking areas in the upper tidal portion of the Delaware River, in the, most of the shoreline is already bulkheaded, and this also prevents coastal erosion (Titus et al. 2009).

Coastal Protected Areas

Marine Sanctuaries/Coastal Reserves

NEP- Delaware Estuary Program

- Sea level rise represents the greatest threat to tidal wetlands in the Delaware Estuary, the habitat situated on the “front lines” (Kreeger et al. 2010).

- A Sea Level Affecting Marshes Model (SLAMM) scenario was run to predict acreage changes for tidal marshes, open water and tidal flats, scrub-shrub swamps, and other habitats in the Delaware Estuary by 2100. Across the whole estuary, 42,558 hectares of tidal wetland were predicted to be lost, with most being located along the microtidal shorelines and tributaries of the Delaware Bay region. In addition, 50,236 hectares are expected to be lost from adjacent habitats that are more landward, including scrub-shrub swamps, non-tidal wetlands, and uplands and these losses will translate into a net gain of 106,529 hectares of open water and tidal flat habitat (Kreeger et al. 2010).

NPS/NWR

Edwin B. Forsythe National Wildlife Refuge

- Warren Pinnacle Consulting (2012) ran Sea Level Affecting Marshes Model (SLAMM) simulations of Edwin B. Forsythe NWR and the results suggested that the area will be severely affected by increases in sea level under multiple sea level rise (SLR) scenarios and wetlands overall are predicted to be more vulnerable to inundation than previously estimated :

- Irregularly-flooded marsh in the refuge has relatively low elevations and is on the verge of converting to regularly-flooded saltmarsh. It is predicted to increasingly lose coverage given greater acceleration in SLR as vertical marsh accretion is not capable of keeping pace. At SLR scenarios of 0.69 m and greater by 2100, simulations suggested near complete loss of irregularly-flooded marsh habitat and more conservative SLR scenarios show irregularly-flooded marshes converted mostly to regularly-flooded marsh.

- As the rate of SLR increases and the marshes cannot keep pace with the rate of sea-level increase, regularly-flooded marsh is predicted to lose significant acreage and is predicted to be converted to open water or tidal flat.

- A large amount of tidal flat is predicted to be formed when regularly-flooded marsh drops below mean-tide level in SLR scenarios under 1.5 m by 2100. For higher SLR rates, gains are less pronounced as inundation of the newly-formed tidal flats is predicted.

- Swamp areas are predicted to be slowly inundated with an overall loss of more than 50% under the 2 m by 2100 SLR scenario.

- Undeveloped and developed dry land is also expected to be inundated, but to a much lesser extent than wetlands.

- Open water is predicted to increasingly inundate refuge areas that are currently covered by wetland, passing from 23% coverage today to more than 70% for the 2 m SLR by 2100 scenario.

Cape May National Wildlife Refuge

- Warren Pinnacle Consulting (2011) ran a SLAMM simulation of the Cape May National Wildlife Refuge and the results suggest that the wetland coverage is predicted to be greatly affected by sea-level rise and each category of wetlands that currently exists in the park is predicted to undergo significant losses:

    - As salt water penetrates further inland, increasing land cover is predicted to be converted to transitional salt marsh and regularly-flooded marsh

    - All existing wetland habitats in the refuge (swamp, irregularly-flooded marsh) are predicted to experience substantial losses.

    - Irregularly-flooded marsh is predicted to be nearly completely lost in SLR scenarios greater than 1 meter.

- Most of the irregularly-flooded “high” marsh habitat is predicted to convert to regularly-flooded marsh.

- Several low elevation habitats (regularly-flooded marsh, transitional salt marsh, tidal flat) are predicted to significantly increase their coverage in the refuge by 2100.

- Regularly-flooded marsh is predicted to increase for most simulated SLR scenarios; however, as sea level continues to rise, for SLR greater than 1.5 m by 2100, this wetland type is also predicted to be unable to keep pace with the relatively high local sea-level rise trend.

- Tidal flat and open water are predicted to increasingly take over refuge land with increasing SLR.

- Swamp, which is currently the dominant wetland type in the refuge with 50% coverage, is predicted to be increasingly affected as sea level rises, culminating in a maximum loss of 55% under the 2 m of SLR by 2100 scenario.

- SLAMM predicts areas that are currently classified as swamp will convert to transitional salt marsh and regularly-flooded marsh.

- Areas covered by undeveloped dry land are predicted to undergo similar changes, although lower percentage losses are predicted.

Supawna Meadows National Wildlife Refuge

- Clough and Larson (2009) ran a SLAMM simulation of Supawna Meadows National Wildlife Refuge and the results suggest that the predicted effects of global sea level rise are fairly severe:

    - Although significant irregularly flooded marsh conversion is predicted in eustatic scenarios of under 1 meter, total refuge marsh acreage (including salt marsh, and transitional marsh), is predicted to increase due primarily to the conversion of dry lands. However, under the highest SLR scenario utilized, 50% of total marsh acreage is predicted to be lost.

    - Roughly half of the refuge’s dry land is predicted to be lost even in the lowest SLR scenario examined and the refuge is predicted to lose between 49% and 88% of its dry land across all scenarios.

        - Dry land, when it falls to an elevation range that suggests regular inundation, is predicted to convert to “transitional marsh.”

    - There is a predicted loss of between 18% and 93% of irregularly flooded marsh, which currently makes up roughly half of the refuge.

        - When marsh accretion rates are unable to keep up with predicted local SLR, Irregularly Flooded marsh is predicted to first convert to regularly flooded marsh (saltmarsh).

        - If this regularly flooded marsh falls to too low of an elevation to maintain itself, it is then predicted to convert to tidal flats and eventually to open water.

    - Tidal swamps, about 10% of the refuge, are predicted to be lost at a rate of 19% to 82% across all SLR scenarios.

Parks

- Cooper et al. (2005) reported the results of a sea level rise simulation done for the Cape May Point area which includes the Cape May Point State Park administered by the New Jersey Division of Parks and Forestry and the Cape May Migratory Bird Refuge administered by the Nature Conservancy. The findings were:

    - Loss of land area by 2100 on the order of 12-100 % due to the combined influence of inundation, flooding and erosion is expected

    - This would result in substantial saltwater intrusion into low-lying wetlands behind the current beach area and compromise the role of Cape May Point as habitat for migratory birds, horseshoe crabs and other wildlife.

    - The increasing salinity would adversely affect established plant and animal communities.

    - The area is backed by residential and agricultural development, and the wetlands are blocked from accreting and migrating inland and it appears that during the next century the current study area will slowly attenuate, change in composition and potentially disappear.

- Strange (2008) reported that there is potential for wetland migration in the unprotected parts of Island Beach State Park, the Forsythe Refuge, and other parks and wildlife management areas in Ocean County and along the undeveloped shorelines of the Mullica and Great Egg Harbor rivers in Atlantic County.

Critical/Significant Habitats

Waterbird Islands

- Large bird populations found on marsh and dredge spoil islands of the back-barrier bays. Strange (2008) reported that although some of the small islands in Barnegat Bay and Little Egg Harbor are several feet above mean spring high water, portions of other islands are very low, and these areas could dissappear as a result of rising seas. These vulnerable islands are used by several species of conservation concern, nesting common terns, Forster's terns, black skimmers, and American oystercatchers including gull-billed tern, common tern, Forster's tern, least tern, and piping plover (Strange 2008). In addition, diamondback terrapin, a state species of special concern and a regional priority, is also known to feed on these marsh islands in the bays.

Essential Fish Habitat (EFH)

- Strange (2008) reported that as marshes along protected shorelines experience increased tidal flooding and tidal creeks become wider, deeper, and more abundant, there may be an initial benefit to some fish species, such as Atlantic silverside, mummichog, and bay anchovy, as these changes may allow for increased access to forage on the marsh surface.

- As sea levels continue to rise, and marshes along hardened shorelines convert to open water, marsh fishes will lose access to these marsh features and the protection from predators, nursery habitat, and foraging areas provided by the marsh, which are especially important for the larvae of mummichog, rainwater killifish, spotfin killifish, and sheepshead minnow (Strange 2008).

Atlantic Flyway

- The New Jersey Coastal Management Program estimated that some 1.5 million migratory shorebirds stop over on New Jersey's shores during their annual migrations and complete conversion of marsh to open water as a result of sea level rise will affect the hundreds of thousands of shorebirds that stop in these areas to feed during their migrations (Strange 2008).

- Strange (2008) reported that the loss of marsh area as a result of sea level rise would have negative implications for the dozens of bird species:

    - Stopover areas for hundreds of thousands of shorebirds, songbirds, raptors, and waterfowl during their seasonal migrations are provided by the tidal marshes of the Cape May Peninsula. These marshes are important staging and overwintering areas for seabird populations. Surveys conducted by the U.S. Fish and Wildlife Service from July through December 1995 in Cape May County recorded more than 900,000 seabirds migrating along the coast (Strange 2008).

- Strange (2008) reported that if marsh pannes and pools continue to be lost in Atlantic County as a result of sea level rise, the tens of thousands of shorebirds that feed in these areas may shift to feeding in impoundments in the nearby Forsythe Refuge, increasing shorebird densities in the refuge by tenfold and reducing population sustainability because of lower per capita food resources and disease from crowding.

Delaware Bay

- Some of the most notable Delaware Bay species that will be the most vulnerable and suffer considerable cumulative adverse impacts from sea level rise and climate change will be shorebirds and horseshoe crabs. Galbraith et al. (2002) reported that a sea level rise modeling study estimated that a 2-foot rise in relative sea level over the next century could reduce shorebird foraging areas in the Delaware Bay by 57 percent or more by 2100.

- Additionally, human infrastructure along the entire bay coast leaves estuary beaches little to no room to migrate inland as sea level rises. This will cause substantial losses of horseshoe crab spawning habitat likely to occur within the next 50 to 100 years (Galbraith et al. 2002).

- Any alternation of the sandy beach areas of southern New Jersey would likely result in declining horseshoe crab densities and bird populations (Cooper et. al 2005). Galbraith et al. (2002) estimated that even under conservative sea level rise projections, a 60 % loss of inter-tidal beach areas in Delaware Bay alone may occur and could severely impair the ability of these locations to support current numbers of migratory birds.

- Loss of horseshoe crab eggs as a result of beach erosion or beach nourishment could have important implications for the 1.5 million migratory shorebirds that stop over on New Jersey's shores to refuel during their annual migrations (Strange 2008). Many shorebirds, including the red knot, feed preferentially on horseshoe crab eggs in spring, and loss of this food source could reduce the growth and survival of migrants if there are insufficient alternative foraging sites nearby (Strange 2008). In spring migrants, such as sanderling, red knot, and ruddy turnstone, must feed nearly continuously to gain sufficient weight for nesting and to continue their long-distance migrations (Strange 2008).

T&E Species/Species of Concern

Seabeach Amaranth

- The federally listed seabeach amaranth (Amaranthus pumilus), a plant found in the foredunes of New Jersey's barrier beaches, is highly susceptible to the effects of rising seas and likely to be irreversibly damaged (Cooper et. al 2005).

Tiger Beetles

- Loss of estuarine beach could also have negative impacts on rare tiger beetles: two subspecies of Cicindela dorsalis are found on New Jersey's coastal shoreline: the northeastern beach tiger beetle, C. dorsalis dorsalis, which is a federally listed threatened species and a state species of special concern and regional priority, and C. dorsalis media, which is considered rare (Strange 2008).

Diadromous Fish

- Blueback herring spawn in shallow waters of creeks over sand or gravel substrate and it is difficult to determine cannot currently say whether this type of habitat will increase or decrease in the Delaware Bay (Kreeger and Titus 2008). Sand, peat/mud, and mud beaches are also important habitat for alewife (Kreeger and Titus 2008).

- Anadromous fish found in the Mid-Atlantic (those that live primarily in salt water but return to freshwater to spawn) include herring and shad, while marine transients such as Atlantic menhaden and drum species are present in summer and fall (Titus et. al 2009) and these species could be impacted by rising sea levels and saltwater intrusion.

Marine Turtles

- Loss of marshes as a result of sea level rise could decrease food sources for sea turtles, such as ribbed mussels (Kreeger and Titus 2008).

- Kemp's Ridley sea turtles rely on the sandy beaches of Delaware Bay to forage on invertebrates such as amphipods and clams (Titus et. al 2009).

Birds (Nesting)

- Strange (2008) reported that the loss of marsh area would also have negative implications for the dozens of bird species that forage and nest in New Jersey's coastal marshes through the following scenarios

    - Deeper tidal creeks and marsh pools will become inaccessible to short-legged shorebirds such as plovers and long-legged waterbirds such as yellow-crowned night heron, which forages almost exclusively on marsh crabs (fiddler crab and others), will lose important food resources.

    - High marsh nesting birds such as northern harrier, black rail, which are state-listed as endangered, clapper rail, and willet may be most at risk.

    - Complete conversion of marsh to open water will affect the hundreds of thousands of shorebirds that stop in these areas to feed during their migrations.

    - Waterfowl also forage and overwinter in area marshes and will likely be impacted by lost habitat as a result of sea level rise- midwinter aerial waterfowl counts in Barnegat Bay alone average 50,000 birds.

    - Local populations of marsh-nesting bird species will also be at risk where marshes drown and this will have a particularly negative impact on rare species such as seaside and sharp-tailed sparrows, which may have difficulty finding other suitable nesting sites.

    - Species that nest in other habitat but rely on marshes for foraging, such as herons and egrets, will also be affected as marshes drown.

Shellfish/Shellfish Beds

- As described in Kreeger et. al, in 2010, a panel of panel of eight experts on bivalve shellfish predicted the impact of sea level rise in the Delaware Estuary in a scenario of 1 meter rise by

2100 and concluded that the salinity gradient would expand up the Estuary, most notably in the middle/upper estuary and tributaries. They concluded the following:

- There are separate potential effects of sea level rise and salinity rise on bivalves, but the strongest effects are from an interaction of these factors; therefore, their effects were considered together.

- For oysters that live in the middle and upper estuary, the greatest concern is regarding a potential salinity increase, partly driven by sea level rise bringing more ocean water into the system. The two diseases that cause high oyster mortality are more virulent and prevalent at higher salinities, and these diseases currently define the downbay range of viable oyster populations.

- Even a slight increase of only a few parts per thousand is likely to push oysters northward, and analysis over the past 50+ years suggests that the bulk of the oyster population has already shifted from the lower and middle beds to the upper middle beds.

- In the freshwater tidal portion of the Estuary, native unionids cannot tolerate any saltwater, and this zone appears to be home to high biodiversity of sensitive species.

- In the fringing salt marshes of Delaware Bay, greater erosion and wetland loss from sea level rise and increased storminess threatens ribbed mussels due to the potential loss of their habitat.

- Blue crab, sea turtles, and shorebirds are among the many species that prey on ribbed mussels (Kreeger and Titus 2008).

Cultural Resources

- As sea level continues to rise and inland marshes and barrier islands erode or subside, cultural resources existing on them or behind them could be exposed to the elements or inundated, putting them at a greater risk of damage or destruction. Resources could also be adversely impacted over time by an increased risk of storm damage. Cultural resources would continue to be affected in coastal areas where there is no protection against storm events. Areas in the New York District which have not received storm damage reduction measures include the North Shore of Long Island, the West Shore of Long Island, Staten Island, and select areas in the Raritan Bay in New Jersey.

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7. Delaware: Environmental Existing and Future Conditions

I. Coastal Characterization - Delaware

Coastal and Marine Habitats

- General Delaware Bay shoreline description (North to South) (USACE 1991):
    - Between the C&D Canal and Woodland beach – eroding marsh land with eroding sandy barriers along the small communities
    - Woodland Beach south to Pickering Beach – marsh and tidal flats, also the location of Bombay Hook NWR
    - Port Mahon – eroding beach
    - Kelly Island, located across from the mouth of the Mahon River, continues to erode
    - Port Mahon to Pickering Beach – shoreline is fringed by marsh and tidal flats gradually changes to washover barriers and continuous beaches
    - Big Stone Beach to Mispillion Inlet – erosion
    - The barrier island just north of the Mispillion jetties (known as Conch Bar) has had a tendency to reorient itself in a counterclockwise direction such that the northward end of the bar (approximately 2000' north of the jetties) migrated landward at a rate of 9 to 11 ft./year between 1961 and 1977 while the southern end in the vicinity of the jetties migrated bayward at a rate of 12 ft./year
    - lower erosion rates for areas south of the Mispillion jetties with variable accretion and erosion
    - The shoreline from Slaughter Beach to Fowler Beach has experienced both erosion and accretion from 1 to 5 ft./year with the majority of areas eroding
    - Broadkill Beach also had a system of five groins installed during the 1950's, further complicating the estimation of long term shoreline change
    - Lewes Beach has had erosion mitigation projects including groins and numerous beach fills due to persistent long term shoreline change. Estimates for shoreline changes along Lewes Beach to the east of the jetties are complicated by the numerous beachfills which have been placed since the Roosevelt Inlet jetties were constructed in 1938
    - Shoreline changes near the eastern end of Beach Plum Island appear to be coupled with the condition of the western jetty of Roosevelt Inlet

  - In 1985, Delaware Bay became a charter member of the Western Hemisphere Shorebird Reserve Network

- General Delaware Atlantic Ocean Coast shoreline description (USACE 2000, 2006):

  - The Delaware Atlantic Coast is approximately 24 miles long and consists of six incorporated communities: Henlopen Acres, Rehoboth Beach, Dewey Beach, Bethany Beach, South Bethany, and Fenwick Island.

  - The northern portion of the Delaware Atlantic Ocean coast contains a spit-headland complex, baymouth barrier beaches, inland bays, tidal marshes, and Atlantic Coastal Waters.

- Features (North to South) (USACE 2000, 2006):

  - Chesapeake and Delaware (C&D) Canal

  - Mispillion Inlet

  - Roosevelt Inlet

  - Indian River Inlet (Atlantic coast)

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Pebble Shoreline

- Although typical beach dunes and the habitats associated with them are either fragmented and highly disturbed or are non-existent within the area; a few elements of beach dune flora and fauna are still present (USACE 2000, 2006).

- The beachfront within these limits is densely developed with houses, stores, and boardwalks with the exception of the Silver Lake area Barrier Islands/Inlets.

- Because of the high development within the area, the beach is frequently disturbed by recreation activities.

- In Rehoboth Beach, the beach, for the most part, lacks a natural dune system due to extensive development (USACE 2006).

- Dunes in Dewey Beach are non-existent due to recent storm events and high development (USACE 2006).

- The northern portion of the Delaware Atlantic Ocean coast contains a high energy beach with land features such as headland in the north (Rehoboth Beach and northern Dewey Beach) and barrier island to the south (middle and southern Dewey Beach) (USACE 2006).

- The barrier island is flanked on the west by Rehoboth Bay and the Atlantic Ocean on the east.

- Primary and secondary dunes are basically non-existent throughout the majority of the state due to high development and erosion. Exceptions to this are at Silver Lake and the northern terminus of the area at Deauville just north of the bend in Lakeshore Drive in Rehoboth Beach (USACE 2006).

- Although typical beach dunes and the habitats associated with them are both fragmented and highly disturbed or are non-existent within the state, a few elements of beach dune flora and fauna are still present. A large stretch of undeveloped beachfront exists at the northern end of the area at Deauville which extends for approximately 2,800 feet (USACE 2006). The beaches of Cape Henlopen State Park and Delaware Seashore State Park exhibit unfragmented natural settings where typical dune flora and fauna are present.

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

- Several different types of wetlands or tidal marshes border the Delaware Estuary: salt marshes, freshwater marshes, and brackish-water marshes (USACE 1991).

- A typical saltmarsh of the Delaware Estuary is characterized as having a salinity range from 20 to 30 parts per thousand (USACE 1991). The area is generally flooded twice daily by the tides and the dominant plant is smooth cordgrass (*Spartina alterniflora*).

- A high diversity of plants characterizes a typical freshwater marsh in the Delaware Estuary (USACE 1991).

- A transitional wetland occurs in brackish water where the salinity may range from 20 to less than 5 parts per thousand. The vegetation is complex, with some typical saltmarsh species intermixed with common freshwater plants (USACE 1991).

- The major portion of the coastal marshes are formed behind barrier beaches and extend inland for varying distances, depending on the elevation of the adjacent upland (USACE 1991).

- The sequence of saltmarsh to brackish-water marsh to freshwater tidal marsh occurs as a progression up the Delaware Estuary.

- Vast expanses of saltmarsh are found in coastal Delaware.

- Typical brackish water marshes are found along much of the estuary. Similarly, this same sequence can be found along many tidal rivers draining into the estuary.

- Several different types of wetlands or tidal marshes border the Delaware Estuary: salt marshes, freshwater marshes, and brackish-water marshes. The sequence of saltmarsh to brackish-water marsh to freshwater tidal marsh occurs as a progression up the Delaware Estuary (USACE 1991).

- Some of the more common bird species which are known to nest in the marsh are: Canada goose (*Branta canadensis*), mallard (*Anas platyrhynchus*), black duck (*A. rubripes*), blue-winged teal (*A. carolinensis*), willet (*Cataptrophorus semipalmatis*), and clapperrail (*Rallus longirostris*).

- Tidal Marsh exists along most of the Bay margin. The major portion of the coastal marshes are formed behind barrier beaches and extend inland for varying distances, depending on the elevation of the adjacent upland (USACE 1991).

    - The shoreline in the southern and central regions is characterized by the presence of a thin washover sand barrier which is advancing over the marsh.

    - To the north, the shoreline is typically an eroding marsh edge with small sandy beaches occurring intermittently in pocket areas.

    - The presence of tidal marshes has limited the amount of development along the bay shore.

    - Considerable acreage is incorporated into Federal wildlife refuges, State park and wildlife management areas.

    - The wildlife habitat value of these areas is excellent and migratory waterbird management is particularly emphasized. Hunting, trapping, boating, fishing, and wildlife observation are important recreational activities. In addition, wetlands play a role in climate regulation as well by exerting a modifying influence on local temperature and humidity conditions.

Salt marsh

- Vast expanses of saltmarsh are found in coastal County, Delaware.

- Salt marsh in the Delaware Estuary is characterized as having a salinity range from 20 to 30 parts per thousand (USACE 1991).

- The area is generally flooded twice daily by the tides and the dominant plant is smooth cordgrass (*Spartina alterniflora*).

- The high marsh, which is flooded less frequently, is located above the tall cord grass zone and populated with a shorter form of cordgrass with occasional patches of salt meadow hay (*Spartina patens*) and/or salt grass (*Distichlis spicata*). Other floral species associated with *spartina alterniflora* in the cordgrass marsh are big cordgrass (*S. cynosuroides*), spikegrass (*Distichlis spicata*), reed grass (*Phragmites communis*), and marsh mallow (*Hibiscus* spp.).

- A border community between this intertidal zone and the drier upland is a community often composed of black grass (*Juncus gerardi*) mixed with scattered shrubs of marsh elder (*Iva frutescens*). Moving more upland, the inhabitants include an impenetrable thicket of groundsel tree (*Baccharis halimfolia*), high tide bush common reed (*Phragmites australis*), and sometimes poison ivy (*Toxicodendron radicans*).

Freshwater marsh

- A high diversity of plants characterizes a typical freshwater marsh in the Delaware Estuary (USACE 1991).

- The low marsh appears as a barren mudflat in winter and early spring. In late spring, however, the low marsh comes alive with such plants as spatterdock (*Nuphar luteum*), pickerelweed (*Pontederia cordata*), and broadleaf arrowhead (*Sagittaria latifolia*). Taller plants such as wild rice (*Zizania aquatica*) or water hemp (*Amaranth us cannabinus*) generally dominate as the growing season progresses (USACE 1991).

- The high marsh is generally a mixed community of narrow-leaved cattail (*Typha angustifolia*), tearthumbs (*Polygonum* sp.), sweet flag (*Acornus calamus*), and bur marigold (*Bidens laevis*). In addition to these herbaceous species, there may be an occasional shrub or tree such as the willow (*Salix* sp.), button bush (*Cephalanthus occidentalis*), and red maple (*Acer rubrum*).

Brackish Marsh

- Typical brackish water marshes are found along much of the estuary.

- A transitional wetland occurs in brackish water where the salinity may range from 20 to less than 5 parts per thousand.

- The vegetation is complex, with some typical saltmarsh species intermixed with common freshwater plants.

- The brackish-water marsh may include an intertidal zone with saltmarsh cordgrass or big cordgrass predominating.

- The high marsh is often composed of salt hay intermixed with common three square sedge (*Scirpus americanus*).

- The greater proportion of plants, however, are common freshwater species such as water hemp, arrow arum (*Peltandra virginica*), and pickerelweed.

Shallow Bay Habitat/Bay Islands

Delaware Bay

- The concentration of spawning horseshoe crabs on Delaware Bay beaches is extraordinary among East Coast estuaries (USACE 1991).
    - Horseshoe Crabs (*Limulus polyphemus*) are a prominent and vital part of the Delaware estuary community.
- Delaware Bay ranks as the largest spring staging site for shorebirds in eastern North America Staging sites serve to link wintering areas with breeding grounds and are critical to the survival of hundreds of thousands of migrating shorebird species (USACE 1991).
    - The birds arrive to the shores of the estuary in early May from the coast of Brazil, Patagonia, Tierra del Fuego, Chile, Peru, Suriname, Venezuela, and the Guyanas. They reach the Bay depleted of their energy reserves after several days of nonstop flight, traveling up to 5,000 miles. The birds feast on horseshoe crab eggs which will fuel their northward migration from the Bay to their Arctic nesting grounds.
    - The shorebirds remain at Delaware Bay for only about three weeks before resuming their northward migration. During this period of heavy feeding, the birds will increase their weight by 40% or more. Sites of particularly high bird concentrations in Delaware include Port Mahon, Deepwater Point, Kitts Hummock, and the mouth of the Mispillion River.

Atlantic Coast

- There are 3 shallow water inland bays – Rehoboth Bay, Indian River Bay, Little Assawoman Bay.
    - Bordered extensively with tidal marshes composed of salt marsh cordgrass *(Spartina alterniflora)*, saltmeadow hay *(S. patens)*, spike grass *(Distichlis spicata)*, and high tide bush *(Iva frutescens)* (USACE 2013).
    - Rehoboth and Little Assawoman Bays are estuaries built on sand bars; Indian River Bay is a drowned river valley. The Bays and their tributaries cover about 32 square miles and drain a 300-square-mile watershed. They have a marsh area of 9 square miles, a mean low-water volume of 4 billion cubic feet, and a freshwater discharge of 300 cubic feet per second (Delaware Inland Bays Comprehensive Conservation and Management Plan, Center for Inland Bays 1995).

- The combination of excessive nutrient levels and high turbidity seems to have eliminated the growth of submerged aquatic vegetation (SAV), such as eel grass, in the Inland Bays (Delaware Inland Bays Comprehensive Conservation and Management Plan, Center for Inland Bays 1995).

- Common estuarine fishes present in the inland bays include: bay anchovy, Atlantic silverside, mummichog, striped killifish, naked goby, and hogchoker.

- The inland bays are important nurseries for a variety of commercial and recreational fishes including: spot, croaker, weakfish, menhaden, bluefish, and summer flounder.

- The inland bays are also important for supporting a variety of waterfowl, shorebirds, and wading birds.

Rehoboth Bay

- Rehoboth Bay is the nearest inland embayment to the study area and borders the barrier island on the west at the town of Dewey Beach.

- High development is present along the back-barrier of Dewey Beach which was previously part of the tidal marsh complex that extends further south along Rehoboth Bay.

- Extensive tidal marshes are present along the western fringes of Rehoboth Bay. Rehoboth Bay has 48 miles of shoreline and a surface area of 14.8 square miles. Water depths at low tide are generally 7 feet or less.

- Saline water enters Rehoboth Bay from Indian River Bay and from the lower Delaware Bay through the Lewes-Rehoboth Canal.

- Rehoboth bay supports adequate numbers of hard clam *(Mercenaria mercenaria)* and blue crab *(Callinectes sapidus)* for recreational and/or commercial fisheries.

Indian River Bay

- Surveys conducted in the 1960s in the area identified 38 species in Indian River Bay. Five of those species accounted for 92% of the catch. These species were striped killifish (*Fundulus majalis*), Atlantic silverside (*Menidia menidia*), mummichog (*Fundulus heteroclitus*), winter flounder *Pseudopleuronectes americanus*), and bay anchovy (*Anchoa mitchilli*) (USACE 2013).

- Although Indian River Bay does not support a commercial fishery, it indirectly contributes by serving as a spawning and nursery area for several economically valuable species. Species known to spawn in the bay include winter flounder, bay anchovy, Atlantic menhaden (*Brevoortia tyrannus*), Atlantic silverside, and hogchoker (*Trinectes maculatus*). Species known to use the upper estuary as a nursery area, include spot (*Leiostomus xanthurus*), weakfish (*Cynoscion regalis*), Atlantic menhaden, and bluefish (*Pomatomus saltatrix*) (USACE 2013).

- Recreational fishing in Indian River Bay is popular and sport fishes include winter and summer flounder, snapper (*Lutjanus campechanus*), blue fish, striped bass (*Morone saxatilis*), and blowfish (*Sphoerides maculatus*). Diadromous species such as alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), striped bass and American eel (*Anguilla rostrata*) use the inlet to reach freshwater tributaries for spawning or growth to maturity USACE 2013).

Submerged Aquatic Vegetation

- There are some freshwater SAVs are in the Delaware River.

- High suspended sediments appear to be the reason why there are no significant areas of submerged aquatic vegetation in Delaware Bay.

Oyster Reefs

- In Delaware, the main oyster grounds are located in the region of the Bay lying between the Smyrna River and Bowers Beach. The natural grounds are located in the upper portion of this area, in particular, northeast of the mouth of the Mahon River, while the planted grounds are in the lower portion (USACE 1991).

Rock Reefs/Habitats

- The nine rock groins in Rehoboth Beach represent an artificial rocky intertidal zone.

- In addition to providing a hard substrate for the attachment of benthic macroalgae, the groins also contain suitable habitats for a number of aquatic and avian species. Barnacles, small crustaceans, polychaetes, molluscs and a variety of shorebirds may reside on, above and around these structures (USACE 2006).

- Mussels (*Mytilus* sp.) are prevalent on the rock surfaces.

- Fish habitats is associated with any bottom structures like breakwaters, rock jetties and groins, rough bottom off of Cape Henlopen, submerged wrecks and artificial reefs.

    - The following species are more associated with these structures: tautog *(Tautoga onitis)*, gray triggerfish *(Balistes capriscus)*, oyster toadfish *(Opsanus tau)*, conger eel *(Conger oceanicus)*, cunner *(Tantogolabrus adspersus)*, and planehead filefish *(Monacanthus hispidus)* (USACE 2006).

Floodplains/Riparian

Tidal Rivers

- Many tidal rivers drain into the estuary and contain a transition of marsh habitats.

- For example, the Broadkill River, located in Delaware near the mouth of the estuary, is lined with extensive saltmarsh cordgrass, grading into brackish-water species and then freshwater species several miles up the meandering tidal stream.

Coastal Protected Areas

National Estuary Program

- Delaware Center for the Inland Bays
- Partnership for the Delaware Estuary (Delaware Estuary Program)

National Park Service Areas

- Bombay Hook National Wildlife Refuge (http://www.fws.gov/refuge/bombay_hook/)
    - Hosts migrating ducks, geese, shorebirds, and neotropical songbirds, all following old traditions of natural history, the spring and fall migrations.
    - Its 16,251 acres include freshwater pools, swamps, upland forests and fields, and one of the largest tidal salt marshes in the Mid-Atlantic region.
- Prime Hook National Wildlife Refuge (http://primehook.fws.gov)
    - Established under the authority of the Migratory Bird Conservation Act for use as an inviolate sanctuary, or any other management purpose, expressly for migratory birds.
    - The refuge is considered to have one of the best existing wetland habitat areas along the Atlantic Coast. Refuge impoundments have become important stop-over sites for spring and fall migrating shorebirds, waterfowl, and wading birds.
    - Endangered and threatened species management activities provide habitat for the Delmarva fox squirrel, nesting bald eagles and migrating peregrine falcons.
    - Neotropical land birds passing through the area utilize the refuge's upland forested habitat during the fall and spring.
    - The refuge's 10,000 acres are a diverse landscape featuring freshwater and salt marshes, woodlands, grasslands, scrub-brush habitats, ponds, bottomland forested areas, and a 7 mile long creek.
    - These cover types provide habitat for approximately 296 species of birds, 38 species of reptiles and amphibians and 37 different mammals.

National Wildlife Refuges

- Prime Hook National Wildlife Refuge is located in the outer Coastal Plain, along the southwestern shore of the Delaware Bay, in Delaware. The refuge consists of coastal marshes and associated estuarine and freshwater creek drainages, and upland habitats. The refuge is an important stopover site for migratory birds as they travel up and down the Atlantic Flyway and provides protected breeding habitat for federally and State-listed threatened and endangered species, as well as many neo-tropical migrating bird species.

- Bombay Hook National Wildlife Refuge is located in Delaware along the western shore of Delaware Bay approximately 36 miles from the mouth. The refuge protects one of the largest remaining expanses of tidal salt marsh in the mid-Atlantic region. The refuge is mostly marsh, but also includes freshwater impoundments and upland habitats that are managed for other wildlife.

- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

State/County Parks

- Three state parks are located along the coast.
    - Cape Henlopen State Park is located in the northern part of the coast from Cape Henlopen to the private community of North Shores.
    - Delaware Seashore State Park exists both north and south of Indian River Inlet in the central part of the coast.
    - Fenwick Island State Park is located in the southern part of the coast between South Bethany and Fenwick Island.

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

A detailed discussion of Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Delaware Bay

- Several threatened or endangered species are known to occur in the bay region.

- Bald eagles (*Haliaetus leucocephalus*), American peregrine falcons (*Falco peregrinus anatum*), and Arctic peregrine falcons (*Falco peregrinus tundrius*) have been sighted in the Bombay Hook National Wildlife Refuge.
  - Bald eagles feed on Delaware Bay coastline marshes year-round, but use is greatest in winter, when migrant eagles from the north are present in the area.

- The Red Knot (*Calidris canutus rufa*) (Proposed) is a medium sized shorebird which uses the Delaware Bay shoreline as a major stopover sight during their northward migration in the spring due to the abundance of horseshoe crab eggs available for foraging.
- The New York Bight Distinct Population Segment of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and shortnose sturgeon (*Acipenser brevirostrum*) are present in the area and are federally listed endangered species;

Atlantic Coast

- The oceanfront beaches of Delaware support a small breeding population of the federally threatened Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986.
  - The bird has declined along the East Coast as it has come into competition with human recreational use of sandy beaches. The piping plover nested at Cape Henlopen State Park although prior to 1988 (USACE 1991).
  - Although there are no know nesting sites now, the potential for nesting exists. These small shorebirds favor nesting sites on coastal beaches and dunes. The State of Delaware has an active program to protect the bird's nesting activities and conduct annual surveys to detect nesting birds and install protective fencing.

- Avian threatened and endangered species may be present in only occasional and transient bases, may include the peregrine falcon *(Falco peregrinus* and *F. peregrinus tundrius)*.

- Two rare plant species, sea beach pigweed (*Amaranthus pumilus*) and chaffseed (*Schwalbea americana)*, can be found in beach and dune habitats in Delaware (USACE 2000).

- Seabeach amaranth (family Amaranthaceae) occurs on Delaware's ocean beaches and is an annual plant native to the barrier island beaches of the Atlantic Coast, from Massachusetts to South Carolina.

- The Delaware coast may be occasionally visited by five species of threatened and endangered sea turtles.

- Sea turtles primarily utilize Delaware coastal waters as a transportation route from the Gulf Stream to Delaware Bay, where significant numbers have been observed utilizing the bay's resources as a nursery and feeding area (USACE 2000).

- These turtles include the loggerhead turtle (*Caretta caretta*), green turtle (Chelonia mydas), hawksbill turtle (*Eretmochelys imbricata*), Kemp's Ridley turtle (Lepidochelys kempii) and leatherback turtle (*Dermochelys coriacea*).

- These species breed much further south from Florida through the Caribbean and Gulf of Mexico.

- The loggerhead turtle and Kemp's Ridley turtle are particularly more common in Delmarva coastal waters during summer months.

- Historically, the breeding range of the loggerhead turtle may have extended to the Delaware Atlantic Coast, however, there are no known nesting sites reported in this stretch of coast.

- Overall, sea turtle utility of Delaware's twenty-five mile stretch of Atlantic Ocean presently or historically has not been significant.

- New York Bight Distinct Population Segment of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and shortnose sturgeon are present in the area and are a federally listed endangered species.

- Species of concern are those species about which NOAA’s National Marine Fisheries Service (NMFS) has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the speciesi under the Endangered Species Act. In Delaware, alewife, blueback herring are species of concern. American eel are being considered for listing under the ESA.

Waterbird Islands

- Since 2009, 11 water bird nesting colonies (> 10 nesting pairs) have been reported form Delaware. A detailed discussion of Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

- A notable waterbird colony is Pea Patch Island

  - Pea Patch Island is a small island approximately 1 mi (1.6 km) long, in the state of Delaware, located in the mid channel of the Delaware River near its entrance into Delaware Bay (USACE 1991).

  - The location of the largest colony of herons in the United States, north of Florida.

Essential Fish Habitat (EFH)

Atlantic Coast

- New York Bight Distinct Population Segment of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) and shortnose sturgeon are present in the area and are a federally listed endangered species;

- There are Habitat Areas of Particular Concern (HAPC) for Sandbar shark (*Charcharinus plumbeus*) in Delaware.

- Delaware provides EFH for:
    - Atlantic cod (*Gadus morhua*)
    - Red hake (*Urophycis chuss*)
    - Windowpane flounder (*Scopthalmus aquosus*)
    - Atlantic sea herring (*Clupea harengus*)
    - Monkfish (*Lophius americanus*)
    - Bluefish (*Pomatomus saltatrix*)
    - Long finned squid (*Loligo pealei*)
    - Short finned squid (*Illex ilecebrosus*)
    - Atlantic butterfish (*Peprilus tricanthus*)
    - Summer flounder (*Paralicthys dentatus*)
    - Scup (*Stenotomus chrysops*)
    - Black sea bass (*Centropristus striata*)
    - Surfclam (*Spisula solidissima*)
    - Ocean quahog (*Artica islandica*)
    - Spiny dogfish (*Squalus acanthias*)
    - King mackerel (*Scomberomorus cavalla*)

- Spanish mackerel (*Scomberomorus maculatus*)
- Cobia (*Rachycentron canadum*)
- Sand tiger shark (*Odontaspis taurus*)
- Atlantic angel shark (*Squatina dumerili*)
- Dusky shark (*Charcharinus obscurus*)
- Sandbar shark (*Charcharinus plumbeus*)
- Scalloped hammerhead shark (*Sphyrna lewini*)
- Tiger shark (*Galeocerdo cuvieri*)
- Atl. Sharpnose shark (*Rhizopriondon terraenovae*)

Shellfish/Shellfish Beds

Delaware Bay

- In the Delaware Bay and Estuary area include the American oyster (*Crassostrea virginica*), blue crab (*Callinectes sapidus*), and the horseshoe crab (*Limulus polyphemus*) (USACE 1991).
  - Some of the commonly occurring species include: Tellina agilis (bivalve), Ensis directus (bivalve), Glycera dibranchiate (polychaete), Heteromastus filiformis (polychaete), Gemma (bivalve), Nethtys picta (polychaete), Mulinia lateralis (bivalve), Neomysis americana (crustacean), Nucula proxima (bivalve), and Protohaustorius wigleyi (crustacean). Other benthic organisms present within the estuary include barnacles, the edible mussel, oyster drill, mudsnail, hermit crab, boring sponge, oyster crab, calico crab, rock crab, spider crab, jonah crab, mud crab, and starfish.
  - Species of economic importance include the blue crab (*Callinectes sapidus*), American lobster (*Homarus americanus*), and American oyster (*Crassostrea virginica*).
    - Oysters
      - In Delaware, the main oyster grounds are located in the region of the Bay lying between the Smyrna River and Bowers Beach (USACE 1991).
      - The natural grounds are located in the upper portion of this area, in particular, northeast of the mouth of the Mahon River, while the planted grounds are in the lower portion.

        - Hard clams (*Mercenaria*)
            - Distributed from Port Mahon to Cape Henlopen in Delaware (USACE 2000).
        - The blue crab (*Callinectes sapidus*)
            - Ubiquitous in Delaware Bay and functions as a scavenger in the estuarine ecosystem.
            - Delaware Bay contains a large population of blue crabs that support a commercial industry of economic importance to the area.
    - A small lobster fishery is located primarily on the outer breakwater near Cape Henlopen.
    - Horseshoe Crabs (*Limulus polyphemus*) are a prominent and vital part of the Delaware estuary community (USACE 1991).
        - The concentration of spawning horseshoe crabs on Delaware Bay beaches is extraordinary among East Coast estuaries.

Atlantic Coast

- The surf clam has been periodically harvested from Delaware's coastal waters for commercial purposes (USACE 2006).
    - The surf clam has a wide distribution and abundance within the mid-Atlantic Region.
    - They most commonly inhabit substrates composed of medium to coarse sand and gravel in turbulent waters just beyond the breaker zone.
    - The abundance of adults varies from loose, evenly distributed aggregations to patchy, dense aggregations in the substrate (USACE 2006). Surveys conducted by the State in 1982, 1986, and 1992 confirmed that no significant numbers of commercial sized surfclams exist within Delaware's three-mile territorial limit (USACE 2006).
- Blue Crab
    - The Delaware coastal area supports a small fishery for blue crabs *(Callinectes sapidus)*, which are harvested in the winter by dredging.
    - The fishery is usually limited to a few licenses to avoid over-harvesting this stock, which consists mainly of female crabs that would be spawning the following spring and summer.

- The major portion of the blue crab population remains in Delaware Bay (USACE 1991).

Fish/Fisheries

Delaware Bay

- The Delaware Estuary is home to over 100 species of finfish, many of which are commercially and recreationally important (USACE 1991).
    - This great diversity is the result of the overlap between northern and southern species in the mid-Atlantic coastal region.
    - Many species use the estuary as a breeding ground and nursery area for their young. The warm, shallow, near-shore and marsh nursery waters shelter small fish from predators and provide them with food while the deeper, cooler waters serve as feeding grounds for larger fish.
    - The majority of adult fish species in the Delaware Estuary are predators at or near the top of the food web, eating plankton, smaller fish, and invertebrates such as crabs, snails, and worms.
    - Anadromous species that utilize the estuary range along the Atlantic coast from the Gulf of Saint Lawrence to Florida and migrate to freshwater to spawn. These species include the American shad (*Alosa sapidissima*), Atlantic sturgeon (*Acipenser oxyrhynchus*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and striped bass (*Morone saxatilus*).
        - Shad – The shad spawning run has been improving in recent years, coinciding with improving water quality conditions below Philadelphia.
        - Atlantic sturgeon move through the Bay in May and June to spawning areas near Philadelphia.
        - Alewife, blueback herring, and white perch spawn in many of the Bay's tributary streams during the spring.
        - A limited number of striped bass spawning occurs in the spring upstream from the Chesapeake and Delaware (C & D) Canal.
- Estuarine species are predominately forage fish which provide an important link in the food web (USACE 1991).
    - Examples of these species include the mummichog (*Fundulus heteroclitus*), Atlantic silverside (*Menidia*), bay anchovy (*Anchoa mitchilli*), and hogchoker (*Trinectes maculatus*).

  - Marine, estuarine-dependent species migrate up and down the Atlantic coast and rely on the estuary for spawning and nursery grounds. These species comprise some of the most economically important fisheries. Examples include the weakfish (*Cynoscion regalis*), bluefish (*Pomatomus saltatrix*), winter flounder (*Pseudopleuronectes americanus*), and summer flounder (*Paralichthys dentatus*), and Atlantic menhaden (*Brevoortia tyrannus*).

  - Five species of shark visit the Delaware Estuary regularly: the common hammerhead (*Sphyrna zygaena*), the sand tiger (*Odontapis taurus*), the smooth dogfish (*Mustelus canis*), spiny dogfish (*Squalus acanthus*) and sandbar shark (*Carcharhinus plumbeus*).

- Sport fishing is a major recreational activity (USACE 1991).

  - Weakfish, summer flounder, and bluefish are the most popular species with anglers.

  - Other species taken in the recreational catch include: sea bass, white perch, striped bass, scup, black drum, channel catfish, tautog, sharks, skates, spot, croaker, and hake.

  - In terms of its abundance and value to the recreational and commercial fisheries, the weakfish ranks as one of the most important species in Delaware Bay. It is a seasonal resident from April through October. The southwest portion of the Bay between the Mispillion River and Lewes is a major spawning area.

Atlantic Coast

- The proximity of several embayments allows the coastal waters of Delaware to have a productive fishery.

- Many species utilize the estuaries of Delaware Bay, Rehoboth Bay, Indian River Bay, and Little Assawoman Bay for forage and nursery grounds (USACE 2006).

- The finfish found along the Delaware Atlantic coast are principally seasonal migrants. Winter is a time of low abundance and diversity as most species leave the area for warmer waters offshore and southward. During the spring, increasing numbers of fish are attracted to the Delaware Atlantic coast because of its proximity to several estuaries which are utilized by these fish for spawning and nurseries.

- Surveys of the finfish in Delaware's coastal waters have been conducted by Maurer and Tinsman 1980 (as reported in USACE 2006), and annually for several years by the National Marine Fisheries Service. Abundant finfish species in Delaware coastal waters include: red hake *(Urophycis chuss)*, northern sea robin *(Prionotus carolinus)*, spot *(Leiostomus xanthurus)*, windowpane flounder *(Scopthalmus aquosus)*, silver hake *(Merluccuns bilinearis)*, clearnose skate *(Raja eglanteria)*, hogchoker *(Trinectes maculatus)*, and weakfish *(Cynoscion regalus)*. Large numbers of bay anchovies *(Anchoa mitchilli)*, butterfish *(Peprilus triacanthus)*, scup *(Stenotomus chrysops)*, weakfish, striped anchovy *(Anchoa hepsetus)*, spot, and bluefish

(Pomatomus saltatrix).

- The numbers of fishes along the Delaware Atlantic Coast are generally not sufficient to support a significant commercial fishing industry, however, the Delaware coast supports a diverse recreational fishery.
  - Approximately 70% of Delaware's shore-based fishing is along the Atlantic coast beaches and jetties (USACE 2006). There are also many private/charter boat fishermen from Indian River Inlet and Lewes that fish the coastal area.
  - The species caught usually include: bluefish, weakfish, croaker, spot, kingfish, red drum, tautog, summer flounder, striped bass, scup, sharks, hakes, sea bass, Atlantic and Spanish mackerel, triggerfish, and blowfish. A sea bass pot fishery and early spring gill net fishing targeting shad and weakfish are the only prevalent commercial fishing operations in the coastal waters of Delaware.

Shorebirds

Delaware Bay

- Delaware Bay ranks as the largest spring staging site for shorebirds in eastern North America.
- Staging sites serve to link wintering areas with breeding grounds and are critical to the survival of hundreds of thousands of migrating shorebird species (USACE 1991).
  - The birds arrive to the shores of the estuary in early May from the coast of Brazil, Patagonia, Tierra del Fuego, Chile, Peru, Suriname, Venezuela, and the Guyanas. They reach the Bay depleted of their energy reserves after several days of nonstop flight, traveling up to 5,000 miles. The birds feast on horseshoe crab eggs which will fuel their northward migration from the Bay to their Arctic nesting grounds.
- The shorebirds remain at Delaware Bay for only about three weeks before resuming their northward migration. During this period of heavy feeding, the birds will increase their weight by 40% or more. Sites of particularly high bird concentrations in Delaware include Port Mahon, Deepwater Point, Kitts Hummock, and the mouth of the Mispillion River.
- Many species of shorebirds inhabit the beach during the spring and fall migrations, although most are even more likely to be found on more protected sand and mud flats, tidal marshes, or along the Delaware Bay shoreline (especially in spring when large numbers of horseshoe crab eggs are available).
- The significance of Delaware Bay as a shorebird stopover area is described in more detail in the USFWS NACCS Planning Aid Report (Attachment A).

Atlantic Coast

- Shorebirds feed on small individuals of the resident infauna and other small organisms brought in with waves.

- Common shorebird species include sanderling *(Calidris alba)*, dunlin *(C. alpina)*, semipalmated sandpiper *(C. pusilla)*, western sandpiper *(C. mauri)*, and willet *(Catoptrophorus semipalmatus)*. Sanderling, dunlin, and western sandpiper also occur on the beach throughout the winter.

- Colonial nesting shorebird habitat is increasingly under pressure from development and human disturbance along Delaware's Atlantic beaches (USACE 2006).

    - Nesting birds such as common tern *(Sterna hirundo)*, least tern *(S. antillarum)*, black skimmer *(Rynchops niger)* and American oyster catcher *(Haematopus palliatus)* are frequent spring and summer inhabitants on unvegetated dunes and upper beaches at Cape Henlopen and Delaware Seashore State Parks.

    - High beachfront development and human disturbance in the Dewey Beach and Rehoboth Beach project area has consequently forced nesting shorebirds to seek the remaining undeveloped beaches (USACE 2006).

    - Undeveloped beaches such as these State Parks are critical for nesting pairs of the Federal and State threatened piping plover *(Charadrius melodus) (USACE 2006)*.

        - The only Federally or state listed endangered or threatened species known to occur along the Delaware Atlantic coast on more than an occasional or transient basis is the piping plover *(Charadrius melodus)*.

        - These small shorebirds, which are classified as endangered on both the Federal and State lists, nest on coastal beaches and dunes.

        - Most of Delaware's Atlantic beach and dune system, except in high development areas is potential nesting habitat.

        - Piping plover have been nesting at Cape Henlopen and Delaware Seashore State Parks.

        - The nesting season usually begins in late March when the birds arrive and ends in July when the young are finally fledged.

        - Shortly after hatching, the young leave the nest and begin foraging along the shoreline. The adults accompany the young during this critical period until they are fledged 25-35 days later.

    - The State of Delaware has an active program to protect the bird's nesting activities. The program includes annual surveys to detect nesting birds and installation of fencing to close the nesting areas to intruders.

  - Several species of gulls are common along Delaware's shores, and are attracted to forage on components of the beach wrack such as carrion and plant parts. These gulls include the laughing gull *(Larus atricilla)*, herring gull *(L. argentatus)*, and ring-billed gull *(L. delawarensis)* (USACE 2006).

Benthic Macroinvertebrates

Atlantic Coast

- The nearshore and offshore waters of the Delaware Coast contain a wide assemblage of invertebrate species inhabiting the benthic substrate and open water (USACE 2000, 2006). Invertebrate Phyla existing along the coast are represented by Cnidaria (corals, anemones, jellyfish), Platyhelminthes (flatworms), Nemertinea (ribbon worms), Nematoda (roundworms), Bryozoa, Mollusca (chitons, clams, mussels, etc.) Echinodermata (sea urchins, sea cucumbers, sand dollars, starfish), and the Urochordata (tunicates).

  - Benthic macroinvertebrates are those dwelling in the substrate (infauna) or on the substrate (epifauna). Benthic invertebrates are an important link in the aquatic food chain, and provide a food source for most fishes. Various factors such as hydrography, sediment type, depth, temperature, irregular patterns of recruitment and biotic interactions (predation and competition) may influence species dominance in benthic communities. Benthic assemblages in Delaware coastal waters exhibit seasonal and spatial variability. Generally, coarse sandy sediments are inhabited by filter feeders and areas of soft silt or mud are more utilized by deposit feeders.

Threatened and Endangered Species

- A detailed discussion of USFWS managed Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

Delaware Bay

- Several threatened or endangered species are known to occur in the bay region.

  - Bald eagles (*Haliaetus leucocephalus*), American peregrine falcons (*Falco peregrinus anatum*), and Arctic peregrine falcons (*Falco peregrinus tundrius*) have been sighted in the Bombay Hook National Wildlife Refuge.

    - Bald eagles feed on Delaware Bay coastline marshes year-round, but use is greatest in winter, when migrant eagles from the north are present in the area.

- The piping plover (*Charadrius melodus*) was listed on federal and state lists of threatened and endangered species in 1985.
  - The bird has declined along the East Coast as it has come into competition with human recreational use of sandy beaches. The piping plover nested at Cape Henlopen State Park although prior to 1988 (Jenkins, 1991).
  - Although there are no know nesting sites now, the potential for nesting exists. These small shorebirds favor nesting sites on coastal beaches and dunes. The State of Delaware has an active program to protect the bird's nesting activities and conduct annual surveys to detect nesting birds and install protective fencing.

Atlantic Coast

- Avian threatened and endangered species may be present in only occasional and transient bases, which may include the peregrine falcon *(Falco peregrinus* and *F. peregrinus tundrius)*.
- Two rare plant species, sea beach pigweed (*Amaranthus pumilus*) and chaffseed (*Schwalbea americana)*, can be found in beach and dune habitats in Delaware (USACE 2000).
- The Delaware coast may be occasionally visited by five species of threatened and endangered sea turtles.
  - Sea turtles primarily utilize Delaware coastal waters as a transportation route from the Gulf Stream to Delaware Bay, where significant numbers have been observed utilizing the bay's resources as a nursery and feeding area (USACE 2000).
  - These turtles include the loggerhead turtle *(Caretta caretta)*, green turtle *(Chelonia mydas)*, hawksbill turtle *(Eretmochelys imbricata)*, Kemp's Ridley turtle *(Lepidochelys kempii)* and leatherback turtle *(Dermochelys coriacea)*.
  - These species breed much further south from Florida through the Caribbean and Gulf of Mexico.
  - The loggerhead turtle and Kemp's Ridley turtle are particularly more common in Delmarva coastal waters during summer months.
  - Historically, the breeding range of the loggerhead turtle may have extended to the Delaware Atlantic Coast, however, there are no known nesting sites reported in this stretch of coast.
  - Overall, sea turtle utility of Delaware's twenty-five mile stretch of Atlantic Ocean presently or historically has not been significant.

II. Habitat Impacts from Hurricane Sandy - Delaware

Coastal and Marine Habitats

Oyster Habitat

- NFWF website: Runoff from Hurricane Sandy is laden with sediment, contaminants and debris. All pose a significant threat to the health of oyster reefs and shellfish beds along the Atlantic Coast.

Marshes

- Hurricane Sandy moved large amounts of coastal sediments, changing barrier landscapes, eroding important bird nesting islands, and blowing out dikes of impoundments managed specifically for breeding, migrating, and wintering shorebirds, seabirds, wading birds, and waterfowl. Important habitats for high priority species like Piping Plover, Red Knot, American Black Duck, Tri-colored Heron, Least Bittern, and American Oystercatcher have been altered by this storm (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).

- Potentially Impacted Species:

    - American Oystercatcher
    - Black Skimmer
    - Gull-billed Tern
    - Least Tern
    - Piping Plover
    - Roseate Tern
    - Red Knot
    - Ruddy Turnstone

- Saltmarsh Systems – including marsh hammocks are critical to saltmarsh obligate breeders, important to feeding nesting and roosting wading birds and migrant shorebirds (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).

- Potentially impacted saltmarsh species:

    - American Black Duck

- Atlantic Brant
- Black-bellied Plover
- Black Rail
- Black Tern
- Forster's Tern
- Greater Yellowlegs
- Little Blue Heron
- Marsh Wren
- Nelson's Sparrow
- Saltmarsh Sparrow
- Seaside Sparrow
- Tricolored Heron
- Whimbrel
- Willet

- Managed coastal salt marsh – important for shorebirds and wading birds:
  - Prime Hook National Wildlife Refuge, Milton, DE – Sandy caused a breach in a coastal impoundment and a 4,200 acre freshwater marsh was inundated by saltwater. A proposal has been made to repair damage to refuge infrastructure and impoundments, clean and remove hazardous materials and debris, and stabilize habitats (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).

Barrier Islands

- Critical to nesting seabirds and shorebirds, critical to migrant and wintering shorebirds for feeding and roosting, important to migrant and wintering seabirds and were likely impacted by Hurricane Sandy (Hurricane Sandy Rapid Assessment, Final Report, Atlantic Flyway Shorebird Business Strategy Planning Team 2013).
- Barrier sand beach systems are critical to obligate beach-nesting shorebirds and seabirds, migrant shorebirds and seabirds, and important feeding areas for some species of wading birds

and were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Business Strategy Planning Team 2013b).

- Possibly impacted spp: American Bittern, American Black Duck, American Oystercatcher, Atlantic Brant, Black-bellied Plover, Black-crowned Night-Heron, Black Rail, Black Skimmer, Black Tern, Canvasback, Caspian Tern, Common Tern, Dowitcher species, Forster's Tern, Great Black-backed Gull, Great Blue Heron, Great Egret, Greater Yellowlegs, Green Heron, Gull-billed Tern, King Rail, Least Bittern, Least Tern, Little Blue Heron, Laughing Gull, Marsh Wren, Northern Pintail, Piping Plover, Ruddy Turnstone, Red Knot, Roseate Tern, Sanderling, Saltmarsh Sharp-tailed Sparrow, Seaside Sparrow, Semipalmated Sandpiper, Snowy Egret, Tricolored Heron, Willet, Whimbrel, Yellow-crowned Night-Heron, Yellowlegs species.

Delaware Bay Beaches

- Interpretation of the available imagery suggests that approximately 30% of Delaware Bay beaches were significantly impacted, with a few hotspots of damage along the southern shoreline on the Delaware side (ALS 2012).

Inlets

- Inlets are highly dynamic barrier features, critical to migrant shorebirds, critical to nesting shorebirds, important for nesting of some seabirds and were likely impacted by Hurricane Sandy (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013a).
  - Coastal Flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Conservation Business Strategy Team 2013a).

Atlantic Coast - Benthic impact

- Large waves from the Atlantic Ocean (up to 20-40 foot wave heights recorded off Ocean City, MD) affected the nearshore benthic habitats on the seaward side of the barrier islands. Resuspension and deposition likely affected sand flats, mud deposits, gravel beds and the soft coral/sponge communities (Dennison, et al. 2012).

III. Future Without Action Conditions - Delaware

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- Delaware's beaches include a berm and dune system that naturally transgresses or migrates landward, but infrastructure built on areas along the coast block that process. Instead, material is eroded and carried offshore which decreases beach width and berm height, eliminating or damaging the dune systems (Delaware Coastal Programs 2012). The loss of these systems leaves infrastructure such as roads, boardwalks, hotels, and houses along the coastline vulnerable to storm damage.

Delaware Bay Beach and Dune Ecosystem

- As reported by USFWS (2012), along the Delaware Bay shore, more frequent periods of sustained high water as a result of sea level rise in combination with high wave energy associated with storms contribute to erosion and overwash of natural beaches. These beach strand habitats along the bay are migrating landward, which is a natural coastal process even under more recent (5,000-7,000 years) historic rates of sea level rise. This process is exacerbated due in part to sea level rise and an imbalance of sediments necessary to maintain shoreline equilibrium.

- Sea level rise impacts will be more obvious on the bay/wetland side of barrier beaches because without replenishment projects, as the water rises, more land is lost and this habitat will no longer be available (Delaware Coastal Programs 2012).

- Sea level rise could lead to a loss of sandy beach, overwash, and dune grassland habitats, adversely impacting rare beetles, horseshoe crabs, diamondback terrapin, and shorebird nesting and foraging habitats (USFWS 2012).

Estuarine Barrier /Inlets

- Estuarine barriers and salt marshes can sustain their features, but not necessarily their location or configuration, in the face of more frequent coastal storm events, provided they are healthy and processes such as vertical accretion and inland migration are not hindered (USFWS 2012).

- USFWS (2012) reported that when subject to sea level rise, narrow, low-elevation barrier island communities, such as those on Prime Hook National Wildlife refuge, will become more susceptible to storm overwash development, barrier segmentation, the formation of new tidal inlets, and closing of previous inlets. These responses expedite landward migration or roll-over of barrier islands as they readjust their equilibrium position in relation to rising sea levels. This could lead to a decrease in back barrier marsh habitat availability, as landward migration is blocked. The estuarine barrier shoreline will eventually collapse and back barrier marshes will not be able to keep up with sea level rise. This could lead to a decrease in habitat availability.

Coastal Wetlands

- Increasing sea level rise would greatly stress coastal wetlands, leading to either accelerated migration landward or wetland disintegration (USFWS 2012). Wetlands that are not able to naturally keep up with increased rates of sea level rise through accretion of sediment and organic matter may be able to migrate landward, given proper soil and hydrological conditions and available space (NOAA 2010).

- Tidal flooding can only be tolerated by marsh vegetation to a certain physiological limit and increases in tidal range associated with rising seas may affect plant productivity, compromising the ability to grow vertically, making it more susceptible to storm surge erosion that accompanies storm events (Kreeger et al. 2010). This erosion will lead to habitat loss, particularly after storm events.

- The vulnerability of tidal marshes to sea level rise can be exacerbated by the presence of excess nutrient loadings that promote greater aboveground plant production at the expense of belowground production leading to diminished peat formation and vertical accretion (Kreeger et al. 2010).

- USFWS (2012) reported that coastal wetland and sea level rise modeling has suggested that under conservative sea level rise projections of 3 to 5 mm/yr, coastal marshes with small tidal ranges (less than 3 meters) and low sediment concentrations (less than 20 mg/l) will likely submerge in the next 30 to 40 years and only marshes with a tidal range of greater than 3 meters and sediment concentrations above 30 mg/l can survive.

- Delaware Coastal Programs (2012) reported that a sea level rise exposure assessment found that 97% of Delaware's tidal wetlands may be impacted at a 0.5 meter scenario, and 99% at both the 1.0 and 1.5 meter scenarios and this would, in turn, result in the loss of over $500 million of ecosystem services (such water filtration, carbon sequestration, flood protection, and habitat critical to fisheries and shellfisheries) per year.

A sea level rise simulation showed that although only a small percentage of interdunal wetlands, a unique coastal dune habitat type in Sussex County, was predicted to be affected in a 0.5 meter sea level rise scenario, a 1.5 m scenario indicate a more drastic impact of 94% loss (Delaware Coastal Programs 2012).

Delaware Bay Coastal Wetlands

- Maintaining an equilibrium position within the Delaware Bay coastal landscape requires that marshes accrete vertically as the sea level rises and the marsh surface sinks because of subsidence (USFWS 2012).

- Unlike other estuaries in the mid-Atlantic, the tidal range of the Delaware Bay estuary is greater than the ocean tidal range, generally about two meters. Bay shoreline and tidal marshes appear to be at the low end of their potential elevation range, which increases their vulnerability to sea level rise (Kearney et al. 2002, USFWS 2012).

Salt/Brackish Marsh

- Delaware salt marshes generally have been keeping up with the rate of sea level rise over the past century, but it is uncertain whether the marshes may experience increasing accretion rates as sea level rise occurs. As reported in USFWS (2012), if sea level rises 0.50 meters in 100 years, a sea level affecting marshes model (SLAMM) assumes that salt marsh accretion keeps pace with current sea level rise rates and that there is full tidal influence along the coast, then Prime Hook National Wildlife Refuge is predicted to lose more than half of its marsh and the amount of open water and tidal mudflat (combined) will more than quadruple. In addition, if the model assumes that salt marsh accretion will increase to 5.0 mm/yr, keeping pace with sea level rise as salt marshes often can, then the loss of marsh is small and conversion to open water and tidal mud flat are not as pronounced (USFWS 2012).

- Submersion of tidal marsh habitats as a result of sea level rise could cause populations of salt marsh dependent species of fish and birds to be reduced in size (USFWS 2012).

- Sea level rise could lead to a loss of tidal marsh areas and brackish impounded areas associated with submerged aquatic plant beds that serve as important nurseries and shelter areas for fish and shellfish, including anadromous river herring species, elvers, striped-bass, white-perch, and blue crab (USFWS 2012).

- In the Delaware Estuary, landward migration of salt marshes is impeded in many areas because of coastal development and hard structures and tidal flooding will limit survival of the remaining marshes and will likely convert to open water or intertidal mud flats (Kreeger et al. 2010).

- Kreeger et al. (2010) reported that the greatest vulnerabilities of salt and brackish marsh to sea level rise are predicted to be: the inability to keep pace with rising sea levels through vertical accretion, the inability to migrate landward, shifts in species composition, loss of suitable marsh area, increased seaward edge erosion, increased susceptibility to storm surge, an expected increase in tidal range, and a change in the ratio of marsh edge to interior area.

Freshwater Marsh

- Coastal freshwater wetlands are sensitive to extreme high tides resulting from an increase in storm frequency or magnitude; these high tides can carry salts inland to salt-intolerant vegetation and soils, and could lead to the displacement of freshwater flora and fauna by salt-tolerant species (Combes 2003). These coastal freshwater wetland communities could be destroyed as saline water invades, if they cannot shift inland due to development or dikes (Combes 2003).

- Sea level rise over time changes the salinity of freshwater tidal wetlands in Delaware and this will result in freshwater tidal wetlands turning into brackish wetlands or open water, which will cause major shifts in species composition (Delaware Coastal Programs 2012).

- Landward migration of freshwater tidal marshes in Delaware is unlikely due to developed coastal areas, and this will, impact over $125 million of associated ecosystem services such as water filtration, carbon sequestration, flood protection, and habitat critical to fisheries and shellfisheries (Delaware Coastal Programs 2012).

- Delaware Coastal Programs (2012) reported that Delaware's freshwater tidal wetlands were predicted to be inundated between 70-95% in a 0.5 meter sea level rise scenario and 98% in a 1.5 meter sea level rise scenario. However, these freshwater tidal wetland couldtheoreticallygrow vertically to keep pace with accelerating rates of sea level rise in most areas, if they are not exposed to salt water. .

- USFWS (2012) reported that sea level rise modeling showed that in both low and high scenarios, freshwater impoundments immediately behind a dynamic coastal barrier, on Prime Hook National Wildlife Refuge are in danger of conversion to salt marsh, as freshwater plants not only die if flooded by salt waters, they also leave the marsh substrate at a depressed elevation compared to salt marsh species. In addition, with the loss of Prime Hook's impoundments, 78% of the freshwater impoundments within the State of Delaware will have a reduced function and value as habitat for migratory waterfowl. Since freshwater wetlands have greater diversity than saltwater wetlands, State rare plants are vulnerable due to saltwater intrusion, resulting in the refuge's loss of biodiversity (USFWS 2012).

- Delaware Coastal Programs (2012) reported that a sea level rise exposure assessment for non-tidal freshwater emergent wetlands estimated a loss of 12-33% in a 0.5 meter sea level rise scenario and 31-39% in a 1.5 meter sea level rise scenario and may result in increases in flooding and/or increased expenditure of funds for stormwater projects to prevent flooding.

- The same study found that a sea level rise exposure assessment of freshwater and brackish impoundments estimated that a 0.5 meter sea level rise scenario could result in inundation of 81% of the state's impoundments and 1.5 meters of sea level rise could results in 99% of all impoundments being affected (Delaware Coastal Programs 2012). Impoundments could convert into a permanent open water body with increasing salinity and accompanying vegetation die back, which would lead to the loss of breeding, migration, and wintering habitat for a variety of birds, including migratory waterfowl, shorebirds, wading, and ground birds (Delaware Coastal Programs 2012). This could result in a large scale shift in the distribution of birds within Delaware and the Delmarva Peninsula.

Tidal Mud Flat

- Galbraith (2002) reported that one sea level rise scenario for the Delaware Bay predicted the loss of 60 percent or more of intertidal shorebird feeding habitats by 2100 due to coastal changes and sea level rise.

- Sea level rise could lead to a loss of tidal flats and emergent marsh areas and conversion to open water habitat, leading to decreased food availablility and productivity for shorebirds and waterfowl (USFWS 2012).

Maritime Forest

- USFWS (2012) reported that as rising sea levels prompt changing habitat conditions along the Prime Hook National Wildlife Refuge coastline, salt marsh and brackish wetlands will migrate landward into forest habitats, which is a natural response mechanism.

    - This sea level rise could lead to potential loss or degradation of freshwater swamps, which are considered globally imperiled and are at very high risk from sea level rise threats; Prime Hook National Wildlife Refuge's 1,300 acres of red maple-seaside alder and Atlantic white cedar will not survive permanent salt water inundation (USFWS 2012).

- Delaware Coastal Programs (2012) reported that Delaware's freshwater tidal forested wetlands were predicted to be inundated between 89-91% in a 0.5 meter sea level rise scenario and 92-98% in a 1.5 meter sea level rise scenario

Delaware Estuary

- The Delaware Estuary has the largest freshwater tidal prism in the world, the freshwater tidal region extends about 70 river miles, with a gradual change in salinity andincreasing sea level could result in larger tidal volumes that bring more salt water further up the estuary, further increasing the tidal range (Kreeger et al. 2010) There is a large array of ecosystem services supplied to human and natural communities, including a rich diversity of marsh types, tied to the extended salinity gradient which could be at risk due to sea level rise (Kreeger et al. 2010).

- Sea level rise represents the greatest threat to tidal wetlands in the Delaware Estuary, the habitat situated on the "front lines" (Kreeger et al. 2010).

- A Sea Level Affecting Marshes Model (SLAMM) scenario was run to predict acreage changes for tidal marshes, open water and tidal flats, scrub-shrub swamps, and other habitats in the Delaware Estuary by 2100. Across the whole estuary, 42,558 hectares of tidal wetland were predicted to be lost, with most being located along the microtidal shorelines and tributaries of the Delaware Bay region. In addition, 50,236 hectares are expected to be lost from adjacent habitats that are more landward, including scrub-shrub swamps, non-tidal wetlands, and uplands and these losses will translate into a net gain of 106,529 hectares of open water and tidal flat habitat (Kreeger et al. 2010).

Oyster Reefs

- Kreeger et al. (2010) reported that the partly narrow geographic configuration of the Delaware Estuary means that, while the oyster resource can migrate up estuary in response to increased salinity, the total population of oysters could decline due to loss of area. The potential for lateral expansion of the estuary due to sea level rise would not be sufficient to provide equivalent areas for reef expansion (Kreeger et al. 2010). Since oyster reefs are an important habitat type for the Delaware Estuary, cascading ecological effects would likely follow if substantial loss of reefs occurred in part of the bay (Kreeger et al. 2010).

Rock Reefs/Rocky Shorelines

- There are artificial rock groins that currently represent an artificial rocky intertidal zone in parts of the Atlantic Coast of Delaware. It is assumed that this habitat will be further submerged with rising sea levels and species intolerant to this change in depth, temperature, and light penetration will no longer use the habitat.

Shallow Bay Habitat/ Bay Islands

- The potential loss of salt marshes as a result of sea level rise is of particular is of concern for Delaware's Inland Bays and tributaries to the Delaware Bay because these marshes provide the valuable function of nutrient storage and sequestration in this nutrient polluted environment (Delaware Coastal Programs 2012).

Terrestrial Upland

- In both high a low sea level rise scenarios run with the sea level affecting marshes model (SLAMM), more than half of upland areas in Prime Hook National Wildlife Refuge are predicted to be lost. The primary difference is whether or not the remaining areas are maintained in some form of wetland cover or are converted to open water, which may depend on marsh accretion processes (USFWS 2012).

Floodplains/Riparian

- Barnett and Dobshinsky (2008) reported that a projection of that sea levels in the Delaware River Basin could rise 0.48 meters by 2050 and 1.06 meters by 2100 showed inundation of small portions of South Wilmington, the riverfront, and the Port of Wilmington, which could present a permanent change that compounds both flooding and storm surge

NPS/NWR

- Both Prime Hook and Bombay Hook NWRs were established primarily for migratory birds, due to their position within the Atlantic flyway and birds in various guilds concentrate at both refuges at different stages of their life history. Reduction or loss of wetland habitats within the protected boundaries of the refuges can impact populations of these species (Delaware Coastal Programs 2012).

Prime Hook National Wildlife Refuge

- USFWS (2012) reported that a sea level rise affecting marsh model (SLAMM) showed that by the year 2050, at least half of the upland area in the refuge will be converted to wetlands or open water and open water and tidal mud flat areas will increase throughout the next 100 years. If these conditions change, the refuge will lose the ability to manage freshwater wetlands through water level manipulation and exclusion of salt water from impoundments (USFWS 2012).

Bombay Hook National Wildlife Refuge

- Delaware Coastal Programs (2012) reported that sea level rise scenarios for Bombay Hook NWR showed that Bombay Hook is predicted to lose more than three quarters of its regularly flooded (salt) marsh in scenarios higher than 1.0 meter, saltmarsh will increase with sea level rise scenarios less than 1.0 meter due to the conversion of irregularly flooded marshes, the refuge could lose between 23% and 62% of its upland, and between 15% and 97% of its irregularly flooded marsh.

State Parks

- Delaware Coastal Programs (2012) reported that under low and high sea level rise scenarios, 37% to 44% of Delaware's permanently protected land could be inundated by sea level rise. These areas are concentrated in areas adjacent to the Delaware Bay in Kent and Sussex Counties and this could affect the tourism industry and recreational opportunities (Delaware Coastal Programs 2012).

Critical Habitat

Waterbird Islands

- Sea level rise could lead to degradation and loss of Prime Hook National Wildlife Refuge's isolated marsh islands, which are currently important as bald eagle nesting sites and for other nesting birds that rely on island habitats for protection from predators and human disturbance (USFWS 2012).

Essential Fish Habitat (EFH)

- Submersion of tidal marsh habitats as a result of sea level rise could cause populations of salt marsh dependent species of fish and birds to be reduced in size (USFWS 2012).

- Sea level rise could lead to a loss of tidal marsh areas and brackish impounded areas associated with submerged aquatic plant beds that serve as important nurseries and shelter areas for fish and shellfish, including anadromous river herring species, elvers, striped-bass, white-perch, and blue crab (USFWS 2012).

- Increased salt content might make the Delaware bay more suitable for coastal fish species that prefer a higher salinity (Delaware Coastal Programs 2012).

Atlantic Flyway

- Freshwater impoundments created to provide habitat for migratory birds at Prime Hook National Wildlife Refuge are in danger of failing under low and high sea level rise scenarios. Although salt marsh and brackish wetlands provide valuable migratory bird habitat, conversion of refuge impoundments creates the potential for significant reduction of waterfowl numbers and loss of shorebird habitat (USFWS 2012). The stresses imposed by climate change and sea level rise will force a shift in quantity and quality of available waterbird habitat on local and regional scales (USFWS 2012).

T&E Species/Species of Concern

- The Atlantic sturgeon, a state and federally endangered species could be impacted by sea level rise as less tidal freshwater acreage reduces the potential area for spawning and early larval stage. Additionally, juvenile foraging area will be reduced and likely reduce the production capacity of the system (Delaware Coastal Programs 2012).

- Fifteen of the 27 Habitats of Conservation Concern (HCC) identified in the Delaware Wildlife Action Plan will be exposed to sea level rise- under the 1.5 m scenario for sea level rise, approximately half of all HCC's will be inundated and potentially lost; and, of those that are exposed to sea level rise, seven types (each a unique type of wetland) could experience inundation of more than 90% (Delaware Coastal Programs 2012). It is unknown if, how, and where HCC's and other wetland habitats might migrate to as water levels rise.

- Approximately 20% of Delaware's native fauna is considered rare and uncommon and 54% could be impacted at the 1.5 m sea level rise scenario which represents 11% of the entire state fauna (Delaware Coastal Programs 2012).

Diadromous Fish

- Changes in salinity as a result of sea level rise will affect fish species like American shad, river herring, and striped bass which live in salt water but return to freshwater rivers to spawn (Delaware Coastal Programs 2012). Rising sea levels and saltwater intrusion could decrease tidal freshwater acreage leading to a decrease in suitable freshwater habitat for spawning and a juvenile foraging, leading to population declines (Delaware Coastal Programs 2012).

Birds (Nesting Habitat)

- Delaware Coastal Programs (2012) reported that a sea level rise of 0.5 meters could result in inundation of 81% and a sea level rise of 1.5 meters could result in inundation of 99% of Delaware's coastal impoundments which could impact important breeding, migration, and wintering habitat for a variety of birds. This could result in loss of historic and cultural connections to such activities as waterfowl hunting, trapping, and bird watching.

- The habitat that is provided by the impoundments has become a core component of the distribution of available habitat in the Mid-Atlantic for migratory waterfowl, shorebirds, wading, and ground birds (Delaware Coastal Programs 2012). The loss of these areas could result in a large scale shift in the distribution of birds within Delaware and the Delmarva Peninsula.

Delaware Bay

- Some of the most notable Delaware Bay species that will be the most vulnerable and suffer considerable cumulative adverse impacts from sea level rise and climate change will be shorebirds and horseshoe crabs. A sea level rise modeling study estimated that a 2-foot rise in relative sea level over the next century could reduce shorebird foraging areas in the Delaware Bay by 57 percent or more by 2100 (Galbraith et al. 2002, USFWS 2012).

- Human infrastructure along the entire bay coast leaves estuary beaches little to no room to migrate inland as sea level rises. This will cause substantial losses of horseshoe crab spawning habitat likely to occur within the next 50 to 100 years (Galbraith et al. 2002).

- The incremental disappearance of salt marsh nesting habitats due to sea level rise- induced habitat fragmentation and conversion to open water would further compound declines for bird species that are already of conservation management concern to federal and state agencies, including American black duck, salt marsh sharp-tailed sparrow, seaside sparrow, coastal plain swamp sparrow, black rail, Forster's tern, American oystercatcher, and black skimmer (USFWS 2012).

Shellfish/Shellfish beds

- As described in Kreeger et al., in 2010, a panel of panel of eight experts on bivalve shellfish predicted the impact of sea level rise in the Delaware Estuary in a scenario of 1 meter rise by 2100 and concluded that the salinity gradient would expand up the Estuary, most notably in the middle/upper estuary and tributaries. They concluded the following:

    - There are separate potential effects of sea level rise and salinity rise on bivalves, but the strongest effects are from an interaction of these factors; therefore, their effects were considered together.

    - For oysters that live in the middle and upper estuary, the greatest concern is regarding a potential salinity increase, partly driven by sea level rise bringing more ocean water into the system. The two diseases that cause high oyster mortality are more virulent and prevalent at higher salinities, and these diseases currently define the downbay range of viable oyster populations.

    - Even a slight increase of only a few parts per thousand is likely to push oysters northward, and analysis over the past 50+ years suggests that the bulk of the oyster population has already shifted from the lower and middle beds to the upper middle beds.

    - In the freshwater tidal portion of the Estuary, native unionids cannot tolerate any saltwater, and this zone appears to be home to high biodiversity of sensitive species.

- In the fringing salt marshes of Delaware Bay, greater erosion and wetland loss from sea level rise and increased storminess threatens ribbed mussels due to the potential loss of their habitat.

Cultural Resources

- Sea level rise impacts to cultural resources range from increased tidal and wave erosion to inundation. Cultural resources within coastal zones will be subjected to gradual sea level rise impacts exacerbated by event-specific impacts such as high tide events and storms. The frequency and intensity of damage from event-specific impacts is expected to increase as sea level rises (Karl et al. 2009). In addition, high regional subsistence rates are expected to increase rates of sea level rise and associated impacts (Johnson 2000).

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8. Maryland and District of Columbia: Environmental Existing and Future Conditions

I. Coastal Characterization - Maryland

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Pebble Shoreline

- The ocean shoreline of Maryland presents greatly contrasting conditions between Ocean City (Fenwick Island) and Assateague Island.

- The beach and dunes along Fenwick Island (Ocean City) north of the Ocean City Inlet are engineered and actively maintained by USACE and Ocean City. Continuous dunes are constructed to a height of 14.5 feet NGVD and vegetated with dune grass. The beach is renourished with sand derived from offshore shoal sources every four years. The island itself is urbanized with little open undeveloped land remaining other than in parks and wetlands. The beaches are regularly groomed and maintained (USACE 1989, USACE 2012).

- Assateague Island is a world-renowned example of unintended consequences of inlet stabilization: sand-starvation caused by USACE jetty construction in 1934 caused accelerated erosion and retreat of the northernmost 7 miles of the island. This condition was corrected by USACE Assateague Island emergency and restoration projects beginning in 1998. USACE now periodically removes accumulated sand from within the coastal bays in the vicinity of the inlet and places it on Assateague Island (USACE 1998 and 2008). The island is maintained in a largely natural condition under entirely public ownership within Assateague Island National Seashore and State Park. Natural dunes are discontinuous and low, and reach heights of perhaps 12 feet NGVD. Constructed dunes are maintained locally where needed to protect built features (USACE 1998).

- The beaches of Maryland's ocean coast are naturally sandy. Some larger sediments (pebbles, gravel, and shell) are present, however.

- Manmade structures comprised of rock and concrete occur along Ocean City and locally at the north end of Assateague Island at the inlet. These structures include groins at Ocean City and breakwaters along the inlet (USACE 1998 and 2008).

- Natural rocks are absent because the coastline and its interior watershed lie in the coastal plain physiographic province hundreds of mile from the nearest natural rock sources.

- Sediments on the ocean seafloor are primarily sandy, and a large field of offshore shoals occurs from the shoreline out to tens of miles offshore.

- Progressing towards the mainland, bottom sediments in the bays become increasingly muddy. Along the mainland, peaty sediments occur at sites of former tidal marshes that have eroded away (USACE 1998).

Barrier Islands/Inlets

- Maryland's ocean coast is comprised of two land masses, both called islands: Fenwick Island (Ocean City) and Assateague Island.

- Fenwick Island is actually a spit that is formed and maintained by net southerly longshore drift from southern Delaware.

- Assateague is an actual island, separated at its northern end from Fenwick Island by the Ocean City Inlet, and separated from the mainland at its southern end by the Chincoteague Inlet.

- Ocean City Inlet is stabilized with jetties and maintained navigation channel. Otherwise, inlets along Maryland's ocean coast would naturally be dynamic, forming during major storms, migrating southward, then closing within decades. Tidal currents cause the Ocean City Inlet to be largely self-scouring and it conveys substantially more water into/out of the coastal bays than would a natural inlet (USACE 1998).

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

- Substantial acreage of salt/brackish marsh occurs along Maryland's coastal bay shorelines of both the mainland and Assateague Island.

- Historically, substantial salt marsh occurred on the bayshore of Fenwick Island, but much of this was destroyed by dredge and fill activities prior to passage of the Clean Water Act in 1972 that restricted this.

- There is very little tidal freshwater wetland in Maryland's coastal bays because of high salinities in the bay and limited freshwater runoff.

- About 18,000 acres of salt marsh occur in the coastal bays.

- About 20,000 acres of non-tidal forested wetlands occur in the coastal bays mainland watershed. There has been substantial loss of non-tidal wetlands over historic time from drainage and conversion to agriculture, and to a lesser extent to support development (Dennison et al. 2009).

- The tidal range in the coastal bays ranges from about 1 foot in the center of Chincoteague Bay to as much as 3 feet in close proximity to the Ocean City Inlet. The low tidal range produces only limited acreage of tidal flats that occur as a band along the shoreline (Dennison et al. 2009).

- Maritime forest occurs on Assateague Island towards the southern part of the island. Maritime forest is apparently naturally largely absent from the majority of Fenwick and Assateague Islands because of their low height, narrow width, and consequent vulnerability to overwash and change (USACE 1998).

- Maryland's coastal bays are lagoons with Fenwick and Assateague Islands forming a barrier to the Atlantic Ocean. The coastal bays are known locally as several individually named bays: Chincoteague Bay, Newport Bay, Sinepuxent Bay, Isle of Wight Bay, and Assawoman Bay. These bays occupy about 69,700 acres and are predominantly shallow, with average depths of 2 to 4 feet.

- The coastal bays are nearly marine salinity because of the influence of ocean waters and minimal runoff from the mainland watershed. Evaporation during summer months can raise salinities above ocean strength. Prior to stabilization of the Ocean City Inlet by USACE in 1934, low salinity conditions prevailed (USACE 1998).

- The Chesapeake Bay is the largest estuary in the United States. It is an incredibly complex ecosystem that includes important habitats and food webs. The Bay and its rivers, wetlands and forests provide homes, food and protection for diverse groups of animals and plants. Fish of all types and sizes either live in the Bay and its tributaries year-round or visit its waters as they migrate along the East Coast. In the Chesapeake Bay, there are over 31,000 acres of wetlands, and approximately 8,438 acres of coastal wetlands.

Non-tidal Wetlands

Chesapeake Bay

- Non-tidal, or palustrine, wetlands contain fresh water. Eighty-six percent of the wetlands in the Chesapeake Bay watershed are non-tidal. Palustrine wetlands are located:

    - On floodplains bordering streams and rivers.

    - Fringing the shorelines of lakes and ponds.

    - Filling isolated depressions.

    - Covering broad, flat areas at or near sea level where water may collect (such as many areas on the Delmarva Peninsula).

- There are over 48 known wetland areas (almost 300 acres) within the Washington D.C. based on the District of Columbia Wetland Conservation Plan (Center for Watershed Protection 1997).

Submerged Aquatic Vegetation

- SAV is absent from ocean waters and waters near the Ocean City Inlet that are otherwise within the photic zone because wave energies are too great and the seafloor too dynamic for SAV to root and grow.

- SAV beds occur in the coastal bays where water depths are less than about 5 feet and sandy bottom sediments occur. Because of the latter factor, SAV beds for the most part are located on the baysides of Assateague and Fenwick Islands, with little along the mainland shoreline. SAV has shown dramatic change in the coastal bays since the early 20th century. Massive declines occurred in the 1930s because of eel grass wasting disease. SAV subsequently gradually recovered with known acreage peaking in 2001 at about 19,000 acres. SAV subsequently declined because of excessively warm water temperatures and reduced water clarity from anthropogenic eutrophication. As of 2009. SAV beds occupied about 14,000 acres (DNR 2013).

- There are less than 1000 acres of SAV within the District of Columbia. The largest patch of SAV in is located just upstream of Woodrow Wilson Bridge (Government of the District of Columbia 2006).

Oyster Reefs

- Historically, oyster beds occurred in Maryland's coastal bays and were commercially harvested. Following inlet stabilization in 1934, salinities in the coastal bays increased substantially. These conditions promoted increased oyster predator populations. Further, oyster diseases were also favored by increased salinity conditions. The oyster beds were destroyed by disease and predators by the 1960s. Oysters occur today as fouling organisms in the intertidal zone and are harvested recreationally (Dennison et al. 2009).

Rocky Shorelines

- Maryland and Washington, D.C., possess limited natural hard rock tidal shoreline in the Susquehanna and Potomac Rivers, respectively (Means 2010).

- About 1,000 miles of Maryland's Chesapeake Bay 7,000 mile shoreline is artificially stabilized with rock and other materials (USACE 2011).

- The northern coastal bays shoreline is substantially anthropogenically hardened with rock and other structures. The southern coastal bays shoreline is predominantly natural.

Shallow Bay Habitat/ Bay Islands

- The coastal bays possess numerous small islands, particularly in the southern bays (Chincoteague and Sinepuxent). Several of these islands are of regional importance as nesting sites for colonial waterbirds, including both beach-nesting and vegetation-nesting species.

- Interestingly, among the most valuable islands for birds today are islands formed by dredge material sidecasting by USACE decades ago, as well as Skimmer Isle in Isle of Wight Bay formed by deposition of sand conveyed into the bays through the Ocean City Inlet.

- Skimmer Island includes sand originating from beach nourishment of Ocean City under USACE's Atlantic Coast of Maryland Project.

Terrestrial Upland

- The mainland watershed of the coastal bays was naturally almost entirely forested historically. Today, substantial forest occurs, but much of the land is in agricultural use. On the mainland in the vicinity of Ocean City, substantial development occurs (Dennison et al. 2009).

- In the D.C. area, there are 5 major types of hardwood forest, including chestnut oak, mixed oak-beech forests, tulip popular forests, loblolly pin-mixed oak forest, and Virginia pine-oak forests (Government of the District of Columbia 2006)

Floodplains/Riparian

- Because of limited freshwater runoff from the mainland, comparatively little floodplain and non-tidal riparian areas occur in the coastal bays (Dennison et al. 2009).

Coastal Protected/Managed Areas

National Estuary Program

- Maryland Coastal Bays
    - The Maryland Coastal Bays Foundation prepares a periodically updated comprehensive conservation management plan for the coastal bays and its watershed. This plan facilitates coordinated environmental management among government agencies and other stakeholders (MCBP 2014)."

National Wildlife Refuges

- Blackwater National Wildlife Refuge, located on the Eastern Shore of Maryland approximately 10 miles south of Cambridge, MD, was established in 1933 as a waterfowl sanctuary for birds migrating along the critical migration highway called the Atlantic Flyway. Blackwater is part of the Chesapeake Marshlands National Wildlife Refuge Complex. Blackwater National Wildlife Refuge (27,000 acres) and adjacent protected lands like Fishing Bay Wildlife Management Area (29,000 acres) contain one of the largest protected complexes of tidal marshes in the Northeastern U.S. These lands constitute the largest conservation complex in the state of Maryland. Blackwater is the largest and most significant wildlife refuge on Maryland's Eastern Shore and plays a key part in the overall ecology of the Chesapeake Bay. These wetlands provide varied services including nursery grounds for commercially important fish and shellfish (blue crab, striped bass, oysters, shad, and other aquatic wildlife), natural filters of sediment and nutrient pollution, storm buffers, and destinations for tourism and recreation. The Refuge provides critical winter habitat for thousands of migratory birds, including numerous species of swans, snow geese, and ducks. The Refuge also provides year-round habitat for a number of species, including the bald eagle, shore birds, otters, and the endangered Delmarva Fox Squirrel. The wetlands also hold tremendous value for biodiversity conservation and have been recognized as an Important Bird Area of global significance for salt marsh bird species and as part of a Ramsar site of global significance for wetlands.

- Eastern Neck National Wildlife Refuge is a 285-acre island refuge that is a major feeding and resting place for migrating and wintering waterfowl. More than 100,000 ducks, geese and swans seek sanctuary here each year, as do migrating and breeding songbirds and shorebirds, and bald eagles that thrive here year-round.

- Martin National Wildlife Refuge , a 4,548 acre refuge that is located on the Easten Shore of Mary land, provides The tidal marsh, coves, creeks and ridges of Glenn Martin National Wildlife Refuge provide an important rest area and winter home for thousands of migratory waterfowl and nesting habitat for a variety of wildlife

- Susquehanna National Wildlife Refuge, also known locally as Battery Island, is located at the mouth of the Susquehanna River in Harford County, Maryland.

- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

National Estuarine Research Reserve

- The Chesapeake Bay National Estuarine Research Reserve consists of more than 6,000 acres of salt marsh, tidal freshwater marsh, and tidal riverine waters. These habitats are contained within three separate parcels: Otter Point, Jug Bay, and Monie Bay (NOAA 2009)

State/County Parks

- Anne Arundel County
    - Patapsco Valley State Park
    - Sandy Point State Park
- Baltimore
    - Gunpowder Falls State Park
    - Hart-Miller Island State Park

  - North Point State Park
  - Patapsco Valley State Park
- Calvert County
  - Calvert Cliffs State Park
- Caroline County
  - Martinak State Park
- Cecil County
  - Elk Neck State Park
- Charles County
  - Chapel Point State Park
  - Chapman State Park
  - Purse State Park
  - Smallwood State Park
- Dorchester County
  - Harriet Tubman Underground Railroad State Park
- Hartford County
  - Palmer State Park
  - Rocks State Park
  - Susquehanna State Park
- Howard County
  - Patapsco Valley State Park
- Prince George's County
  - Rosaryville State Park

- Queen Anne's County
  - Tuckahoe State Park
- St. Mary County
  - Greenwell State Park
  - Point Lookout State Park
  - St. Clement's Island State Park
  - St. Mary's River State Park
- Talbot County
  - Bill Burton Fishing Pier State Park
  - Wye Oak State Park
- Washington County
  - Frederick State Park
- Fort Tonoloway State Park
  - Gathland State Park
  - Greenbrier State Park
  - South Mountain State Park
  - Washington Monument State Park
- Worchester County
  - Assateague State Park
  - Pocomoke River State Park

National Parks Service Areas

- Anacostia Park is one of Washington, DC's largest recreation areas with more than 1200 acres stretching along the Anacostia River from the Frederick Douglas Memorial Bridge to the

DC/Maryland border. The park has shoreline access, a swimming pool, ball fields, trails, picnic facilities.

- Rock Creek Park is green national park runs from the border of Maryland down to the Potomac River. Rock Creek Park serves as a natural oasis within the heavily urbanized District of Columbia. Many plant and animal species consider the forested landscape of the park home. Meadows and stream habitats provide even more biodiversity; the Hay's spring amphipod is an endangered species found within the park. Rock Creek Park is also an important resting spot for neo-tropical migrant birds on their way south to their wintering grounds or on their way north to their breeding grounds.

- Georgetown Waterfront Park curves along 10 acres of the Potomac extending from the Washington Harbor complex to Key Bridge, creating the vital last link in 225 miles of parkland from Mt. Vernon, Virginia, to Cumberland, Maryland.

- Kenilworth Park & Aquatic Gardens is a National Park Service site located in the north eastern corner of Washington, D.C., and the Maryland state border. Nestled near the banks of the Anacostia River and directly south of the Baltimore Washington Parkway, Kenilworth Park & Aquatic Gardens preserves a plethora of rare waterlilies and lotuses in the cultivated ponds near the river. The park also contains the Kenilworth Marsh, the only remaining tidal marsh in Washington, D.C. and an adjacent recreational area.

- Potomac Heritage National Scenic Trail, Linking the Potomac and upper Ohio River basins, follows the paths explored by George Washington. You can follow the same routes today—on foot, bicycle, horse and by boat—exploring contrasting landscapes between the Chesapeake Bay and the Allegheny Highlands

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

- A detailed discussion of USFWS managed Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

- Several species of sea turtles occur in ocean and estuarine waters of Maryland's coastal bays. These include Kemp’s Ridley, leatherback, green turtle, and Atlantic loggerhead. Among these species, only loggerhead sea turtles occasionally nest within Maryland on Assateague Island. Historically, loggerhead presumably occasionally nested on Fenwick Island on what is now Ocean City. Any nesting there would presumably have occurred prior to about the 1950s when the human population was much sparser and beaches without intense seasonal recreational use still existed (USACE 1998).

- Fin and right whales occur as transients off the Maryland coast. They do not occur commonly (USACE 1998 and 2008).

- Seabeach amaranth occurs on Assataegue Island. After decades of not being seen, seabeach amaranth was rediscovered on Assateague Island in 1998. Consequently, NPS and MDDNR undertook an amaranth restoration program on the island and the plant became relatively abundant, numbering some years in the 100s of individuals.

- Atlantic sturgeon (*Acipenser oxyrinchus*) may occur in Maryland coastal ocean waters as subadults or adults during migration and overwintering. However, they are not known to concentrate in these waters and coarse sandy ocean substrates are of comparatively low value as foraging habitat (NMFS 2013). Shortnose sturgeon prefers estuarine salinities and is therefore unlikely to be present in coastal ocean waters. Minimal riverine and tidal low salinity habitat occurs in Maryland's coastal bays, and their occurrence other than as transients is unlikely.

- The Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986. Piping Plovers nest along the Atlantic Coast region of Maryland.

- Seabeach amaranth (family Amaranthaceae) is an annual plant native to the barrier island beaches of the Atlantic Coast, from Massachusetts (MA) to South Carolina (SC). In Maryland, the plant occurs on the upper beach zone of Assateague Island.

- The Puritan Tiger Beetle (Cicindela puritan) is a medium-sized terrestrial beetle. It has long legs and dark bronze-brown to green wing covers with cream-colored markings on the upper surface. They are found in Maryland, along the Chesapeake Bay where they inhabit high eroding bluffs and adjacent beaches. The Putitan Tiger Beetle was listed as threatened under provisions of the Endangered Species Act in 1990.

- Northeastern Tiger Beetle (*Cicindela dorsalis dorsalis*) is a tiny, sand-colored beetle that lives on sandy beaches throughout the middle and lower Chesapeake Bay in Maryland and Virginia. The Northeastern Tiger Beetle was listed as threatened under provisions of the Endangered Species Act in 1990.

- Within the District of Columbia, there are 5 federally listed T&E species. They include the Bog Turtle, Atlantic Sturgeon, Shortnosed Sturgeon, Dwarf Wedgemussel, and Hay's Spring Amphipod.

Waterbird Islands

- Assateague Island is of regional significance as a nesting ground for several species of beach-nesting shorebirds, including the federally listed Piping Plover (USACE 1998; Dennison et al. 2009).

- There is no formally designated critical habitat for federal rare species in the coastal bays or coastal ocean waters of Maryland.

- A detailed discussion on Waterbird Nesting Colonies can be found in the USFWS NACCS Planning Aid Report (Attachment A).

NOAA Habitat Focus Area

- The Delmarva/Choptank River watershed, which includes the Choptank and Little Choptank Rivers, is located on Maryland's Eastern Shore. The Choptank River is the longest river on the Delmarva Peninsula and empties into the Chesapeak Bay. The river system is home to oyster, menhaden, river herring and shads, prey for commercially and recreationally important species like striped bass, weakfish, bluefish and predatory birds such as osprey and eagles. Continues human population growth and development threaten key habitats for fish and aquatic resources.

Atlantic Flyway

- The Chesapeake Bay is critical habitat for a number of migratory birds. For some birds, the Chesapeake Bay is their winter destination while others use the Bay as fueling grounds. About 1 million swans, geese and ducks winter on the Bay, roughly one third of all waterfowl wintering along the Atlantic Coast (USFWS 2008). Many migratory songbirds, shorebirds and raptors rest and refuel here during their spring and fall migrations. Still others winter south and return to the Chesapeake Bay watershed each spring to breed (USFWS 2008). Birds migrate along four main routes or flyways: the Atlantic, Central, Mississippi and Pacific. The Atlantic Flyway may be described as extending from the offshore waters of the Atlantic Coast west to the Allegheny Mountains where, curving northwestward across northern West Virginia and northeastern Ohio, it continues in that direction across the prairie provinces of Canada and the Northwest Territories to the Arctic Coast of Alaska (Figure 9-1). The Atlantic Flyway route from the northwest is of great importance to migratory waterfowl and other birds some of which are flocks of Canvasbacks, Redheads and Lesser Scaups that winter on the waters and marshes south of Delaware Bay, including those of the Chesapeake. As is evident from Figure 9-1, the Chesapeake Bay is an area where many migratory routes converge. Specifically, the Chesapeake Bay is an important wintering area for the Canada Goose, three scoter species and the long-tailed duck.

Figure 8-1. Atlantic Flyway (USFWS)

Least Terns

- Least Terns nest in various locations in the Maryland portion of the Chesapeake Bay. The least tern is robin sized and is the smallest tern in North America. The breeding adult, like the other terns, has a gray back and winds, a black cap and nape, a white forehead, and a forked tail. However, the bill is pale yellow to light orange with a black tip, and the legs are yellow rather than black. Least terns breed in their second year all along the Atlantic Coast, including the Chesapeake Bay. Typically, they construct a shallow unlined nest on a sand bar or beach in which they lay one to three olive-buff eggs marked with brown. They occasionally build their nests on flat rooftops. The eggs hatch in about three weeks, and less than a month later, the hatchlings are ready to begin flying. Their peak breeding season in the Chesapeake Bay area is June to mid-July. They are common throughout the Chesapeake Bay area during the spring and summer and migrate in the fall as far south as Brazil.

- Poplar Island is the only location within the Maryland portion of the Chesapeake Bay that supports nesting populations of Common Terns and one of few that supports nesting populations of Least Terns. By design, Poplar Island provides several areas of ideal nesting habitat for these two tern species, both of which are listed as Birds of Greatest Conservation Need by the state of Maryland The least tern is listed as Endangered for the State of Maryland. The State of Maryland is in the process of trying to get Common Terns listed as endangered as well but as of October 2013, no new developments have been made on this front. Recent statistical analysis of Common Tern nesting pair data suggests that within the end of this decade, the species may no longer nest in Maryland unless aggressive conservation measures are undertaken.

Essential Fish Habitat (EFH)/Fish

- The Atlantic Ocean coastal waters in the study area are designated by the National Marine Fisheries Service (NMFS) as "Essential Fish Habitat" (EFH) for 31 species of shellfish and finfish.

- Demersal finfish species utilizing offshore shoals that could be affected by loss of habitat from mining sand include black sea bass, summer flounder, Atlantic angel shark, and sandbar shark. Bottom finfish inhabiting offshore shoals could be entrained and killed by dredging conducted in cold water temperatures because they are sluggish. Demersal species present in cool weather on the Maryland offshore shoals include Atlantic cod, Atlantic sea herring, red hake, scup, windowpane flounder, winter flounder, and witch flounder. Surf clam inhabiting offshore shoal borrow areas would be destroyed during dredging.

- Several species of finfish have EFH designated off the Maryland ocean coast in waters greater than 25 m depth (NMFS, 2006): bluefin tuna (*Thunnus thynnus*), skipjack tuna (*Katsuwonus pelamis*), swordfish (*Xiphias gladius*), blue shark (*Prionace glauca*), and shortfin mako shark (*Isurus oxyrhyncus*). These species would not likely be affected by any actions undertaken to provide coastal storm damage reduction and are not covered further in this document.

- Maryland's coastal bays are designated as EFH for 16 species of finfish. EFH in Maryland coastal bays includes many of the habitat types and substrates present, including SAV beds, salt marsh, tidal creeks, tidal flats, inlets, and open water channels.

- The coastal bays are designated as "Habitat Areas of Particular Concern" (HAPC) for summer flounder and red drum (USACE 2008; Dennison et al. 2009). SAV bed and inlet habitat constitute HAPC for red drum. Macroalgal beds, SAV beds, and tidal wetlands constitute HAPC for summer flounder.

- EFH has been identified within some parts of the Chesapeake Bay and its tributaries for 16 species (NMFS 2006).

- Anadromous fish found in the State of Maryland and the District of Columbia include: hickory shad, American shad, alewife herring, and blueback herring.

- Two of the species for which Maryland's coastal bays are listed as EFH, dusky shark and sand tiger shark, are considered species of concern by NMFS.

- Tables 8-1 through 8-5 list the species with EFH in the Maryland Coastal Ocean Waters and Maryland's coastal Bays.

Table 8-1. Bony finfish species and their life history stages for which MD coastal ocean waters are designated as EFH (NMFS 2006).

Species common name	Scientific name	Eggs	Larvae	Juveniles	Adults
Atlantic butterfish	*Peprilus triacanthus*	x		x	x
Atlantic cod	*Gadus morhua*				x
Atlantic mackerel	*Scomber scombrus*				x
Atlantic sea herring	*Clupea harengus*			x	x
black sea bass	*Centropristus striata*	n/a	x	x	x
bluefish	*Pomatomus saltatrix*		x	x	x
cobia	*Rachycentron canadum*	x	x	x	x
king mackerel	*Scomberomorus cavalla*	x	x	x	x
monkfish	*Lophius americanus*	x	x		
red hake	*Urophycis chuss*	x	x	x	
scup	*Stenotomus chrysops*	n/a	n/a	x	x
Spanish mackerel	*Scomberomorus maculatus*	x	x	x	x
summer flounder	*Paralicthys dentatus*	x	x	x	x
windowpane flounder	*Scopthalmus aquosus*	x	x	x	x
winter flounder	*Pleuronectes americanus*			x	x
witch flounder	*Glyptocephalus cynoglossus*	x	x		
yellowtail flounder	*Pleuronectes ferruginea*		x		

"n/a" indicates there is insufficient data for the life stages listed, and no EFH designation has been made as of yet.

Table 8-2. Cartilaginous finfish species and their life history stages for which MD coastal ocean waters are designated as EFH (NMFS 2006).

Shark species common name	Scientific name	Eggs	Neonate / Early Juveniles	Late Juveniles / Sub-adults	Adults
Atlantic angel	*Squatina dumerili*		x	x	x
Atlantic sharpnose	*Rhizopriondon terraenovae*				x
dusky	*Charcharinus obscurus*		x		
sand tiger	*Odontaspis taurus*		x		x

sandbar	*Charcharinus plumbeus*		x	x	x
scalloped hammerhead	*Sphyrna lewini*			x	
tiger	*Galeocerdo cuvieri*		x	x	

Table 8-3. Mollusc species and life history stage for which Maryland coastal ocean waters are designated as EFH (NMFS 2006).

Species common name	Scientific name	Eggs	Larvae	Juveniles	Adults
long finned squid	*Loligo pealei*	n/a	n/a	x	
surf clam	*Spisula solidissima*	n/a	n/a	x	x

*For these mollusks, NMFS utilizes "n/a" to indicate either that no data is available on the designated lifestages, or those lifestages are not present in the species' reproductive cycle. For population management purposes, long finned squid and surf clam are typically referred to as pre-recruits and recruits, this corresponds with juveniles and adults in the table.

Table 8-4. Bony fish life history stages for which the Maryland coastal bays are designated as EFH as of 2001.

Species Common Name	Scientific Name	Eggs	Larvae	Juveniles	Adults
Black sea bass	*Centropristus striata*			X	X
Bluefish	*Pomatomus saltatrix*			X	
Butterfish	*Peprilus triacanthus*			X	X
Cobia	*Rachycentron canadum*	X	X	X	X
King mackeral	*Scomberomorus cavalla*	X	X	X	X
Red drum	*Sciaenops occelatus*	X	X	X	X
Scup	*Stenotomus chrysops*			X	X
Spanish mackeral	*Scomberomorus maculatus*	X	X	X	X
Summer flounder	*Paralichthys dentatus*			X	X
Windowpane flounder	*Scopthalmus aquosus*			X	X
Winter flounder	*Pseudopleuronectes americanus*			X	X

Table 8-5. Cartilaginous fish life history stages for which the Maryland coastal bays are designated as EFH as of 2001.

Species Common Name	Scientific Name	Eggs	Neonate/Early Juvenile	Late Juvenile/ Subadult	Adults
Atlantic angel shark	*Squatina dumerili*		X	X	X
Dusky shark	*Charcharinus obscurus*		X	X	
Sand tiger shark	*Odontaspis taurus*		X	*	X
Sandbar shark	*Charcharinus plumbeus*		X	X	X

Tiger shark	*Galeocerdo cuvieri*		X		

Shellfish /Shellfish Beds

Hardshell Clams

- Hard clams live in the salty waters of the lower Chesapeake Bay and mostly found in Virginia waters. In the Maryland portion of the Bay, hard clams are restricted to Tangier and Pocomoke sounds.

Softshell Clams

- The soft shell clam burrows deeply in soft sediments in the middle of the Chesapeake Bay from the shoreline to a depth of about 20 feet and spends its entire adult life in one place, unless disturbed. It is widely distributed throughout most of the Chesapeake Bay. It is concentrated in the middle Bay, from Eastern Bay to Pocomoke Sound on the Eastern Shore and from the Severn River to the Rappahannock River on the western shore.

Oysters

- The eastern oyster forms beds and reefs in brackish and salty waters throughout the Chesapeake Bay. Reefs occurred historically in warmer bay waters from the Potomac River south. No natural reefs still occur. In more northerly waters, only beds occurred. Oysters are concentrated in areas with shell, hard sand or firm mud bottoms. Oysters are found in the middle and lower Chesapeake Bay, as well as its rivers.

- Historically, oyster beds occurred in Maryland's coastal bays and were commericially harvested. Following inlet stabilization in 1934, salinities in the coastal bays increased substantially. These conditions promoted increased oyster predator populations. Further, oyster diseases were also favored by increased salinity conditions. The oyster beds were destroyed by disease and predators by the 1960s. Oysters occur today as fouling organisms in the intertidal zone and are harvested recreationally (Dennison et al. 2009).

Blue Mussels

- Blue mussels are generally abundant only at the mouth of the Chesapeake Bay.

Blue Crab

- The blue crab is one of the most distinctive and recognizable species in the Chesapeake Bay. Blue crabs are bottom dwellers and use all of the Chesapeake Bay habitats during the course of their life. They live year round throughout the Chesapeake Bay and its tributaries. Distribution varies depending on age, sex and season. They are abundant in shallow waters during warm weather, particularly among bay grass beds. They hibernate in the Bay's deep trenches in winter. Males range farther up into fresher waters of the Bay and its rivers. Females tend to congregate in saltier waters. Blue crabs mate from May through October in the brackish waters of the middle Bay. Prior to mating, a male cradles a soft-shelled female in his legs, carrying her for several days while he searches for a protected area for her final molt. Once she molts, the pair mates. After mating, the male continues to cradle the female for several more days until her shell hardens. The male eventually leaves to search for another mate, while the female migrates to the saltier lower Bay. The female releases her larvae (called zoea) into the salty waters near the mouth of the Bay. Currents transport the planktonic zoea to the ocean, where they molt several times as they grow. Eventually, zoea returns to the Bay and other estuaries. During their last larval molt, the zoea metamorphoses into a post-larval form called megalops. The megalops crawl over the Bay's bottom to reach the upper Bay and its rivers.

Bay Scallops

- The bay scallop is a bivalve that lives in the lower Chesapeake Bay's salty, shallow waters.

- Scallops occur in Maryland's coastal bays in limited numbers, much too small to support a fishery. They were absent from the coastal bays for many decades following the eel grass blight of the 1930s, only reappearing in the coastal bays in the late 1990s following simultaneous natural repopulation and active reintroduction efforts. Numbers remain low, however (Dennison et al. 2009).

Surf Clams

- Surf clams occur in the coastal ocean waters on the continental shelf off Maryland, although numbers are apparently less today than several decades ago. Populations periodically increase to the point where they support commercial fishing activity, particularly on large offshore shoals (USACE, 1998 and 2008).

Lobster

- Lobsters can occur off Maryland's ocean coast, but they are in numbers too small to support commercial fishing activity. Hard bottom habitat suitable for lobsters is very limited in occurrence.Blue crab are harvested commercially and recreationally in substantial numbers in Maryland's coastal bays. Numbers harvested and crab size are less than for Chesapeake Bay because of higher salinity in the coastal bays and smaller waterbody size (DNR 2012).

II. Habitat Impacts from Hurricane Sandy - Maryland

- Runoff from Hurricane Sandy was laden with sediment, nutrients, contaminants, and debris. All pose a significant threat to the health of aquatic grass beds throughout the Chesapeake Bay and coastal bays. These underwater habitats provide shelter for many fish species, help improve water quality, and protect our shorelines. The seasonal timing of key species in Chesapeake Bay and the occurrence of major storms affects the level of impact. By the time

Hurricane Agnes (June 1972) reached the Mid-Atlantic region, it had been downgraded to tropical storm status; however the timing of the storm was particularly devastating, as it occurred during important reproductive stages for oysters and crabs, and the early growing season for aquatic grasses. In comparison, Tropical Storm Lee occurred in late September, while Hurricane Sandy occurred in late October, leading to reduced impacts based on seasonal timing.

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- The Atlantic Coast of Maryland Shoreline Protection Project succeeded in performing its CSDR function and storm damage to Ocean City was minimized. The engineered beach and dunes at Ocean City lost substantial volumes of sand. Flooding occurred in the downtown. Areas of the city most severely impacted are at the northern terminus of the project and at erosional hot spots centered at 81st Street and 32nd Street. In its current condition, significant property damage would likely occur if another even moderately severe storm occurred before the project can be rehabilitated. The recommended alternative is to place approximately 355,000 CY of sand at the project in Ocean City and appurtenant materials (sand fence, rope fence, clay base, wooden railing, and vegetation) to restore the damaged dune and shoreline system to the minimum design template (USACE 2012).

Barrier Islands/Inlets

- Hurricane Sandy created a temporary inlet at the southern end of Assateague Island. Substantial overwash occurred on northern Assateague Island. Much of the island was flooded during the storm.

- The Ocean City Inlet bottom was likely affected by substantial scour and wave energy, but the inlet training structures were not known to be affected and the inlet remains stable and navigable.

Maritime Forest

- The southern end of Assateague Island has substantial area of loblolly pine forest that is stressed by pinebark beetle (a native species) with many trees dying. It is likely that low-lying maritime forest was damaged by saltwater flooding.

Estuaries

- The coastal bays water levels were elevated by about 4 feet during Hurricane Sandy. This would have allowed movement of marine-strength salinity seawater into low-lying lands around the coastal bays and promoted salt water movement upstream into the small tidal tributaries flowing into the coastal bays.

Submerged Aquatic Habitat

- SAV on the bayside of Assateague Island was locally buried by overwash. Waves and tidal currents occurring with the storm likely scoured existing SAV beds locally within the coastal bays.

Chesapeake Bay, Maryland

- It is likely that these impacts were minor in comparison to previous storm events, as turbidity was lower and the storm happened late in the growing season when plants had already begun to mature (Dennison et al. 2012).

Shallow Bay Habitat/ Bay Islands

- Hurricane Sandy waves and currents would have caused substantial movement of bottom sediment in the coastal bays, locally scouring and shoaling. Over time, it is expected that bathymetry in the inlet vicinity would largely recover to pre-storm patterns in channel areas because of tidal scour.

Terrestrial Upland

- Substantial rainfall and high winds probably caused a substantial number of trees to blow down. Saltwater encroachment into low-lying areas of the mainland may have stressed/killed trees..

Floodplains/Riparian

- Localized flooding from excess runoff and elevated coastal waters occurred in floodplain areas of the mainland. It is possible that salt water from coastal flooding may have detrimentally affected trees in low-lying floodplain areas because the storm occurred during the growing season, although late.

Fish

- Because Hurricane Sandy occurred in the fall, and the path of the storm did not go up the Chesapeake Bay, the actual impact to these species such as the Atlantic sturgeon, Shortnose sturgeon, Alewife/Blueback herring, Shad, American eel, and Striped bass were very minimal if nonexistent.

Essential Fish Habitat (EFH)

- Large waves in the Atlantic Ocean (up to 20-40 foot wave heights recorded off Ocean City, MD) affected the nearshore benthic habitats in coastal ocean waters out to depths of many 10s of feet. Substantial movement of bottom sands would have occurred. Locally, live bottom habitats in flats on the seabed with muddier sediment may have been detrimentally affected by physical removal of organisms, as well as scour and or burial of bottom sediment (Dennison et al. 2012).

- Effects upon components of EFH in Maryland's coastal bays (SAV, shallow water, inlets) are discussed under those individual topics.

Birds (Nesting)

- Due to the time of year and the path of the storm, it is likely that nesting species of birds such as Piping Plover, Least Terns, Rosette Terns, and Red Knot were not negatively impacted. These species nest in early to late summer and are migratory species. They had already departed from the Maryland portion of the Chesapeake Bay by the time Hurricane Sandy hit in late October (Dennison et al. 2012).

- Habitat for Piping Plover and other beach-nesting waterbirds along the Atlantic coast of Maryland was improved by beach over wash that occurred during Hurricane Sandy. The overwash scoured off vegetation and established bare sand substrate nesting habitat (Dennison et al. 2012).

Waterbird Islands

- Key bird nesting and roosting islands of the Sinepuxent Bay Wildlife Management Area, in particular Skimmer Island in Isle of Wight Bay, may have been damaged by the storm surge and sand erosion (Dennison et al. 2012). Loss of island land mass of bay islands would be generally detrimental to nesting waterbirds. Flooding would likely reduce vegetative cover, which would be beneficial to beach-nesting waterbirds such as Black Skimmer and Least Tern.

T&E Species/Species of Concern

- The beach overwash that occurred on Assateague Island may have created more suitable habitat for rare flora and fauna dependent upon sparsely vegetated conditions. In particular, beach-nesting bird species (discussed elsewhere), plus a federally threatened plant species (seabeach amaranth), and a rare insect (tiger beetle) could benefit from new overwash habitat. Other state-rare plant species dependent upon these conditions would also have benefited on Assateague Island.

Hardshell Clams

Chesapeake Bay

- Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the blue mussels here in the Maryland portion of the Chesapeake Bay.

Softshell Clams

Chesapeake Bay

- Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the blue mussels here in the Maryland portion of the Chesapeake Bay.

Oysters

- Oysters within the Chesapeake Bay can benefit from reductions in salinity as result of tropical storms and hurricanes since the two major diseases (MSX and Dermo) are intolerant of low salinity. Infections are rare at low salinities, and significant increases to parasites usually occur during periods of reduced rainfall when higher salinity waters protrude into the northern bay. In addition, MSX and Dermo are highly influenced by temperature, and if oysters are exposed during lower temperatures (late in the season), infection can be delayed until the following summer (Dennison et al. 2012). Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the oysters here in the Maryland portion of the Chesapeake Bay since they spawn during the summer months not the fall.

Blue Mussels

Chesapeake Bay

- Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the blue mussels here in the Maryland portion of the Chesapeake Bay.

Blue Crabs

Chesapeake Bay

- Are highly mobile and can migrate to optimal regions and avoid negative impacts associated with storm events, such as decreased water temperature or reduced salinity but on the other hand increased freshwater inputs can trigger early migration of female crabs to more saline waters at the mouth of the Chesapeake Bay (Dennison et al. 2012). Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the blue crabs here in the Maryland portion of the Chesapeake Bay.

Bay Scallops

Chesapeake Bay

- Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the bay scallops here in the Maryland portion of the Chesapeake Bay.

Assateague Island National Seashore Effects

- Ecological effects of the storm on Assateague Island are discussed under the individual topic headings. The storm deposited large volumes of sand on roads, eroded dunes, damaged vegetation, and damaged fencing at the campground at the state park and national seashore. The campgrounds have been repaired enough to open.

- Effects of the storm on Sinepuxent Bay Wildlife Management Area are discussed elsewhere under discussions covering bay islands.

Sea Level Rise

- Tidal wetlands on the coastal bays mainland may have received large slugs of sediment delivered by storm waters that could serve to increase marsh surface elevation. Overwash on Assateague Island would create new intertidal substrate on bayside of island in Sinepuxent and Chincoteague Bays, creating substrate suitable for future salt marsh development over the next several years. Existing salt marsh in areas where severe overwash occurred was buried and converted to upland dune habitat. Shoreline erosion in the coastal bays may have eroded substantial marsh locally. Full balance between these process of creation, maintenance, and destruction will become apparent over the next several years.

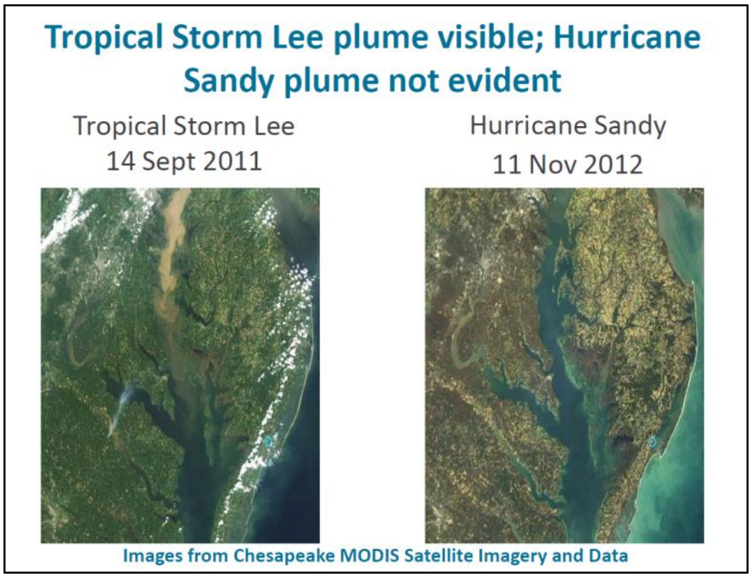

Figure 8-2. Comparison of sediment plumes from Tropical Storm Lee and Hurricane Sandy

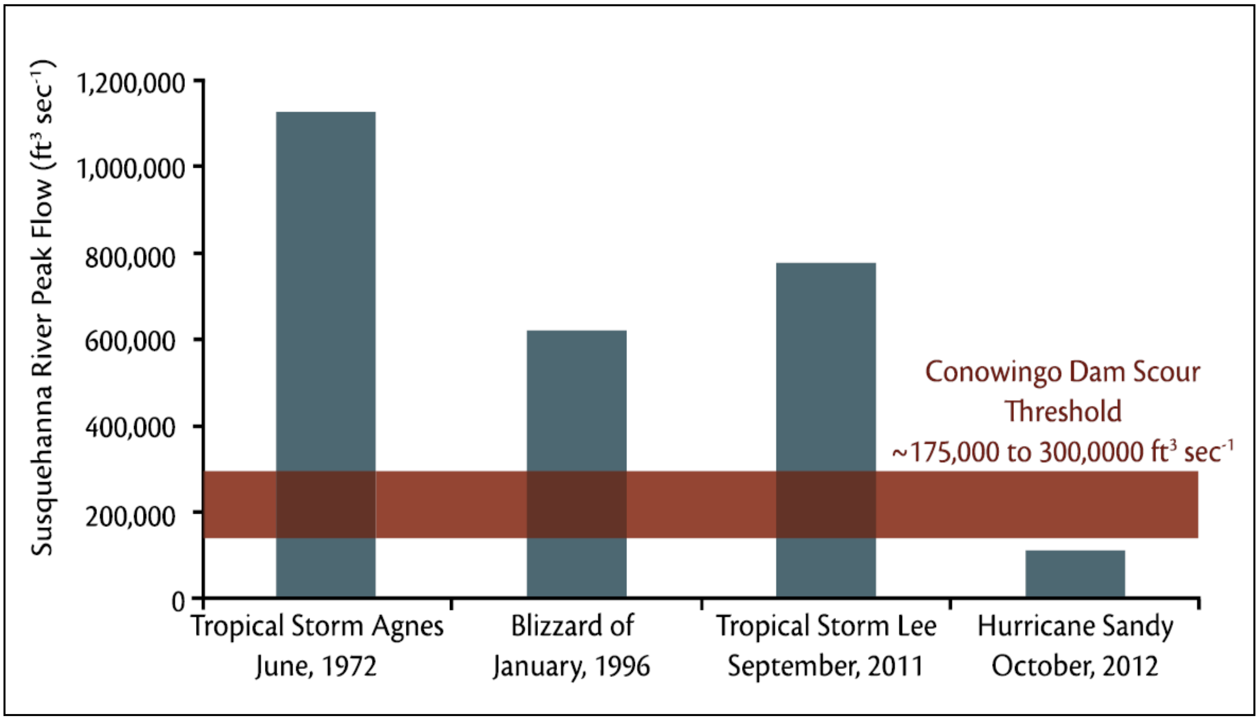

Figure 8-3. Susquehanna River flow during major events

- The storm track and timing of Hurricane Sandy in October 2012 lessened its impacts on Chesapeake Bay compared to Tropical Storm Lee for example (Dennison et al. 2012, PowerPoint Presentation).

- Coastal storm surge in The Chesapeake Bay was not as substantial as experienced in New Jersey and New York. The Conowingo Dam reservoir has been losing capacity for sediment trapping since it was constructed in 1928; sediments and phosphorus now largely bypass the dam during flow events. Scouring will occur more frequently during high flow events. Feasibility, costs, and benefits of options to manage Conowingo Dam sediments are being investigated in the ongoing USACE/MDDNR “Lower Susquehanna River Watershed Assessment.”

- Erosion impacts within the Chesapeake Bay during Hurricane Sandy were quite different than what occurred during Hurricane Isabel in 2003. Isabel washed away approximately 20 acres of coastal uplands and contributed about 81,000 metric tons of fine-grained sediment to the Bay (Hennessee et al. 2005). But according to documentation of storm effects, the impacts to the Maryland portion of the Chesapeake Bay resulting from Hurricane Sandy erosion were less significant.

- With Hurricane Sandy, impacts to Maryland’s Coastal Bays included loss of habitats on Skimmer Island, and other important bird island, due to storm surge and erosion.

Critical Habitat

- Coastal Flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Atlantic Flyway Shorebird Business Strategy Planning Team 2013a).

III. Future Without Action Conditions - Maryland

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Atlantic Coast

- It is expected that sand for the Ocean City beaches would continue to be dredged from offshore sources under the auspices of the USACE Atlantic Coast of Maryland Shoreline Protection Project to maintain the engineered beach. However, it is anticipated that state from offshore shoals in state waters to the 3 mile limit will be exhausted in the near future, and that sand from Federal waters would be used. USACE completed an EIS in 2008 preparing for this possibility that incorporates mitigation measures to protect long-term geologic integrity of seafloor habitats. As the sea rises over the next several decades, increased volumes of sand could be added to the beachfront to compensate. In light of uncertain future Federal budgets and lower level of political support, the Assateague Island Long Term Sand Management project is vulnerable to interruption or cancellation. It is an annual appropriation. Failure to continue funding of this project could destabilize the northern end of Assateague Island. This could cause conversion of 10s to 100s of acres of barrier island habitat to open water (ocean and bay). Sparsely vegetated habitat of the north end of the island is of great importance for rare species. This habitat is dependent upon disturbance by overwash limiting further vegetative succession. Island destabilization could potentially create additional comparable overwash habitats further south along the island, or cause a net loss of these habitats. Maintenance of the island in its current condition via the LTSM Project is probably the safest course to take to maintain rare beach species habitats (Pendleton et al. 2004, Theiler and Hammar-Klose 1999).

Barrier Islands/Inlets

Atlantic Coast

- See discussion above in Section I. for Fenwick and Assateague Islands beach and dunes.

- The Ocean City Inlet is largely self-scouring and is highly successful from a navigation perspective. It is anticipated that USACE will continue maintain the training structures (jetties) along the north and south sides of the inlet and continue routine dredging for decades into the future. There is no sunset date on project service life. At some point in the future, when the fate of Ocean City itself becomes tenable as described above, relocation and or continued maintenance of the inlet would be evaluated.

Coastal Wetlands

Atlantic Coast

- Sea-level rise planning underway in Maryland is identifying migration corridors for coastal wetlands as the sea rises. Because of naturally steeper topography on the landward side of Maryland's coastal bays, opportunities for coastal wetlands migration (retreat) are naturally limited. Additionally, substantial portions of the northern coastal bays shoreline are hardened with development landward of existing wetlands, which generally limits migration opportunities. (The shoreline of the southern coastal bays is generally rural and this concern does not apply). Consequently, it is likely that there would be a natural loss of wetlands as the sea rises. (Note: I would like to utilize the DNR coastal atlas to generate acreage estimates for future habitats as sea-level rises of Atlantic Coast watershed (http://dnr.maryland.gov/ccp/coastalatlas/shorelines.asp).

Chesapeake Bay, Maryland

- Maryland's coastline is susceptible to Nor'easters, tropical storms, and hurricanes. Elevated sea levels will exacerbate the coastal flooding associated with these episodic storms. Sea level rise will impact a variety of habitats within Maryland and the Chesapeake Bay. These include: coastal wetlands and marshes, urban and developed shorelines, Bay islands, coastal bluffs, and low-lying coastal plains. Coastal wetlands and marshes-Maryland's coastal wetlands and marshes will be heavily impacted by a relative rise in sea level. While erosion can damage the wetland edge, coastal marshes are particularly susceptible to submergence. For instance, there is a strong correlation between past marsh loss and relative sea level rise within the Blackwater Wildlife Refuge on the Eastern Shore (Stevenson et al. 2000).

Submerged Aquatic Vegetation

Atlantic Coast

- SAV acreage within Maryland's coastal bays is at risk from eutrophication and increase algal growth further limiting water clarity. There are efforts underway to track important nutrient sources and it is likely that important point sources of nutrient loads will be reduced in the future. However, nonpoint source load management will likely remain problematic. This problem is occurring independently of climate change or sea-level rise.

- SAV within Maryland's coastal bays includes only two species (eel grass and widgeon grass) because of the nearly marine salinities. Eel grass is at about the southern limit of its range here, and is vulnerable to warming water temperatures. In the event water temperatures warm substantially, eel grass could be eliminated. In that event, it is likely that coastal bays SAV acreage would decrease because widgeon grass is a highly dynamic species with boom/bust years, whereas eel grass has generally been more constant.

Chesapeake Bay, Maryland

- With SLR, it is likely that some areas that currently support SAV will become too deep leading to habitat loss. Creation of new SAV habitat will be dependent on whether land is permitted to migrate and become shallow open water. The Chesapeake Bay is particularly vulnerable to climate changes because many of its native plants and animals are already at the edge of their range. For example, eelgrass, an underwater grass that currently dominates much of the lower Bay, is at the southernmost edge of its range. As Bay temperatures increase, we are likely to see marked decreases of eelgrass—a critical habitat for fish, crabs, and many other Bay species (from http://chesapeakebay.noaa.gov/features/climate). Unfortunately, rising sea levels and deepening waters will shade the deeper areas of submerged aquatic vegetation (SAV) beds, limiting photosynthesis. The landward edges of SAV may move inland onto areas that are currently tidal wetlands if the water bottoms have suitable sediments. (Page 189, Mid-Atlantic Coastal Habitats and Environmental Implications of Sea Level Rise). Loss of SAV affects the large number of species that depend on the vegetation beds for protection and food such as blue crabs, as well as a variety of juvenile fish species. A decline in SAV also affects larger predators, including shorebirds and sea turtles. Birds that are primarily herbivorous are directly affected by the loss of SAV.

Shallow Bay Habitat/ Bay Islands

Atlantic Coast

- Shallow waters of the coastal bays would likely increase in area as the sea rises concomitant with shoreline erosion and drowning of coastal wetlands. Bay islands appear to be on a general downward trend in the northern coastal bays because the natural and anthropogenic processes by which they form (island overwash, flood tidal delta formation via inlet migration, and erosion of mainland) are reduced by effects of the Atlantic Coast Project and hardening of mainland shorelines. Extensive flood tidal delta formation occurred in the northern coastal bays from inlet stabilization and from sand from the Atlantic Coast Project; however it has not led to new island formation in recent years. (This could be a consequence of the Assateague LTSM Project). Instead, the existing flood tidal delta island there (Skimmer Isle) is diminishing in size. However, deposition of dredge materials on Skimmer Isle from a variety of sources may serve to maintain it into the future.

- The southern coastal bays islands also appear to be on a downward trend. No new inlets have formed through Assateague Island in many decades that could cause their formation on the island bayside. However, islands can still form by erosion of the mainland along Chincoteague Bay. One important bird colony island formed by historic dredged material deposition – South Point Spoils – would continue eroding to the point where its value to colonial waterbirds diminishes unless human intervention occurs. Future sand additions to this island or creation of new adjacent islands have been proposed but would impact SAV habitat. Accordingly, these proposals have been controversial and not implemented. Whether they are implemented in the future would depend on natural resource management agencies taking an expanded vision on acceptable resource trade-offs.

Terrestrial Upland

Atlantic Coast

- Various Smart Growth and Clean Water Act policies will likely focus future development into existing developed areas that are controlled by public wastewater systems. Future development would occur in accordance with the Maryland Forest Conservation Act that maintains inventory, so it is expected that total forested acreage would remain about constant.

Floodplains/Riparian

Atlantic Coast

- Low-lying developed areas on the mainland Ocean City, Ocean Pines, and Snug Harbor) would gradually become increasingly vulnerable to coastal flooding during storm surges as the sea rises. Undeveloped areas within the 100 year coastal and riverine flood hazard area would remain so or be developed in such a manner as to minimize risk to infrastructure and structures from flooding. However to deal with effects of rising sea-level on the 100 year flood hazard area are an active topic of investigation by government agencies.

Coastal Protected Areas

National Park Service Areas

Chesapeake Bay, Maryland

- Within the Chesapeake Bay region in Maryland, there are several National Park areas including: Chesapeake Bay, Chesapeake Bay Gateways and Water trails Network, Captain John Smith Chesapeake National Historic Trail, the Fort McHenry National Monument, and the Star Spangled Banner National Historic Trail. Without future project conditions or proper storm management practices, strong storms and hurricanes will cause damage to these parks, making them dangerous for public use and requiring additional funding to repair damages. With increased sea level rise going as high as 2.1 feet by 2050 and 3.7-5.7 by 2100, water levels will inundate these national park service areas to the point where the general public would not be able to access the area due to increase water levels.

State Parks

Atlantic Coast

- See discussions above coastal, island, and wetlands habitat for future of Sinepuxent Bay Wildlife Management Area and Assateague Island National Seashore.

- Vaughn and Isle of Wight Wildlife Management Areas would gradually have more of their habitats affected by tidal waters. Existing coastal wetlands on these WMAs would be lost to erosion. It is anticipated that the net balance of coastal wetlands would be negative as described above.

Chesapeake Bay, Maryland

- In the Maryland portion of the Chesapeake Bay, there is a large network of state parks both inland and within the tidal portion of Chesapeake Bay. Some of the more prominent are Sandy Point State Park, Assateague State Park, and Janes Island. Without future project conditions or proper storm management practices, strong storms and hurricanes will cause damage to these parks, making them dangerous for public use and requiring additional funding to repair damages.

- By 2050, it is anticipated that there will be a 2.1 rise in sea level and by 2100, that number could increase to anywhere from 3.7 feet to 5.7 feet. (http://www.umces.edu/sites/default/files/pdfs/SeaLevelRiseProjections.pdf). As the sea level rises, National Parks located on coast of the Chesapeake Bay will most likely be inundated with water. Areas such as Blackwater and Eastern Neck Wildlife Refuge on the Eastern Shore of Maryland by 2118 will be completed inundated with water impacting not only the valuable fish and wildlife species that use the parks for habitat, but also prevent the public from enjoying them.

Critical/Significant Habitats

Waterbird Islands

Atlantic Coast

- See above discussion on island habitats.

Chesapeake Bay, Maryland

- Natural islands are being lost to sea level rise and it can be estimated future unabated sea level rise will lead to the complete or near complete loss of these islands. Sea level rise poses a unique threat to islands, in that migration is not an option and sediment inputs may be limited. In some cases, rising sea level may cause additional islands to form, as portions of peninsulas erode and higher water levels separate high ground from the mainland. Many islands along the mid- Atlantic Coast, and particularly in Chesapeake Bay, have been lost or severely degraded because of sea level rise. Although armoring can be used to protect these islands, it is not generally employed because the islands are undeveloped (Page 199, Mid-Atlantic Coastal Habitats and Environmental Implications of Sea Level Rise). By 2050, it is anticipated that there will be a 2.1 rise in sea level and by 2100, that number could increase to anywhere from 3.7 feet to 5.7 feet which means that many of these waterbird islands that are barely hanging on now will be completely underwater in the next 100 years or so. The best examples of water bird island within the Maryland portion of the Chesapeake Bay that are providing valuable habitat for various water birds include the Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island, and Hart-Miller Island. Both Poplar Island and Hart-Miller Island are island restoration projects using dredged material to restore lost habitat due to erosion. If these projects are halted and are left to be affected by sea level rise, valuable habitat for various water bird species will be lost. These projects are incorporating features to adapt to sea level rise, but strong storms can cause flooding and washouts which lead to additional construction and maintenance costs and potentially lost or impaired habitat until repairs are made.

Essential Fish Habitat (EFH) and Fish

Atlantic Coast

- EFH of the ocean waters would remain in its current state, except that minor increase in surf zone habitat via landward retreat of Assateague Island would occur. Future offshore wind farm activities would require construction of structures that would likely benefit fish species that orient to structures. Increased awareness of live bottom habitats is likely to lead to efforts to avoid their destruction via fishing that utilizes bottom dragging gear.

- The water area of Maryland’s coastal bays is likely to increase as sea-level rises, increasing availability of designated EFH generally other than for SAV. SAV within the coastal bays though would be likely to decline in the future as discussed above.

Chesapeake Bay, Maryland

- The water area of Maryland’s coastal bays is likely to increase as sea-level rises, increasing availability of designated EFH. Storms are unlikely to affect EFH.

- Populations of marine fish that favor warmer water and whose northern range ends near the Chesapeake, including include southern flounder, cobia, Spanish mackerel, mullet, tarpon, black drum, red drum, spotted sea trout, spot and Southern kingfish can be expected to increase as water temperatures increase. Species that favor cold water will disappear or become less abundant in the Chesapeake Bay including yellow perch, white perch, striped bass, black sea bass, tautog, summer and winter flounder and scup. Additionally, fish susceptible to winter die-offs due to the seasonal cold weather of the Chesapeake may see a strengthening of their populations due to warmer water, with more juveniles surviving through the winter.

- Warmer water also may result in longer growing seasons for fish, resulting in increased yield by some commercial fisheries.

- Lack of surface freezing in shoreline habitats could improve opportunities for oysters and other intertidal species to colonize shorelines. Some fish parasites also will likely benefit from warmer water, increasing their impact on fish and oysters in the bay.

- Rising sea levels will submerge some of the Bay's wetlands, which many ecologically and economically important fish use as nursery areas and as foraging grounds. Degradation of these habitats could affect the larger ecosystem of the Northeast U.S. continental shelf, as many of these species spend their lives in the coastal Atlantic.

Critical Habitat

- It is likely that without future with project conditions, more critical habitat will be designated as more remote island habitat, more marsh and coastal wetlands and more low lying ecosystems are lost due to increase sea level rise.

- For example, two areas in the upper bay—Eastern Neck and Elk Neck— appear most vulnerable to sea-level rise effects. First, Eastern Neck Wildlife Refuge lies at the southern tip of Maryland's Kent County. Ongoing shoreline protection efforts seek to reduce erosion of habitats supporting many migratory waterfowl and residential birds, as well as turtles, invertebrates, and the Delmarva fox squirrel, federally listed as endangered. (Coastal Sensitivity to Sea Level Rise 2009). Other sea-level rise impacts are possible in Cecil County, in and around the Northeast and Elk rivers. The headwaters of the rivers are tidal freshwater wetlands and tidal flats, spawning and nursery areas for striped bass and a nursery area for alewife, blueback herring, hickory shad, and white perch, as well as a wintering and breeding area for waterfowl. Accretion is likely to be sufficient in some areas due to the large sediment inputs in the Upper Bay as a result these spawning areas would be impacted. On the lower Eastern Shore of Chesapeake Bay in Maryland, habitats vulnerable to sea-level rise are diverse and include beaches, various types of tidal marsh, non-tidal marshes, and upland pine forests. Narrow sandy beaches exist along discrete segments of shoreline throughout the region, particularly in Somerset County. Given the gradual slope of the shoreline, one might infer that these habitats could accommodate moderate sea-level rise by migrating upslope, assuming no armoring or other barriers exist. Many of the beaches provide critical nesting habitat for the diamondback terrapin (Malaclemys terrapin), and proximity of these nesting beaches to nearby marshes provides habitat for new hatchlings (Coastal Sensitivity to Sea Level Rise 2009). With the loss of the beaches due to erosion and increase sea level rise, valuable habitat for various fish and wildlife species will be lost.

Atlantic Flyway

Atlantic Coast

- The general character and function of mainland areas as migratory stopover habitat would likely remain consistent. There would likely be a loss of intertidal flats foraging habitat in the northern coastal bays where shoreline hardening has occurred as the sea rises. The character of the southern coastal bays and the barrier islands would likely remain consistent.

Chesapeake Bay, Maryland

- The Chesapeake Bay is critical habitat for a number of migratory birds. For some birds, the Chesapeake Bay is their winter destination while others use the Bay as fueling grounds. Strong storms with excessive winds could prevent bird species from making their flights or causing them to go off course. The general character and function of mainland areas as migratory stopover habitat would likely remain consistent. There would likely be a loss of intertidal flats foraging habitat in the northern coastal bays where shoreline hardening has occurred as the sea rises. The character of the southern coastal bays and the barrier islands would likely remain consistent. Wetlands that provide forage for migratory birds will be lost to SLR and possibly during storms. Another result of sea level rise is the increased turbidity and eutrophication in near shore areas and increased water depths which may reduce light penetration to SAV beds, reducing photosynthesis, and therefore the growth and survival of the vegetation. Degradation and loss of SAV beds will affect the numerous organisms that feed, carry on reproductive activities, and seek shelter in seagrass beds.

T&E Species/Species of Concern

Anadromous/Diadromous Fish

- Removal of a fish blockage at Bishopville Pond would likely lead to a limited increase in use of upstream habitat by migratory fish species. Unfortunately, those waters are highly eutrophic at this time, limiting value of these habitats. Increasing attention on eutrophication may lead to improved water quality condition in Bishopville Prong in the future, increasing its quality as habitat for migratory fish.

- Diadromous fish species, including anadromous river herring and catadromous American eel, occur in Maryland's coastal bays. However, as a consequence of the small size of the watershed compared to the area of open water, and strong ocean influence in the coastal bays because of the efficiency of the Ocean City Inlet, at this time little to no spawning by anadromous fish species occurs in the coastal bays because of a lack of low salinity habitat. Historically prior to inlet stabilization by USACE in 1934, Maryland's coastal bays were much lower salinity (a condition common to other lagoonal estuaries along the Atlantic Coast prior to inlet stabilization, including Barnegat Bay, N.J., and Delaware's Inland Bays). It is likely that spawning by anadromous fish species in the watershed and perhaps in the coastal bays themselves did historically occur prior to inlet stabilization when water salinities were much lower. Currently efforts are underway to open up a fish blockage formed by a dam at Bishop's Pond in the Saint Martin's River Watershed that would open up freshwater habitat for spawning by anadromous fish. American eel do migrate up freshwater streams in Maryland's coastal bays to utilize the limited amount of freshwater stream habitat there for growing to adulthood (Dennison et al. 2009). Shortnose sturgeon is also found in Maryland and are federally listed as endangered. With sea level rise and climate change, habitat for these fish species will most likely change. With increase sedimentation, those waters used by these fish species will become cloudy which will lead to eutrophic conditions limiting the value of these habitats.

Marine Turtles

Atlantic Coast

- With warming temperatures, it is likely that increased nesting on Assateague Island by sea turtles would occur. The concern with sea level rise and climate change is that the water levels will continue to rise, drowning valuable sandy habitat for these species, making it harder for them to find nesting habitatChesapeake Bay, Maryland

- N/A for the Maryland Portion of the Chesapeake Bay- these turtle species occasionally do enter Chesapeake Bay but do not nest. With the increase in sea level rise, and as temperature increase, it could be possible for these species to become more prevalent in the Maryland portion of the Chesapeake Bay.

Marine mammals

Atlantic Coast

- No known change.

Chesapeake Bay, Maryland

- N/A for the Maryland Portion of the Chesapeake Bay-With the increase in sea level rise, and as temperature increase, it could be possible for species such as the humpback male to utilize the Maryland portions of the Chesapeake Bay to mate. Usually the humpback whales mate in the warmer waters in the winter time in the tropics, but as of 2012, it was found that about 30 whales were counted off the coast of Virginia Beach. Unusually mild winters have attracted the whales to this portion of the Chesapeake Bay. If these trends continue, it would not be unlikely to perhaps see these species come up further north to the Maryland portion of the Chesapeake Bay.

Birds (Nesting)

Atlantic Coast

- Assateague Island is significant from an ecological perspective because it possesses a notable concentration of rare beach-nesting bird species at the northern end. Beach-nesting bird species also occur elsewhere on the island. At the north end, frequent overwash limits vegetation, and there are substantial unvegetated open sandy areas. These conditions limit the suitability of the area for most species of animals, but provide nearly perfect habitat for beach-nesting bird species. Rare bird species nesting on the north end include Piping Plover, Least Tern, and American Oystercatcher. Roseate Tern may have historically nested on the island (USACE 1998). Piping Plover is federally listed as threatened for the state of Maryland and least terns are covered by the Federal Migratory Bird Treaty Act of 1918, so they are of great importance as well. Continued loss of bay island area would reduce populations of colonial waterbirds in the coastal bays making it harder and harder for those speices to find suitable breeding habitat.

Chesapeake Bay, Maryland

- Common and Least terns nest in loose colonies on coastal dunes and on sand or shell beaches just above the high tide line that are swept clear of vegetation. Both Least and Common terns are tolerant of urban sites; they sometimes breed on rooftops or dredge spoil sites. During the breeding season the Common and Least terns are vulnerable to human disturbance at nesting colonies (e.g. from off-road vehicles, recreation, motor-boats, personal watercraft and dogs) and to the flooding of nest sites as a result of naturally fluctuating water levels. On its breeding grounds the species is also threatened by habitat loss as a result of coastal development. It also suffers from avian and mammalian predation during nesting season. For instance, expanding populations of large gull species such as Herring Gulls may also prevent the terns from nesting in the area by colonizing it first. Also, on Poplar Island, the project team has determined that Great Horned Owls are a significant threat to the common and least tern populations on site. The owls are coming out at night, disturbing the nests, causing the adults to leave the eggs in order to protect themselves. When this occurs, the eggs cannot fully develop due to being not incubated properly and therefore don't hatch. There is also some evidence that the owls are eating the heads off of the young chicks for food as well. Unfortunately, high quality remote island nesting habitat for Common and Least Terns (and other similar species) in the Chesapeake Bay is extremely limited due to dramatic island loss (due to erosion, sea level rise, and subsidence), particularly in the Maryland portion of the Bay. Without project conditions, if action is not taken, habitat for these species will slowly but surely disappear as sea level rises and loss of islands and marshes continue. For example, Poplar Island in the Chesapeake Bay has the only nesting colony of common terns in the Maryland portion of the Chesapeake Bay and one of a few colonies of least terns in the Maryland portion of the Chesapeake Bay. Without remote island habitat such as Poplar Island, habitat for the valuable species will become more and more rare and harder to come by. Manmade restoration sites will likely be the only remaining nesting habitat for these species as their preferred natural habitat along the east of coast the United States will slowly disappear over time, and they have very specific habitat requirements before they will use a site to reproduce so this will cause their overall populations to decline. Recent statistical analysis of Common Tern nesting pair data suggests that within the end of this decade, the species may no longer nest in Maryland due to unsuitable habitat unless aggressive conservation measures are undertaken.

- By 2050, it is estimated that there will be a sea-level rise of 2.1 feet and by 2100, it is anticipated that there will be a sea-level rise of about 3.7 feet, with the worst case scenario go up to about 5.7 feet (http://www.umces.edu/sites/default/files/pdfs/SeaLevelRiseProjections.pdf).

- Rising sea levels will affect sensitive resources within the Chesapeake Bay including: sandy beaches, which are a rare resource in Maryland. Loss of sandy beaches will mean a loss of valuable habitat for nesting birds such as least and common terns. The least and common tern are listed in the 2012-2015 Audubon Strategic Plan as priority species for the Atlantic Flyway (Audubon Strategic Plan 2012-2015. New York, New York: Audubon, 2012. Print). The least tern is listed by the State of Maryland as threatened and is listed under the Federal Migratory Bird Treaty Act of 1918 and the common tern is being proposed to be listed as threatened by the State in the near future as well as being listed under the Federal Migratory Bird Treaty Act of 1918. Poplar Island is the only common tern nesting site in the Maryland portion of the Chesapeake Bay, and by 2100, with the anticipated 3.7-5.7 feet of sea level rise projected for the area, Poplar Island and other remote island habitat will covered in several feet of water, if not completely under water by 2118.

Shellfish/Shellfish beds

Atlantic Coast

- Ocean waters are likely to occasionally support high populations of surf clams. When this occurs, commercial fishing activity for these may occur. It is anticipated that shellfish of the coastal bays would likely remain in about the same status that they occur today.

Chesapeake Bay, Maryland

- Without project conditions, habitat conditions for shellfish within the Maryland portion of the Chesapeake Bay could be impacted by strong storms by increasing the amount of sedimentation which could harm the reproductive process of the species listed below. More water means more grainy sediment, which wreaks havoc on the bay by burying life-sustaining grasses, the nurseries of many species of baby fish. It can smother slow-moving bivalves, such as oysters, and the living things that attach to their shells, such as mussels.

- An increase of carbon dioxide in the water of the Chesapeake may raise the acidity of the Bay and gradually reduce the ability of oysters, clams, mussels and other animals to build calcium carbonate shells.

- With sea level rise, wetland habitat will gradually be converted to open water and as a result, valuable aquatic and nursery areas for various species including blue crabs will be lost. By 2050, it is estimated that there will be a sea-level rise of 2.1 feet and by 2100, it is anticipated that there will be a sea-level rise of about 3.7 feet, with the worst case scenario go up to about 5.7 feet (http://www.umces.edu/sites/default/files/pdfs/SeaLevelRiseProjections.pdf). With the increase in sea level rise, valuable habitat such as tidal flats and tidal marshes will be converted to open water, and there by losing valuable habitat that supports various species such as clams, snails, and other shellfish.

  - Hardshell clams-these species could be smothered/buried by excess sediment

  - Softshell clams- these species could be smothered/buried by excess sediment. Oysters-sea level rise is likely to make some of the currently deepest habitat (15-20 ft) unsuitable if low dissolved oxygen extends with sea level rise. New habitat could be created in shallower areas that become submerged. Increasing acidification of estuarine waters due to climate change and eutrophication could negatively impact oyster populations by making it harder for oysters to produce shell and leading to faster dissolution of reef substrate.

  - Blue mussels- these species could be smothered/buried by excess sediment

  - Blue crabs-blue crabs, are highly mobile and can migrate to optimal regions and avoid negative impacts associated with storm events, such as decreased water temperature or reduced salinity. Loss of wetlands due to increasing sea level rise could have a negative impact on blue crab populations. The effects of climate change on blue crab populations is not clear, but increased temperature and acidification of estuarine waters (climate change) could positively increase crab growth (Waldbusser et al. 2011).

  - Bay Scallops-these species could also be smothered/buried by excess sediment but could also be harmed by contaminated water (from human and animal waste) as a result of tidal flooding.

  - Surf clams-these are predominately found on the Atlantic Coast of Maryland, not the Chesapeake Bay side

Quality

Water Quality/Impaired Waters

Atlantic Coast

- There has been a trend of increasing eutrophication of Maryland's coastal bays. Heightened public and government awareness of this has focused concern on point and non-point sources and their remediation. With imposition of TMDLs for the highly eutrophic bay tidal tributaries by

MDE, it is expected that eutrophication conditions in Maryland's coastal bays would improve somewhat.

Chesapeake Bay, Maryland

- The Chesapeake TMDL is being implemented to improve water quality of surface waters throughout the Bay watershed by reducing Nitrogen, Phosophous, and Total Suspended Solids within the Chesapekea Bay waters. In coordination with the Environmental Protection Agency (EPA) and the Chesapeake Bay Program, the State of Maryland has developed and is implementing Maryland's Chesapeake Bay tributary strategy and TMDL Watershed Implementation Plan to achieve reductions from point and nonpoint sources necessary to meet Maryland's TMDL sediment and nutrient allocations. One example of improvements already being seen in the Chesapekae Bay are actions being taken out on Poplar Island. Currently at Poplar Island, monitoring is being performed to determine if nutrient fluctuations exist within the dredged material containment facility based on time of day and the time of year. The data is analyzed to evaluate the nitrogen and phosphorus loadings to the receiving waters from Poplar Island. The discharge data, along with inflow water, bulk sediment measures, and atmospheric inputs (rainfall) will provide for the assessments used to evaluate the sequestration of TMDL contaminants of concern. The data will serve as a management tool to assist in development of Best Management Practices (BMPs) and aid in the planning for the discharge of ponded water based on nutrient fluctuations. This is just one example, but other dredged material containment facility sites are doing similar efforts not to mention the other sites that are being tasked to do similar efforts. As a result, it is expected the eutophication condiotns in the Maryland portion of the Chesapeake Bay will impove over time.

- The Susquehanna River watershed (27,000 square miles) is the largest watershed within the greater Chesapeake watershed (64,000 square miles), providing roughly 50% of freshwater flow into the Bay. There are three large hydroelectric dams on the lower Susquehanna River. These dams trap sediment and associated pollutants behind them, and act as an important control on the downstream transport of nutrients and sediments from the Susquehanna River Basin into Chesapeake Bay. The Conowingo Dam is the furthest downstream of the three dams. As the Conowingo Reservoir is approaching its sediment storage capacity, more sediment and associated nutrients are being passed into the Chesapeake Bay.

- Depending on the storm event, impacts of major scouring can persist for an extended period of time. Impacts to waters include increase turbidity, increased nitrogen and increased phosphorus levels within the Chesapeake Bay.

- Global warming not only contributes towards higher average air and water temperatures and more extreme weather events such as floods, droughts, etc, but it is also contributing to the increase of sea level rise. In the summertime, the waters of Chesapeake Bay heat up, algae blooms increase, and dissolved oxygen decreases. The temperature increase is most pronounced in the surface waters, while dissolved oxygen depletion is most pronounced in deeper waters. These results in a habitat squeeze for many species, where surface waters are too hot and deep water dissolved oxygen levels are too low. Changes in the Chesapeake Bay region's coastal habitats due to sea-level rise will have a significant impact on the fish and wildlife they support. Given that all habitat types, from tidal freshwater marshes and swamps to salt marsh and beach, are linked in one way or another, changes in their composition due to sea-level rise will have consequences for the coastal ecosystem within the Chesapeake Bay (Najjar et al. 2010).

- Climate change is expected to increase the dissolved carbon dioxide of Chesapeake Bay waters and increase water temperatures.

Toxins/contaminants (HTRW)

- No change expected**.**

Cultural Resources

- Sea level rise impacts to cultural resources range from increased tidal and wave erosion to inundation. Cultural resources within coastal zones will be subjected to gradual sea level rise impacts exacerbated by event-specific impacts such as high tide events and storms. The frequency and intensity of damage from event-specific impacts is expected to increase as sea level rises (Karl et al. 2009). In addition, high regional subsistence rates are expected to increase rates of sea level rise and associated impacts (Johnson 2000).

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9. Virginia: Environmental Existing and Future Conditions

I. Coastal Characterization - Virginia

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Coastal Sand Dunes/Sandy Shorelines/Pebble Shoreline

- The ocean beaches and dunes in Virginia are mostly associated with the Eastern Shore and False Cape State Park and Back Bay National Wildlife Refuge, both of the latter encompassing the great majority of Virginia Beach's undeveloped shoreline.

- The Eastern Shore portion, which includes the majority of these habitats in Virginia, hold a total of 85.3 miles of coastal dunes and associated beaches, almost exclusively on a chain of barrier islands running along the Eastern Shore (VIMS 2004 - Accomac County Dune Inventory).

- The remaining coastal beach and dune habitat lie along undeveloped coastline of the City of Virginia Beach area, which includes False Cape State Park and Back Bay National Wildlife Refuge. These two areas contain 38.5 miles of beaches with associated dunes.

- The commonwealth of Virginia has 29% of its landmass in the Coastal Zone, which includes 5,000 total miles of shoreline.

- In Virginia, Northumberland, Lancaster, Mathews, Accomack and Northampton Counties contain coastal dunes, along with the cities of Hampton, Norfolk and Virginia Beach.

- Northumberland County, which lies along the western shore of Chesapeake Bay and is the northernmost region on the western shore of Virginia waters of the Bay to have any dunes, was found to hold 59 dune sites, of which 39 were found along the Bay and the remaining along shorelines of the Potomac River. The sites cover 6.3 miles of shoreline in the region.

- Lancaster County, which encompasses portions of the Rappahannock River and western shore of Chesapeake Bay, is the middle region in Virginia waters of Chesapeake Bay that has extensive coastal dunes. A total of 45 dune sites were documented in the region. These dunes consist of mostly short dune systems, ranging from 100 feet to 1,200 feet in length covering a total of 14,020 feet of shoreline.

- Mathews County, which lies south of Lancaster County on the Western shore of Chesapeake Bay along Virginia's middle peninsula and the southernmost area along the western shore of Virginia waters of the Bay that have dunes. Dunes were located at 18 sites, 13 of which are located on Chesapeake Bay. Dunes varied in size from 225 feet to 3,150 feet and covered a total of 18,835 feet of shoreline(VIMS 2003 - Mathews County Dune Inventory).

- Accomack County held 35 dune sites along the coastal (Bayside) region. This region is the northernmost locale along the eastern side of the Chesapeake Bay. The dunes here range in size from 180 to 3,780 feet and total 26,050 feet of shoreline.

- Northampton County is located immediately south of Accomack County and forms the southernmost portion of Virginia's Eastern Shore. Its bayside shorelines hold 30 dune sites covering 10.2 miles of shoreline.

- The City of Hampton lies along the western shore of Chesapeake Bay at the confluence of the James River and the Bay. Hampton is heavily urbanized with only six dune sites covering 10,540 feet of shoreline documented, most of which lie along a local nature preserve (Grandview Nature Preserve).

- The City of Norfolk lies along the southern shoreline of Chesapeake Bay and has 8 dune sites covering 4.5 miles of shoreline (VIMS 2004 -City of Norfolk Dune Inventory).

- The City of Virginia Beach holds eight coastal dune sites along the southern shore of Chesapeake Bay, encompassing 6.1 miles of shoreline. In general, dune sites were found in areas of sand accretion and stability, such as tidal creek mouths, embayed shorelines, in front of older dune features such as washovers, as spits and against man-made structures such as channel jetties or groin fields (VIMS 2003. City of Virginia Beach Dune Inventory). In total, this is a rare habitat in Chesapeake Bay, covering 0.4% of total Bay shoreline.

- Sandy beaches are found in the same areas that dune systems are located. In Virginia, there are approximately 1,300 estuarine beaches that cover 75 miles of Bay coastline.

- There no Pebble Shoreline/Beaches.

Barrier Islands/Inlets

- Virginia's Eastern Shore has a chain of uninhabited barrier islands stretching from Assateague Island at the Maryland border to Fisherman's Island at the southern tip of the Eastern Shore where the Atlantic Ocean and Chesapeake Bay meet.

- From North to South, in order, are Assateague, Wallops, Assawoman, Metompkin, Cedar, Parramore, Hog, Cobb, Wreck, Ship Shoal, Mink, Myrtle, Smith, Mockhorn and Fisherman's Islands.

- Many of these Islands are protected by The Nature Conservancy and contained within the Virginia Coast Reserve and comprise the longest expanse of coastal wilderness remaining on the eastern seaboard of the United States and have been designated as an International Biosphere Reserve by the United Nations.

Coastal Wetlands

Salt, Brackish or Freshwater Marsh/Tidal Mud Flat/Maritime Forest/Estuaries

- At this time, there is no comprehensive inventory of existing wetlands in Virginia.
- The National Wetlands Inventory (NWI) has mapped the wetlands in most (over 90%) of the state, identifying 1,267,000 acres of vegetated wetlands.
- Non-tidal wetlands, a significant portion of which lie outside the area considered in the present study, are the great majority of the state's wetlands at 1,075,000 acres, leaving at a minimum 192,000 acres of various wetlands that could be impacted by a coastal storm such as sandy, though some non-tidal wetlands (ponds, small lakes, cattail marshes, vernal pools, etc.) could also be affected.
- In Virginia, there are more than 180,000 acres of such isolated non-tidal wetlands.
- Approximately 72% of Virginia wetlands are in the Coastal Plain, with another 22% in the Piedmont and the remaining 9% in other physiographic provinces.
- Virginia is estimated to have lost about 40% of its pre-colonial wetland acreage (Moulds et al. 2005, VDEQ 2011).
- Most of the tidal wetlands in Virginia are salt marsh of varying types, with *Spartina* sp. being dominant. This type of wetland covers 195,237 acres in Virginia.
- Virginia holds both tidal and non-tidal freshwater wetlands. Of these, 16,000 acres are tidal freshwater wetlands, with the rest being non-tidal.
- There are extensive tidal mud flats throughout Virginia's waters of Chesapeake Bay and its tributaries, though no extensive inventory of this wetland type has been done to date.
- Within the region of interest, there are approximately 4,792 acres of maritime forest (Chesapeake Bay watershed) (EPA 1994).
- Virginia has a significant portion of Chesapeake Bay, with Maryland having the northern portion and Virginia, the southern.

Submerged Aquatic Vegetation

- Submerged aquatic vegetation (SAV) coverage varies from year to year in the Chesapeake Bay, though many areas are relatively stable.

- In 2011 there were 57,964 acres of SAV in Chesapeake Bay and its tributaries, which continues a downward trend noted in recent years (-16,574 acres in 2011 and -6,247 acres in 2010). Of this, 24,217 acres are in Virginia waters of the Bay, and 7,779 acres are in seaside embayments along Virginia's Eastern Shore in the lee of the barrier island chain found there (http://web.vims.edu/bio/sav/index.html).

Smith/Tangier Island SAV

- Some of the most extensive SAV beds in Chesapeake Bay lie in the shallow waters of Tangier Sound, around a complex of islands in both Maryland and Virginia waters. These SAV beds have been very persistent over time, and typically average approximately 10,000 acres in size (http://web.vims.edu/bio/sav/maps.html). They represent the largest beds of eelgrass (*Zostera marina*) and widgeongrass (*Ruppia maritima*) in the Bay.

- SAV provides important nursery habitat to a wide range of species, perhaps the most economically important being blue crabs, (*Callinectes sapidus*) which are a major fishery in Chesapeake Bay. These SAV beds form by far the largest area of nursery habitat and likely supply a significant portion of upper-Bay blue crab young-of-the-year (Lipcius et al 2005). These islands, Smith (MD) and Tangier (VA), along with a series of smaller, mostly unnamed islands that lie between and around them, are the remaining landmass of a sunken peninsula.

- The shallow, somewhat sheltered sand flats where the SAV is found formed in and around the Smith (MD) and Tangier (VA) Islands which provided significant protection against the long fetch across Chesapeake Bay and resultant high wave and current energy. Additionally, the SAV beds are semi-protected by the islands and sunken ridges of submerged islands, aiding the SAV to accumulate sufficient sediments within the beds to persist. This capability will almost certainly be lost and the SAV will experience significant decline if the protection of the islands is lost. These islands are in great jeopardy due to SLR and, unless measures are taken to prevent it, are predicted to be lost within 100 years. If this is allowed to occur, the large, ecologically important SAV beds currently protected by this island complex will be exposed to much higher wave and current energies and most likely lost. Both the islands and the SAV beds in this local region warrant particular attention due to their unique and considerable ecological importance.

Oyster Reefs

- Oyster reef habitat in Virginia waters of the Bay have been greatly reduced due to overfishing, sedimentation and impacts due to disease since they were first mapped in the late 1800's when 243,000 acres were delineated, which encompassed the grounds in Chesapeake Bay as well as seaside Eastern Shore of Virginia. Of this, perhaps 47% actually contained oyster reef habitat based on analysis conducted during the joint NAB-NAO NORMP (Native Oyster Restoration Plan 2012).

- Today approximately 11,500 acres of degraded oyster reefs remain in Virginia waters.

- These reefs, which have been almost entirely flattened due to fishing such that they do not have significant bottom relief, are more prone to damage by anoxic events and high sedimentation than former reefs that did have significant bottom relief.

Rock Reefs

- There is very little rock reef habitat in Virginia waters of Chesapeake Bay, and what is present is man-made.

- Eighteen manmade reefs have been constructed within Virginia waters of Chesapeake Bay since the inception of the Virginia Marine Resources Commission's (VMRC) artificial reef program. These reefs have been constructed of a variety of materials, only some of which are stone, typically donated concrete from bridge deconstruction. Most of these reefs are one to several acres in size.

Shallow Bay Habitat/ Bay Islands

- Regarding islands in Virginia waters of Chesapeake Bay, most consist of sandy shoreline, dune, and estuarine marsh with limited riparian habitat.

- Two islands hold significant upland, Gwynn's Island which lies near the southern shore of the mouth of the Piankatank River, and Tangier Island, the only remaining inhabited island in Virginia waters of the Bay. Tangier Island has three ridges of upland that encompass the town of Tangier. An island to the immediate North of Tangier Island, which lies near the Maryland border of the Bay several miles from the Bayside Eastern Shore, is known as Uppards Island and was formerly inhabited. Superstorm Sandy exposed a number of graves from an abandoned cemetery near the former town of New Canaan, which lies at the northern tip of Uppards Island.

Coastal Protected Areas

Marine Sanctuaries/Coastal Reserves

- Virginia's Coastal Reserves consist of a chain of barrier islands along the Eastern Shore, mostly held by The Nature Conservancy.

National Wildlife Refuges

- Back Bay National Wildlife Refuge was established on June 6, 1938 as a 4,589-acre refuge to provide feeding and resting habitat for migratory birds. It is a critical segment in the Atlantic Flyway. The refuge contains more than 9,000 acres, situated around Back Bay, in the southeastern corner of the City of Virginia Beach.

- A detailed discussion on National Wildlife Refuges can be found in the USFWS NACCS Planning Aid Report (Attachment A).

State/County Parks

- Kiptopeake State Park located in Accomac County, part of the Eastern Shore.
- False Landing State Park located near Virginia Beach.
- False Cape State Park located south of Virginia Beach just north of the North Carolina Border, Chippokes Plantation State Park, which contains one of America's oldest working farms and located near historic Jamestown on the shores of the James River.
- York River State Park, which holds extensive estuarine marshlands.
- Belle Isle state park along the shore of the lower Rappahannock River in Lancaster County.

Federally Listed Threatened and Endangered Species and Critical/Significant Habitats

Threatened and Endangered Species

- The Piping Plover (*Charadrius melodus*) is a small, sand colored shorebird approximately seven inches long with a wing span of approximately 15 inches. The piping plover was listed as threatened under provisions of the Endangered Species Act in January 10, 1986.
- Roseate tern (*Sterna dougallii*) is a medium-sized, black-capped sea tern about 15 inches long and weighs about four ounces. On November 2, 1987, the USFWS determined the population that nests in the Northeast to be endangered, and the population that nests in the Caribbean to be threatened.
- Northeastern Tiger Beetle (*Cicindela dorsalis dorsalis*) is a tiny, sand-colored beetle that lives on sandy beaches throughout the middle and lower Chesapeake Bay in Maryland and Virginia. The Northeastern Tiger Beetle was listed as threatened under provisions of the Endangered Species Act in 1990.
- The Red Knot (*Calidris canutus*) (Proposed) is a medium sized shorebird and the second largest Calidris sandpiper. Measuring 23 to 26 cm long with a 47 to 53 cm wingspan, their body shape is typical for the genus. The Virginia Barrier Islands represent a second, spring staging area for red knots within the mid-Atlantic. The island chain includes more than 100 kilometers of open beach and represents one of the most pristine set of coastal barriers remaining in North America.
- Seabeach amaranth (family Amaranthaceae) is an annual plant native to the barrier island beaches of the Atlantic Coast, from Massachusetts to South Carolina. The original range of this

species extended from Cape Cod, MA, to central SC, a stretch of coast about 994 miles (mi). In New York, the range of seabeach amaranth is also characterized by islands developed by high wave energy, low tidal energy, frequent overwash, and breaching by hurricanes with resulting formation of new inlets (Weakley and Bucher 1992).

- In Virginia, sea turtle nesting is primarily limited to the loggerhead sea turtle (*Caretta caretta*). The loggerhead sea turtle was initially listed as threatened throughout its range on July 28, 1978. The loggerhead is widely distributed within its range. It may be found hundreds of miles out to sea, as well as in inshore areas such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers. Nesting occurs mainly on open beaches or along narrow bays having suitable sand.The first confirmed nesting by the federally listed green sea turtle (*Chelonia mydas*) occurred on Back Bay NWR in 2005, and the first confirmed nesting by a Kemp's ridley sea turtle (*Lepidochelys kempii*) occurred in 2012 on U.S. Naval Air Station Oceana.

- A detailed discussion of USFWS managed Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

- A detailed discussion of USFWS managed Federally Listed Threatened and Endangered Species can be found in the USFWS NACCS Planning Aid Report (Attachment A).

- The Atlantic sturgeon, is also quite rare locally, and the Chesapeake Bay sub-population, along with most other subpopulations, has been listed as endangered in 2013. However, it does have a small breeding population in the James River (Musick and Hager 2007) that appears to be slowly growing, and there are active efforts to increase this species numbers in the State.

- The shortnose sturgeon is endangered. Shortnose sturgeon were once abundant in Chesapeake Bay; however, the population has declined significantly since the first published account of their presence in 1876 (NMFS 1998). In 1996, eight shortnose sturgeon were captured in the upper Bay between Kent Island and the Chesapeake and Delaware Canal, and one in the Potomac River. In 1997, nine shortnose sturgeon were captured in the upper Chesapeake Bay between Miller's Island and the mouth of the Susquehanna River. In 2006, two female, egg-bearing shortnose sturgeon were found in the Potomac River (Blankenship 2007). There are very few records of the shortnose sturgeon south of the Potomac river in recent decades, with the only modern record being a single capture at the mouth of the Rappahannock River. No evidence of juvenile sturgeon have been documented in Chesapeake Bay in recent decades, indicating very little, if any, breeding is occurring locally for this species.

- Other species of concern in Virginia's Chesapeake Bay and Eastern Shore waters but not listed are: alewife, blueback herring, sand tiger shark and American eels (eels are a candidate species at this time but not currently listed).

Critical Habitat

- U.S. Fish and Wildlife Service critical habitat designations only occur in the western part of the state. Critical habitat benefits a number of fish species (3) and mussel species (4) located in the upper Tennessee River watershed. NOAA Fisheries designates the following critical habitat (habitat areas of particular concern, HAPC) in waters of Virginia. Open Bay waters covering much of Virginia's portion of the mainstem Chesapeake Bay along with the mouths of major tributaries (James, York, Rappahannock) are HAPC for the sandbar shark, Carcharinus plumbeus, who use these waters as pupping grounds and habitat for young juvenile sharks. The shallow coastal Bays of Virginia's lower Eastern Shore also contain HAPC for red drum (Sciaenops ocellatus) and summer flounder.

II. Habitat Impacts from Hurricane Sandy - Virginia

General Impact

- Runoff from Hurricane Sandy was laden with sediment, nutrients, contaminants, and debris. All pose a significant threat to the health of aquatic grass beds, oyster reefs and wetlands throughout the Chesapeake Bay and coastal bays. These habitats provide shelter for many shellfish and finfish species, help improve water quality, and protect our shorelines. The seasonal timing of key species in Chesapeake Bay and the occurrence of major storms affects the level of impact. By the time Hurricane Agnes (June 1972) reached the Mid-Atlantic region, it had been downgraded to tropical storm status; however the timing of the storm was particularly devastating, as it occurred during important reproductive stages for oysters and crabs, and the early growing season for aquatic grasses and it supplied much more precipitation into the Chesapeake Bay watershed than any storm event since. In comparison, Hurricane Irene and Tropical Storm Lee occurred in late August and early September, with their combined rainfall totaling considerably less than Hurricane Agnes, while Hurricane Sandy occurred in late October, leading to reduced impacts to living resources based on seasonal timing. Due to the track of the storm, which veered offshore as the storm neared Virginia, Hurricane Sandy inflicted much less damage to Virginia than to more northern coastal states where it made landfall. Virginia was essentially struck a "glancing blow" by Hurricane Sandy (Governor McDonnell 2013).

Rainfall

- Very high rainfalls were recorded in Virginia, with over 8 inches of rain falling over the course of the storm in portions of the state, particularly the Southeast and Eastern Shore region. The highest recorded total in Virginia, 9.57 inches, fell at Oceana airport in the City of Virginia Beach.

- Peak flows from Bay tributaries were significantly lower than after Hurricane Irene and Tropical Storm Lee in August-September 2011. The Susquehanna's peak flow was approximately 155,000 cfs on November 1, 2012, compared to the peak flow after Irene/Lee of over 775,000 cfs. The Potomac River peak flow was estimated at 140,000 cfs after Sandy, much lower than the all-time record of 484,000 cfs that occurred in 1936.

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

- The storm surge caused by Hurricane Sandy was estimated to have removed 190,000 cubic yards of sand from the Virginia Beach Oceanfront and 138,000 cubic yards from Sandbridge Beach. Both of these beaches are periodically nourished by the Army Corps of Engineers, and this loss will require replacement (Norfolk District Public Affairs and City of Virginia Beach 2013)

- Along Virginia's Eastern Shore, the barrier island system experienced significant overwashing, which deposited some of its sands onto inshore estuarine wetlands, resulting in loss of sandy material from the islands and burial of some estuarine wetlands by the deposited sand.

Barrier Islands/Inlets

- Hurricane Sandy created a temporary inlet at the southern end of Assateague Island. This would be expected to gradually close via shoaling from longshore transport. Substantial overwash occurred on northern Assateague Island. Much of the island was flooded during the storm. No roads or infrastructure were impacted by the breach.

- Rudee Inlet, located along the Atlantic Coast along the south beach of Virginia Beach, required emergency dredging due to shoaling caused by Hurricane Sandy. It provides significant harbor facilities to both recreational and commercial vessels.

Estuaries

- The coastal bays water levels were elevated by about 4 feet during Hurricane Sandy. This would have allowed movement of marine-strength salinity seawater into low-lying lands around the coastal bays and promoted salt water movement upstream into the small tidal tributaries flowing into the coastal bays. It is unknown what level of damage this saltwater intrusion caused, however, areas already experiencing saltwater intrusion may have been particularly hard hit, such as First Landing State Park, which lies near the Bay confluence with the Atlantic Ocean just northeast of the City of Virginia Beach.

Submerged Aquatic Habitat

- SAV on the bayside of Assateague Island was locally buried by overwash. This damaged the HAPC of the red drum and summer flounder in the area, though it has the potential to recover over time, local conditions permitting. Waves and tidal currents occurring with the storm likely scoured existing SAV beds locally within the coastal bays Full effects of this will likely be apparent when the VIMS annual SAV survey is conducted later this year. Preliminary information indicates a significant loss in 2012 in the Chincoteague Bay region, which covers this area. Other regions along the seaside Eastern Shore documented increases in SAV coverage, so the loss was almost certainly due to Hurricane Sandy sand overwash and burial of SAV in the Assateague/Chincoteague area (http://web.vims.edu/bio/sav/sav12/exec_summary.html).

Chesapeake Bay

- Submerged Aquatic Habitat increased sediments can cause widespread seagrass die-off. Though we won't know if there were any impacts on aquatic grasses within the Chesapeake Bay from Hurricane Sandy until the 2013 growing season, it is likely that these impacts will be minor in comparison to previous storm events, as turbidity was lower and the storm happened late in the growing season when plants had already begun to mature (Dennison et al. 2012). Based on a more recent survey in 2013 (http://web.vims.edu/bio/sav/index/html), SAV is recovering and if trends continue, may fully recover over the next few years.

Shallow Bay Habitat/ Bay Islands

- Hurricane Sandy waves and currents would have caused substantial movement of bottom sediment in the coastal bays, locally scouring and shoaling. Over time, it is expected that bathymetry in the inlet vicinity would largely recover to pre-storm patterns in channel areas because of tidal scour. One exception to this is Rudee Inlet in southern Virginia, which does need regular maintenance to remain navigable and open, even without major storms that can quickly fill the navigation channel to non-navigable depths.

- Tangier Island, the only inhabited island in Virginia's portion of the Bay, experienced extensive flooding and storm related damage. Roads were flooded, a number of homes were flooded, docks and piers destroyed, and several fishing boats were sunk (Richmond Times Dispatch, 11/01/12). A Cultural Resource, a cemetery for a town abandoned in the 1920's on the Island of Uppards Island, immediately north of Tangier, was damaged with graves disturbed and exposed by the storm.

Terrestrial Upland

- Substantial rainfall and high winds probably caused a substantial number of trees to blow down. Saltwater encroachment into low-lying areas of the mainland may have stressed/killed trees. Effects of this would become apparent in the 2013 growing season.

Floodplains/Riparian

- Localized flooding from excess runoff and elevated coastal waters occurred in floodplain areas of the mainland. It is possible that salt water from coastal flooding may have detrimentally affected trees in low-lying floodplain areas because the storm occurred during the growing season, although late. Any affects upon trees should be apparent by full leaf-out in May of 2013.

Essential Fish Habitat (EFH)

- Large waves in the Atlantic Ocean (up to 12-27 foot wave heights recorded along the Virginia coastline) affected the nearshore benthic habitats in coastal ocean waters out to depths of many 10s of feet. Substantial movement of bottom sands would have occurred. Locally, live bottom habitats in flats on the seabed with muddier sediment may have been detrimentally affected by physical removal of organisms, as well as scour and or burial of bottom sediment (Dennison et al. 2012). This may have caused negative impacts to the HAPC of the sandbar shark, but the habitat and the shark are likely to recover due to the short term disruption of the storm itself and the dynamic nature of the open Bay habitat. In general, impacts to EFH were limited due to the sub-tidal open water nature of EFH.

- Effects upon components of EFH in the coastal bays (SAV, shallow water, inlet) are discussed under those individual topics.

Waterbird Islands

- Birds nest locally on Craney Island, and on small islands that are man-made and part of the Chesapeake Bay tunnel system, along with natural islands along Virginia's Eastern Shore, may have been damaged by the storm surge and sand erosion (Dennison et al. 2012), though this was only documented for the natural, not man-made, islands. Loss of island land mass of bay islands would be generally detrimental to nesting waterbirds. Flooding would likely reduce vegetative cover, which would be beneficial to beach-nesting waterbirds such as Black Skimmer and Least Tern. Full effects of Hurricane Sandy on nesting suitability of bay and Eastern Shore islands should become apparent during the Spring/Summer 2013 nesting season.

T&E Species/Species of Concern

- The beach overwash that occurred on Assateague Island may have created more suitable habitat for rare flora and fauna dependent upon sparsely vegetated conditions. In particular, beach-nesting bird species (discussed elsewhere), plus a federally threatened plant species (seabeach amaranth), and a rare insect (tiger beetle) could benefit from new overwash habitat. Other state-rare plant species dependent upon these conditions would also have benefited on Assateague Island.

Fish

Chesapeake Bay

- Fish species, such as these below could be impacted during a strong summer storm by impacting spawning activities, but because Hurricane Sandy occurred in the fall, and the path of the storm did not go up the Chesapeake Bay, the actual impact to these species such as the Atlantic sturgeon, Shortnose sturgeon, Alewife/Blueback herring, Shad, American eel, and Striped bass were very minimal if nonexistent.

Birds (Nesting)

Chesapeake Bay

- Due to the time of year and the path of the storm, it is likely that nesting species of birds such as Piping Plover, Least Terns, Rosette Terns, and Red Knot were not negatively impacted. These species nest in early to late summer and are migratory species. They had already departed from the Maryland portion of the Chesapeake Bay by the time Hurricane Sandy hit in late October.
    - Coastal Flooding as a result of Hurricane Sandy may have created areas of inlet, beach, and overwash habitats which will likely provide important new or improved foraging and breeding sites for shorebirds (Consequences of Hurricane Sandy: Opportunities and Imperatives for Coastal Bird Conservation 2013).

Shellfish

Hard Clams

Chesapeake Bay

- Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the hard clams in the Virginia portion of the Chesapeake Bay, either to the wild fishery or to aquaculture clams, the latter of which comprises the majority (~90%) of the clam meats produced in Virginia.

Oysters

- Oysters within the Chesapeake Bay can benefit from reductions in salinity as result of tropical storms and hurricanes since the two major diseases (MSX and Dermo) are intolerant of low salinity. Infections are rare at low salinities, and significant increases to parasites usually occur during periods of reduced rainfall when higher salinity waters protrude into the northern bay. In addition, MSX and Dermo are highly influenced by temperature, and if oysters are exposed during lower temperatures (late in the season), infection can be delayed until the following summer (Dennison et al. 2012). On the other hand, runoff from Hurricane Sandy is laden with sediment, contaminants and debris. All pose a significant threat to the health of oyster reefs and shellfish beds along the Atlantic Coast. Increased sediments can also do a lot of damage by burying oyster beds. Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the oysters here in the Virginia portion of the Chesapeake Bay since they spawn during the summer months not the fall. Sediment plumes were more limited to the Susquehanna River and upper Bay, which reduced such impacts in the lower Bay. There was sedimentation in the lower Bay as a result of Hurrican Sandy but it does not appear to have buried any oyster reefs. While there were temporary closures to shellfish harvesting due to the storm, this did not appear to negatively impact the subsequent wild harvest or the private lease harvest, both of which were larger in fall-winter 2012-2013 than in the past several years.

Blue Crabs

Chesapeake Bay

- Are highly mobile and can migrate to optimal regions and avoid negative impacts associated with storm events, such as decreased water temperature or reduced salinity but on the other hand increased freshwater inputs can trigger early migration of female crabs to more saline waters at the mouth of the Chesapeake Bay (Dennison et al. 2012). Due to the time of year and the path of the storm, Hurricane Sandy had very minimal impacts to the blue crabs in the Virginia portion of the Chesapeake Bay. Due to shellfish closures because of Hurricane Sandy, the blue crab fall pot season was extended by six days to allow fishermen to recover lost work days due to the storm.

Sea Scallops

- There is a significant sea scallop fishery in Virginia's coastal oceanic waters, now one of the most profitable fisheries along the East Coast, with current landings in Virginia worth well over 50 million dollars. The sea scallop is typically found from depths ranging from 50-350 feet (most common from 130-230 feet), tending towards deeper waters, which are cooler, as the animal ranges from the Gulf of Maine to the Virginia-North Carolina border. In Virginia, this means the scallops are typically found in deeper waters offshore on the continental shelf. Due to the depths and distance from the shore these scallops are found at, it is expected that only severe storms would directly impact them, possibly by reducing recruitment if a storm strikes when their planktonic larvae are in the water column. It is expected that these types of storms will increase in frequency due to climate change. Impacts from storms could be more severe on their planktonic larvae and newly settled juveniles, which are vulnerable to strong currents and shifting sands, respectively, which could significantly reduce recruitment (Hart and Chute 2004). Hurricane Sandy, due to its time of impact, would have had a small impact on larval survival, as during this time of year, most scallop reproduction has occurred and the larvae have settled to the bottom, where few impacts from the storm would have occurred.

III. Future Without Action Conditions - Virginia

Coastal and Marine Habitats

Ocean Beach and Dune Ecosystem

Sandy Nearshore Habitat—Beaches, Dunes, and Barrier Islands

- In the future, ocean beaches and dune ecosystems will be subject to increased storm activity (http://nrc.noaa.gov/sites/nrc/Documents/SoS%20Fact%20Sheets/SoS_Fact_Sheet_Hurricanes_and_Climate_FINAL_May2012.pdf) and increased sea level rise, the latter of which will be locally exacerbated due to subsidence related glacial rebound in the local region. With no action taken, it is expected that this will have a profound effect on these habitats. Overall impacts will be a loss of beach and migration of the shoreline inland, loss of sand in the present dune system, with a migration of dunes inland (where they are not lost), and loss of wetlands by conversion to shoreline (mudflats) and loss due to erosion and sea level rise (conversion of wetlands to open water). Beaches will become narrower under predicted scenarios, reducing the acreage of this habitat type available. It is expected that most of the current beach habitat will be lost without replacement under the 2068 and 2118 USACE SLR high scenarios. There is little if any conversion of present uplands into new beaches expected. It is expected that coastal sand dunes lining the ocean-side barrier islands of the Eastern Shore of Virginia and the Bay-Atlantic Coastline will be reduced in extent and migrate landward due to predicted future conditions, potentially lost entirely under the high-end scenarios for sea level rise.

- Compared to the rest of Virginia within the study area, the Eastern Shore holds the most land especially vulnerable at 394 square miles, as approximately 264 square miles within the rest of the study area being particularly vulnerable (VIMS 2013). This is in close agreement with the 2118 USACE High SLR scenario, which predicts that most of the Eastern Shore will be inundated and the present barrier islands completely lost. As a result, the Eastern Shore would become a very narrow peninsula likely consisting of estuarine marsh with limited uplands and the entire present beach, dune, and barrier island habitat lost with little replacement. However, it is likely that a narrow beach will form along the new shoreline due to longshore transport and the peninsula should still provide enough landmass to allow the Chesapeake Bay to continue to exist.

- This will result in the loss of bay habitat to open shallow oceanic habitat along the seaside eastern shore as well as losses in dune extent throughout in the region. Dunes on the Chesapeake Bay shoreline currently found along the lower Rappahannock River and in the lower Bay near and in Virginia Beach are also likely to migrate similarly to, though not as extensively as, those along the Eastern Shore, with the exception of those near the mouth of the Bay in the south Hampton Roads region. These dunes are much smaller in extent than those found in the more coastal regions of Virginia, including the Eastern Shore, First Landing State Park, and Back Bay National Wildlife Refuge, which range from the northern border of Virginia to the border with North Carolina, respectively.

- Barrier islands naturally migrate towards the mainland coastline naturally over time. Natural processes often create new barrier islands via longshore sand transport to replace those lost to inland migration, though not always. As shorelines are armored with groins and jetties, longshore transport processes are disrupted, which can inhibit sand deposition that could potentially form new barrier islands. This, along with general sea level rise effects, will reduce or prevent new barrier islands from forming in many areas. Modeling projections show a majority of the barrier islands will be lost by 2100 (0.69 m of global sea level rise) or near total (1.0 m sea global level rise). Due to local subsidence, higher local sea level rise is expected, making higher sea levels (0.69 -1.0 m by 2100) more likely locally. If the barrier islands are lost, survival of nearshore wetlands currently protected by these islands will be in jeopardy. Besides the physical protection the islands provide, they also provide sandy soils to the wetlands during storm events, which drive sand over the islands onto nearby inland marsh areas during storms. This addition to nearby wetlands soils will cease if the barrier islands are lost.

Wetlands—Salt, Brackish, Fresh, and Tidal Mud Flat

- Freshwater wetlands, including forest, blackwater swamp, emergent, and scrub-shrub, can be found throughout most of Virginia, though major acreage is predicted to be lost in the region encompassing the western shore of Chesapeake Bay and its tributaries and the heavily urbanized Hampton Roads, a major population center that lies in the southeast portion of the State. The Mobjack Bay and the Poquoson River areas are predicted to lose major acreage by 2118, under the USACE High SLR Scenario. Under the predicted scenarios, the Mobjack Bay and its tributaries will essentially cease to exist, becoming open waters of the Chesapeake Bay, due to inundation of mostly wetlands and low-lying riparian habitat. Smaller losses are predicted along the shoreline of the York River area. The two major tributary rivers that flow together to create the York River, the Mattaponi to the North and Pamumkey River to the South, are both expected to undergo significant inundation by 2118 under the USACE High SLR scenario, especially the Pamumkey, which has significant wetland acreage lining its shores. Along the York River, significant losses of wetlands are predicted along most of its shoreline, especially the northwest segment though the southwest, but one reach along the southeast shore, approximately 12 km long, is not expected to lose extensive land area. The rest of the York, however, will experience significant land loss along its shoreline due to expected sea level rise under the 2068 and especially the 2118 USACE High SLR scenarios. Smaller losses are predicted for the lower James River and along the rest of the Virginia coast, due mainly to these habitat types being more rare and limited in acreage in these reaches. The largest such losses for the James are expected to occur in the Chickahominy river, a small tributary river that flows into the James along its northwestern shore of VA-2.

- Along the shores of the James River, the largest tributary river of Chesapeake Bay in Virginia, some areas, particularly the southern shore, are not expected to experience much land loss due to sea level rise. Losses are expected to be much more significant along the Northern shoreline of the James River, which includes the expected loss of Mulberry Island, which consists of mostly estuarine wetlands and maritime forest. Mulberry Island also constitutes most of the training grounds of Fort Eustis. The nearby Hog Island Wildlife Management area, which lies on a peninsula just upriver of Fort Eustis, is also expected to be inundated, as is Jamestown Island and the Colonial Parkway roadway that lies immediately northeast of the Island, connecting it to the mainland. The Northern Neck of Virginia's western Chesapeake region holds freshwater wetlands of particular note along the Piankatank River, the Dragon Run reach of blackwater swamp and forested wetlands, much of which are undisturbed. The Dragon Run region of the Piankatank, currently held in trust by TNC as one of the most pristine, undisturbed reaches of any river in the Chesapeake Bay region, will be partly converted to open water under the 2068 and 2118 scenarios, resulting in a much wider river than in this reach at present with concomitant loss of wetlands. Blackwater swamps, which this area has in abundance of, are the largest remaining such riverine habitat in Virginia and will be lost. Gywnn's Island, which lies at the southern mouth shoreline of the Piankatank River, is expected to be lost due to SLR under the 2118 scenario.

- The south Hampton Roads region, which is heavily urbanized, does hold significant palustrine forested wetlands acreage within First Landing State Park, portions of Back Bay National

Wildlife Refuge that extends westward along the southern edge of the City of Chesapeake, and in undeveloped land within Fort Story that is predicted to be mostly lost under the 2068 and 2118 scenarios. Along the Eastern Shore, both bayside and seaside, significant losses of estuarine marshland are expected due to conversion to open water with little conversion of upland to marsh to replace it. In other regions of interest, including the lower western shore of the Bay and Hampton Roads, it is expected that marshlands will increase significantly in extent due to conversion of uplands to wetlands, mainly due to rising sea levels. Under the no action scenario, it is predicted that there will be extensive losses of freshwater marshlands within the region that could be impacted by storms similar to hurricane Sandy and is subject to impacts from SLR, which will raise the water level in the Bay and its tributaries. This is not a habitat type with extensive acreage (found in small amounts in freshwater upriver reaches along the western tributaries of Virginia's Chesapeake Bay), in comparison to estuarine marshlands. This makes it particularly vulnerable to impacts related to climate change, including SLR and storm events.

- Under most predictions, it is expected that there will be significant losses of tidal mud flat habitat throughout the state due to conversion to deeper water without replacement due to impacts from SLR and increased storm activity within the region. This will be especially true near developed areas that have natural shorelines. As land is lost, property owners will employ hard shoreline protective measures that will prevent conversion near any developed areas. This is likely to be most extensive in the Hampton Roads region. These losses of wetlands are extensive within tributary rivers of Chesapeake Bay, particularly in areas that introduce curves, meanders and oxbows. The loss of wetlands in these reaches will essentially straighten many of the Bay's tributary rivers, increasing their flow speed and making the river bottom more channelized and uniform. This will significantly and negatively alter the habitat quality of the rivers. Species that require wetlands and slower moving waters are likely to decline. TSS is likely to increase due to increased water speeds as well as the erosion and land loss expected in the 2068 and 2118 USACE SLR scenarios. While SLR will increase the salinity in the rivers as well as drive the salt wedge further upriver, the loss of wetlands, meanders and increased channelization of the rivers, along with expected increased storm activity, will likely mean more powerful freshets, which can kill downriver estuarine organisms. Oysters, which cannot move, are particularly vulnerable to freshets, and these may restrict the upper reaches that oysters can survive to more down-river reaches, even though salinities further upriver could support them.

SAV and Open Shallow Water Habitat

- There are two species that can live in the high salinity waters that cover most of the region of interest, *Ruppia maritima,* widgeongrass and *Zostera marina*, eelgrass (VA1-7). They are typically found in waters no deeper than – 6 ft MLW with salinity of at least 5 ppt. Under the no action scenario, it is expected that rising water temperatures coupled with increased turbidity due to erosion of local shorelines and sheltering natural structures (such as the seaside Eastern Shore barrier islands and Tangier Island) will result in severe losses of eelgrass. Widgeongrass, a more environmentally tolerant species, may gain in acreage though there are no modeling predictions to assess this at this time. It is also possible that a more southern species with similar appearance and function to eelgrass, *Halodule wrightii*, whose current northern limit is approximately 75 miles south of the Virginia border, may migrate north and into Chesapeake

Bay. Due to the sub-tropical/tropical temperature preference of *Halodule* sp., it is unknown when this might occur, and if it does, how extensive it might become in Chesapeake Bay. However, based on current water temperature predictions, if it does migrate into the Bay it will likely be restricted to its warmer, southernmost waters.

- Within the region of Virginia influenced by Hurricane Sandy, waters are mostly estuarine and tidal. Freshwater riverine habitat that could support freshwater SAV is rare in the area and little of this type of SAV is found in the region included in the current study.

- Predicted impacts under the USACE SLR high 2068 and 2118 scenarios are described as follows, starting from northwest Chesapeake Bay to Hampton Roads, then along Virginia's Eastern Shore.

- The Great Wicomico River holds considerable SAV beds, with smaller beds found in tributary rivers of the Potomac. Due to expected inundation along the Potomac/Great Wicomico Region, this river will experience major modifications under the 2068 and especially 2118 scenarios. Most of what is now the Great Wicomico River will be part of Chesapeake Bay. Due to the large increases in wave energy, currents, and storm surges, it is expected that the SAV habitat currently in these rivers will be lost. SAV may expand into new, more saline waters upriver, but due to the lack of large, sheltered estuarine waters as is currently found in these two rivers, it is expected under the Future Without Project Condition that SAV acreage will be lost, and this lost will be significant.

- Moving south, there are extensive SAV beds in the Piankatank River as well as smaller beds in the lower Rappahannock River. Due to increasing water temperatures, eelgrass populations are in jeopardy and may be extirpated from the Bay and its tributaries in coming decades. SAV will likely decrease in extent by 2068 and 2118, unless sub-tropical species such as *Halodule* expand their range northward and colonize the lower Chesapeake Bay.

- Extensive SAV beds can be found in the Poquoson River area, with smaller beds in the York River and Mobjack Bay. All of these SAV beds will be in jeopardy under predicted scenarios for 2068 and 2118. Increasing water temperatures may extirpate one of the two species, eelgrass, found in this area, while inundation and increases in sedimentation due to land loss and erosion along with concomitant increases in wave energy, may reduce in area current beds of the more environmentally hardy widgeongrass.

- Further south along the western shore of the Bay, there can be found significant SAV beds in the lower James River. Similar to other reaches, predicted trends favor the extirpation of eelgrass, while the more environmentally tolerant widgeongrass may or may not proliferate enough to replace it. This region is far enough south that, if *Halodule wrightii*, the nearby subtropical species, may be able to become established if it ranges north as waters continue to warm.

- On Virginia's Eastern Shore, the system of barrier islands there provides sheltered shallow water that holds large reaches of currently healthy and expanding SAV beds. Due to the predicted loss of the barrier islands, it is expected that most, perhaps all, of the current SAV in this region will be lost without replacement. Along the Bayside portion of the Eastern Shore, the SAV found there may be able to migrate onto newly exposed shallow water habitat as the shoreline retreats due to predicted sea level rise and erosion. For Bayside SAV populations, it is likely that some SAV will remain, though following expected trends elsewhere, eelgrass may be extirpated and widgeongrass may become the dominant species, with *Halodule* possibly inhabiting the area if it expands northward due to rising sea temperatures.

- Considering that SAV will experience negative impacts under the future without project condition, this HAPC for summer flounder will be reduced in size and likely quality.

Coastal Protected Areas

Wildlife Refuges and Nature Preserves

- There are numerous refuges and preserves scattered throughout Virginia. Many of these will be subjected to negative impacts related to climate change according to the USACE SLR high 2068 and 2118 scenarios under the Future Without Project Condition.

- The main natural preserve in the northwestern corner of Virginia considered in the present study is the Dragon Run region of the upper Piankatank River, owned and managed by TNC. This area holds 4118 acres consisting of pristine, undisturbed blackwater swamps, as well as tidal freshwater wetlands and other forested habitat and it is expected to be severely impacted under the Future No Project Condition.

- Moving South into the Middle Peninsula region of Virginia, this region holds several large areas, including York River State Park, Colonial National Historic Park, Chickahominy Wildlife Management Area, Plum Tree Island National Wildlife Refuge and the James River National Wildlife Refuge. York River State Park lies along the estuarine portion of the York River and holds extensive wetland marsh acreage.

    - Colonial National Historic Park likes near the mouth of the York River where it meets Chesapeake Bay. It includes a number of historic sites, including Jamestown, Yorktown Battlefield, and the Green Spring Plantation, in addition to natural habitat, mainly upland though it does contain significant marshlands along the shore.

    - The Chickahominy Wildlife Management Area holds 5,217 acres of woodlands lying along the Chickahominy River. These woodlands are primarily uplands, though the river is lined with marshlands.

    - The James River National Wildlife Refuge is 4,325 acres in size and lies along the tidal oligohaline (0.5 – 5 ppt) portion of the James River. It is an important area for a wild variety of native bird species, and anadromous fish including various shad species, yellow perch, striped bass and the Federally Endangered Atlantic Sturgeon can be found in its nearshore waters. The sturgeon is known to spawn in the James River and there are efforts to improve its spawning habitat and increase the local population of sturgeon in the James.

- The Chickahominy Wildlife Management Area, out of all the sites within this reach, appears the least vulnerable to climate change and storm impacts, though passing hurricanes can inflict major damage to the forested areas if powerful enough.

- Plum Tree National Wildlife Refuge lies along the shoreline of Chesapeake Bay near the Poquoson River, which flows through it. It is comprised of 3,501 acres of saltmarsh, scrub-shrub and maritime forest habitat. Much of the refuge consists of very low-lying lands, where it is not marsh, leaving it vulnerable to climate change related sea level rise and increased storm activity. Unlike other refuges, this Plum Tree is almost entirely closed to the public due to its former use as a bombing range and resultant unexploded ordnance issues. It is also part of the Atlantic Flyway for migratory birds, which heavily utilize the refuge during annual migrations.

- The other sites all lie along major rivers and are tidal. Storm surges and other storm related impacts could inflict significant damage to any of these sites, as all of them consist of varying amounts of marshlands and low-lying upland. Climate change will likely render the waters bordering these sites more saline, altering the species composition, as well as leading to a loss of land due to increase erosion and conversion of land to open water. For Plum Tree Island, it is expected by 2118, this area will be completely inundated under the USACE High SLR scenario. The lower James River, the western border of the Hampton Roads region, holds the Nansemond National Wildlife Refuge, lying along the Nansemond River. It is a small refuge holding 411 acres of mostly estuarine salt marsh. It is not open to the public. It is expected to be partly converted to open water under the 2068 scenario and fully converted to open water under the 2118 scenario. The Hampton Roads holds Bayville Farms Park and First Landing State Park. Bayville is a small park encompassing 68 acres, 20 of which are used for a 20-hole disc golf course. The remainder of the park also has extensive recreational areas, some of which are developed athletic fields. There are natural resources, however, only birds, small mammals, reptiles and amphibians use these semi-developed habitats. First Landing State Park contains 2,888 acres of undeveloped land, most of which is maritime forest, estuarine wetlands and dune/beach habitat. While there are hiking trails, the park is maintained as natural habitat and it is one of the largest undeveloped areas along Virginia's coastline. It is one of the few sites in Virginia where the Federally Endangered (Northeast Atlantic subpopulation) loggerhead sea turtles nest. Due to the loss of habitat under the 2068 and 2118 scenarios, the Future Without Project Condition for these areas is near-total loss. Only a small area of upland in First Landing State Park is predicted to remain, it would be a barrier island under the predicted scenarios, with the rest of the park converted to open water.

Critical/Significant Habitats

Waterbird Islands

- There are no islands exclusively used by waterbirds in Virginia, though a number of them along the seaside Eastern Shore, Tangier Island, Gwynn's Island off the Piankatank River, and Craney Island do provide good nesting sites. Also, small islands associated with the various tunnels that run along the bottom of Chesapeake Bay are heavily used by seabirds as nesting habitat. A wide variety of seabirds, including species such as terns that require sandy shoreline habitat with few, if any, terrestrial predators utilize most of these sites. Under the Future Without Project Condition, much of the island habitat along the seaside Eastern Shore will be lost due to sea level rise and more severe storm activity associated with climate change. Small man-made islands associated with the tunnel system will likely be built up with stone to maintain their integrity as sea level rises. This may or may not impact the birds nesting there, though they will likely remain usable by the seabirds as nesting habitat. The Craney island dredged material disposal site is likely to be maintained, as there will be continued needs to dredge local shipping channels and this site will remain a preferred disposal area. Gywnn's island is likely to experience significant losses in land area due to expected climate change trends, which will reduce its utility for waterbirds. The barrier islands along Virginia's seaside Eastern Shore, which are important to waterbirds, are discussed in detail in the following section, as they are a managed refuge.

Essential Fish Habitat (EFH)

- EFH under the Future Without Project Condition, is likely to shift significantly for a number of species due to changes in the salinity profile of Chesapeake Bay and its tributaries due to sea level rise (Rice et al. 2011). Additional changes to EFH are expected due to rising sea temperatures. Some commercially important species that use the Bay, such as striped bass, are experiencing significant physiological stress due to higher water temperatures coupled with deep water hypoxic zones, which prevent the fish from inhabiting deeper, cooler water. The recently listed Atlantic sturgeon has a remnant breeding population in the James River. This cool water fish may, similar to the striped bass, experience significant thermal stress in the Bay and the James River, which holds its spawning grounds, due to rising water temperatures. Species profiles within the Bay will change due to changes in temperature and salinity, with cold-water species being marginalized and possibly extirpated from the Bay while southern, warmer water preferring species will range northward, perhaps becoming permanent instead of seasonal residents in the Bay. These species include southern flounder, *Paralichthys lethostigma*, cobia, *Rachycentron canadam*, spadefish, *Chaetodipterus faber*, Spanish mackerel, *Scomberomorus maculates*, mullet, *Mugil curema*, and many sub-tropical drums (*Sciaenidae*) such as black drum, red drum, weakfish, spot, spotted sea trout, and southern kingfish. Cold water species that are expected to be negatively impacted include yellow perch, Centropomis fulvenscens, white perch, tautog, *Tautoga onitis*, black sea bass, *Centropomis striata*, summer flounder, *Paralichthys dentatus*, winter flounder, *Pleuronectes americanus*, silver hake, *Merluccius bilinearis*, and scup, *Stenotomus chrysops*. Summer flounder will likely have their HAPC, SAV beds, reduced, as well as experience negative impacts due to rising water temperatures. Red drum, which have HAPC in the shallow bays of the lower Eastern Shore, will likely have their habitat reduced due the loss of the barrier islands, which will significantly alter the habitat of this region. Migratory alosids, including striped bass and shad as well as American eels, will likely migrate upriver sooner as water temperatures warm (a trend already being observed in some shad species), and eggs may hatch earlier. This may result in a de-coupling of newly hatched larvae and the spring phytoplankton bloom, which, via grazing zooplankton, provides critical early nutrition to the fish larvae. Reproductive success of alosid species is likely to be reduced under predicted conditions if current trends in climate change continue unabated.

Atlantic Flyway

- Millions of birds utilize the coastal route, which lies along Virginia's Eastern Shore. It is a major attraction for birders during the annual bird migrations north and south along the Flyway. The numerous bird species utilizing the Atlantic Flyway migrate along Virginia's Eastern Shore, with many species using the barrier islands and nearshore habitat, which includes estuarine wetlands, maritime forest and uplands, as feeding and resting areas, especially the islands. These habitats are all likely, based on projections of increased storm activity and sea level rise, to experience major losses, especially along the southernmost regions and to the barrier island system, as described. This will reduce the ability of these lands to provide the ecological services they currently provide as critical stop-over habitat for birds on the coastal portion of the Atlantic flyway prior to the migration across the Chesapeake Bay to points further south. As a result, bird species that utilize this migratory pathway will experience additional stress due to lack of food and rest because of the extensive habitat loss expected and a significant drop in their numbers.

Threatened and Endangered Species/Species of Concern

Fish

Atlantic Sturgeon

- Future conditions are an increase in salinity due to rising sea level, increased water temperatures, and concomitant alterations in habitat. Atlantic sturgeon are likely to be negatively impacted by these changes. The sturgeon is known to spawn in the James River and there are efforts to improve its spawning habitat and increase the local population of sturgeon in the James. Spawning sites will move upriver, possibly into soft sediment habitats or waters too shallow and warm for sturgeon to breed successfully. The warmer water will also stress migrating adults and juveniles, which prefer colder waters.

Shortnose Sturgeon

- Future conditions for the shortnose sturgeon are relatively unknown for Chesapeake Bay. The current remnant population has not been documented to breed in the Bay or its tributaries, the present population appears to consist of adults and large juveniles that migrate into the Bay through the Delaware Canal. They are naturally found ranging into warmer waters than the Atlantic sturgeon and may not be as impacted by expected increases in temperature, however, they may experience loss of current spawning habitat due to changing salinity in rivers where they spawn. Similar to Atlantic sturgeon, they prefer to spawn on rocky, soft sediment free bottom areas above the tidally influenced portion of rivers where they are found.

Alewife/Blueback Herring

- Under the Future Without Project Condition, it is expected that these fish will have their migration patterns altered by higher salinity waters moving further upriver into Chesapeake Bay tributaries due to rising sea level. Another possible impact is that the timing of the spawning season may be altered due to warmer water temperatures, which may decouple the newly hatched larvae from spring plankton blooms that they are dependent on for their early growth.

Shad

- Under the Future Without Project Condition, it is expected that these fish will have their migration patterns altered by higher salinity waters moving further upriver into Chesapeake Bay tributaries due to rising sea level. Another possible impact is that the timing of the spawning season may be altered due to warmer water temperatures, which may decouple the newly hatched larvae from spring plankton blooms that they are dependent on for their early growth. Shad have been found to be negatively correlated with rising sea surface temperatures (O'Conner et al. 2012) in the Hudson River estuary. They will likely experience similar, negative impacts to their numbers in Chesapeake Bay due to expected trends of rising sea temperatures.

American Eel

- The American eel is a catadromous fish, living most of its life in freshwater but returning to the ocean to spawn. It is expected that these fish will have their migration patterns altered due to greater penetration upriver by higher salinity waters as sea level rises. This will likely constrict the habitat of eels, which could reduce their numbers.

Marine Turtles

Loggerhead Turtle

- Storm events that affect tides and move sand can be severely detrimental to nesting success of this species. These types of storm events are predicted to occur more often under the Future Without Project Condition. Damage to beaches by storms or generalized thinning of beaches due to sea level rise may reduce the amount of nesting habitat for this species locally. One potential benefit locally to sea turtles is the expected increase in water temperatures may increase the numbers of turtles locally, as well as increase the numbers of egg-laying females and associated number of nests along the Virginia coastline. Turtles have been documented to nest along the Eastern Shore, Virginia Beach, First Landing State Park and Back Bay National

Wildlife Refuge's coastal beach habitat. This is the current northern limit for nesting for this species.

Green Turtle

- Hurricanes in late summer or fall may negatively affect an individual if it is in open water during the event. These types of storm events are predicted to occur more often under the Future Without Project Condition. Additionally, warming waters may reduce the amount of *Zostera* seagrass that is the primary local food source for this species.

Kemp's Ridley Turtle

- This species doesn't nest in Virginia but juveniles will use the Chesapeake Bay. Major storm events could disrupt feeding. These types of storm events are predicted to occur more often under the Future Without Project Condition.

Marine Mammals

- The North Atlantic Right Whale, Humpback Whale, Fin Whale- Major whales found along the Virginia shore; storms probably don't affect these species. In Virginia, it is unlikely that the Future Without Project condition will have much of an impact on these whales, as they are intermittent and migratory through local waters.

Birds (Nesting)

- Species include the Piping Plover/Least Tern/Roseate Tern/Red Knot. In the Future Without Project Condition, most of the existing barrier island habitat in Virginia will be lost in the next several decades. Significant wetland acreage will be converted to open water. This species, part of the avian assemblage that uses the coastal Atlantic Flyway, will likely be severely negatively impacted due to loss of these important stopover grounds where the birds rest and feed before continuing their annual migrations along the coast.

Shellfish/Shellfish Beds

Oysters

- Oyster reefs in the region included in the current study are both subtidal and intertidal, with the intertidal reefs consisting of oysters that have colonized shoreline protective structures and various shallow water restoration sites. The restoration sites are found mostly along the seaside Eastern Shore at this time, though small reefs of this type are being constructed in the Hampton Roads area by various environmental groups at the time this study is being written. Increased sedimentation due to increased storm events and intensity coupled with erosion due to rising sea levels will likely have negative impacts on the small, remaining oyster population. Remnant reef habitat could be covered by sediment, and increased salinity may bring increased predation on the oysters due to expansion of the range of major predators such as black drum fish and the cow-nose ray.

- Under the Future Without Project Condition, oysters may continue to experience a slow increase in abundance, though the threat of habitat and population loss due to overfishing will remain. Additionally, it is likely that most remnant habitat not being actively maintained as put-and-take public fishery or sanctuaries will be lost lost because current population densities on much of this habitat is too low to supply sufficient shell to maintain it. This amounts to thousands of acres, and is the majority of the current oyster habitat in Virginia. Impacts due to increased storm activity may drive oysters further down tributary rivers due to increased number and severity of freshets. The resulting increases in sedimentation may also cause loss of marginal oyster habitat by burying it in sediment. Predicted land losses under the 2068 and 2118 scenarios will significantly impact oysters. The Great Wicomico and Piankatank Rivers, whose configuration allows them to retain larvae at high rates, will be altered due to land loss such that these rivers will become part of the open Bay. They will lose their ability to retain larvae, and their associated status as important seed oyster rivers and likely their ability to be locally self-sustaining populations. Mobjack Bay and its tributary rivers will suffer similarly, predicted land losses will completely alter the character of this region, transforming it from a sheltered embayment and tributary rivers to open waters of Chesapeake Bay. The lower James River's hydrodynamics also allow for oyster larvae to be retained and moved upstream with tidal action. The land configuration that causes this will be lost due to inundation of nearshore habitat in Hampton Roads and along both banks of the lower James. This will significantly alter the James River's oyster population dynamics, decreasing oyster recruitment and as a result this population will likely decrease in numbers. . Dual-purpose fish/oyster reefs proposed in the Lynnhaven River (U.S. Army Corps of Engineers 2013), will become exposed to Atlantic ocean waters and likely lose the oyster population due to introduction of oceanic predators, such as starfish. Ocean acidification is a concern, as it is for all Bay bivalves. It is expected that the pH of the oceans worldwide will continue to drop in pH due to climate change. Increased temperature and salinity will bring both positive and negative impacts. One potential positive benefit due to rising temperatures will be increased survival rates of intertidal oysters, many of which are killed by freezing over the winter. If winter kills cease to occur, the intertidal population could significantly expand, perhaps aiding in population recovery (Hines et al. 2010). Other positive benefits will include faster growth rates and increased fecundity, while disease and predation pressures may both be increased.

Blue Crabs

- There are potential positive and negative impacts to blue crabs in Chesapeake Bay under the Future Without Project Condition. Positive impacts include increased foraging and growing seasons for both adults and juveniles, and increased reproductive output due to increases in water temperature (Hines et al. 2010). Negative impacts include changes in larval recruitment into the Bay due to shifting oceanic currents and increased storm activity during the summer when larvae are in nearshore oceanic waters. If nearshore currents shift significantly, this could be a major impact on blue crab larval survival. *Zostera* seagrasses are predicted to be reduced in extent due to increased water temperatures, seagrasses provide important nursery habitat for juvenile blue crabs. Increased storm activity may increase sedimentation into the Bay, and expand the Bay "dead zone" of hypoxic waters, which will reduce both the habitat quantity and quality for blue crabs in the Bay. *Macoma balthica*, a small non-commerical bivalve, is a major prey item of the blue crab and near their southern range limit in Chesapeake Bay. Warming waters may extirpate the Bay population of these bivalves, which will significantly reduce the prey available to the blue crabs. Warming waters will also bring additional predators on blue crabs into the Bay, which could significantly reduce their numbers. Overall impacts to blue crabs under the Future Without Project Condition appear to be negative.

Blue Mussels/Softshell Clams

- Both of these species are at the southern end of their range in Virginia, being found in much larger numbers in more cooler, northern waters. Rising sea temperatures may extirpate the softshell clam and blue mussel from Virginia waters (Jones et al. 2010). Under the Future Without Project Condition, this is very likely to occur in the future within the next 50-100 years.

Bay Scallop

- Under the Future Without Project Condition, the Eastern Shore scallop population would be endangered by the loss of barrier island landmass, which would expose the coves and embayments to increased oceanic currents and wave energy. Populations in the Bay, should they become established, could possibly expand in range due to increased salinity. However, all bay scallops could be endangered by the loss of SAV due to warming waters. However, more southern species serve as scallop habitat, primarily *Halodule wrightii.* This SAV species current northern limit is in waters of Dare County, North Carolina, which lies approximately 75 miles south of Virginia could move northward as water temperatures warm and colonize the southern extent of Chesapeake Bay. If this occurs, this could ameliorate the loss of local *Zostera* seagrass. Overall, however, impacts are expected to be negative as the primary bay scallop population would be located along Seaside Eastern Shore and therefore more vulnerable to expected impacts from increased storms and climate change.

Surf Clam

- Under the Future Without Project Condition, nearshore beach habitat will decline in extent, reducing the habitat for this species. Additionally, increased storm activity will disrupt the shallow sandy bottom habitat these clams prefer, causing mortality. Impacts to this species are expected to be primarily negative.

Sea Scallops

- There is a significant sea scallop fishery in Virginia's coastal oceanic waters, now one of the most profitable fisheries along the East Coast, with current landings in Virginia worth well over 50 million dollars. The sea scallop is typically found from depths ranging from 50-350 feet (most common from 130-230 feet), tending towards deeper waters, which are cooler, as the animal ranges from the Gulf of Maine to the Virginia-North Carolina border. In Virginia, this means the scallops are typically found in deeper waters offshore on the continental shelf. Due to the depths these scallops are found at, it is expected that only severe storms would directly impact them. It is expected that these types of storms will increase in frequency due to climate change. Impacts from storms could be more severe on their planktonic larvae and newly settled juveniles, which are vulnerable to strong currents and shifting sands, respectively, which could significantly reduce recruitment (Hart and Chute 2004).

Cultural Resources

- Sea level rise impacts to cultural resources range from increased tidal and wave erosion to inundation. Cultural resources within coastal zones will be subjected to gradual sea level rise impacts exacerbated by event-specific impacts such as high tide events and storms. The frequency and intensity of damage from event-specific impacts is expected to increase as sea level rises (Karl et al. 2009). In addition, high regional subsistence rates are expected to increase rates of sea level rise and associated impacts (Johnson 2000).

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10. Cultural and Tribal Resources - North Atlantic Coast

I. Study Area Overview

The Study Area includes a variety of historic properties including architectural properties, archaeological sites, historic buildings and structures, and submerged historic properties (shipwrecks and inundated archaeological sites) which are discussed in this section of Appendix P. Please note that the level of detail, accuracy, and usefulness of information used in this report varies from state to state and there may be uncertainties with regard to both historic properties and GIS data.

More information on cultural resources can be obtained directly from each of the States. In addition, each State has a *Historic Preservation Plan* that can be used when planning projects.

National Register and State Historic Sites

Each state has a listing of historic properties that have been formally nominated to the National Register of Historic Places (NRHP) under a process defined by the Department of Interior, National Park Service. Properties listed in the Register include districts, sites, buildings, structures, and objects that are significant in American history, architecture, archeology, engineering, and culture. The National Register is administered by the National Park Service, which is part of the U.S. Department of the Interior. Additionally, there are properties that are listed on each state's register of historic sites that may or may not be listed on the NRHP.

Please note that the NRHP listings only include historic properties that have been formally evaluated and nominated to the NR. However, these are not the only properties afforded consideration under the National Historic Preservation Act (NHPA). Under Section 106 of the NHPA any historic property that has been determined eligible for the NRHP, even if the said property has not been formally nominated, must be taken into account during project planning and review with the same protection as a listed property. The vast majority of NRHP eligible historic properties are not listed on the NRHP; many are evaluated as part of Federal undertakings and usually in coordination with the respective State Historic Preservation Officer.

Areas of Archaeological Sensitivity

Terrestrial Sites

- In general, archaeological sites are typically in proximity to a water source and/or navigable stream or river. Sites are frequently located along the coast due to the available of fish and shellfish and also for purposes of travel and trade. Shell middens found along the shore are essentially trash deposits of discarded shells and other organic material that can be studied to determine subsistence practices of Native peoples. During the winter, many sites were located inland, again along a stream/river or water source with an abundance of game and wild animals.

- Generally, coastal areas and floodplains along navigable waters have the highest potential for archaeological sensitivity. Sites are generally level and with good drainage properties. However, the degree of disturbance must always be ascertained whether from natural (storms, erosion) or man-made factors (modern development).

Submerged Terrestrial Sites

- The Bureau of Ocean Energy Management (BOEM), formerly the Minerals Management Service of the Department of Interior recently commissioned a study of the Outer Continental Shelf (TRC Environmental Corporation 2012) that examined the sensitivity and presence of both shipwrecks and Native American archaeological sites in a study area stretching from the Gulf of Maine to Florida. The BOEM study provides numerous archaeological sensitivity maps and the locations of shipwrecks throughout the NACCS project area.

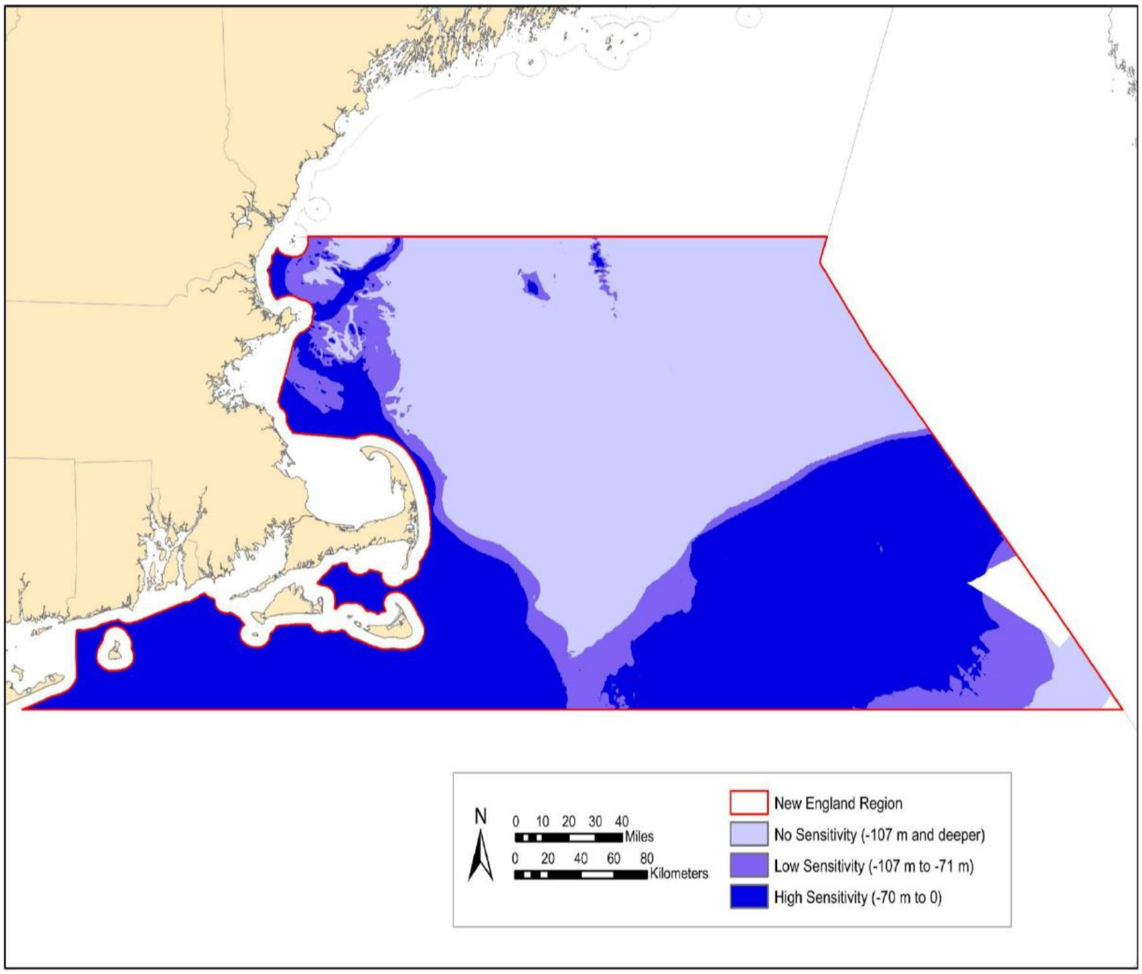

Figure 10-1 Submerged Terrestrial Archeological Sensititiy Map for the South New England Georges Bank Region (TRC Environmental Corporation 2012)

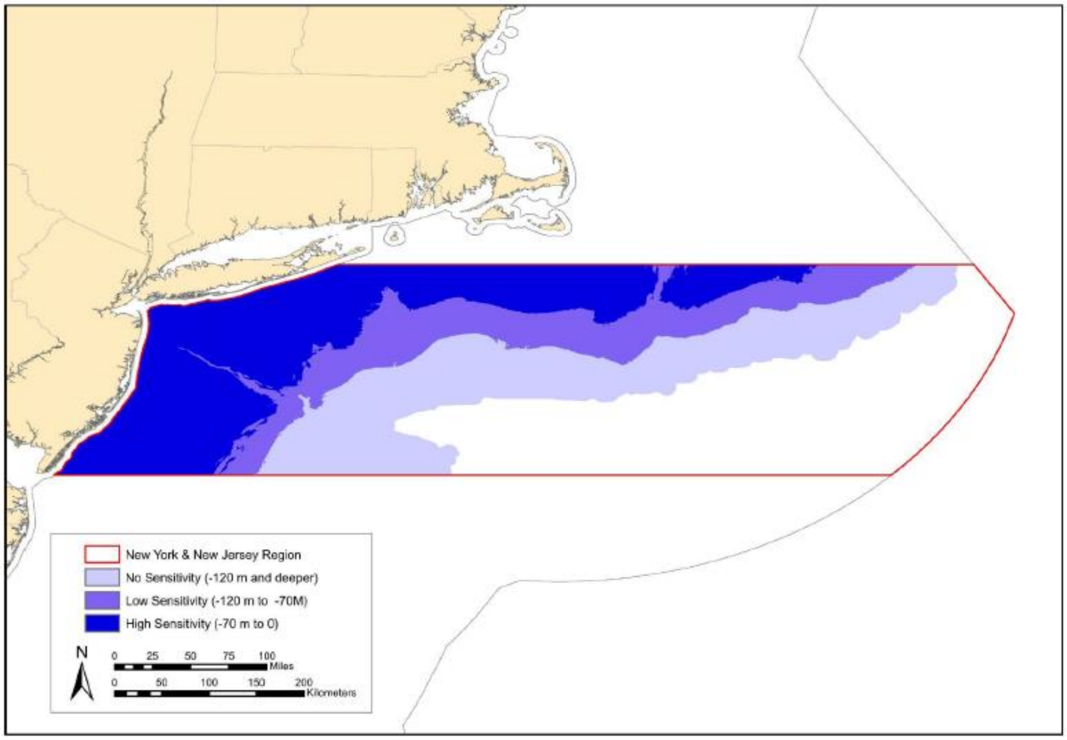

Figure 10-2. Submerged Terrestrial Archaeological Sensitivity Map for the New York and New Jersey Areas (TRC Environmental Corporation 2012).

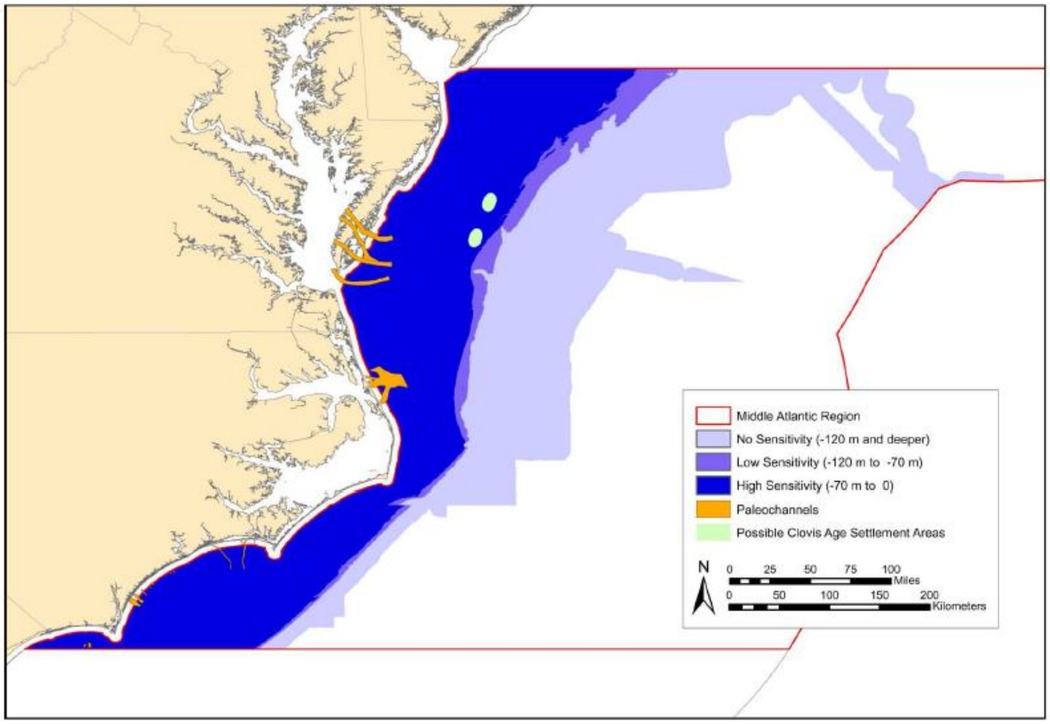

Figure 10-3. Submerged Terrestrial Archaeological Sensitivity Map for the Delaware, Maryland, Virginia, and North Carolina Areas (TRC Environmental Corporation 2012).

Shipwrecks

- Shipwreck data for the study area has been acquired over the years from a variety of primary and secondary sources including NOAA's Office of Coast Survey AWOIS database (Automated Wreck and Obstruction Information System Database: http://www.nauticalcharts.noaa.gov/hsd/awois.html), the Global Wrecks database (a commercial shipwreck inventory compiled by General Dynamics, and the BOEM shipwreck database. The 2012 BOEM study was an attempt to update and refine the existing information and provide more defined location and sensitivity mapping. In addition to the archaeological sensitivity mapping in the BOEM report described above, there are also shipwreck locational and sensitivity maps for the study area.

- BOEM also provides a distribution of shipwrecks by state and region that is helpful in characterizing the extent and distribution of submerged sites within the study area both by state and region.

- Some general remarks can be made regarding the distribution and location of shipwrecks from BOEM's research. The vast majority of wrecks are located within 50 miles of shore, with the greatest concentration off the coast of New Jersey, Delaware, and Maryland. Significant clusters were identified around Cape Cod, the entrance to Chesapeake Bay, the North Carolina capes (Hatteras, Lookout, and Fear), and the entrances to the Savannah and St, John's rivers (outside of the NACCS study area). The farther from shore, the more widely distributed wrecks were located although notable concentrations are found around the Georges Bank fishing grounds and off Cape Hatteras (TRC Environmental Corporation 2012).

- Two maps from the BOEM study are relevant to the present NACCS project are reproduced here. The first (Figure 10-4) depicts the relative location of shipwrecks along the Atlantic Seaboard based on all data sources. The second (Figure 10-5) stratifies the study area into zones of high, medium, and low potential for shipwrecks based on shipwreck density and geographic factors which were discussed above.

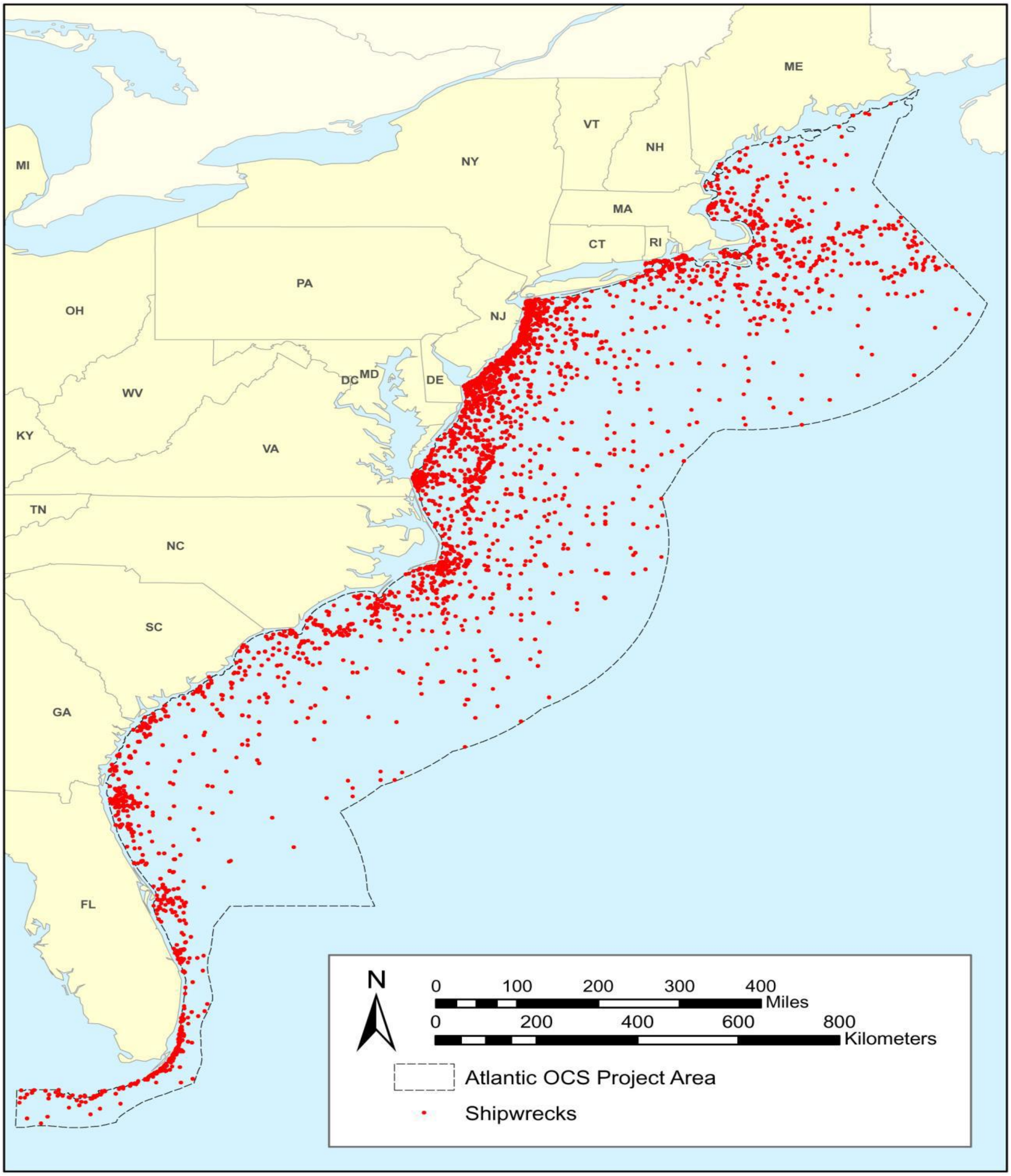

Figure 10-4. Location of shipwrecks with coordinate data from all sources in the ASD (TRC Env. Corp. 2012)

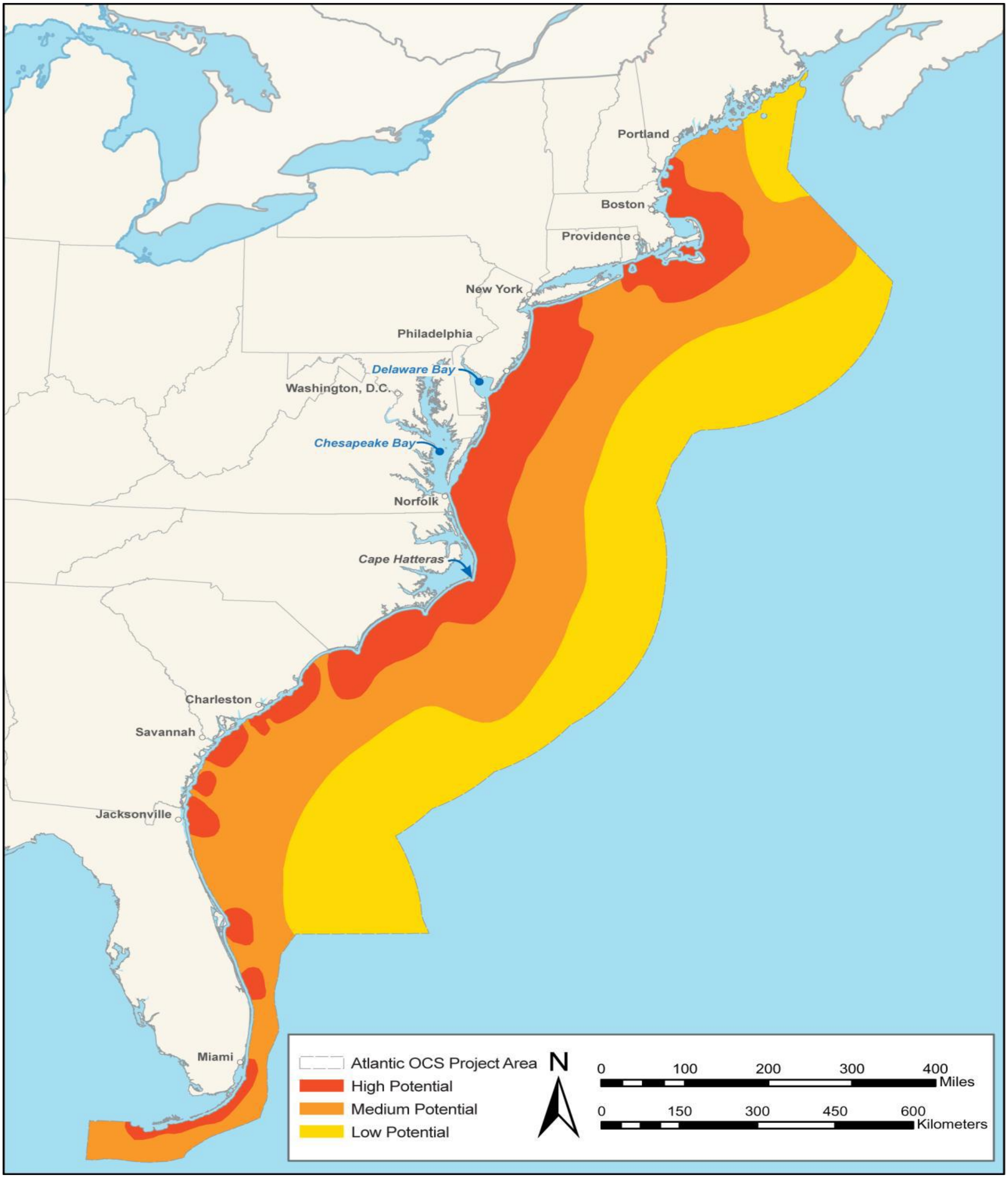

Figure 10-5. High, medium, and low potential for shipwrecks in the Atlantic OCS (TRC Env. Corp. 2012)

Summary of Historic Properties in the Study Area by State

New Hampshire Cultural Resources

The earliest archaeological sites in New Hampshire date from as far back as 12,500 to 13,000 years ago according to the New Hampshire State Historic Preservation Office. Occupation and settlement evidence are present for all periods prior to and including European Contact and to the present. Settlement began during the early 17th Century along the seacoast with earlier encounters with traders and Native Americans occurred even earlier. According to the State Historic Preservation Plan, European populations in the 18th Century quickly displaced Native peoples and are represented throughout the state's archaeological record (New Hampshire Division of Historical Resources 2010).

There are approximately 126 NRHP properties in Rockingham County which is the county most affected by the hurricane (Reach NH 1). Of this total, 41 are located in the City of Portsmouth including the Strawberry Banke Historic District and Museum, an outdoor history museum in downtown Portsmouth that preserves life in the community dating back to the 17th Century. There are 12 properties in the study area in New Hampshire that are National Historic Landmarks (NPS 2013a). These include the USS Albacore, a Navy research submarine built in and currently housed at the Portsmouth Maritime Museme that served in the Pacific during World War II; and the Robert Frost Homestead and Historic Site in Derry, home of the famous American poet.

Massachusetts Cultural Resources

Historic properties in Massachusetts range from Native American archaeological sites as far back as 10,000 years old to Colonial period settlements and fortifications, industrial sites, to more recent 20th Century military installations. The coastal communities affected by Hurricane Sandy have a rich legacy of Native American settlement, European influences from the establishment of Plymouth, Massachusetts Bay (Boston), and Salem, and more recent historic and military usage. Areas such as the Boston Metropolitan Area, the North and South Shores of Massachusetts, Cape Cod and the islands of Martha's Vineyard and Nantucket, and the south coastal areas that border Rhode Island have a wealth of historic properties and are also the areas most affected by the Hurricane (Reach MA 1-6).

Historic Properties

- There are over 5,000 NRHP properties within the state of Massachusetts. The majority of these historic properties (app. 3,200) are within the 9 coastal counties impacted by Hurricane Sandy. The Cape Cod National Seashore's Marconi Site in Wellfleet (Reach MA 5) is the location of the first transatlantic wireless communiciation between the US and England in 1903. Nearby is the former Camp Wellfleet, an artillery training facility that was later transferred to the National Park Service. Numerous historic districts and lighthouses are located in the coastal counties and are either listed on or eligible for listing on the NRHP. The remaining counties not included are located in central and western Massachusetts. There are 156 National Historic Landmark properties in the NACCS study area in Massachusetts (NPS 2013a). Of note is the Boston Naval Shipyard, home to the USS Constitution and the Chain Forge Building that manufactured chain for naval vessels; the House of the Seven Gables Historic District in Salem; the Old North

Church of Paul Revere fame in Boston; a variety of lighthouses and military fortifications (Fort Independence at Castle Island, Boston), and Walden Pond in nearby Concord (Reaches MA 2 and 3). Nantucket Island, off the coast of Massachusetts, is also a National Historic Landmark.

- It should be noted that the Nantucket Sound area (MA) (Reach MA 5) has been determined by the Keeper of the National Register of Historic Places to be eligible for inclusion in the NRHP as both a significant archaeological resource and as a “traditional cultural property” of importance to the nearby Wampanoag Tribes. The Nantucket Sound seabed is characterized as the “former aboriginal lands of the Wampanoag's and the potential location for intact archaeological sites…” (TRC Environmental Corporation 2012).

- The area surrounding the Massachusetts coast is considered having “high potential” for submerged historic properties including shipwrecks. Cape Cod and the islands of Martha’s Vineyard and Nantucket Reaches MA 5 and 6) are prime areas as well.

Traditional Cultural Properties

- As noted above, the Nantucket Sound area (MA) has been determined by the Keeper of the National Register of Historic Places to be eligible for inclusion in the NRHP as both a significant archaeological resource and as a “traditional cultural property” of importance to the nearby Wampanoag Tribes. The Nantucket Sound seabed is characterized as the “former aboriginal lands of the Wampanoag and the potential location for intact archaeological sites…” (TRC Environmental Corporation 2012).

Rhode Island Cultural Resources

Rhode Island borders Narragansett Bay which opens onto the Atlantic Ocean, Rhode Island Sound, and Block Island Sound. The capital of Providence is situated at the head of the Bay and was founded by Roger Williams in 1636. Native American groups composed of Narragansetts and Wampanoags occupied the lands of Rhode Island for the last 12,000 years. Settlement was seasonal in nature with summer quarters along the coast and islands and winter quarters further inland. European Contact resulted in epidemics that killed a large number of Native Americans beginning around 1617. Further incursions into tribal lands and the loss of Native autonomy resulted in the conflict known as King Philip’s War in 1675 that pitted the colonists against both the Narragansetts and Wampanoags. Following the defeat of the tribal confederacy in 1676, Indian lands were acquired and the settlement of additional Rhode Island towns accelerated (RIHPHC 2012).

- There are approximately 800 NRHP properties within the five RI Counties impacted by Hurricane Sandy (Bristol, Kent, Newport, Providence, and Washington). Of this amount, 423 are located in Providence County and 141 are in Newport County (Reach RI 1). These properties run the gamut from historic homes, farmsteads, forts, lighthouses, industrial facilities, and maritime resources including shipwrecks. The Roger Williams National Monument is located in downtown Providence, commemorating its founder. The Blackstone River Valley National Heritage Corridor, managed by the National Park Service, documents the mills and canals along the Blackstone River that represent significant contributions to the development of the textile industry in America.

- Notable National Historic Landmarks in RI include the Block Island Light Station, Block Island; (Reach RI 2) the Breakers, Fort Adams and the US Naval War College in Newport; Old Slaters Mill (first water-powered textile mill in America on the Blackstone River) in Pawtucket, and College Hill Historic District, home of Brown University (Reach RI 1).

- The BOEM report indicates a high potential for submerged cultural resources in the waters within and surrounding the State of Rhode Island. Additionally, there are 128 recorded shipwrecks (TRC Environmental Corporation 2012).

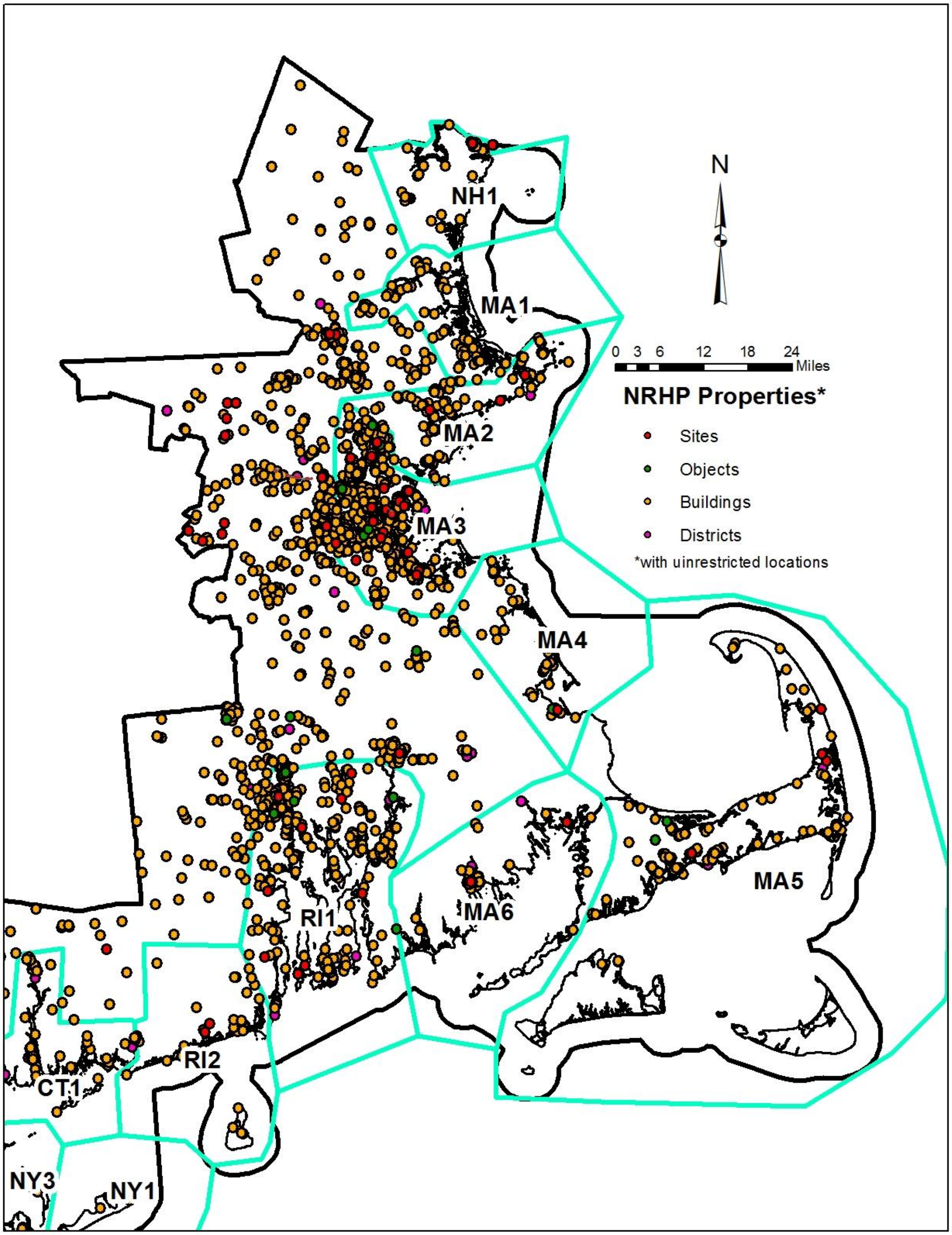

Figure 10-6 NRHP Properties in New Hampshire, Massachusetts, and Rhode Island portions of the study area.

Connecticut Cultural Resources

There are four Connecticut counties within Reach CT1, all located along the coast: Fairfield, Middlesex, New Haven, and New London Counties. The Colony of Connecticut was established by English Puritans in the 1630’s, supplanting the earlier Dutch traders. The fertile land around the Connecticut River was found to be most attractive and led to the establishment of the communities Hartford, Windsor and Wethersfield by 1635 (Thomason and Associates and The Walker Collaborative 2011). However, indigenous peoples have been present in Connecticut going back at least 10,000 years. Archaeological sites attest to the presence of these native populations from all periods up to and including European Contact. By around 1,000 years ago, Native Americans populated large coastal areas and along the major rivers (Thomason and Associates and The Walker Collaborative 2011).

Historic Properties

- Fairfield County: approximately 293 NRHP properties. Fairfield County is the westernmost of the CT coastal counties and notable communities includes Bridgeport, Greenwich, Norwalk, Stamford, and Westport. The majority of NHRP properties consist of historic buildings and districts and industrial/railroad properties. Of note is the Merritt Parkway which connects CT with New York and was built during the Works Progress Administration of the 1930’s.

- Middlesex County: 113 NRHP properties. Middlesex County includes coastal communities such as Old Saybrook, Westbrook, Clinton, and Essex along the Connecticut River. Notable NRHP properties include the Saybrook Breakwater and Lynde Point Lighthouses in Old Saybrook and the Pratt Read Company Factory Complex in Ivoryton, established in 1798 which manufactured ivory products and later specialized in the manufacture of ivory piano keys.

- New Haven County: 263 NRHP properties. New Haven County is characterized by the coastal communities of Milford, New Haven, West Haven, East Haven, Branford and Guilford along Long Island Sound. Notable properties include the Stony Creek-Thimble Islands Historic District in Branford, the Faulkner Island Lighthouse in Guilford, and the Farmington Canal, Fort Nathan Hale, University Hall and Yale Bowl (Yale University) in New Haven.

- New London County: 204 NRHP properties. New London County is noted for coastal communities that include Mystic, Groton, New London, East Lyme and Old Lyme. Historic properties of note include the USS Nautilus at the Navy Submarine Base in Groton; the Mashantucket Pequot Reservation in Ledyard; Fort Shantok in Montville, and the Mystic Seaport Musuem in Mystic (Data courtesy of the Connecticut National Register listings at the University of Connecticut, Dodd Library of Special Collections and the National Register database: http://nrhp.focus.nps.gov/natreghome.do?searchtype =natreghome).

- Of the NRHP listed properties in the study area, 34 are National Historic Landmarks (NPS 2013a). The Nathan Hale Homestead in Coventry; the Mashantucket Pequot Reservation Archaeological District in Ledyard; the Charles W. Morgan at Mystic Seaport; the USS Nautilus submarine in Groton; and the Fort Stantok Archaeological District in Montville are notable examples.

Archaeological Sites (terrestrial and underwater)

- The state of Connecticut has established a program of state archaeological preserves which are significant archaeological sites that are listed on either the National or the State Register of Historic Places and for which *in-situ* conservation is the agreed upon preservation condition. Sites on private property must have the consent of the landowner. Of the 31 total preserves, (17) are within the four counties impacted by Hurricane Sandy and are listed below. More info on the preserves can be found on the Connecticut Historical Commission website (http://www.cultureandtourism.org/cct/cwp/view.asp?a=2127&q=293854).

- Connecticut's Archaeological Preserves
    - Putnam Memorial State Park, Redding and Bethel (1/01)
    - Axle Shop-Spring Factory Archaeological Site, Hamden (2/01)
    - Fort Wooster Park, New Haven (7/01)
    - New London Engine House & Turntable, New London (4/03)
    - Aunt Polly, East Haddam (5/03)
    - Cornfield Point Light Ship LV51, Old Saybrook (5/03)
    - Air Line Railroad, Colchester and East Hampton (12/03)
    - World War II "Hellcat" Sites, Preston (11/05)
    - Henry Whitfield State Museum, Guilford (4/06)
    - Fort Griswold State Park, Groton (10/06)
    - Ebenezer Story Homestead & Tavern, Preston (10/06)
    - Fort Stamford, Stamford (10/06)
    - New England Hebrew Farmers of the Emanuel Society Synagogue and Creamery Archaeological Site, Chesterfield (Montville) (9/07)
    - CCC Camp Filley, Haddam (12/08)
    - Pine Island Archaeological Site, Groton
    - Ash Creek Corduroy Road, Fairfield (3/09)

    - West Parish Meeting House, Westport (2/10)

- For the State of Connecticut there are 13 shipwrecks recorded in the BOEM study (TRC Environmental Corporation 2012).

New York Cultural Resources

- According to the GIS database at the NY State Historic Preservation Office website (http://pwa.parks.ny.gov/nr/), there are 1,875 NRHP properties within the 11 counties affected by Hurricane Sandy.

New York – Long Island Sound Area Historic Background (Reaches NY 1. 3, and 4)

- The eastern end of the north shore remained mostly uninhabited through the end of the eighteenth century. During the Revolutionary War British forces confiscated and encamped on many of the local farms in the area. The area remained rural until the Long Island Rail Road development in the 1840s. With easier access to markets, the economy of the local farmers changed from wheat and grains to vegetables. Other than saw mills, grist mills, and sand mining, there was very little industry on the North Shore into the twentieth century. Much of the relatively undeveloped North Shore was transformed in a Gold Coast of large estates from 1860-1930 as wealthy families centered in New York City began to build summer residences in the area partially due to the Long Island Railroad expansions and the development of other transportation corridors. Automobile traffic and a proliferation of ferries, bridges, and highways beginning after WWI have extended residential settlement into most area of the north shore and Peconic Bay. Historic structures/sites relating to the agriculture, Revolutionary War, fishing, sand mining, resort communities, lighthouses, lifesaving stations, and Gold Coast estates, etc. can be found throughout the region. There are also a large number of submerged shipwreck sites along the north coast and within the Peconic Bay (North Shore of Long Island Cultural Resources Assessment Appendix E of Reconnaissance Report 1995).

Historic Sites and Structures

South Shore of Long Island - Fire Island Inlet to Montauk Point Region (Reaches NY 1 and 2)

- The early uses of Fire Island did not require concentrated settlements. Whaling was commonly done from the beach until about 1750, when whales were no longer found near the beach. Salt hay from the marshes was harvested for mulch and insulation. Horseshoe crabs were gathered as fertilizer by farmers. Shipwrecks were common along Fire Island and in the mid-nineteenth century, to reduce the number of groundings and shipwrecks, the federal government began to build lighthouses for safe navigation. The first lighthouse was built at Fire Island Inlet in 1825. The second lighthouse was built in 1858 at Shinnecock Inlet (USACE 2009).

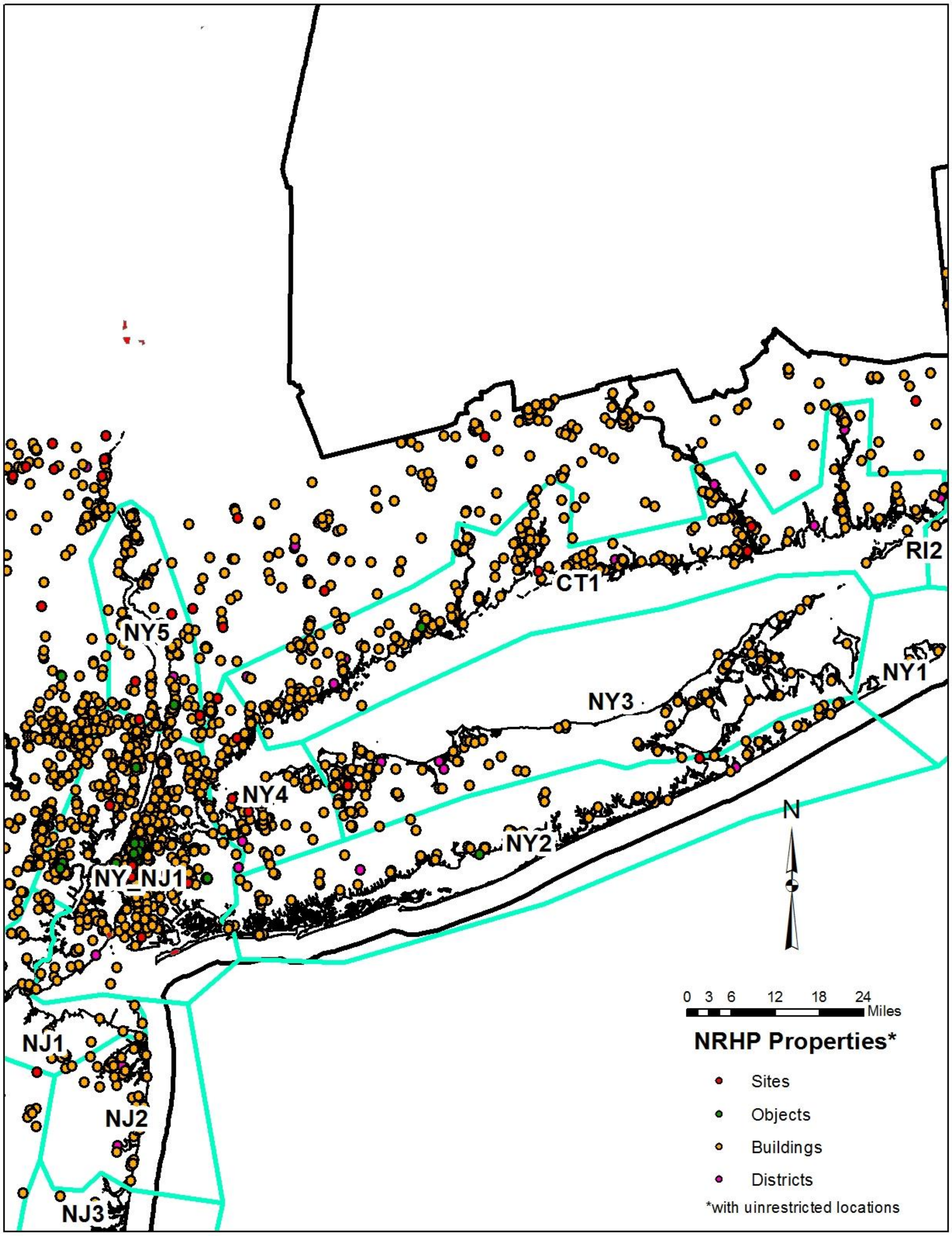

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Figure 10-7 NRHP properties in New York and Connecticut portions of the study area.

- There are many historic sites and Districts in the study area relating to the Revolutionary War, railroad, farming and fishing, shipping, mills, beach resorts and recreation, lighthouses, and lifesaving stations. Some of the more prominent historic resources include the Fire Island Light

Station (Town of Islip) and the Beach Road Historic District (Village of Southampton). There are also numerous submerged shipwreck sites along the coast and in the back-bay area. A total of 453 vessels are known to have wrecked along this stretch of coast. While the present disposition and exact location of most of the wrecks is not known, at least 120 of the ships were described as wrecked on, or near, the beach (USACE 2009).

South Shore of Long Island - Rockaway Inlet to Fire Island Inlet (Reach NY 2)

- From the seventeenth century to the middle of the nineteenth century, most of Rockaway Beach was used primarily for pasturage. By the end of the nineteenth century, this area gradually became home to many resorts and communities centered on beach recreation (Kopper 1979, as discussed in USACE 1993). There are a number of historic sites and districts along the coast in this stretch of the shoreline. More prominent among them are the Jacob Riis Park Historic District, and the Fort Tilden Historic District, both a part of the National Park Service's Gateway National Recreation Area. Further east is the Jones Beach State Park. There is potential for many historic sites to exist in the area which relate to the Revolutionary War, railroad, farming and fishing, shipping, mills, beach resorts and recreation, lighthouses, and lifesaving stations. There are also numerous submerged shipwreck sites along the coast (USACE 2009).

North Shore of Long Island and Peconic Bay (Reaches NY 3 and 4)

- The eastern end of the north shore remained mostly uninhabited through the end of the eighteenth century. During the Revolutionary War British forces confiscated and encamped on many of the local farms in the area. The area remained rural until the Long Island Rail Road development in the 1840s. With easier access to markets, the economy of the local farmers changed from wheat and grains to vegetables. Other than saw mills, grist mills, and sand mining, there was very little industry on the North Shore into the twentieth century. Much of the relatively undeveloped North Shore was transformed in a Gold Coast of large estates from 1860-1930 as wealthy families centered in New York City began to build summer residences in the area partially due to the Long Island Railroad expansions and the development of other transportation corridors. Automobile traffic and a proliferation of ferries, bridges, and highways beginning after WWI have extended residential settlement into most area of the north shore and Peconic Bay. Historic structures/sites relating to the agriculture, Revolutionary War, fishing, sand mining, resort communities, lighthouses, lifesaving stations, and Gold Coast estates, etc. can be found throughout the region. There are also a large number of submerged shipwreck sites along the north coast and within the Peconic Bay (USACE 1995a).

Hudson-Raritan Estuary (Reaches NY 5 and NY/NJ 1)

Jamaica Bay

- Native American presence and European exploitation of the area in the nineteenth century, marsh vegetation was harvested, agriculture, early settlements included harvesting shellfish, mills, Revolutionary War and the British outposts, fertilizer, fish oil, and waste processing was carried out on the islands. Also railroad, ferry, and eventually resort facilities like hotels and amusements in Canarsie. Gateway National Recreation Area and Floyd Bennett Field which became the Naval Air Station and then Naval Reserve Air Station, coast guard and Naval squadron also had a presence (Harris and Hood 2013).

Upper Bay

- Historic neighborhoods in Red Hook, Bay Ridge, Park Slope and Gowanus Bay, also Breuckelen (Brooklyn), Bergen (present day Bayonne) and Constable Hook. Also includes such significant sites as Governors Island, Ellis Island, and Statue of Liberty. Agriculture and shipping are major themes. Gowanus Canal, fortifications including Fort Jay on Governors Island, Fort Gibson on Ellis Island, and Fort Wood on Bedloe's Island. Shipbuilding, mills, steel industry, civil war, immigration, wealthy estates along Bergen neck peninsula and Bay Ridge, Brooklyn and early infrastructure in the early twentieth century are other themes (Harris and Hood 2013).

Lower Hudson

- Significant historic settlements are located in Jersey City, Hoboken, New Jersey and lower Manhattan, Upper West Side and Yonkers, New York. The Lower Hudson played a significant role as a component in the defense system of New York Harbor. Significant Revolutionary War fortifications along the Hudson are Fort Lee, Fort Washington and Fort George. Other historic sites are related to agriculture, early industrialization, urbanization, shipping, railroad, and suburban development. Potential for submerged wrecks and ruins (Harris and Hood 2013).

Lower Bay

- Setters were drawn to Monmouth County's rich farm land and its proximity to the colonial ports of New York and Philadelphia. Revolutionary War sites, most notable is Monmouth Battlefield. There are many mill sites, Richmond Town, and evidence of salt hay harvesting in Staten Island. In the early nineteenth century summertime retreats were developed along the shores of Staten Island. Agriculture, shipping, industrialization and suburban development are also major themes of historic sites in this region. There are numerous submerged shipwrecks and ruins within the lower bay (Harris and Hood 2013).

Arthur Kill

- The region includes the Raritan Bay, Arthur Kill, Kill Van Kull, and Rahway River. Significant historic towns with this region include Elizabeth Town, Rahway, Woodbridge, Perth Amboy, Union, Scotch Plains and Irvington, New Jersey as well as Castle Town and Richmond Town on Staten Island New York. Common themes among the historic sites in this region are the Revolutionary War, summertime resorts in Staten Island, turnpike, railroad, canals and shipping development, agriculture, dairy farming, warehouses and shipping, brick manufacture, oystering, and copper refineries (Harris and Hood 2013).

Harlem, East River, Long Island Sound

- The Harlem River, East River and Western Long Island Sound HRE Region encompass a vast area which includes the portions of New York County, Bronx County, Westchester County, Kings County, Queens County and Nassau County of New York. The defining geographical features are the Bronx River, Hutchinson River, East River, Newtown Creek, Flushing Creek, Westchester Creek, Eastchester Bay, and Long Island Sound. Major historic sites of significance are the Croton Dam, Bronx River Parkway Reservation, Bronx Park, Brooklyn Navy Yard, and the Westchester Turnpike among other historic roadways and turnpikes. Major themes of the historic sites in the region are Revolutionary War, agriculture, railroads, wealthy country estates, industrialization, ship building, the Parks and Recreation movement and suburbanization. Brickyards were established in Croton and marble quarries in Tuckahoe, Ossining, Hastings, and Thornwood supplied the building material for neoclassical architecture which was popular in public buildings during this era. Lager industries such as iron making developed in Port Chester, Peekskill and Morrisania (now part of the Bronx) where foundries produced stoves and plowshares (Harris and Hood 2013).

Archaeological Sites (terrestrial and underwater)

- Archaeological site locational data is confidential and exempt from the Freedom of Information Act (FOIA) provisions. Several general assumptions can be made regarding archaeological sites in the NACCS study area. Sites range from the earliest (Paleo-Indian 12,000 years BP) to the European Contact period and beyond, although Paleo-Indian sites are rare. In addition, submerged archaeological sites (shipwrecks and formerly terrestrial sites) are likely along the coastal areas and offshore.

- There is an extensive inventory of Native American archaeological sites from all periods of time on land in New York, New Jersey, Connecticut, Massachusetts, and Rhode Island. No pre-Contact archaeological deposits have been identified to date within federally controlled waters along the Atlantic seaboard (TRC Environmental Corporation 2012).

New York – Long Island Sound Area

- The area of northern Long Island has a rich Native American history. The Long Island shore was located more seaward during glaciation and early post-glaciation periods, when sea level was dramatically lowered (c. 10,000 and c. 6000 B.P.). Evidence of occupation therefore may exist along the present shoreline as well as in near shore and offshore areas. There is potential for submerged prehistoric archaeological sites dating to the Archaic/Paleo-Indian Period in the study area. Many of these sites were located along early rivers, estuaries, and portions of the coastline that are now submerged. By the beginning of the Late Archaic period, the sea level and the location of the coastline were at approximately current levels (John Milner Associates 1998). Long Island Sound afforded the Native American inhabitants with a wealth food sources. Both terrestrial (game animal and limited agriculture) and aquatic (fish and crustaceans) resources were plentiful. The Matinecock, Nissequogue, Setalcott, and Corchaug lived on the North Shore of Long Island at the time of European contact when individuals documented seasonal villages dotting the landscape. Large numbers of Late Archaic, Woodland, and Contact Period Native American sites have been documented on or near the north shore and much of the area has high potential for sites from this period to exist. Although not heavily represented in the area, there is evidence to suggest that there is some potential for Paleo-Indian and Early or Middle Archaic terrestrial sites to exist in the area as well (USACE 1995a).

South Shore of LI - Fire Island Inlet to Montauk Point Region

- Evidence suggests that Native Americans utilized the barrier islands of Long Island for shell fishing, fishing, and hunting. No prehistoric sites have been identified on Fire Island and the island was not used for intensive human habitation by Europeans until the second half of the 19th century. No underwater, former terrestrial archaeological sites have been identified off-shore of Long Island, however, there is potential for submerged prehistoric archaeological sites dating to the Archaic/Paleo-Indian Period in the area. It is likely that many early sites, dating from the Paleo-Indian period through the Middle Archaic period (ca. 3000 BC), were probably inundated as sea level rose. Many of these sites were located along early rivers, estuaries, and portions of the coastline that are now submerged. The potential for these buried deposits along Fire Island is relatively high. By the beginning of the Late Archaic period, the sea level and the location of the coastline were at approximately current levels. Woodland Period and Contact period archaeological sites are known to exist on Long Island. The Matinecock, Nissequogue, Setalcott, and Corchaug lived on the North Shore of Long Island at the time of European contact. Late Archaic to Woodland Period Native American sites have been documented. Potential for Paleo-Indian and Early or Middle Archaic (USACE 2009).

South Shore of LI - Rockaway Inlet to Fire Island Inlet

- The Long Island shore was located more seaward during glaciation and early post-glaciation periods, when sea level was dramatically lowered (c. 10,000 and c. 6,000 B.P.). Evidence of occupation therefore may exist along the present shoreline as well as in near shore and offshore areas. Although there are no known prehistoric middens or other prehistoric sites along this portion of the shoreline, prehistoric shell middens have been identified in Jamaica Bay and in Kings County (USACE 2009).

- There is potential for submerged prehistoric archaeological sites dating to the Archaic/Paleo-Indian Period in the study area. Many of these sites were located along early rivers, estuaries, and portions of the coastline that are now submerged. The potential for these buried deposits along the coast and the back bay areas is relatively high. By the beginning of the Late Archaic period, the sea level and the location of the coastline were at approximately current levels. Much of the area is sensitive for Woodland Period and Contact period archaeological sites and many have been identified on Long Island. There is some potential for Paleo-Indian and early Archaic sites as well. The Matinecock, Nissequogue, Setalcott, and Corchaug lived on the North Shore of Long Island at the time of European contact (USACE 2009).

North Shore of Long Island and Peconic Bay

- The area of northern Long Island has a rich Native American history. The Long Island shore was located more seaward during glaciation and early post-glaciation periods, when sea level was dramatically lowered (c. 10,000 and c. 6000 B.P.). Evidence of occupation therefore may exist along the present shoreline as well as in near shore and offshore areas. There is potential for submerged prehistoric archaeological sites dating to the Archaic/Paleo-Indian Period in the study area. Many of these sites were located along early rivers, estuaries, and portions of the coastline that are now submerged. By the beginning of the Late Archaic period, the sea level and the location of the coastline were at approximately current levels (John Milner Associates 1998). Long Island Sound afforded the Native American inhabitants with a wealth food sources. Both terrestrial (game animal and limited agriculture) and aquatic (fish and crustaceans) resources were plentiful. The Matinecock, Nissequogue, Setalcott, and Corchaug lived on the North Shore of Long Island at the time of European contact when individuals documented seasonal villages dotting the landscape. Large numbers of Late Archaic, Woodland, and Contact Period Native American sites have been documented on or near the north shore and much of the area has high potential for sites from this period to exist. Although not heavily represented in the area, there is evidence to suggest that there is some potential for Paleo-Indian and Early or Middle Archaic terrestrial sites to exist in the area as well (USACE 1995a).

Hudson-Raritan Estuary

- There is potential for submerged prehistoric archaeological sites dating to the Archaic/Paleo-Indian Period in the Bays, harbor and Rivers. Woodland Period and contact period terrestrial archaeological sites are known to exist in the area. The Lenape comprised a dozen-odd groups living between eastern Connecticut and central New Jersey. To the west were the Raritans (of Staten Island and Raritan Bay), the Hackensacks (of New Jersey's Hackensack and Raritan river valleys), the Tappans (northern New Jersey), and the Rechgwawanches (Orange County). Their counterparts and sometimes enemies to the east include the Weichquaesgecks (northern Manhattan, the Bronx, and Westchester) and the Siwanoys (along the northern banks of the East River and Long Island Sound as far as the Connecticut line), as well as the Matinecocks, Massapequas, Rockaways, Merricks and others on Long Island (Harris and Hood 2013).

Areas of Archaeological Sensitivity

- The NJ and NY State Historic Preservation Offices have web-based mapping tools and downloadable GIS data layers available displaying areas of archaeological sensitivity throughout the state: http://pwa.parks.ny.gov/nr/. Sensitivity maps for each of the counties impacted by Hurricane Sandy can be queried and displayed.

- BOEM also provides a distribution of shipwrecks by state and region that is helpful in characterizing the extent and distribution of submerged sites within the study area both by state and region. For the State of New York, there are 346 shipwrecks (TRC Environmental Corporation 2012).

Traditional Cultural Properties

Long Island

- There are two prominent tribes who inhabit Long Island. These are the Unkechaug Nation, a state recognized tribe, and the Shinnecock Indian Nation, a federally recognized tribe (USACE 2009).

Hudson-Raritan Estuary

- While there are no prominent Native American tribes currently inhabiting this portion of New York and New Jersey, the Delaware Nation and the Delaware Tribe of Indians are both federally recognized tribes whose ancestors inhabited this area (Harris and Hood 2013).

New Jersey Cultural Resources

There are approximately 21,500 historic properties, 382 historic districts, and 300 archaeological sites and districts on file at the New Jersey State Historic Preservation Office that are within the counties impacted by Hurricane Sandy. Of these, 56 are in the National Historic Landmarks program (NPS 2013a)

Historic Sites and Structures

Hudson-Raritan Estuary (Reach NJ 1)

Upper Bay

- Historic neighborhoods in Red Hook, Bay Ridge, Park Slope and Gowanus Bay, also Breuckelen (Brooklyn), Bergen (present day Bayonne) and Constable Hook. Also includes such significant sites as Governors Island, Ellis Island, and Statue of Liberty. Agriculture and shipping are major themes. Gowanus Canal, fortifications including Fort Jay on Governors Island, Fort Gibson on Ellis Island, and Fort Wood on Bedloe’s Island. Shipbuilding, mills, steel industry, civil war, immigration, wealthy estates along Bergen neck peninsula and Bay Ridge, Brooklyn and early infrastructure in the early twentieth century are other themes (Harris and Hood 2013).

Lower Hudson

- Significant historic settlements are located in Jersey City, Hoboken, New Jersey and lower Manhattan, Upper West Side and Yonkers, New York. The Lower Hudson played a significant role as a component in the defense system of New York Harbor. Significant Revolutionary War fortifications along the Hudson are Fort Lee, Fort Washington and Fort George. Other historic sites are related to agriculture, early industrialization, urbanization, shipping, railroad, and suburban development. Potential for submerged wrecks and ruins (Harris and Hood 2013).

Lower Bay

- Setters were drawn to Monmouth County's rich farm land and its proximity to the colonial ports of New York and Philadelphia. Revolutionary War sites, most notable is Monmouth Battlefield. There are many mill sites, Richmond Town, and evidence of salt hay harvesting in Staten Island. In the early nineteenth century summertime retreats were developed along the shores of Staten Island. Agriculture, shipping, industrialization and suburban development are also major themes of historic sites in this region. There are numerous submerged shipwrecks and ruins within the lower bay (Harris and Hood 2013).

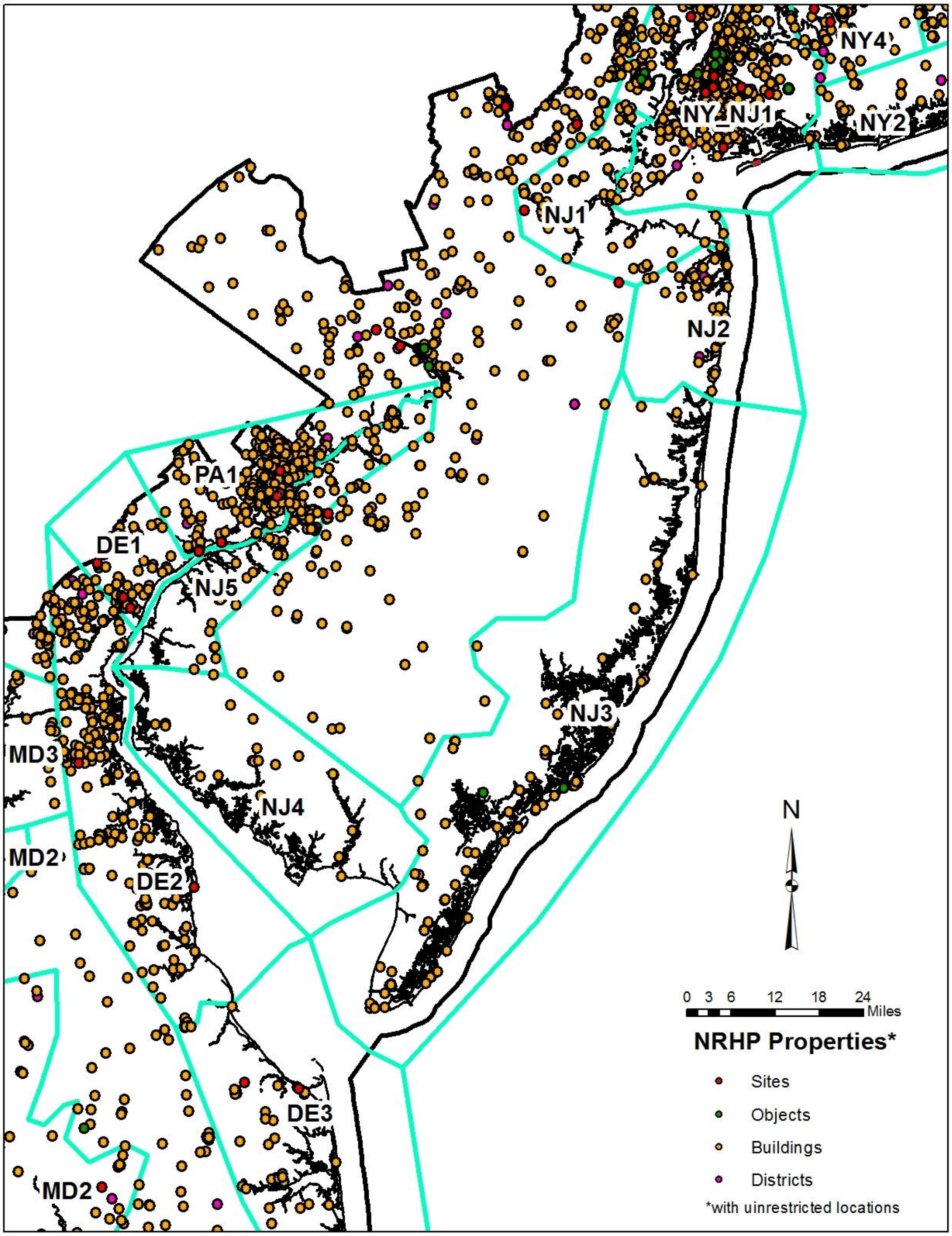

Figure 10-8 NRHP properties in New Jersey, Pennsylvania, and Delaware portions of the study area.

Raritan River (Reaches NJ1 and 2)

- Significant industrial cities in the area are the western portion of Perth Amboy, Metuchen, Edison, New Brunswick, South Plainfield, Plainfield and Sayreville New Jersey. These cities developed into industrial, urban, and residential centers; and all are densely populated, and well-served via transportation routes. Milling and agriculture were originally the cornerstones of the economy of the Raritan River Valley. The tidal aspect of near shoreline land served to reduce its value for agricultural purposes; however, the presence of quality deep clay deposits created a commercial value for the land. Products such as flour, grain, lumber, fish, beef, pork, iron, and copper were exported down river to Perth Amboy, where they were shipped out. Georges Road and the Kings Highway were early transportation routes. Later canals (the Morris Canal and the Delaware and Raritan Canal), railroad, and ferries would improve transportation and shipping to and from the area. Similar themes are seen as in other regions in the later part of the nineteenth and through the twentieth century with industrialization, urbanization, and suburbanization. There is potential for submerged shipwrecks (Harris and Hood 2013).

Arthur Kill (Reach NY/NJ 1)

- The region includes the Raritan Bay, Arthur Kill, Kill Van Kull, and Rahway River. Significant historic towns with this region include Elizabeth Town, Rahway, Woodbridge, Perth Amboy, Union, Scotch Plains and Irvington, New Jersey as well as Castle Town and Richmond Town on Staten Island New York. Common themes among the historic sites in this region are the Revolutionary War, summertime resorts in Staten Island, turnpike, railroad, canals and shipping development, agriculture, dairy farming, warehouses and shipping, brick manufacture, oystering, and copper refineries (Harris and Hood 2013).

Passaic River and Hackensack River (Reaches NY/NJ 1 and NJ 1)

- Bergen County has been referred to as the gateway to New Jersey, Essex County the financial hub of New Jersey, and Hudson County the gateway to New York. Given their location between New York and Philadelphia—and the multiple modes of transportation available within them—Middlesex and Union Counties serve as major crossroads in the state. Major themes are agriculture, industry, Revolutionary War, iron works, the city of Paterson and the Great Falls, railroad, brick manufacture on Hackensack River, suburban development. By the mid-1800s Newark had become a center of commerce and industry being the terminus of the Morris Canal the New Jersey Railroad and the Morris and Essex railroad it also had developed its port into a major shipping venue (Harris and Hood 2013).

Atlantic Coast (Reach NJ 3)

- Historic structures/sites themes include the Revolutionary War, railroad, farming and fishing communities, mills, aeronautical and radio development, resort communities, lighthouses, and lifesaving stations. There are also numerous submerged shipwreck sites offshore along this stretch of the New Jersey coast (USACE 1989 and 1995b).

Archaeological Sites (terrestrial and underwater)

Hudson-Raritan Estuary

- There is potential for submerged prehistoric archaeological sites dating to the Archaic/Paleo-Indian Period in the Bays, harbor and Rivers. Woodland Period and contact period terrestrial archaeological sites are known to exist in the area. The Lenape comprised a dozen-odd groups living between eastern Connecticut and central New Jersey. To the west were the Raritans (of Staten Island and Raritan Bay), the Hackensacks (of New Jersey's Hackensack and Raritan river valleys), the Tappans (northern New Jersey), and the Rechgwawanches (Orange County). Their counterparts and sometimes enemies to the east include the Weichquaesgecks (northern Manhattan, the Bronx, and Westchester) and the Siwanoys (along the northern banks of the East River and Long Island Sound as far as the Connecticut line), as well as the Matinecocks, Massapequas, Rockaways, Merricks and others on Long Island (Harris and Hood 2013).

Atlantic Coast

- Prehistoric Archaeological sites, Paleo-Indian to Woodland Period terrestrial sites have been documented. There are numerous contact period archaeological sites in the area; the Lenni-Lenape lived in this region of NJ. There is documented and physical evidence of submerged prehistoric archaeological sites dating to the Archaic/Paleo-Indian Period on the Outer Continental Shelf (USACE 1989 and 1995b).

Areas of Archaeological Sensitivity

- The NJ and NY State Historic Preservation Offices have web-based mapping tools and downloadable GIS data layers available displaying areas of archaeological sensitivity throughout the state: http://pwa.parks.ny.gov/nr/. Sensitivity maps for each of the counties impacted by Hurricane Sandy can be queried and displayed.

BOEM also provides a distribution of shipwrecks by state and region that is helpful in characterizing the extent and distribution of submerged sites within the study area both by state and region. For the State of New Jersey, there are 1,684 shipwrecks (TRC Environmental Corporation 2012).

Delaware Cultural Resources

National Register and State Historic Sites

- The NACCS study area encompasses the entire state of Delaware, although the western portion of the state is excluded from the planning reaches, with some included in the Maryland reaches. There are 78 NRHP listed historic districts, and 75 individual listings (NPS 2013c). Among these are 13 National Historic Landmarks (NPS 2013a).

- Reach DE1 is a limited area covering only the northern tip of New Castle County, Delaware, and the southern edge of Delaware County, Pennsylvania. In spite of the limited area, the NRHP

GIS data show 101 buildings, 3 sites, and 4 districts in this area. Included in the four sites is NHL Fort Cristina, the 17th century Swedish settlement which was the initial attempt at European colonization in Delaware. There are four other NHL's in this reach as well.

- Reach DE2, in contrast to DE1 is an expansive area covering most of the rest of New Castle County and the eastern part of Kent County. Delaware is a small state, but its three counties are large in comparison with those in other eastern states. The NRHP GIS data includes 2 sites, 222 buildings, and 5 districts. There are six NHL's in this reach, including the New Castle historic district, which is not included in the NRHP number.

- Reach DE3 is comprised of the Atlantic and Delaware Bay coast of Sussex County. The NRHP GIS data includes 53 buildings and 2 sites. There is one NHL in this area, the lightship L-118 moored at Lewes. The most notable focus of historic properties in reach DE3 is at Lewes.

Archaeological Sites (terrestrial and underwater)

- BOEM also provides a distribution of shipwrecks by state and region that is helpful in characterizing the extent and distribution of submerged sites within the study area both by state and region. For the State of Delaware, there are 295 shipwrecks (TRC Environmental Corporation 2012).

Pennsylvania Cultural Resources

National Register and State Historic Sites

- . Only a small sliver of southeastern PA is within the NACCS study area, yet this encompasses one of the greatest concentrations of historic properties in the nation. Reach PA1 includes all of Philadelphia and most of Delaware County, as well as a small part of Bucks County along the Delaware River.

- The NRHP GIS data shows 5 sites, 491 buildings, and 20 historic districts within reach PA1. Philadelphia alone has 67 NHL's.

- Independence Hall, along with being a National Monument, is listed by UNESCO as a World Heritage Site. Although only a few blocks from the Delaware River, Independence Hall is on relatively high ground and at low risk from storms and flood.

Maryland Cultural Resources

National Register and State Historic Sites

Maryland

- Over half of the state of Maryland is included within the NACCS study area. These areas are rich in historic resources. Within it are 173 historic districts and 267 individual properties listed on the NRHP (NPS 2013c). Of these, 63 are included in the National Historic Landmarks program (NPS 2013a). A large portion of these figures are in the Baltimore area, although there are ample numbers in other places around the Chesapeake Bay.

- Reach MD1 is the short, but highly exposed Atlantic coastal portion of Maryland, including Ocean City and Assateague Island, and is entirely within Worcester County. There are only about a dozen NRHP properties in this reach, and none are in the NHL program.

- Reach MD2 covers the eastern Bay Shore, or west side of the Eastern Shore of Maryland in Queen Anne's, Talbot, Caroline, Dorchester, and Somerset Counties. It also extends into the southwest corner of Sussex County Delaware. This region is low lying, fringed with tidal marshes, and cut my many tidal creeks and rivers. There are several NHL's, but they are all vessels, and as such might be damaged in storms, but not threatened by flooding or sea level rise. The NRHP GIS database for this area shows 153 NRHP properties within it. They are rather spread out in this generally rural region, if a slight concentration in Somerset County. Also in this reach is Smith Island, where ongoing inundation and erosion have greatly reduced the land area in the 20th century.Reach MD3 covers the north end of the Chesapeake Bay including most of Harford, Cecil, and Kent Counties. As well as a slim section of western New Castle County, Delaware. There as 67 properties from the NRHP GIS data within the reach, all of which are buildings; however the database, for some reason, omits many historic districts. Notable historic districts within MD3 and with waterfront areas include Port Republic and Chestertown, the latter of which is an NHL.

- Reach MD4 covers Baltimore and Baltimore County. There is a very noticeable clustering of historic properties focused on Baltimore Harbor. The NRHP GIS data shows 192 buildings, 10 historic districts, 3 sites, and one object within reach MD4. By far the most historic properties of any of the Maryland reaches, despite it being by far the smallest. There are 24 National Historic Landmarks in the City of Baltimore. Notable properties include National Monument Fort McHenry, and the Fell's Point historic district. Floods threaten the latter to the point where the non-structural approach of filling basements and converting first floors to basements of townhouses has been considered.

- Reach MD5 includes Calvert, Charles, and Saint Marys Counties, along with the southern half of Prince George's. The NRHP GIS data shows 28 buildings, one site, and one historic district within the reach. Not included in this number is the Saint Mary's City historic district, an NHL which was the site of the first settlement in Maryland. There are six other NHL's in this reach, one of which is the Accokeek Creek site, a Late Woodland and Contact Period Native American Site of considerable regional importance. National Monument Fort Washington is also in this reach, located in Prince George County just south of Washington on the Potomac River.

District of Columbia

- Reach MD6 covers the District of Columbia and Arlington County, Virginia. The NRHP GIS data shows 416 buildings, 5 sites, 46 objects, and 8 historic districts in this reach. There are 74 NHL's, in the District of Columbia, including the Georgetown and Washington Navy Yard historic districts, not included in those numbers. There are four NHL's in Arlington County. Of national and international significance, the National Mall is low lying, and the western half of it, including the sites of the Lincoln and Jefferson Memorials is on fill. There are measures currently being implemented for flood risk management.

- The District of Columbia Inventory of Historic Sites is the District's list of officially designated historic properties. Properties in the inventory are deemed worthy of recognition and protection for their contribution to the cultural heritage of the city and nation.

- In 2009 the Inventory contained more than 700 designated Historic Sites encompassing nearly 25,000 properties. Included in the Inventory are: 500 historic landmark designations covering more than 800 buildings; 150 historic landmark designations of other structures, including parks, engineering structures, monuments, building interiors, artifacts, and archaeological sites; and 50 historic districts, including 28 neighborhood historic districts (http://planning.dc.gov/DC/Planning).

Archaeological Sites (terrestrial and underwater)

Maryland

- BOEM also provides a distribution of shipwrecks by state and region that is helpful in characterizing the extent and distribution of submerged sites within the study area both by state and region. For the State of Maryland, there are 617 shipwrecks (TRC Environmental Corporation 2012).

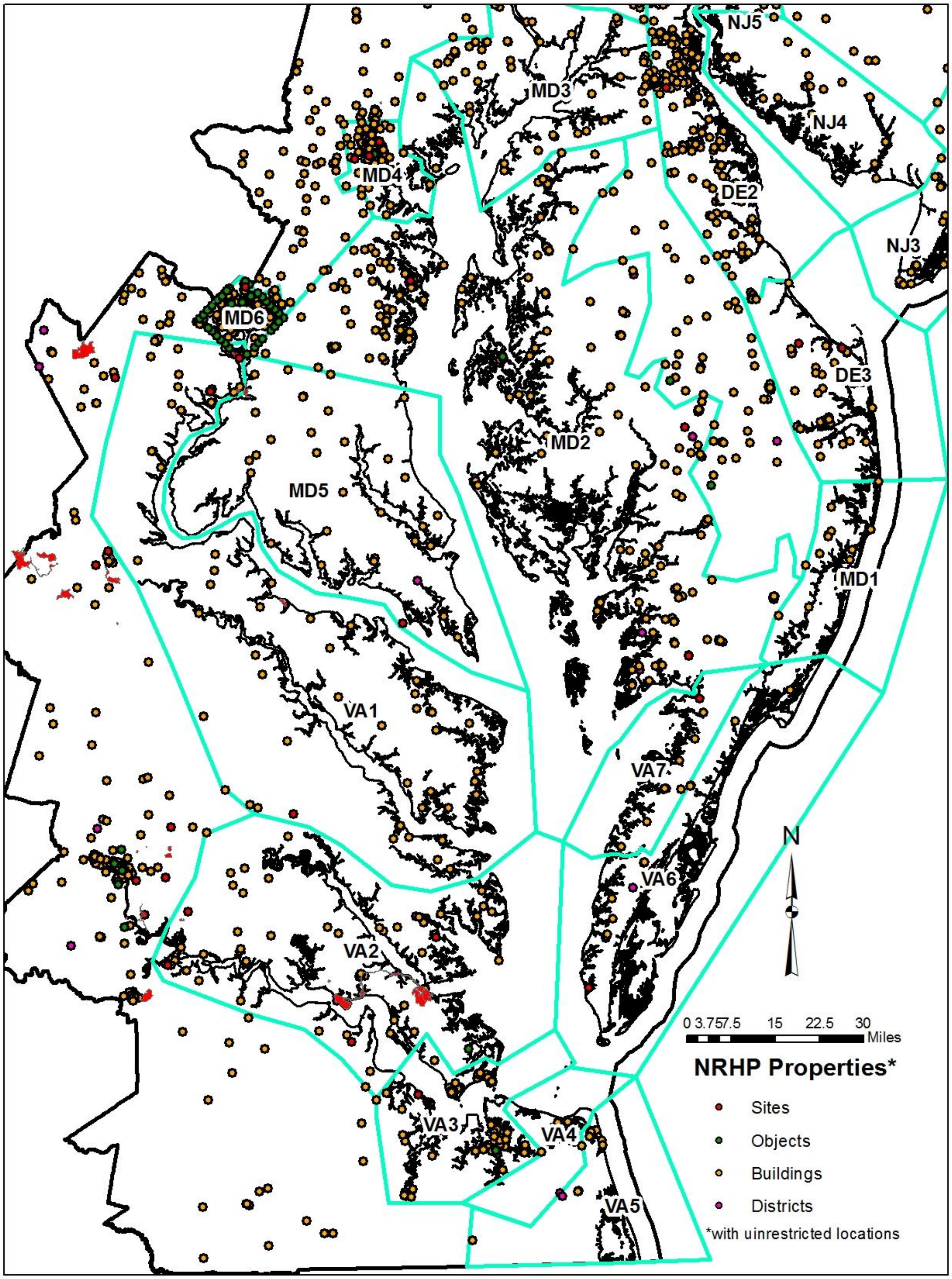

Figure 10-9 NRHP properties in Maryland and Virginia portions of the study area.

Virginia Cultural Resources

National Register and State Historic Sites

- Within the NACCS study area, there are approximately 900 properties are either listed on or eligible for listing on the NRHP; however, another 28,000 historic properties in the state's database are unevaluated at this time (VDHR 2012a, VDHR 2012b).

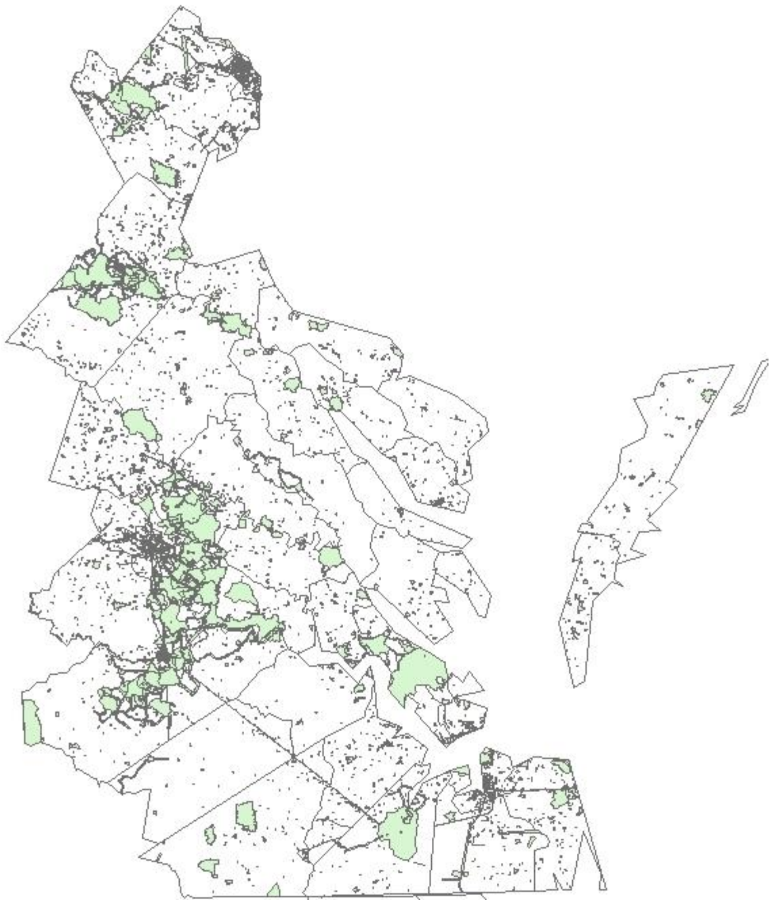

Figure 10-10. Study Area: Properties in the VDHR Architectural Database.

- The Virginia Department of Historic Resources (VDHR) has records of 34,522 properties within the study area jurisdictions in its GIS data base (Data Sharing System [DSS] (VDHR 2012b). These include buildings, structures (e.g., bridges), objects (e.g., statues), landscapes (e.g., battlefields), cemeteries, and historic districts which may include all other types. Out of this number 939 have been either listed in or determined eligible for the National Register of Historic Places (NRHP), 5612 have been determined not eligible for the NRHP, but 27,971 are unevaluated. There are 4171 properties within at risk areas, defined by the 0.2% and 1% annual flood probability (500 year and 100 year) zones, as well as open water areas. Included in this number are portions of NRHP listed historic districts in the cities of Alexandria, Richmond, Norfolk, and Portsmouth. Other NRHP listed or eligible historic districts and individual properties, too numerous to list here, are subject to risk from storm and flood.

- Virginia did not go unscathed by Hurricane Sandy, but the effects were less than those of Hurricane Isabel in 2003 (Hennessee and Halka 2005), and far less than Sandy's impacts further north. No notable damages were incurred to architectural properties, however minor to moderate flooding occurred in various areas. Listed and eligible NRHP historic districts were flooded including Norfolk's Ghent historic district, Alexandria's Old Town, and the town of Tangier on Tangier Island in Accomack County. A late 19th-early 20th century cemetery was partially washed out with burials exposed on northern Tangier Island. Accomack County suffered the worst effects of Sandy of any locality in Virginia, with flooding on both the Atlantic coast and shores of the Chesapeake Bay. Flooding and wave damage in Accomack prompted the governor to request disaster relief from FEMA for that county, but it was denied. BOEM also provides a distribution of shipwrecks by state and region that is helpful in characterizing the extent and distribution of submerged sites within the study area both by state and region. For the State of Virginia there are 1,367 shipwrecks (TRC Environmental Corporation 2012).

- Clustering of significant properties is most notable in reach VA3. Norfolk, Portsmouth, and Hampton have a number of NHL properties, as well as the recently designated Fort Monroe National Monument. Fort Monroe is highly vulnerable to storm surge, as are the nearby historic districts of Hampton Institute and Phoebus. Portsmouth's Old Town and Downtown historic districts are already subject to frequent flooding, and Cradock, Port Norfolk, and Park View district are vulnerable. Norfolk's Ghent, West Freemason, districts and Fort Norfolk are immediate to potential flooding threats.

- Reach VA2 has many Colonial and Pre-Colonial archaeological resources with exposure to erosion and flooding along the James and York Rivers. Most striking is the Jamestown Island Historic District, truly of national if not international importance. Sea level rise has already transformed what was an arable peninsula here into a marshy island. Portions of have eroded away, and measures, ongoing, to control this erosion date back to the 19th century. Many of the great estates of the 18th century "Golden Age of Virginia" are along the James River, including Berkeley, Shirley, Brandon, and Carter's Grove. While the manor houses themselves are generally set on high ground, archaeological assets of these properties may be threatened by erosion. Native American sites including Maycocks Point, Werowicomico, and the Pamunkey Indian Reservation suffer from erosion or flooding.

- In planning reach VA1 along the Potomac and Rappahannock Rivers, some of the most highly significant properties, e.g., Mount Vernon and Old Town Alexandria fell outside of the data coverage; however, the further inland areas of reach VA1 have higher elevations, and would suffer much lesser impacts. Wakefield, George Washington's birthplace in a low area along the northern neck is vulnerable. Properties at the eastern end of the Northern Neck and Middle Peninsula, and on lower elevations along the rivers would suffer the most. For example, the Reedville, Urbana and Irvington historic districts.

- Planning reaches VA4 and VA5 are in the Cities of Norfolk and Virginia Beach in low lying areas near high energy shorelines. Notable properties at risk include the old Cape Henry Lighthouse, an NHL. Built in 1792, it is one of the oldest standing lighthouses in the nation. The Adam Thorohgood House, also an NHL is exposed to some encroachment during major flooding, and a number of regionally important colonial era properties in the Lynnhaven basin such as Upper Wolfsnare and Pembroke Manor are even more exposed as is the Seatack Lifesaving Station, and the DeWitt Cottage in the ocean front area of Virginia Beach.

- In planning reach VA6, on the eastern side and southern end of the Eastern Shore, Eyre Hall, one of the two NHL's in this reach is a property at risk. Arlington House, the original seat of the Custis Family and for which the more widely known Arlington House was later named is also along with the Custis Tombs. Historic Districts at Chincoteague are projected highly vulnerable. Exceptional finds of Native American artifacts spanning more than 10,000 years as well as 17th and 18th century colonists have been made at sites on rapidly shifting, already disappearing Mockhorn Island along the Atlantic seaboard side of the Eastern Shore. In planning reach VA7, on the northern Chesapeake Bay side of the Eastern Shore all but three of the NRHP listed properties in this reach are in peril. The most at risk is Tangier Island, where erosion is rampant. Resources not listed include archaeological sites along the bay shore of the mainland as well as islands in Pocomoke Sound. Also at risk of partial inundation during storms is the exceptional Onancock Historic District.

Tribal

- Native Americans have a unique perspective on cultural and natural resources, and federally recognized tribes are accorded a special role in the consulting process under Section 106 of the NHPA. Federally recognized tribes in the NACCS study area are concentrated in the southern New England area (Figure 11-7). Other federally recognized tribes, formerly residents of other portions of the NACCS study area, relocated to western states in the face of colonial settlement beginning in the 17th century. They were mandated to move to other territories during the 19th century. Still other tribes had cultural affiliation with those residing in the study area through alliances, or were known to have transiently resided there. Unlike federally recognized tribes, state recognized tribes do not consult with the federal government on a government to government basis; however, many of them are seeking federal recognition, and are often included in consultations as non-governmental organizations.

- There are six federally recognized Indian tribes located within the boundaries of the NACCS study area (Figure 11-7):

    - Mashantucket Pequot Tribal Nation, Connecticut
    - Mashpee Wampanoag Tribe, Massachusetts
    - Mohegan Tribe, Connecticut
    - Narragansett Indian Tribe, Rhode Island
    - Wampanoag Tribe of Gay Head (Aquinnah), Massachusetts
    - Shinnecock Indian Nation, Long Island, New York.

- In addition, there are three relocated federally recognized Indian tribes which historically inhabited the NACCS:
    - Stockbridge Munsee Community, Band of Mohican Indians, Wisconsin (formerly in Connecticut and New York)
    - Delaware Nation, Oklahoma (formerly in 'Delaware, Pennsylvania, and New Jersey)
    - Delaware Tribe of Indians, Oklahoma (formerly in 'Delaware, Pennsylvania, and New Jersey)
- Federally recognized tribes outside of the NACCS study area which may have interests in the study area as shown by past interest in consulting, or by historic or cultural association include:
    - Absentee-Shawnee Tribe of Indians of Oklahoma
    - Cayuga Nation (NY)
    - Delaware Tribe of Indians
    - Eastern Shawnee Tribe of Oklahoma
    - Oneida Indian Nation (NY)
    - Oneida Tribe of Indians of Wisconsin
    - Onondaga Indian Nation (NY)
    - Saint Regis Mohawk Tribe (NY)
    - Seneca-Cayuga Tribe of Oklahoma
    - Seneca Nation of New York
    - Shawnee Tribe (OK)
    - Tonawanda Band of Seneca Indians of New York
    - Tuscarora Nation (NY)
    - Cherokee Nation (OK))
    - Eastern Band of Cherokee Indians (NC)
    - United Keetoowah Band of Cherokee Indians (OK)

- Catawba Indian Nation (SC)

- State recognized tribes do not have recognition as governmental entities, and therefore are not accorded the limited sovereignty of the federally recognized tribes; however, they may be considered as non-governmental organizations which special interests in the effects of projects on cultural and natural resources. The following state recognized tribes are within the NACCS study area (Figure 10-11):
  - Hassannamisco, Massachusetts
  - Paucatuck Eastern Pequot, Connecticut
  - Golden Hill Paugussett, Connecticut
  - Poospatuck, New York
  - Ramapough, New Jersey
  - Nanticoke Lenni Lenape, New Jersey
  - Lenape Indian Tribe of Delaware
  - Nanticoke Indian Tribe, Delaware
  - Piscataway Indian Nation, Maryland
  - Piscataway Conoy Tribe, Maryland
  - Pamunkey, Virginia
  - Mattaponi, Virginia
  - Nansemond, Virginia
  - Nottoway of Virginia
  - Cheroenhaka, Virginia
  - Chickahominy, Virginia
  - Eastern Chickahominy, Virginia
  - Upper Mattaponi, Virginia
  - Rappahannock, Virginia

- Patawomeke, Virginia

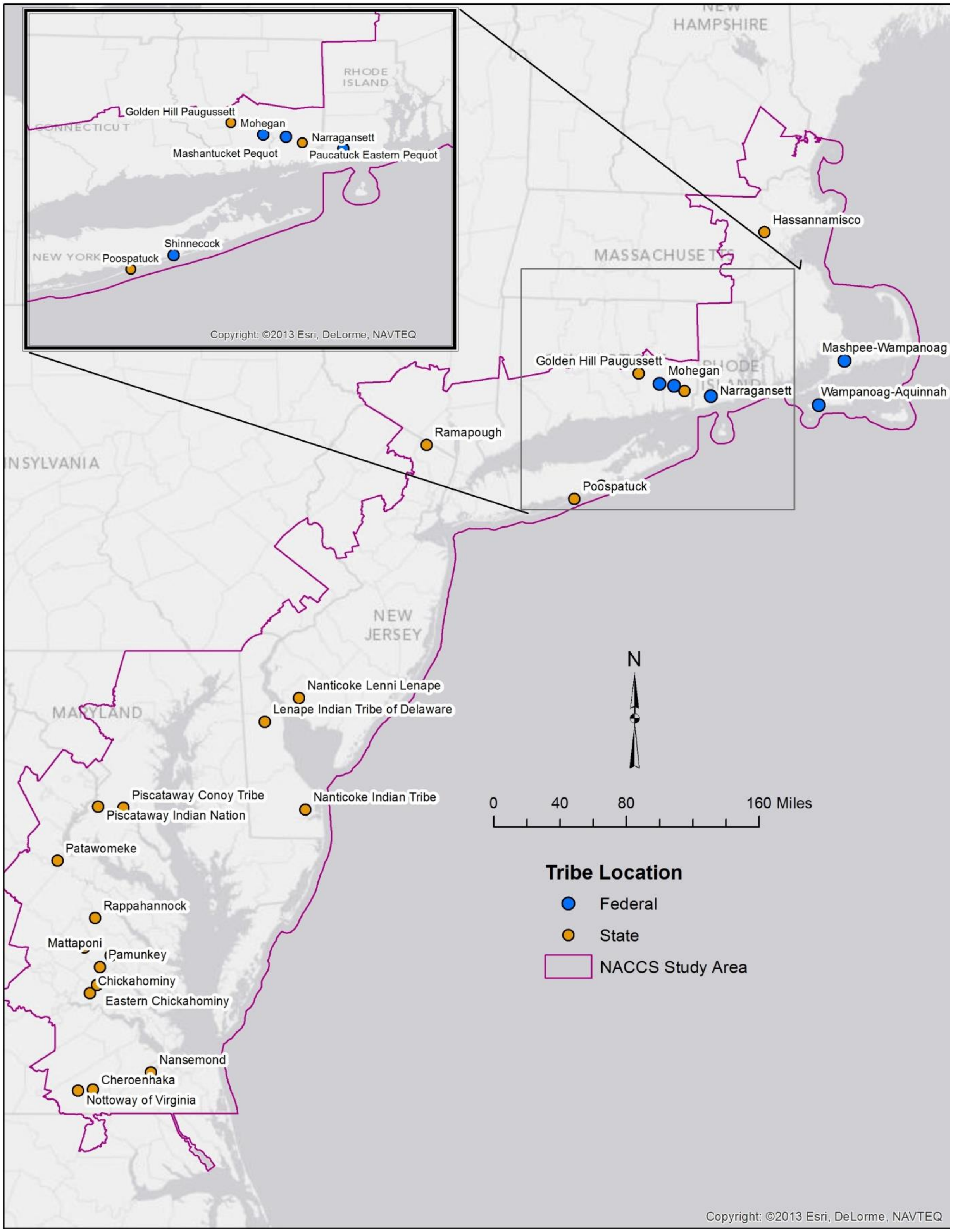

Figure 10-11. Indian Tribes Within the Study Area (U.S. Census Bureau 2010)

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Attachment A. USFWS NACCS Planning Aid Report

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21401
http://www.fws.gov/chesapeakebay

April 30, 2014

Tomma Barnes, PhD
Sr Planner
USACE- Wilmington District
69 Darlington Ave
Wilmington NC 28405

RE: North Atlantic Coast Comprehensive Study, U.S. Fish and Wildlife Service Planning Aid Report: Biological Resources and Habitats Vulnerable to Sea Level Rise and Storm Activity in the Northeast U.S.

Dear Dr. Barnes:

The U. S. Fish and Wildlife Service Is pleased to provide the North Atlantic Coast Comprehensive Study, Planning Aid Report: Biological Resources and Habitats Vulnerable to Sea Level Rise and Storm Activity in the Northeast. This report is the final product in the agreed upon work plan under MIPR W81W3G32531572. We appreciate the continued opportunities to partner with the Army Corps of Engineers on projects that benefit U.S. Fish and Wildlife Service Resources and look forward to partnering with you on future projects. If you have any questions, please feel free to contact Chris Guy at 410-573-4529.

Sincerely,

Christopher, P. Guy
Acting Division Director
Strategic Habitat Conservation

Cc: Troy, Anderson, VAFO
Rick Bennett, RO
Gregory Breese, DBEP
Tom Chapman, NEFO
Patricia Cole, NYFO
Mike Drumond, VAFO

Robert Houston, GMCP
Steve Papa, LIFO
Carlo Popolizo, NJFO
Ron Popowsi, NJFO
Spencer Simon, RO
Maria Tur, NEFO
Wendy Walsh, NJFO
John Warner, NEFO

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U.S. Fish & Wildlife Service

North Atlantic Coast Comprehensive Study

Biological Resources and Habitats Vulnerable to Sea Level Rise and Storm Activity in the Northeast U.S.

Photo by JF Photography 2006

North Atlantic Coast Comprehensive Study

Planning Aid Report:

Biological Resources and Habitats Vulnerable to

Sea Level Rise and Storm Activity in the Northeast United States

Prepared for:

U.S. Army Corps of Engineers

Prepared by:

U.S. Fish and Wildlife Service

April 2014

TABLE OF CONTENTS

INTRODUCTION

The U.S. Army Corps of Engineers is conducting the North Atlantic Coast Comprehensive Study for the purpose of developing a strategy to reduce risk and enhance resiliency of the coastal populations affected by Hurricane Sandy within the boundaries of the North Atlantic Division. This involves assessing the risk of tidally induced flooding and storm surge projected out over the next 50 to 100 years, and then developing a risk reduction framework for the vulnerable areas. Concepts that are being investigated include nature based options such as creation/restoration of wetlands, coastal barrier islands, dunes, and reefs; and nonstructural, programmatic and interagency options to provide short-term and long-term coastal resilience.

This report provides information on coastal ecosystems and certain biological resources in the Northeast U.S. that are likely to be affected by sea level rise and storm activity over the next 50 to100 years. It is organized in two parts. Part I provides an overview of the threat that sea level rise poses for natural ecosystems. Part II provides information on vulnerable priority biological resources and the risk to coastal national wildlife refuges.

Part I

A Review of the Threat that Sea Level Rise Poses for Natural Ecosystems in the Northeast United States

Introduction

Rising sea level can affect coastal ecosystems in a number of ways. It can cause low lying lands to be inundated, and shorelines to experience increased erosion. Salinity intrusion into upland environments or into freshwater areas can result in major changes in the vegetative community. Tidal marshes, barrier islands, low-lying uplands, beaches and other tidal shorelines, and estuaries and coastal bays are the environments which are most vulnerable.

How Much Sea Level Rise is Expected?

Geologic evidence indicates that for the past 2000 years up to the late 1800s or early 1900s the sea level was rising slowly at rates less that 1 millimeter/year (mm/yr) (Kemp et al. 2011). Since that time the sea level has been rising at an increasing rate. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013), released in 2013, reviews the history of sea level rise and makes projections out to the end of this century. Between 1901 and 2010, the mean rate of globally averaged sea level rise (also termed the eustatic rate) was 1.7 mm/yr. However, toward the end of that period, between 1993 and 2010, the rate of sea level rise accelerated to 3.2 mm/yr. Global sea level rise is a result of thermal expansion of the oceans and melting of glaciers and ice sheets induced by atmospheric warming. The IPCC predicts that global mean sea level will continue to rise at an increasing rate during the 21st century. The amount of rise will vary depending on number of factors such as the amount of greenhouse gas emissions. However, the IPCC has “medium confidence” that the rise by 2100 relative to 1986 to 2005 would be in the range of 0.52 to 0.98 meters (m), with a rate of 8 to 16 mm/yr during 2081 to 2100. The current prediction is more than 50 percent higher than the prediction that the IPCC made in their Fourth Assessment Report in 2007, mostly due to inclusion of a larger contribution from ice sheet melting.

Another set of plausible global sea level rise trajectories developed in 2012 by the National Oceanic and Atmospheric Administration for the U.S. National Climate Assessment (Paris et al. 2012) give a somewhat higher upper range. They indicate that the sea level could rise by up to 2.0 m by 2100. The NOAA predictions rely more on semi-empirical models than the IPCC predictions which are based on process based models. The semi-empirical approach assumes that sea level rise is proportional to the amount of warming, and uses past sea level rise and temperature data to quantify the effect (Rahmstorf 2010).

Sea level rise is a complicated phenomenon. The oceans do not rise steadily and uniformly as water in a bathtub would as water is added. Instead, sea level rise varies spatially and temporarily across the globe due to variations in ocean circulation, temperature and salinity, and static equilibrium processes involving mass redistributions, changing gravity, and the Earth's rotation and shape (Sallenger et al. 2012). Regional sea level trends often reflect periodic climate conditions like El Nino that can persist for years before dissipating.

There is evidence to indicate that the northeast coast of the United States will experience a higher rate of sea level rise than the global average. Tide gage data from the mid-Atlantic region (North Carolina to New York) indicate that the sea level rise rates ranged between 2.4 and 4.4 mm/yr over the 20th century compared to the global average of 1.7 mm/yr (CCSP 2009). The primary reason for the difference is believed to be land subsidence possibly caused by post-glacial isostatic adjustment and/or groundwater pumping. Subsidence exacerbates the effect of sea level rise and is often termed relative sea level rise to indicate that it is measured relative to the land and not the actual sea level. This is especially an issue in the states of Virginia, Maryland, and Delaware (Paris 2012). The northeast coast also appears to be under the influence of another factor that caused an acceleration of the rate of sea level rise over the last few decades (Boon 2012; Sallenger et al. 2012). Sallenger et al. (2012) postulated that the acceleration was due to a weakening of the Atlantic Meridional Overturning Current. While it is unclear how long this acceleration will persist, a model developed by Yin et al. (2009) predicts that the change in ocean currents will continue to expose the northeast coast to higher rates of sea level rise during the 21st century.

Effects on Tidal Marshes

Since tidal marshes occupy the transition zone between the land and the sea, they are particularly exposed to the effects of sea level rise. Many of the salt marshes that are present along the northeast coast became established over the last 3000 to 4000 years as post-glacial sea level rise slowed from approximately 2.5 mm/yr to 1 mm/yr (Redfield and Rubin 1962, Redfield 1965, Keene 1971, Van de Plassche et al. 1989; Warren and Niering 1993). During this period of relatively slow sea level rise salt marshes were able to maintain a position within the intertidal zone in two ways: by migrating upslope and landward; and by increasing their absolute elevation. In today's environment, landward migration may be important in some rural low lying areas (Brinson et al.1995), but the space available for this migration will be often quite limited by the slope of the upland and the presence of human development (Moorhead and Brinson 1995, Feagin et al. 2010). Under the best circumstances landward migration may help to offset ongoing erosion at the marsh's seaward edge, but would not compensate for more extensive losses associated with sea level rise. Therefore, in order to be sustainable, tidal marshes must be able to increase their elevation at a rate that allows them to keep pace with sea level rise (Redfield 1972; Orson et al. 1987, 1998; Morris et al. 2002). Historically, they accomplished this by accumulating sediment and organic matter using feedback mechanisms that self-adjust to the water level (Friedrichs and Perry 2001; Nyman et al. 2006; Cahoon et al. 2006). For example as sea level rises, there will be increased delivery of sediment to the marshes, which helps to raise their elevation and at least partially offset sea level rise. However, there are limits on the adaptability of coastal marshes to sea level rise, and there is great concern that under the higher rate scenarios, by the end of this century there will be a wide scale loss of tidal marshes as excessive inundation converts them to unvegetated open water (Orson et al. 1985; Reed 2002; FitzGerald et al. 2008; Kirwan et al. 2010a; Gedan et al. 2011).

Tidal marshes vary in their ability to accommodate sea level rise through sediment and organic matter accumulation. Important factors that contribute to this variability include the relative sea level rise, suspended sediment availability, tidal conditions, physiographic setting, internal water circulation, vegetative composition, nutrient availability, and salinity. Suspended sediment availability is viewed as a key element for many marshes, and those that receive sediment deposition are expected to be better able to keep pace with rising sea level (Ward et al. 1998; Christiansen et al. 2000; Temmerman et al. 2004; Neubauer 2008; Stammermann and Piasecki 2012). The tide range affects the delivery of sediment to the marsh. Marshes in microtidal environments (tide range <2m) generally receive less sediment deposition than marshes in mesotidal (2-4m tide range) or macrotidal (>4m range) environments, and are likely to be less resilient to sea level rise (Stevenson et al. 1986; Moorhead and Brinson 1995; Simas et al. 2001; Friedrichs and Perry 2001; French 2006; Kirwan et al. 2010b). Microtidal marshes also have the disadvantage of having a small range of elevation where plant growth can occur. Their lower growth range means they will have less potential leeway to accommodate a rise in sea level. The elevation of a marsh relative to the lowest elevation within the tidal frame at which the plants can survive is sometimes referred to as its “elevation capital”, and is an indication of its tolerance to sea level rise (Cahoon and Guntenspergen 2010). Other factors being equal, the more elevation capital a marsh possesses, the more sea level rise it should be able to endure before inundation impacts plant growth.

Pulsing events such as storms and river floods can be an especially important source of sediment for marshes in microtidal environments (Stumpf 1983; Cahoon et al. 1995a; Day et al. 1995; Goodbred and Hine 1995; Schuerch et al. 2012). However, it should be noted that a major storm surge can also compact the marsh substrate and lower the surface elevation even while depositing sediment (Cahoon et al. 1999; Cahoon 2006). Other factors that affect marsh sediment delivery include the amount of suspended sediment, the tidal velocity, tidal asymmetry, wave climate, and the marsh interior channel network (Stevenson et al. 1985; Reed 1988; Ward et al. 1998; Reed et al. 1999; Christiansen et al. 2000; Friedrichs and Perry 2001; Chmura and Hung 2004; Temmerman et al. 2004). In addition, human activities such as dam construction, modification of river discharge, shoreline stabilization, and other coastal engineering works, have altered the sediment input to tidal marshes at local and regional scales (Hackney and Cleary 1987; Stevenson et al. 1988; Adam 2002; Syvitski et al. 2005; Day et al. 2008; Ravens et al. 2009; Kirwan and Megonigal 2013).

Marshes can also raise their elevation by accumulating organic material (Craft et al. 1993; Nyman et al. 2006). This accumulation can occur on the marsh surface (e.g., leaf litter accumulation) or below ground (e.g., root production offset by decomposition and compaction), although in coastal marshes the below ground contribution is considered to be the primary organic accumulation pathway for increasing the marsh elevation (Cahoon 2006; Mudd et al. 2009). There are many factors that affect below ground biomass production. They include degree of inundation, wrack deposition, soil chemistry, nutrient availability, plant species composition, overgrazing, temperature, and salinity (Howes et al. 1981; Linthurst and Seneca 1981; Mendelssohn et al. 1981; DeLaune et al. 1983; Koch et al. 1990; Bandyopadhyay et al. 1993; Miller et al. 2001; Cahoon et al. 2004; Darby and Turner 2008a,b; Neubauer 2008; Turner 2011; Fox et al. 2012). Another potential factor could be the concentration of CO_2 in the atmosphere. There is some experimental evidence to suggest that an increase in the CO_2 concentration will stimulate below-ground productivity of some marsh plants (especially those with the C3 photosynthetic pathway such as the sedge *Schoenoplectus americanus*), producing a gain in marsh elevation that could help to offset sea level rise (Langley et al. 2009).

It is sometimes assumed that marshes that rely more on organic matter accumulation for raising their elevation (e.g., high marshes on the U.S. northeast coast, Cahoon et al. 2004; Kolker et al. 2009) would be particularly vulnerable to rapid sea level rise because the increased inundation is likely to slow their production and cause waterlogging before they are able to adjust (Nyman et al. 1993). However, it would be a mistake to assume that the amount of sediment accumulation alone would be sufficient to determine the sea level rise vulnerability. For example, Craft et al. (1993) found that irregularly flooded high marsh on the North Carolina coast, relying primarily on *in situ* organic matter accumulation, accreted elevation at a greater rate than the regularly flooded marsh even though the regularly flooded marsh had the benefit of greater allochthonous sediment input. In this case the regularly flooded marsh was considered to be more vulnerable to increased sea level rise. Similarly, a study by Day et al. (2011) comparing two interior salt marshes (*Spartina alterniflora*) in the Mississippi Delta, one stable and one deteriorating, found that the deteriorating one received sediment at twice the rate of the stable one because it had a lower elevation and was flooded a higher percent of the time. Because organic matter accumulation is such an important factor in the vertical accretion of salt marshes (Bricker-Urso et al. 1989), any of the many site specific factors that affect this component could have an overriding effect on a marsh's vulnerability to accelerated sea level rise.

In addition to increased inundation, sea level rise will induce increasing salinity in many landscape settings, affecting tidal wetlands vegetation. Even dominant salt marsh species such as *S. alterniflora* and *S. patens* experience salt stress at higher salinities. The growth of *S. alterniflora* is reduced at salinities greater than approximately 20 parts per thousand (ppt) (Mendelssohn and Morris 2000). *S. patens* is even more sensitive with growth reduced when salinities exceed approximately 10 ppt (Broome et al. 1995; Ewing et al. 1995; Hester et al. 1996; Merino et al. 2010). Salinity increase in oligohaline and freshwater tidal marshes is likely to produce major changes in species composition (Baldwin et al. 1996). The stress and disturbance to the existing vegetation in these areas may encourage an undesirable expansion of *Phragmites australis* (Chambers et al. 2003)

Tidal marshes in some areas are already showing signs of degradation that are at least partly due to the effects of sea level rise. The most dramatic effects have occurred in the Mississippi Delta region where tidal marshes have been lost at rates as high as 10,000 (hectares/year) ha/yr since the 1930s (Day et al. 2000). The high loss rate is mainly due to a combination of a high rate of relative sea level rise that is approximately 12 mm/yr (due to subsidence) and human activities that have led to a reduction of sediment input to the wetlands (Day and Templet 1989). The Galveston Bay region of southeastern Texas has also experienced major salt marsh loss with approximately 5,000 ha lost since the 1940s (White and Morton 1997). The cause of this loss has been attributed primarily due to the high relative rate of sea level rise, 6.5 mm/yr, that was a consequence of groundwater pumping and hydrocarbon extraction, with a contributing factor being a reduction in sediment supply due to major dam construction in the 1950s and 1960s (Ravens et al. 2009). The rising sea level is postulated to be the underlying force responsible for large marsh losses within the Blackwater and Nanticoke river systems in Chesapeake Bay (Stevenson et al. 1985; Kearney et al. 1988). Since the 1940s the brackish marshes in these areas have been lost at a combined rate of nearly 100 ha/yr. The average relative rate of sea level rise during this period was 3.5mm/yr (Boon et al. 2010) which was nearly double the mean global rate because of local subsidence exacerbated by groundwater withdrawal (Stevenson et al. 2000). While the marsh losses observed in the Gulf Coast and Chesapeake Bay areas are not typical because of their unusually high rates of relative sea level rise and other factors, they illustrate that high rates of marsh loss could be expected to occur under the higher rates of sea level rise that are predicted by the end of the century.

In recent years there have been increased reports of sudden marsh dieback (Alber et al. 2008). The reasons for these events, which are generally transient, are often not clear. Most are believed to be happening not as a result of sea level rise but rather due to a variety of other causes (e.g., drought). Nevertheless, in an environment of increased sea level rise, the disturbance caused by even a temporary loss of the plants could provide a catalyst for persistent vegetation change (Baldwin and Mendelssohn 1998; Kirwan et al. 2008).

Marshes that are deteriorating from excessive sea level rise may display a variety of symptoms as they progress towards eventual conversion to unvegetated flats and open water. As the period of inundation increases, tidal channels may develop, widen, and/or erode headward in response to the increased tidal prism (Downs et al. 1994; Hartig et al. 2002; Hughes et al. 2009). Some studies have suggested that sea level rise may also increase erosion of the seaward edge, but the significance depends on factors such as the wave, climate and nearshore sediment dynamics (Phillips 1986; Finkelstein and Hardaway 1988; Wray et al. 1995; Schwimmer and Pizzuto 2000). Plant vigor may decline. The peat substrate may begin to decompose, develop a more soupy consistency, and collapse downward (DeLaune et al. 1994; Day et al. 2011). This is likely to be accompanied by interior pond and mudflat development (Stevenson et al. 1985; Wray et al. 1995). As the ponds enlarge and coalesce, they may become large enough so that erosion from wind driven wave action occurs, accelerating the process of marsh loss.

Before the marsh platform begins deteriorating, there may be changes in the vegetative composition. High marshes appear to be particularly at risk. Several studies at marshes in New England have found striking reductions in the extent of high marsh, particularly since the 1980s, that were attributed mainly to sea level rise (Orson and Howes 1992; Warren and Niering 1993; Kelly et al. 1995; Donnelly and Bertness 2001; Smith 2009). The typical high marsh species such as *S. patens*, were replaced by *S.alterniflora*, forbs, or occasionally bare mud flat. This trend is contrary to the normal long-term pattern of development in which *S. alterniflora* succeeds to *S. patens* (Redfield 1972; Orson et al. 1987). As sea level rise accelerates, *S. alterniflor*a is expected to displace *S. patens* because it is better adapted to waterlogging and high salinity conditions (Naidoo et al. 1992). The ability of high marsh species to respond by migrating into adjacent uplands is often limited because of slope and human land use. Even where these factors are favorable, the disturbance of the vegetative community tends to favor colonization by invasive species such as *P. australis* instead (Smith 2013).

There are a number of ways to assess the vulnerability of marshes to sea level rise before they begin showing obvious signs. One way is to directly measure surface accretion and the net change in the marsh's elevation with surface elevation tables (SETs) and marker horizons (Cahoon et al. 1995b, 2002). The rate of elevation change is then compared with the rate of sea level rise to determine whether it is keeping pace. These measurements, along with the amount of "elevation capital", provide an indication of the marsh sustainability under the current sea level rise conditions and the buffer capacity available for future increases. Preliminary findings reported by Cahoon (2006) from 34 locations around the world indicated that most marshes were keeping up with sea level rise. However, because of within marsh temporal and spatial variability, it is recognized that more stations and longer records are needed to adequately assess marsh vulnerability (Cahoon et al. 2011; Webb et al. 2013). Extrapolating the results of point measurements over broader geographical areas is questionable.

Satellite imagery has been used to detect early changes in marsh surface condition produced by the stress of sea level rise in Chesapeake Bay and Delaware Bay (Kearney et al. 2002). The technique involved using the Landsat Thermatic Mapper imagery to develop a spectral mixing model calibrated with ground site investigation. The model measures variations in marsh surface reflectance that indicate various degrees of substrate degradation arising from increased inundation. The technique detected large areas of marsh substrate degradation in middle portion of the eastern shore of Chesapeake Bay near Blackwater National Wildlife Refuge and on the northeast shore of Delaware Bay that expanded on previously observed patterns. While this technique has the advantage of being able to cover large geographical area, its utility may be limited by confounding factors such as temporary surface wetness caused by tidal and/or meteorological factors.

A number of sea level rise impact models have been developed to assess the vulnerability of tidal marshes to various sea level rise scenarios (McFadden et al. 2007; Kirwan and Temmerman 2009; Mcleod et al. 2010). They vary in complexity from simple inundation models to rule based models that use simplifying assumptions on critical processes to more elaborate numerical models that can make more intricate process representations (Cahoon and Guntenspergen 2010).

One widely used model is the Sea Level Affecting Marshes Model (SLAMM). The U.S. Fish and Wildlife Service used the SLAMM model to assess the vulnerability of tidal marshes on more than 120 National Wildlife Refuges. This model has been intermittently under development since 1985 with the most recent version, SLAMM 6, released in 2010 (www.warrenpinnacle.com/prof/SLAMM). The model simulates five dominant processes that affect the fate of tidal marshes under different scenarios of sea level rise: inundation, accretion, erosion, soil saturation, and barrier island overwash. The developer describes it as a relatively simple model, relatively easy to apply, with modest data requirements. Some of its limitations include: accretion rates are based on empirical relationships rather than the more intricate process-based mechanistic approaches; the erosion rates and barrier island overwash components are based on simple assumptions subject to considerable uncertainty; and future changes in hydrodynamic conditions are not well accounted for. Until SLAMM 6 the accretion component did not account for feedbacks that are known to be an important part of the marsh response. Because of this shortcoming, the model has been criticized for overestimating marsh loss (Kirwan and Guntenspergen 2009). Of course, the quality of the input data parameters, especially elevations, will affect the predicted outcomes. Since the SLAMM predictions are subject to considerable uncertainty, the newest version includes an uncertainty analysis procedure to provide perspective for the results. The model developers caution users that, since there is not any one right prediction, it is much preferable to consider a range of possible outcomes.

Development of models to predict the response of tidal marshes to sea level rise is difficult because of the complex interactions of the physical and biological processes that contribute to maintenance of the surface elevation. The effects of sea level rise often cannot be distinguished from sediment supply reduction, disturbance to vegetation, and a variety of other anthropogenic effects that influence marsh accretion rates (Kennish 2001; Bertness et al. 2002; Cahoon and Guntenspergen 2010; Kirwan and Megonigal 2013). It is generally recognized that more research is needed for the development of improved predictive models.

While there is currently a healthy degree of uncertainty regarding predictions of the expected amount of sea level rise and the wetland response, the available evidence indicates that increase in the rate of sea level rise, combined with the detrimental effects of human activities (e.g., actions that limit sediment delivery, enhance subsidence, alter nutrient inputs, and preclude landward migration) will cause substantial deterioration of coastal wetlands over the next century. In turn, this will affect the ability of tidal marshes to perform a variety of ecosystem services such as protecting coastal regions from storms, sequestering carbon, transforming nutrients, supplying organic matter for use in estuarine food webs, and providing habitat for fish and wildlife.

Erwin et al. (2006), after examining long-term marsh core data and short-term (3 to 4 year) elevation data using surface elevation tables at five coastal marsh islands between Massachusetts and Virginia, found evidence of increased inundation that will threaten the annual fecundity of marsh nesting waterbird species including several of federal and state concern: American black duck (*Anas rubripes*), Nelson's sharp tailed sparrow (*Ammodramus nelsoni*), saltmarsh sparrow (*A. caudacutus*), seaside sparrow (*A. maritima*), coastal plain swamp sparrow (*Melospiza geogiana nigrescens*), black rail (*Laterallus jamaicensis*), and Forster's tern (*Sterna forsteri*). In addition to the effects of increased flooding, which they viewed as a near-term problem, they predicted further decline in nesting habitat over the coming decades as high marsh is converted to low marsh and finally to open water.

As marshes deteriorate their habitat value for some groups may actually increase. For example, an increase in the period of submergence and prevalence of channels and interior ponds will improve habitat value for fish and crabs (Rozas 1995). Foraging habitat for wading birds would also increase. However, these benefits would be reversed as the marsh converts to open water.

Freshwater and oligohaline marshes will be particularly vulnerable to the combined effect of sea level rise and salinity intrusion (Craft et al. 2009). The changes in community structure would depend on the rate of sea level rise and the salinity, and would likely result in a large decease in diversity (Baldwin et al. 1996). Rare species such as the sensitive joint vetch (*Aeschynomene virginica*), an annual legume listed as threatened under the Endangered Species Act, which inhabits fresh to slightly brackish tidal systems in four mid-Atlantic states, would be at great risk. The impact may be lessened in situations where the geomorphic condition involves a gradual increase in elevation, and human development is limited enough to enable inland marsh migration.

Effects on Ocean Coasts

The ocean coast of the northeast United States is primarily characterized by the presence of a sandy shoreline except in northern New England (especially Maine) where rocky coastlines prevail. The effect of sea level rise on the rocky coasts should be minor and will not be discussed further. Sea level rise is believed to be a principle cause of beach erosion and shoreline retreat. Approximately 80% to 90% of the beaches along the East Coast, excluding those modified by coastal engineering projects or affected by lateral spit accretion, are experiencing long-term erosion, and sea level rise is considered to be a principle cause (Galgano et al. 1998). It should be noted that the use of the term "erosion" in this context, while in common usage, may be misleading because in many cases (especially on barrier islands), the beaches simply shift their position and are maintained as a geomorphic feature.

There is reason to believe that an increase in the rate of sea level rise will cause beach erosion (i.e., retreat) to increase substantially. Sea level rise exerts this effect by allowing waves to reach higher up on the beach and move the sand seaward. The Bruun Rule (Bruun 1962, 1988; Schwartz 1967) is the most widely cited model for predicting the amount of beach erosion that will occur as a result of sea level rise (Cooper and Pilkey 2004). It is a simple two-dimensional model based on the assumption that sandy shorelines will maintain an equilibrium profile as the shoreline recedes in response to sea level rise. According to the model, as the sea level rises, the volume of material that is eroded from the beach will equal the volume needed to raise the bottom in the nearshore area enough to compensate for the amount of sea level rise and thus maintain the equilibrium profile. The geometric relationships dictate that small increases in sea level rise will cause relatively large amounts of shoreline recession. Using values typical of coastal regions, the rate of shoreline recession would be 50 to 100 times the rate of sea level rise (FitzGerald et al. 2008). Indeed, observed erosion trends along selected reaches on the East Coast suggest that the rate of coastal erosion is approximately two orders of magnitude greater than the rate of sea level rise (Leatherman et al. 2000; Zhang et al. 2004). However, the Bruun Rule has been widely criticized for various perceived shortcomings including: relying on assumptions that are so restrictive that they cannot be met in most natural field situations (e.g., there must be no net longshore transport); omitting important variables (e.g., slope of the upland, sediment characteristics, and bottom currents; and relying on erroneous relationships (e.g., all shorelines have a similar shaped equilibrium profile) (Cooper and Pilkey 2004). Some revised models based on the Bruun Rule have been proposed to overcome some of its limitations (SCOR Working Group 1991; Davidson-Arnott 2005), but they have generally not been widely embraced. A basic problem is that there are numerous factors that cause changes in coastal morphology including sediment supply, variations in wave energy, wind action, sediment type, and tidal inlet dynamics. As a result, isolating the effect of sea level rise is very difficult. Consequently, while it is doubtful that the Bruun Model or other existing models have the capability to predict erosion rates over the next century, there is general agreement that sea level rise will aggravate the problem (Ashton et al. 2007).

The U.S. Geological Survey used six physical variables to conduct a national assessment of coastal vulnerability to sea level rise (Thieler and Hammar-Klose 1999). The variables included geomorphology, shoreline erosion rate, coast slope, relative rate of sea level rise, mean tidal range, and mean wave height. They were used to develop a Coastal Vulnerability Index to indicate the relative risk of coastal change. The pattern that emerged showed the most vulnerable coastal region in the Northeast was located between Virginia and New York. This area is where barrier islands are the most prevalent. Since barrier islands are dynamic, low elevation environments that are sensitive to a variety of driving forces, they have the potential to be substantially affected by an increase in the rate of sea level rise. Historically, barrier islands have responded to sea level rise by slowly but progressively migrating landward (Leatherman

1979). Sand is transported across the island by storm overwash or through inlets that occur when breaches occur. Under natural conditions inlets form, shift their position, close, and then reform at another location. If the rate of sea level rise accelerates, at a minimum there would be incremental increases in barrier island migration and the associated processes involving overwash and island breaching (Gutierrez et al. 2007). More vulnerable barrier islands could undergo fundamental changes in their state such as a major decrease in barrier width and height, rapid island migration, and disintegration. One response model (FitzGerald et al. 2004) is based on the possibility that accelerated sea level rise will cause a loss of wetlands in the back bays and an increase in the tidal prism at the inlet. The larger tidal prism would reduce sand supply to the barrier by diverting more sand to the ebb-tidal shoal, thus weakening the barrier island and promoting a more transgressive system. While it does not appear that this model would be widely applicable, it does draw attention to the importance of sand supply and inlet dynamics for maintaining barrier island integrity.

The response of barrier islands to an increase in the rate of sea level rise may be also affected by an increase in storm activity and associated wave heights that may occur as a result of the change in the Earth's climate. There is increasing evidence to indicate that severe storms such as hurricanes will increase in both frequency and intensity during the 21st century (Webster et al. 2005; Emanual 2005, 2013; Komar and Allan 2008). It is generally accepted that storms provide concentrated pulses of energy responsible for a major portion of the sand movement (Leatherman 1979; SCOR Working Group 1991; Doran et al. 2013). However, the role of storms in barrier island dynamics is not entirely clear. An analysis of the storms that occurred during the last century on the East Coast concluded that they were not a big factor in long-term beach erosion over this period (Zhang et al. 2002). This study found that even though large storms caused severe beach erosion and even breaching of the barrier, the beaches tended to recover back to their long-term trend positions. It is believed that the recovery, which can take 4 to 5 years or more for a major storm, is effected by fair weather long period swell waves that transport sand from offshore back onto the beaches. In addition, plant community development and aeolian sand transport on the barrier eventually rebuild the dune vertical profile although this takes longer to accomplish than restoration of the shoreline horizontal position. The role of storms in long-term erosion of the shoreline is difficult to discern because the short-term fluctuations in shoreline position are much larger than the underlying long-term rate of erosion (Galgano et al. 1998). Notwithstanding the ability of barrier beaches to recover from storms, there is still concern that if the frequency and/or magnitude of strong storms increased to the point where the time for recovery was not available, they could be affected to a greater degree than they have been in the past (Ashton et al. 2007; Gutierrez 2007).

Natural barrier islands and spits may consist of a variety of components including open beach, dunes, shrub zone, maritime forest, saltmarsh and intertidal flats. The beaches and dunes may be important nesting grounds for several species of shorebirds, terns, and gulls. Large numbers of songbirds may rest and feed there during the spring and fall migrations. The saltmarsh and shallows also provide habitat for many different types of birds. The presence of these barriers is also necessary to allow the coastal bays and lagoons to be the biologically productive environments that they are. The barriers also shield mainland areas from the full force of the ocean. These natural values have led to many being incorporated into federal and state wildlife refuges and parks. As the rate of sea level rise accelerates, there is likely to be increased erosion, landward migration, overwash, and inlet formation. These changes will promote early successional habitats, such as open beach and early dune formation at the expense of the more advanced successional stages such a shrub zones and maritime forest. If the sea level rises fast enough, overwash could become so frequent that even the early successional species could be harmed.

Many of the coastal barrier islands have been developed, and various structural engineering projects (e.g., jetties, groins, bulkheads) have been implemented to stabilize the barriers in place. Natural processes such as overwash, inlet formation, and inlet migration have been halted. Under natural conditions these processes would help the barrier to persist over time through landward migration and vertical accretion. Therefore, while structural engineering measures may provide an interim degree of stabilization, they will probably increase the vulnerability to sea level rise over the longer term (Charlier and De Meyer 2000). For example, a study of the effects of storms and storm-generated currents on beaches in southern Maine (Hill et al. 2004) found beaches in developed areas experienced a greater loss of sand during a storm than beaches in less developed locations where the sand was able to be redistributed across the profile. The less developed beaches also recovered their pre-storm profiles faster than the more developed beaches during the months after the storm. Stabilization measures on developed barriers also have the potential to adversely affect neighboring undeveloped barriers by interrupting the littoral drift system of sand transport, effectively making them more vulnerable to sea level rise.

In areas where development occurs landward of the dunes, coastal erosion will progressively narrow the habitat and alter the plant community composition (Feagin et al. 2005). A study of projected effects of sea level rise on the breeding habitat of piping plover (a federally listed threatened species) in Suffolk County, New York, concluded that the presence of human development would become an increasing critical problem by limiting plover habitat migration (Seavey et al. 2011). In the absence of development, breeding habitat would actually increase even under the 1.5 m/100 yr scenario, although nest failures were likely to dramatically rise if storm activity increases also. As developed shorelines become increasingly threatened by sea level rise, there may be efforts to implement further structural stabilization measures that could have unintended consequences including adversely affect neighboring undeveloped barriers (Bernatchez et al. 2011). Even softer approaches such as some forms of beach nourishment (e.g., inlet backpassing), could divert sand that would otherwise be transported along the shoreline.

Predicting long-term effects of sea level rise on the ocean coast involves a high degree of uncertainty. Regional sediment budgets and anthropogenic influences (e.g., beach nourishment) are important unknowns. Nevertheless, it is likely that there will be increased erosion and shoreline retreat, increased occurrence of overwash and inlet breaching, and for some especially vulnerable barriers systems, major changes in state (Gutierrez et al. 2007).

Effects on Estuarine and Coastal Bay Shorelines

Wave exposed shorelines within estuaries and coastal bays are likely to see higher rates of erosion as sea level rise increases (Rosen 1978; Stevenson and Kearney 1996). Sea level rise has this effect because it allows waves to impact the shoreline at a higher elevation (National Research Council 2007). Erosion rates on non-ocean tidal shorelines may be significantly higher than on the more exposed ocean coast (French 1990). One reason for this is that the non-ocean beaches lack exposure to the long period swell wave that return sand to ocean beaches (Nordstrom 1980). Since erosion of estuarine and bay beaches is typically storm-driven (French 1990), if the storm activity increases, this would compound the effect of rising sea level. While sea level rise is believed to be an underlying driving force, there are many other factors that directly affect shoreline erosion including the material composition of the shoreline, bank height, supply of sandy material in the littoral zone, wave energy exposure, tidal range, and human influences (Rosen 1977, 1980; Stevenson and Kearney 1996; Perry 2008). These factors often make it difficult to discern the effect of sea level rise.

While there are many types of shorelines in estuaries, beaches tend to be the most common especially in the region closer to the ocean where sand is more available. These beaches, which are smaller than on the ocean coast, may occur either along the upland edge or as so called "fetch limited" barriers (Lewes et al. 2005). Their presence also tends to reduce erosion of uplands and wetlands by absorbing wave energy. Beaches tend to be relatively resilient to sea level rise since they are able to migrate landward as the shoreline retreats. However, the combination of sea level rise and increased storm activity could cause more of the sand to be lost offshore. Since bank erosion may be an important source of sand to maintain beaches, structural shoreline stabilization projects can impact them by reducing the sand supply (Bernatchez and Fraser 2012). Beaches can also become trapped between development on the land side and rising sea level on the water side, leaving little room for normal landward migration and sediment dynamics (Defeo et al. 2009). The net result of these effects will probably be a net reduction in beach habitat. A decline in beaches would particularly affect estuarine beach dependent species such as many shorebirds (e.g., red knot which is federally proposed as a threatened species), gulls, terns, horseshoe crabs (*Limulus polyphemus*), diamondback terrapin (*Malaclemys terrapin*), and the federally threatened Puritan and northeastern beach tiger beetles (*Cicindela puritana* and *C. dorsalis dorsalis*).

A study by Galbraith et al (2002) illustrates the potential effect of sea level rise on prime migratory shorebird habitat. The study used the SLAMM version 4 to investigate the effect of sea level rise on beach and intertidal flat habitat at Delaware Bay and four other sites on the west and Gulf coasts known for their importance to migrating or wintering shorebirds. Delaware Bay supports the second largest spring concentration of migrating shorebirds in the Western Hemisphere and is a critical stopover site for the red knot. Under a conservative scenario where a global sea level rise of 0.34 m by 2100 is adjusted with tidal gage records, the model predicted a 20% loss of Delaware Bay beach and intertidal flat habitat by 2050 and a 57% loss by 2100.

Inundation from sea level rise could be a significant factor affecting low lying uplands. For example, a vulnerability assessment for the State of Delaware (Delaware Coastal Programs 2012) determined that a sea level rise of 1 m would inundate 7,890 acres of forest. However, this only represents 4% of the state's upland forest. In Maryland, sea level rise is expected to inundate a substantial area of forest inhabited by the federally endangered Delmarva Peninsula fox squirrel (*Sciurus niger cinereus*). The greatest risk is in southwest Dorchester County where approximately 23,000 acres of occupied squirrel habitat is projected to be inundated and lost under a 0.6 m (2 feet) sea level rise scenario (USFWS 2012). While a loss of this magnitude is a concern, it is not considered an extinction threat, and almost 60,000 acres of occupied habitat would remain in this important part of its range.

There is reason to expect that some forest communities will be affected before they are actually inundated. For example, a study examining the reduction of slash pine forest in the Florida Keys following a modest 15 centimeter (cm) rise in local sea level, found that the increase in the ground and soil water salinity was a major factor in the decline of the community (Ross et al. 1994).

Many small islands in estuaries and bays are at especially high risk since they are being affected by both erosion and inundation. In Chesapeake Bay for example, large numbers of small islands have already been completely lost (Cronin 2005), especially during the last century when the rate of loss is believed to have accelerated (Wray et al. 1995). A further increase in the rate of sea level rise will compound the problem. The loss of small islands receives little attention in sea level rise vulnerability assessments because the area lost is relatively low. However, these islands are critical as nesting sites for a variety of waterbirds including herons, egrets, terns, gulls, American black ducks, and black skimmers (*Rynchops niger*) (Erwin et al. 1995, 2011; Erwin 1996; Brinker et al. 2007). In addition to outright loss, the habitat quality of the islands is being detrimentally affected by increasing overwash, elimination of low dune habitat, and death of woody vegetation (Erwin et al. 2011; Springston 2012).

Effects on Estuarine and Coastal Bay Aquatic Habitats

Sea level rise will affect estuarine and coastal bay aquatic zones in a variety of ways. It will promote deeper water depth, although the effect may be locally modified by changes in the bottom elevation due to shoaling or scouring. An increase in depth will have a great effect on beds of submerged aquatic vegetation which are limited to the shallow zones where light is sufficiently available (Orth and Moore 1988). The increased water depth will eventually reduce light availability and render the habitat unsuitable. In some areas the plants may have the option of shifting their distribution landward. However, as shorelines become increasingly hardened, the landward transgression of shallow subtidal zones will likely be limited (Orth et al. 2010). Also the shallows that are created by erosion of marshes typically are not colonized by aquatic grasses (Stevenson et al. 2002). In fact it has been postulated that the erosion of marshes will adversely affect aquatic grasses by producing higher turbidity in the water column and causing fine-grained particulates to cover the preferred sandy bottom substrate (Stevenson et al. 2002). The aquatic plant community in the freshwater and brackish water areas will likely become stressed as sea level rise brings higher salinity water further up the estuaries (Short and Neckles 1999). How effectively higher salinity tolerant species will be able to replace them is uncertain. The loss of aquatic grass beds would be a particular concern because they constitute a rich habitat and food source for numerous fish, invertebrates, and waterfowl including many of commercial and recreational importance, as well as modulating key biogeochemical, physical, and sedimentological processes (Kemp et al. 2004).

There is a general consensus that sea level rise will tend to raise salinity levels in estuaries (Najjar et al. 2000; Hilton et al 2008), although the amount of increase will vary depending on the specific type of estuary. Some models are also predicting that there will be increases in the tidal range of shallow estuaries like Chesapeake Bay (Zhong et al. 2008; Hong and Shen 2012). This seems to be a result of reduced friction and a change in the resonant period. A numerical model study in Chesapeake Bay found that the net result would be an increase in water column stratification which could exacerbate hypoxic conditions in the bottom layer (Hong and Shen 2012). Changes in salinity and circulation patterns would have important consequences for estuarine ecosystems. The effects of sea level rise on estuarine aquatic habitats may be exacerbated or mitigated by other aspects of climate change. For example, it is likely that climatic changes will include alteration of the seasonal pattern and intensity of rainfall which would affect estuarine salinity, suspended sediment loading, water column stratification, and dissolved oxygen concentration. The following accounts provide information on the broader aspects of sea level rise and climate change that are useful to consider in this context: Scavia et al. 2002; Titus 2009; Najjar et al. 2010; Burkett and Davidson 2012. There would also likely be interactions with anthropogenic stressors such as nutrient loading.

Summary Conclusions

Tidal marshes, ocean coasts, estuarine shorelines, and estuarine aquatic habitats will all be affected by accelerating sea level rise. Unlike urban areas where the effect of sea level rise is primarily through flooding and can be relatively easily predicted, the effect on many natural functioning ecosystems such as beaches, unconsolidated cliffs, barrier islands, and wetlands is more complicated because of their dynamic nature. This is due in part to the presence of physical and bio-physical sedimentation and erosion processes that, when altered by sea level rise, produce changes that are difficult to predict. It is clear that if sea level rise accelerates, there will be an increase in the rate of coastal retreat and wetland loss. However, the development of more quantified predictions of the ecosystem responses is constrained by the complexities of coastal sedimentary and other system processes, uncertain future anthropogenic actions and effects, and by the variability of the meteorological forces that drive coastal change. The uncertainty involved in forecasting effects on particular species is even greater because of the need to consider specific species-habitat relationships as well as interactions between species. This issue is likely to become an increasing focus of research if the rate of sea level rise continues to increase as expected.

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Part II

Vulnerable Priority Biological Resources and Risk to Coastal National Wildlife Refuges

Introduction

The changes in coastal habitats that occur as a result of sea level rise and storm activity will have important consequences for biological resources. The effects on federally threatened and endangered species that live in these coastal habitats are a particular concern. Waterbird nesting areas and concentration areas are also expected to be especially vulnerable. Many of the nation's national wildlife refuges (NWR) are located in the coastal zone where they will be at risk. This section of the report provides information on these vulnerable biological resources and refuges. The information is focused on those resources and refuges that are most at risk and is not intended to be a comprehensive listing of all that might be affected. The information is organized by state and covers the 10 coastal states from Virginia to Maine. Geographic location information in GIS format is being supplied to the U.S. Army Corps of Engineers separately. Summary maps are included as an appendix to the report.

VIRGINIA

Federally Listed Threatened and Endangered Species

Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis*)

The Northeastern beach tiger beetle (NBTB) was federally listed as a threatened species on August 7, 1990. Adult NBTBs are present on occupied shorelines from June to September. The adults mate and lay eggs from late June through August. Females are thought to lay eggs at night in shallow burrows in the mid to high tide zone on coastal beaches. Larval burrows are 15 to 50 cm deep and are found anywhere from the mean low tide line to the base of the dunes above the beach. Larvae will move their burrows up the beach to avoid winter storm floods and narrowing of the beach. Larvae are active primarily at night and plug the entrance to their burrow during warm days when the sand surface dries out. Depending on the prey base availability, larvae transition through three stages in 1 to 2 years before they pupate and emerge as adults. Larvae are present year round on the beach, hibernating through the winter.

Adults are active predators that forage on small invertebrates or scavenge on dead fish, crabs, and amphipods. Larvae are sedentary ambush predators that live in well-formed burrows from which they extend to capture passing prey.

NBTB favors beaches with low human disturbance that are moderate to wide in width, have a functional dune system, and are highly exposed to the shoreline dynamics of erosion and accretion. NBTB favors beaches with a mean sand grain size between 0.40 to 0.70 mm, a sand grain size linked to healthy and stable beach habitat conditions.

NBTB was historically abundant along coastal beaches from Massachusetts to New Jersey, and along the Chesapeake Bay in Maryland and Virginia. NBTB has been extirpated from Connecticut, Rhode Island, and New York. The status of the translocated population at Gateway National Recreation Area, Sandy Hook, New Jersey is uncertain. Only two known populations of this beetle can be found north of the Chesapeake Bay, both in Massachusetts (Martha's Vineyard and a translocated population established at Monomoy NWR). There are only four occupied sites remaining in Maryland, the highest number of occupied sites lie along sections of beaches found in Virginia's portion of the Chesapeake Bay. Studies have shown that adults can disperse up to 7 kilometers (km) after emergence.

Few NBTB sites are protected and many are threatened by human activities. Loss of this beetle from most of its range has been attributed primarily to destruction and disturbance of natural beach habitat from shoreline development, beach stabilization, and high levels of recreational use. Additional threats include pollution, pesticides, oil slicks, and off-road vehicle traffic. Natural limiting factors include winter storms, beach erosion, flood tides, hurricanes, parasites, and predators. Recovery of the tiger beetle primarily focuses on protecting it within the Chesapeake Bay. The increased threat from severe storms, land subsidence along much of Virginia's coastline, and sea level rise, has resulted in much of the developed shoreline areas being hardened with bulkheads, stone revetments, and groins. These hardening structures provide limited protection to the human infrastructure backing them, and result in the complete loss of a functional shoreline. The U.S. Fish and Wildlife Service, working with the Virginia

Institute of Marine Sciences (College of William and Mary) has determined that the use of stone breakwaters combined with beach/dune reconstruction with appropriate plantings, will provide the best protection to the human infrastructure backing these shoreline areas, while allowing the beach to maintain its natural functions.

Piping Plover (*Charadrius melodus*)

Piping plovers occur in three disjunct populations in North America: Northern Great Plains, Great Lakes, and Atlantic Coast. The piping plover was federally listed as a threatened species along the Atlantic Coast on January 10, 1986. In the Northern Great Plains, it is federally listed threatened and in the Great Lakes, endangered. Virginia is part of the Atlantic Coast Piping Plover Southern Recovery Unit, and Virginia was 66% of the total productivity for this unit in 2012. In Virginia, the plover's nesting habitat includes ocean-facing beaches, dunes, and over-washed sand flats as well as several inland sites along the shores of the Chesapeake Bay and associated river systems.

In 2012 as part of the annual Virginia Plover Survey, 17 ocean-facing sites were included in the survey covering an estimated 194 km of Virginia ocean-facing coastline along with 2 inshore sites on the western shore of the Chesapeake Bay (Grandview Beach and Plum Tree Island NWR) and Craney Island, a dredged material disposal site located near the mouth of the Elizabeth River in Portsmouth, VA. The survey found a total of 207 breeding pairs and 19 unpaired single adults along Virginia's barrier islands. This is a 16% increase from the number of pairs documented in 2011 (179 pairs). The 2012 distribution was confined to the barrier islands (Assateague Island to Fisherman Island) with the majority of birds occurring on the northern barrier islands (Assateague Island to Cedar Island). No piping plovers were documented at ocean-facing sites south of the Chesapeake Bay (i.e., Back Bay NWR and False Cape State Park) or on the western shore of the Chesapeake Bay and the James River; a trend that has been ongoing since 1997. The 2012 end-of-season breeding pair total which includes additional pairs discovered during productivity monitoring efforts following the breeding survey) was 259 pairs. This reflects a 38% increase from last year's end-of-season pair total of 188 pairs and represents the highest breeding pair total documented in Virginia since monitoring efforts began in 1986. The greatest annual increase occurred on Cedar Island where the pair total rose from 32 in 2011 to 66 in 2012. The second largest increase was documented on Smith Island where the number of pairs increased by 10 pairs in 2012. Piping plover breeding activity has been steadily increasing on Smith Island since 2004 when only one pair was recorded at the site.

Destruction and degradation of habitat and disturbance during the nesting season by humans and pets are threats to this species. Piping plovers are extremely sensitive to disturbance during the nesting season. Predation by red foxes, skunks, raccoons, feral cats, herring gulls, fish crows, grackles, and ghost crabs is an additional threat to the eggs and young. The piping plover nesting season is from late April to late July with one brood raised per year. If there is a disturbance or the nest is lost, the birds may renest. Plovers nest on beaches, dunes, and washover areas. They also nest on areas where suitable dredged material is deposited. The nest is a shallow scrape in the sand dug by the adults and is usually lined with broken seashells and small pebbles. The female usually lays four eggs. Shortly after hatching, the flightless chicks must leave the nest to move to suitable feeding areas. They feed on small invertebrates in intertidal surf, barrier flats, and sand flats and along the ocean and barrier bays. In many locations moist flats on the back side of the barrier are preferred foraging areas. Dense vegetation can be a problem since it impedes movement of the flightless chicks to suitable feeding areas. Plovers migrate to breeding grounds from February through early April, and to wintering grounds from late July through September.

All plover habitat located on coastal barrier islands or spits will be affected by sea level rise and increased stormy conditions. These dynamic geomorphic features can experience major changes in ecology as a result of severe storms. As the rise in sea level accelerates, extreme storms will likely cause barrier islands to experience more beach and dune erosion, more overwash, more frequent island breaching, and more rapid landward migration. These types of changes could be beneficial to piping plover, which prefer sparsely vegetated areas, unless nest flooding becomes too frequent. The plover habitat in Virginia is located on relatively naturally functioning barrier islands that should be relatively resilient. These changes in barrier islands will also affect coastal bay and lagoon habitats; so bird nesting colonies and listed species habitats located on bay islands or along the shoreline would also be considered vulnerable. Exposed coastal headland beaches and dunes will also be susceptible to substantial change following major storms.

Rufus Red Knot (*Calidris canutus rufa*)

The red knot is the second largest *Calidris* sandpiper, measuring 23 to 26 cm long with a 47 to 53 cm wingspan. The body shape is typical for the genus, with a small head and eyes, a short neck and a slightly tapering bill that is no longer than its head. It has short dark legs and a medium thin dark bill. The winter, or basic, plumage becomes uniformly pale grey, and is similar between the sexes. The alternate, or breeding, plumage is mottled grey on top with a cinnamon face, throat and breast and light-colored rear belly. The alternate plumage of females is similar to that of the male except it is slightly lighter and the eye-line is less distinct. The transition from alternate to basic plumages begins at the breeding site but is most pronounced during the southwards migration. The molt to alternate plumage begins just prior to the northwards migration to the breeding grounds, but is mostly during the migration period. Both sexes incubate the eggs but the female leaves parental care to the male once the eggs have hatched. Juvenile birds have distinctive submarginal lines and brown coverts during the first year. The weight varies with subspecies, but ranges between 100 and 200 grams. Red knots can double their weight prior to migration. Their diet varies according to season; arthropods and larvae are the preferred food items at the breeding grounds, while various hard-shelled mollusks are consumed at other feeding sites at other times. North American breeders migrate to coastal areas in Europe and South America, while the Eurasian populations winter in Africa, Papua New Guinea, Australia, and New Zealand. This species forms enormous flocks when not breeding.

The red knot (*Calidris canutus*) is divided into six subspecies, the subspecies *rufa* has been proposed for listing as threatened by the U.S. Fish and Wildlife Service. The mid-Atlantic Coast is a terminal staging area where the *rufa* population of red knots stops in spring to prepare for the last leg of its migration to breeding grounds in the high Arctic. Numbers stopping at Delaware Bay, the most significant mid-Atlantic staging area, have declined by nearly 90% over the last 30 years. In Delaware Bay, red knots depend on horseshoe crab eggs to rapidly restore fat reserves before departing. Overharvest of horseshoe crabs in Delaware Bay and the related degradation of foraging conditions has been one of the leading factors proposed to explain knot declines.

The Virginia Barrier Islands represent a second, spring staging area for red knots within the mid-Atlantic. The island chain includes more than 100 kilometers of open beach and represents one of the most pristine set of coastal barriers remaining in North America. Unlike Delaware Bay, the islands support no significant spawns of horseshoe crabs. Red knots that stage along the Virginia's islands feed on clams (*Donax*) within the surf zone and mussels on intertidal peat deposits. There are strong indications that Hurricane Sandy may have severely impacted the population of the *Donax* clams in Virginia. The biggest threat to the *rufa* red knot in Virginia is the loss of foraging and resting habitat associated with the barrier islands. Severe storms, climate change, land subsidence, and sea level rise are all threats to this essential habitat.

Seabeach Amaranth (*Amaranthus pumilus*)

Seabeach amaranth is endemic to beaches of the Atlantic coast from Massachusetts to South Carolina. It occurs on sparsely vegetated overwash flats and fore dunes, often around inlets on accreting barrier island ends. By 1988, seabeach amaranth was reduced to beaches in North and South Carolina. Its decline was likely caused by beach development, dune stabilization and enhancement projects, off-road vehicles, recreation, exotic species, and hurricanes. Severe weather in 1989 and 1990 (Hurricane Hugo, Hurricane Bertha, and nor'easters) caused the South Carolina population to decline significantly. It is also believed that as a result of such severe storms, 13 populations were established on Long Island, New York (the plant was extirpated from New York in 1960) from seeds washed from sites in the south and transported by currents to the beaches on Long Island.

Seabeach amaranth was federally listed as threatened on April 7, 1993. Since listing, the species has recolonized New Jersey, Delaware, Maryland, and Virginia. Extirpated from Virginia in 1973, the Virginia portion of Assateague Island (Chincoteague NWR) was recolonized in 2001 from seeds produced by plants planted on the Maryland portion of the island in 2000.

Hurricanes and storms reduce and eliminate populations, but also create new habitat by reducing competing ground cover. They may also aid large-scale dispersal. The amaranth traps sand, initiating dune formation and creating suitable habitat for other plants, such as sea oats and beach grass. Numerous shorebirds, including the least tern (*Sterna antillarum*), Wilson's plover (*Charadrius wilsonia*), black skimmer (*Rhynchops niger*), Caspian tern (*Sterna caspia*), and the endangered piping plover (*Charadrius melodus*) and roseate tern (*Sterna dougallii dougallii*), nest in seabeach amaranth stands.

Sea Turtles

In Virginia, sea turtle nesting is primarily limited to the loggerhead sea turtle (*Caretta caretta*). The first confirmed nesting by the federally listed green sea turtle (*Chelonia mydas*) occurred on Back Bay NWR in 2005, and the first confirmed nesting by a Kemp's ridley sea turtle (*Lepidochelys kempii*) occurred in 2012 on U.S. Naval Air Station Oceana - Dam Neck Annex. Nesting by the green and Kemp's ridley sea turtles has only recently occurred in Virginia, the primary nesting sea turtle is the loggerhead. For the purpose of this study, the loggerhead sea turtle (loggerhead) will serve as our representative species.

Confirmed nesting by loggerheads is believed to be limited to Assateague Island (Chincoteague NWR), Wallops Island (NASA's Wallops Flight Facility), and the stretch of shoreline from Fort Story to the Virginia/North Carolina Stateline (this stretch includes Virginia Beach, the U.S. Naval Air Station Oceana - Dam Neck Annex, Back Bay NWR and False Cape State Park).

Loggerhead Sea Turtle (*Caretta caretta*)

The loggerhead sea turtle was initially listed as threatened throughout its range on July 28, 1978. On September 22, 2011, the listing was revised from a single global threatened species to a listing of nine Distinct Population Segments (DPS); four listed as threatened (Northwest Atlantic Ocean, South Atlantic Ocean, Southwest Indian Ocean, Southeast Indo-Pacific Ocean, and South Atlantic Ocean DPSs) and five listed as endangered (Northeast Atlantic Ocean, Mediterranean Sea, North Pacific Ocean, South Pacific Ocean, and North Indian Ocean DPSs). Nesting turtles in Virginia are listed as threatened and fall within the Northwest Atlantic Ocean DPS.

The loggerhead is widely distributed within its range. It may be found hundreds of miles out to sea, as well as in inshore areas such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers. Nesting occurs mainly on open beaches or along narrow bays having suitable sand. Loggerhead hatchlings originating from U.S. beaches are believed to lead a pelagic existence in the North Atlantic gyre for an extended period of time, perhaps as long as 7 to 12 years, and are best known from the eastern Atlantic near the Azores and Madeira. Once juvenile loggerheads reach a certain size, they move to coastal areas in the western Atlantic where they become benthic feeders in lagoons, estuaries, bays, river mouths, and shallow coastal waters. The juveniles occupy coastal feeding grounds for about 13 to 20 years before maturing and making their first reproductive migration, the females returning to their natal beach to nest.

Loggerheads nest within the U.S. from Texas to Virginia, although the largest nesting concentrations are found in Florida, Georgia, South Carolina, and North Carolina. The U.S. nesting season occurs from April through September, with a peak in June and July. In Virginia, nesting occurs later due to lower water temperatures. Nesting occurs primarily at night. Loggerheads are known to nest from one to seven times within a nesting season. The clutch size varies around an average of 120 eggs. Incubation duration ranges from about 42 to 75 days, depending on incubation temperatures. Hatchlings generally emerge at night. Remigration intervals of 2 to 3 years are most common in nesting loggerheads, but remigration can vary from 1 to 7 years. Age at sexual maturity is believed to be about 32 to 35 years. During non-nesting years, adult females from U.S. beaches are distributed in waters off the eastern U.S. and throughout the Gulf of Mexico, Bahamas, Greater Antilles, and Yucatan.

The number of nesting sea turtles in Virginia continues to grow, and in 2012 there were 17 loggerhead nests (4 on Chincoteague NWR, 2 on Wallops Island, 1 on Virginia Beach, 2 on Sandbridge, 4 on Back Bay NWR, and 4 on False Cape State Park). The expansion in numbers and the first nesting by a Kemps ridley in Virginia may be an indicator of an expansion in numbers and/or a response to climate change. If the increase is related to climate change, this could mean that Virginia may become even more important to the overall loggerhead population recovery. The colder waters and conditions in Virginia skew the hatchling sex ratio in favor of males. These males are considered important to the overall population recovery, and the genetic variance.

Sea turtles face many natural hazards. It is estimated that only 1 out of every 5,000 eggs develops into an adult animal. Sea turtle nests are vulnerable to predators such as raccoons, foxes, and ghost crabs. Additional threats to nests include high winds and severe storms, which cause extensive beach erosion.

Many human activities have placed additional stress on sea turtle populations. Many human activities result in indirect threats to sea turtle survival, including entanglement in fishing gear, ingestion of marine debris, collisions with boats, and increasing beachfront development, which reduces the availability of suitable nesting habitat.

Every year, hundreds of dead sea turtles wash ashore or strand on Virginia's shorelines within the Chesapeake Bay and along the ocean side. Typically, the majority of strandings occur during the latter part of May through June. The cause of death for the majority of strandings in Virginia remains unknown, although every year a number of animals are found with injuries indicative of boat strikes. Additionally, several turtles strand each year with ingested fishing hooks and/or with some type of fishing gear trailing from the animal.

Waterbird Nesting Colonies

The majority of waterbird nesting colonies in Virginia are associated with the barrier islands found along the seaward side of the Eastern Shore, and the many waterways of the Chesapeake Bay system. These areas are comprised of the following habitat types: forested uplands, scrub/shrub wetlands, marsh wetlands, and non-vegetated wetlands. The colonies are comprised of the following 23 species: cattle egret (*Bubulcus ibis*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), great black-backed gull (*Larus marinus*), herring gull (*L. argentatus*), laughing gull (*L. atricilla*), great blue heron (*Ardea herodias*), green heron (*Butorides virescens*)**,** little blue heron (*E. caerulea*), tricolored heron (*E. tricolor*), glossy ibis (*Plegadis falcinellus*) white ibis (*Eudocimus albus*), black-crowned night-heron (*Nycticorax nycticorax*), yellow-crowned night-heron (*Nyctanassa violacea*), brown pelican (*Pelecanus occidentalis*), black skimmer, Caspian tern, common tern (*Sterna hirundo*), Forster's tern, gull-billed tern (*Gelochelidon nilotica*), least tern, royal tern (*Thalasseus maximus*), and sandwich tern (*T. sandvicensis*).

The colonies range considerably in size and diversity, and often a site supports multiple species. The well protected sites are used annually and many have been used for many years.

Sites along isolated shoreline segments within the Chesapeake Bay, the barrier islands, and the bay islands, are favored for their inaccessibility which in turn results in lower human disturbance. These areas already low in elevation are being impacted greatly by severe storms, sea level rise, and land subsidence. The species that use these wetland habitats for their colonies are most visibly being impacted by these issues. Species like the great blue heron are at the lowest threat from storm surges due to their use of forested upland areas adjacent to wetlands. However, these species are being impacted by secondary threats like saltwater inundation. On the Eastern Shore of Virginia NWR, there are vast sections of trees that have died-off due to saltwater inundation from past storm events. Some of these areas formally supported heron rookeries but no longer do. The nesting habitat preferred by the great blue heron is the most resilient at this time due to the amount of it available in Virginia and the fact that they nest in higher elevation areas. The secondary impacts can be greater than the initial storm surge depending on the time of year and the severity. As the rate of sea level rise increases, coastal wetlands will be lost at an increasing rate which will have an extreme impact on colonial waterbird nesting success.

The data used for this study was provided to the U.S. Fish and Wildlife Service by a database maintained by the Virginia Department of Game and Inland Fisheries. This database contains colony locations from the 2003 and 2008 surveys conducted by the Center for Conservation Biology, College of William and Mary, Virginia. The data from surveys conducted in 2013 was not available in time for this study. The data is point locations of known colonial nesting bird rookeries that are located within low-lying terrain threatened by storm surges, sea level rise, and land subsidence. The 2003 survey had 276 colonies within the geographic zone that has the potential to be impacted by storm surge and sea level rise.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

Chincoteague National Wildlife Refuge (NWR)

Chincoteague NWR, located primarily on the Virginia side of Assateague Island (Accomack County, Virginia), consists of more than 14,000 acres of beach, dunes, marsh, and maritime forest. Chincoteague NWR was originally established in 1943 to provide habitat for migratory birds, there are more than 320 species of birds are known to occur on the refuge. The refuge has been designated a Globally Important Bird Area, is part of the Western Hemisphere Shorebird Reserve Network and designated as one of the top ten birding Hotspots by the National Audubon Society.

More than 2,600 acres of man-made marshes, or moist soil management units, are managed for wintering waterfowl and shorebirds during migration. The saltwater marshes which lie to the west of the barrier islands are some of the most productive habitat found anywhere. A variety of mollusks and crustaceans live and feed in the refuge's salt marshes. This habitat is vital to American black ducks and many other migratory birds for nesting and feeding.

The shrub/scrub and wooded maritime habitats are an important component of the barrier islands, providing essential stopover areas for a wide diversity of neotropical migratory birds. The refuge is also managed for the threatened and endangered species that use the refuge resources. The maritime forests that occupy the higher ground are important to the endangered Delmarva Peninsula fox squirrel, while the beaches and overwash areas support the threatened piping plover, seabeach amaranth, and nesting loggerhead sea turtles. Unique residents of the island, the famous Chincoteague ponies, are housed in two areas on the refuge through a special agreement with the ponies' owners, the Chincoteague Volunteer Fire Company. This agreement over the pony management with the refuge boundaries, ties the refuge directly to the survival of the local economy for the Town of Chincoteague.

Approximately 1.4 million visitors a year use the facilities and resources available on Chincoteague NWR, making it one of the most visited refuges in the nation. Chincoteague NWR provides visitors with extraordinary educational and recreational opportunities. In addition, a special partnership exists with the National Park Service which allows Assateague Island National Seashore to administer public activities on a five-mile portion of the refuge beach. The refuge provides many recreational opportunities including, fishing, hunting, canoeing/kayaking, trail hiking, photography, and wildlife observation.

In recent years the barrier islands managed by Chincoteague NWR have experienced major changes as a result of storms. Hurricanes Isabel (2003), Ernesto (2006), and Sandy (2012), along with a number of major nor'easters have made major shoreline changes to the refuge. The refuge's primary infrastructure is restricted to Assateague Island, the primary portion that received the annual refuge visitors. Overwash of the beach road and parking lot has occurred numerous times, and the service road access for the public beach is under severe threat from future storm events. The refuge recently received more than $553,000 to address the two road areas impacted by storm surge and wave energy associated with Hurricane Sandy. The loss of these roads would impact both the tourism associated with access to the ocean beach and the U.S. Fish and Widlife Service's ability to manage the natural resources. The two living shorelines and the oyster reefs proposed for construction under this project are intended as natural infrastructure that will increase the resiliency and capacity of the beach and service roads to withstand/reduce impacts caused by future storms. Additionally, protection of the service road will also help to maintain one of the largest freshwater ponds on the refuge. If this area would breach, it would open more of the inner infrastructure of the refuge to direct impacts due to storm surges.

Chincoteague NWR is responsible for Virginia's portion of Assateague Island, the adjacent Wallops Island NWR, and refuge lands on Assawoman, Metompkin, and Cedar Islands. Chincoteague NWR is in the process of completing a comprehensive conservation plan (CCP) for the refuge. The plan will evaluate three alternative strategies for managing wildlife, recreational uses, and other activities on the refuge over the next 15 years. The environmental and economic impacts of the alternatives will be carefully evaluated and will guide management decisions. A draft plan is expected to be released by the middle of May 2014, and there will be an opportunity for public review and comment, including information sessions and at least one public hearing, for 60 days following publication of the draft plan.

The CCP describes the desired future conditions of a refuge or planning unit; provides long-range guidance and management direction to achieve the purposes of the refuge; helps fulfill the mission of the Refuge System; maintains and, where appropriate, restores the ecological integrity of each refuge and the Refuge System; helps achieve the goals of the National Wilderness Preservation System; and meets other mandates. In the CCP, the refuge will address the sensitive resources (both natural and man-made) present on refuge properties, and will address management planning to address the threats posed by severe storms, land subsidence, climate change, and sea level rise.

Eastern Shore of Virginia NWR and Fisherman's Island NWR

The Eastern Shore of Virginia NWR is located in Northampton County, Virginia, at the southern end of the eastern shore, near the tip of the Delmarva Peninsula. The refuge is approximately 1,127 acres in size, and it was established in 1984. Much of the land was previously part of Fort John Custis, a base used by the United States Air Force until 1981; also within the refuge's boundaries is Fisherman Island, classed as a "Wetland of International Importance". The refuge is an important staging area for migratory birds, and is used as well for the management and study of the federally listed threatened Northeastern beach tiger beetle and piping plover. Fisherman's Island NWR is just south of the tip of the eastern shore of Virginia peninsula. The island is transected by the Chesapeake Bay Bridge Tunnel system which is part of U.S. State Route 13, the main connection between the peninsula and Norfolk, Virginia.

The refuge serves as one of the country's most valuable stopovers for migratory birds. Each fall millions of songbirds, monarch butterflies, and thousands of raptors converge at the tip of the peninsula as they move south. The focus of refuge management efforts is protecting, restoring, and enhancing habitat for forest and shrub-dependent migratory birds. By increasing the amount of hardwoods like oak, hickory, maple, and sweet gum and increasing shrublands, these migratory species will have additional sources of high-quality food. Future conservation efforts lie in the refuge's commitment to protecting and enhancing the migration corridor through preserving, acquiring, and revegetating hardwood, shrub, and grassland areas. Alliances with nearby landowners will increase available habitat, and research will focus on augmenting our knowledge to make biologically sound management decisions.

The Fisherman's Island NWR component is closed to the general public and is primarily maintained in a natural condition, the only infrastructure of importance is the road and bridges of US Route 13. Visitation is limited to the peninsula portion of the refuge, and in fiscal year 2013 the refuge had an estimated 41,201 visitors. This estimation is broken down as follows: 16,945 at the visitor center; 12,043 used the Wise Point Boat Ramp; 4,380 used the bike trail; 325 hunted on the refuge; and 7,508 used the refuge for wildlife observation and other uses.

Sea level rise of more than 1 to 2 feet coupled with a storm surge would severely impact the refuge and its management capability. Habitat losses and the change in habitat conditions remaining would be considerable. There is already extensive tree losses at the southern tip (Wise Point) due to saltwater intrusion from past storm events. This area is important to the great blue heron rookery, 4-5 osprey nests, and a bald eagle nest. Fisherman's Island has already shown significant changes in shoreline conditions with sections receding and others areas showing extensive accretion. The refuge infrastructure, maintenance facilities, work camper area, and the eastward side of the refuge quarters area will need to migrate to the west towards the spine of the peninsula. Two of the residence buildings are owned by the Coastal Virginia Wildlife Observatory, and the College of William and Mary. Access to Fisherman Island by vehicle will only be possible by moving the road inland thereby reducing upland habitat (this assumes there will higher elevation from the road to the beach). It is estimated that sections of the Bull Causeway and Wise Point Road will be lost, but at this time an alternate would not be needed. The Wise Point Boat Ramp and the road to it will be lost and replacement will need to be considered. The Wise Point Boat Ramp is a facility maintained for commercial waterman and the public. Loss of this ramp will have an impact on the local economy.

Back Bay National Wildlife Refuge

Back Bay NWR was established in 1938 to provide habitat for migrating and wintering waterfowl. The refuge contains more than 9,000 acres, situated around Back Bay, in the southeastern corner of the City of Virginia Beach. Because of its unique geographic location along the Atlantic Coast that provides overlapping ranges for both northern and southern species, biodiversity is high. Habitats include barrier island beach and dunes, shrub-scrub, woodlands, farm land, and fresh and brackish marsh. Since 1939, an additional 4,600 acres of Chesapeake Bay waters within the refuge boundary have been closed to migratory bird hunting by Presidential Proclamation.

Today the refuge continues to be an important link in the chain of national wildlife refuges along the Atlantic Flyway. More than 300 species of birds have been observed at the refuge. During the fall and winter months, large flocks of waterfowl use the Bay and the 880 acres of freshwater impoundments. Snow and Canada geese, tundra swans, and many duck species are abundant. Migrating songbirds and shorebirds arrive at the refuge each spring and fall. Brightly colored warblers dot shrub and woodland areas while shorebirds search for food in shallow waters. Habitats are also used by a wide assortment of other wildlife, including the federally listed threatened loggerhead sea turtle and piping plover, and the federally listed endangered Kemp's ridley sea turtle (the first confirmed nesting of this turtle in Virginia occurred on refuge property in 2012). There are no colonial nesting bird colonies using the over 4 miles of Atlantic Ocean shoreline.

The 4 miles of Atlantic Coast shoreline along the refuge east boundary is showing impacts of storm events and sea level rise. The dune system fronting the impoundments is wide and extensive, and has the highest probability of surviving major storm surges. However, if these dunes fail, it will impact the impoundments and the majority of the refuge facilities. The dune portion east of the Visitor Contact Station and the Entrance Road (adjacent to northern mile of beach) is considered to be inadequate. This section of shoreline consists only of a low primary dune and higher elevation sands behind it. Improvements to this dune area would improve the dunes ability to handle a major storm surge. A storm surge could impact the entrance road, cutting off access to the visitor facility, waterfowl impoundments, and access to False Cape State Park which is only accessible through the refuge. The refuge has moved its administration building and maintenance building inland to move them from the storm surge zone.

MARYLAND

Federally Listed Threatened and Endangered Species

Puritan Tiger Beetle (*Cicindela puritana*)

Certain bluff shorelines located within the Maryland portion of the Chesapeake Bay support populations of the Puritan tiger beetle, a federally listed threatened species. The Puritan tiger beetle has a very limited and disjunct range that consists of the Connecticut River in New England and the Chesapeake Bay in Maryland. The Connecticut River populations are relatively small and are located well up the river where they are not exposed to coastal storm surge. The main populations are in Maryland. The Maryland populations are restricted to bluff shorelines located in the counties of Calvert, Kent, and Cecil.

In Maryland the beetles inhabit high eroding bluffs and adjacent beaches. The adult beetles are approximately 1.2 cm in length and are capable of flight. They emerge from larval burrows in the bluff face in mid- to late June and are present on the beach through August by which time nearly all will have expired. Peak numbers occur in late June to early July. The adults feed on small invertebrates that they capture primarily on the beach, but possibly to some extent on the bluff face. They mate during the early summer and then deposit eggs on unvegetated portions of the bluff face. After hatching in late July or August, the larvae dig deep burrows into the bluff face, particularly favoring sandy strata. The larvae feed during the warmer months of the year (spring, summer, and fall). They position themselves at the entrance of the burrow using abdominal hooks and ambush small passing invertebrates. The larval period lasts for approximately two years until adult emergence.

The Puritan tiger beetle occupies a narrow niche. Stable bluffs tend to be unsuitable for larval habitat either because the substrate is unacceptable for burrow construction or because of the presence of too much vegetation. Bluffs that erode too rapidly dislodge the larvae. Beetle population numbers often fluctuate in response to varying erosion rates. The primary threat to this species is shoreline erosion control projects that alter larval bluff habitat and/or the adjacent adult beach habitat. However, the expected increase in the rate of sea level rise and potential for increased storminess could directly affect the habitat and pose a substantial risk to the species.

Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis*)

A few selected beaches located within the Maryland portion of the Chesapeake Bay shorelines support populations of the northeastern beach tiger beetle, a federally listed threatened species. This beach dwelling flying insect historically was common on coastal beaches from Cape Cod, Massachusetts to central New Jersey, and along Chesapeake Bay from Calvert County, Maryland through Virginia. However, its current natural distribution, except for experimental reintroductions (Monomoy NWR in MA and Sandy Hook in NJ), is restricted to Chesapeake Bay and a small remnant population at Martha's Vineyard in Massachusetts. The populations are larger and more widely distributed in the Virginia portion of Chesapeake Bay. In Maryland the beetles occur only at a few sites along the Calvert County and Somerset County shorelines.

In Chesapeake Bay the adult beetles, which are approximately 1.4 cm in length, emerge from their larval burrows in the sand in early June, reach peak abundance in July, and are present on the beach through early September when nearly all will have expired. They forage along the water's edge for small amphipods, flies, and other beach arthropods. They also scavenge on dead crabs and fish. The adults mate and lay their eggs on the beach during this summer period. The resulting larvae reside in burrows that are located in a band centered on the upper intertidal beach. The larvae pass through three developmental stages and emerge approximately two years after the eggs are laid. The larvae are predators which position themselves at the burrow entrance where they capture passing prey such as small amphipods. They plug the entrance and retreat down into the burrow when not actively seeking prey and during winter hibernation.

The extirpation of this species from most of its range resulted primarily from destruction and disturbance of natural beach habitat associated with shoreline developments, stabilization structures, and high recreational use. Shoreline alterations that directly or indirectly affect the character of the beach (i.e., width, profile, grain size, and vegetation) are a particular concern. In addition to the anthropogenic threats, this species is vulnerable to severe storms and beach erosion.

Piping Plover (*Charadrius melodus*)

In Maryland, Assateague Island comprises the only important nesting area for piping plover, a federally listed threatened species on the Atlantic Coast. During the 10-year period from 2003 through 2012, the Maryland portion of Assateague supported an average of 53 breeding pairs with a high of 66 and a low of 33 pairs. Except for a 3.2 kilometer section that comprises Assateague State Park, the 35 km Maryland portion of Assateague is owned and managed by the National Park Service (NPS) as the Assateague Island National Seashore. As a result, much of the area has been kept in an undeveloped, albeit not completely natural condition. The NPS conducts some important management and monitoring activities to reduce impacts to piping plover. These include closely regulating public use in the nesting areas, installing nest site predator exclosures, and occasionally conducting direct predator control. Between 2005 and 2009, the NPS excavated a total of 22 overwash flow paths across the crest of the north end of the island to reestablish the overwash process and more closely replicate the natural topography which had been altered by berm construction. First constructed in 1998 to reduce the potential for island breaching and subsequently reconfigured in 2002, the berm had inhibited the periodic overwash that was necessary to maintain habitat suitable for piping plover.

The Atlantic Coast piping plover breeding population nests on suitable beaches located from North Carolina north to the western coast of Newfoundland. Locations suitable for breeding are uncommon because these ground nesting birds are especially sensitive to human related disturbance and predation. The nesting ecology varies depending on the location and habitat. At Assateague the birds begin arriving mid-March, with nest initiation in early/mid-April, hatching from mid-May to mid-July, and young completely fledged by September 1. Nests are typically constructed on the upper beach berm and on sparsely vegetated dune and washover areas. Piping plover chicks are somewhat unusual in that they must leave the nest shortly after hatching in order to begin foraging. Since the chicks cannot fly, suitable foraging areas need to be located within a reasonable walking distance of the nest site. The chicks utilize three types of foraging habitats: wet portions of the ocean beach, the bay beach, and moist overwash areas within the island interior. Chicks using the bay beach and interior island foraging areas have significantly higher survival than those that use the ocean beach which have relatively low survival. Studies have indicated that this is apparently due to higher available arthropod abundance on the bay beach and interior moist washover areas. It should be noted that in other areas along the Atlantic Coast plover chicks feed primarily in the ocean beach habitat and have good survival. However, at Assateague preserving access to the high quality chick foraging habitat on the interior and bay side of the island is critically important. If the vegetation proliferates, it will eliminate foraging areas and/or inhibit the ability of the chicks to reach them. Periodic overwash by storm generated waves is needed to maintain quality chick foraging habitat and vegetation-free travel corridors.

The expected increase in the rate of sea level rise and storm activity is virtually certain to affect plover habitat at Assateague and across the Atlantic Coast range. It is quite possible that there will be improved conditions for piping plover at Assateague in the near term. However, there is concern that the acceleration in sea level rise and associated storm surges could reach a point where some barrier islands such as Assateague would not be able to adjust quickly enough and they would begin to experience frequent cross-island overwash or even inundation. Concern about the effect of barrier island erosion on neighboring human development could also result in the implementation of shoreline and dune stabilization measures that could degrade plover nesting habitat.

There is a recognized need to improve understanding of threats from sea-level rise and increased storm activity to Atlantic Coast piping plovers. The North Atlantic Landscape Conservation Cooperative has contracted with a research team led by Sarah Karpanty at Virginia Tech to develop a model that can predict how piping plover breeding habitat will change as a result of sea level rise and altered storminess. The model is being developed using habitat data collected from Assateague and will also be able to address how varied conservation actions may affect plover habitat use and habitat change. The three-year project is expected to be completed in 2014.

Seabeach Amaranth (*Amarantus pumilus*)

Seabeach amaranth is a federally listed annual plant that occurs on the upper beach zone at Assateague Island, Maryland. It was listed as a threatened species in 1993 after it had been extirpated from much of its historic range which included nine states from Massachusetts to South Carolina. It was believed to be extirpated in Maryland until two plants were found growing on Assateague in 1998. This was the first sighting of the species between New York and North Carolina in 26 years. With Hurricane Bonnie approaching, officials from the National Park Service and the Maryland Department of Natural Resources transferred one of the plants to a greenhouse. This plant produced thousands of seeds which were germinated in the greenhouse. Approximately 5,400 of the offspring were planted back in the natural beach habitat between 2000 and 2002. Since that effort, Assateague has maintained a natural population that fluctuates between 400 and 900 plants. Assateague Island is a barrier island which extends for 35 kilometers in Maryland. Except for a 3.2 km section that comprises Assateague State Park, it is owned and managed by the National Park Service as the Assateague Island National Seashore. As a result, much of the area has been kept in an undeveloped, albeit not completely natural condition. The NPS protects a portion of the population by placing wire cages around them to deter deer and horse grazing and to alert drivers of over sand vehicles.

Seabeach amaranth is restricted to open sandy portions of ocean beaches between the high tide line and the toe of the primary dune. It favors barrier island beaches, especially the lower foredunes and upper strands of non-eroding beaches and overwash flats at the accreting ends. It is as annual plant which has a relatively long germination period that may begin as early as April and extend at least thru July. The plants exhibit low sprawling growth that progresses from a small unbranched sprig into a much branched clump that often reaches 30 cm in diameter. The clumps are generally widely scattered. Seed production begins in July or August, reaches a peak in September, and then declines until senescence in early winter. The seeds are dispersed mainly by water and wind and are believed to remain viable for long periods. As a result, the plant has a high dispersal ability that allows it to colonize habitat as it becomes available. Seabeach amaranth is considered to be a “fugitive” species that is intolerant of competition and does not occur on well vegetated sites. It tends to trap sand, creating habitat for other dune plants which will eventually outcompete it. Despite its habit of colonizing relatively low elevation areas on the beach, it is intolerant of even occasional flooding during its primary growing season (June to September). Storm tides and/or beach erosion cause substantial mortality. Storms that occur earlier in the growing season are especially damaging because they limit seed production which this annual plant depends upon for producing the next generation. Because of these natural vulnerabilities, there can be large population fluctuations, even to the point where the plants vanish for years before reappearing.

Seabeach amaranth appears to need extensive areas of dynamic naturally functioning barrier islands that allow it to move within the coastal landscape in response to changing conditions. Populations that are eliminated by natural forces can be reestablished, once the conditions become suitable, by seeds transported from neighboring areas. Habitat fragmentation can be a significant problem because it inhibits reestablishment after periodic episodes of natural depopulation. Where the dynamic landscape is altered by installation of shoreline stabilization structures or by construction of vegetated dunes, the habitat usually becomes unsuitable. The extirpation of the plant in Maryland on Assateague is believed to have been caused by dune construction and stabilization. Recreational development and public use of beaches typically renders them unsuitable as habitat. Based on its life history and ecology, it appears that seabeach amaranth will be vulnerable to impact from the increases in the rate of sea level rise and storm activity that are expected to occur over the next several decades. While it has survived in this dynamic environment for thousands of years, its current populations and habitat are more reduced and fragmented than the historic ones, making it less resilient.

Waterbird Nesting Colonies

Numerous waterbird nesting colonies occur in Maryland where they are generally associated with the Chesapeake Bay and the coastal bays. The vast majority of these colonies occur on island sites that are experiencing substantial losses due to erosion and sea level rise. Preliminary results from a survey conducted by the Maryland Department of Natural Resources during the 2013 breeding season have counted a total of 106 waterbird nesting colonies of which 86 are located in a landscape position where they are vulnerable to sea level rise and erosion. Of the vulnerable colonies, 55 are located in the Maryland portion of Chesapeake Bay where they are primarily concentrated within the lower Eastern Shore counties of Dorchester, Talbot, and Somerset. Thirty one of the vulnerable colonies are located within the coastal bays region in Worcester County.

The colonies range in size from a few nesting pairs up to 2,364 pairs. They are composed of 17 different species including various herons, egrets, gulls, and terns, as well as glossy ibis, double-crested cormorant, and black skimmer. In Maryland, these species, with the exception of great blue heron and least tern, show a strong preference for remote island locations. Four general habitat types are used: trees, scrub/shrub, marsh, and beach. The specific type of habitat that is used varies among the species, but quality sites often support multi-species colonies. Successful colony sites are typically used year after year for many years. However, there are also frequent shifts among sites or changes in the amount of colony usage due to factors such as the level of human disturbance, predation pressure, habitat alteration, and changes occurring in the larger regional populations.

Island colony sites are particularly favored because of their isolation and reduced level of mammalian predation. Unfortunately, island habitat in Maryland's Chesapeake Bay and coastal bays is declining due to erosion and sea level rise. Because colonial waterbirds concentrate their reproductive effort at few locations on the landscape, ensuring the long-term viability of occupied colonies is especially important. As the rate of sea level rise increases, the remaining island habitat will be lost at an increasing rate which is likely to seriously impact colonial waterbird nesting success. Wildlife managers are responding to this troublesome trend by attempting to create new island habitat using sediment dredged from navigation channels. This approach may take the form of constructing new upland habitat or using dredged material to create perimeter marshes to reduce island erosion. For example, dredged material has recently been used to create new nesting colonies for common and least terns at Poplar Island in Chesapeake Bay. These and other strategies will need to be pursued to counteract the expected loss of quality nesting habitat.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

Blackwater National Wildlife Refuge

The Blackwater National Wildlife Refuge is located on the Eastern Shore of Maryland, approximately 12 miles south of the town of Cambridge, in Dorchester County. Blackwater is part of the Chesapeake Marshlands National Wildlife Refuge Complex which also includes Eastern Neck NWR, the Chesapeake Islands Refuges unit (Martin NWR, Susquehanna NWR, Barren Island, Watts Island, Bishops Head, Garrett Island, and Spring Island), and the Nanticoke Unit. It encompasses more than 27,000 acres that are dominated by tidal wetland habitats of variable salinity. It also includes evergreen and deciduous forests (comprising about 36% of the total acreage), and small amounts of cropland and freshwater impoundments, both managed for waterfowl use. Approximately 20,000 to 25,000 ducks and geese utilize Blackwater during the peak of the fall migration. Commonly occurring species include: American black duck, blue-winged teal, wood duck, green-winged teal, pintail, widgeon, gadwall, ring-necked duck, common merganser, Canada goose, snow goose, and tundra swan. Blackwater is also known for its large breeding population of bald eagles. Its forested habitats constitute one of the largest contiguous protected tracts on the Delmarva Peninsula and are especially valuable for forest interior dwelling birds including many neotropical migrants. The forest also supports a robust population of the federally endangered Delmarva Peninsula fox squirrel (*Sciurus niger cinereus*). The refuge provides substantial public recreational and educational activities including fishing, hunting, canoeing/kayaking, trail walking, wildlife observation, and interpretation programs. A large visitor center and a 6.5-mile long wildlife drive also help to make Blackwater a showcase for wildlife. Even with an entrance fee, the number of annual visitors can exceed 500,000.

Blackwater's tidal marshes are particularly vulnerable to sea level rise, which, because of regional land subsidence, is effectively progressing at about twice the rate of the worldwide average. Almost 7,000 acres of marsh have devolved to shallow water since the refuge was established in 1933. The bulk of this extraordinary loss has been in the tidal brackish Olney three-square marsh at the center of the refuge near the confluence of the Blackwater and Little Blackwater Rivers. The effect of relative sea level rise on the marsh loss has been exacerbated by weak tidal flushing and excessive herbivory, especially by nutria, a semi-aquatic South American rodent introduced on the refuge in 1943, but also by muskrats and geese. As the area of marsh loss enlarges, the edges become more prone to erosion by wave action, and the loss process accelerates.

The great loss of marsh compromises the ability of the refuge to fulfill its mandate to provide habitat for waterfowl, as well as impacting the populations of other waterbirds and marsh dependent wildlife. After the marsh plant cover is lost, the shallow water which remains has low aquatic habitat value since the bottom substrate is composed of soupy organic muck and the water column is highly turbid. Marsh erosion at the head of the Blackwater River has created an additional problem by establishing a connection to the Little Choptank River. First noticed in 1989, this connection has permitted relatively high saline water to enter the formerly freshwater zone of the upper Blackwater River. In 2007 the refuge installed a structure to close the connection, but it was only partially successful. The current conditions remain too saline to permit spawning by anadromous fishes which historically occurred there. The refuge also can no longer use this water for the seasonal flooding of the freshwater impoundments, but must rely instead on rainfall. Since Blackwater is a low lying refuge where the elevations do not exceed 8 feet above mean sea level, sea level rise is also a major concern in the upland areas. Frequent tidal flooding and salt water intrusion already impacts many forested areas.

The refuge has been intensively monitoring changes in marsh elevation. The monitoring indicates that the marshes are accreting elevation, but not fast enough to keep up with the rise in sea level. Therefore it is expected that marsh conversion to open water will continue. Over the next 50 to 100 years, it is believed that much of the existing marsh will be inundated and lost. Some new marshes will develop on the adjacent land, but this will only be a partial replacement for what is lost and the vegetation composition and general character may not be the same. Undesirable *Phragmites* invasion has been a particular problem in these newly established marshes. The forested areas will suffer net losses. This will include a substantial amount of forest habitat currently used by the Delmarva Peninsula fox squirrel. There would likely also be effects on the refuge infrastructure. Frequent flooding will remain a problem for the roads. The main buildings are expected to be minimally impacted for the next 50 years, but would face an uncertain fate after that.

The refuge has several strategies to attempt to sustain the quality and quantity of the marsh habitat. Steps are being taken to reduce marsh eat-outs and other disturbance caused by marsh herbivores. A major trapping effort was recently successful in eradicating nutria from the refuge. The feeding habits of this introduced rodent, which include a tendency for digging into the marsh's organic mat, were a significant cause of marsh deterioration. The populations of muskrat and resident Canada geese are also being managed to maintain them at acceptable levels. The placement of locally dredged material to restore suitable elevation for marsh restoration has been tested successfully on a relatively small scale. The refuge is considering thin layer deposition of sediment on existing priority marshes to help them keep up with the rise in sea level. A large scale restoration using material imported from dredging of the main Chesapeake Bay ship channel was initially explored but judged to be too infeasible to pursue.

In response to the threat that sea level rise presents, the refuge has entered into a partnership with The Conservation Fund, Audubon Maryland/DC, and Maryland Department of Natural Resources, supported by a grant from the Town Creek Foundation, to form the Blackwater Climate Adaptation Project. The goal is to ensure the long-term persistence of high tidal marsh habitat in Dorchester County along with the marsh's full assemblage of associated bird and other wildlife species.

The first step, completed in 2012, assessed the vulnerability of the tidal marshes in the county. This involved using a combination of available landscape scale data, the Sea Level Affecting Marshes Model (SLAMM), and survey data for seven salt marsh specialist bird species chosen as focal species. The assessment identified and modeled the largest and highest quality habitat blocks up to one meter of sea level rise. The second step involved developing a strategy for adapting to the threat of sea level rise and related effects of climate change. The strategy, completed in 2013, recognizes that marsh inundation cannot be stopped, but that it will occur gradually and go through different stages of transition. Therefore, it outlines a series of management interventions that can improve outcomes by affecting the rate and type of change in prioritized locations. They would generally include actions for marsh enhancement, strategic land conservation in key marsh migration corridors (upland areas adjacent to current marshes), and active management of the marsh transition in those corridors.

Some examples of the recommended management actions will illustrate the approach. Thin layer deposition of sediment on existing marsh surfaces is recommended to help them keep up with sea level rise. However, reestablishment of lost marshes by importing sediment to convert open water areas back to marshes is deemphasized because it would require such a large effort relative to the area of marsh that could be affected. Another technique for reducing the rate of marsh drowning involves lowering the water level of waterlogged marshes by excavating shallow drainage channels to connect with natural tidal creeks. *Phragmities* control is also anticipated to be an important management action to retain quality marshes in areas where they are transitioning into upland areas. By focusing actions in priority high value areas, there is optimism that it will be possible to increase marsh resilience so that thousands of acres of productive marsh habitat will remain on the refuge and the surrounding lands of southern Dorchester County for the rest of the century and beyond.

DELAWARE

Federally Listed Threatened and Endangered Species

Piping Plover (*Charadrius melodus*)

The oceanfront beaches of Delaware support a small breeding population of the federally threatened piping plover. During a typical nesting season 10 or fewer breeding pair would be present. Over the last several years their nesting has been restricted to Cape Henlopen State Park (especially the Point of Cape Henlopen and the Gordon's Pond area), although there are earlier records of sporadic nesting within Delaware Seashore State Park which extends southward to the vicinity of the Indian River Inlet. Areas with suitable nesting habitat are closed to public access by the Delaware Division of Fish and Wildlife. The Division also has established a program utilizing volunteers to monitor the nesting areas so that the public understands and respects the need for limiting disturbance there.

The Atlantic Coast piping plover breeding population nests on suitable beaches located from North Carolina north to the western coast of Newfoundland. Wide flat, sparsely vegetated barrier beach habitats are particularly favored. These habitats include abundant moist sediment areas that are associated with dune blowouts, washover areas, sand spits, unstabilized and recently closed inlets, ephemeral pools, and sparsely vegetated dunes. Locations suitable for breeding are also limited because these ground nesting birds are especially sensitive to human related disturbance and predation. The nesting ecology can vary depending on the location and habitat. In Delaware the birds begin arriving in mid-March to set up territories and perform courtship behavior. Egg laying begins mid-April. The birds may renest one or more times if their nest is lost prior to hatching. Hatching takes place from mid-May to mid-July. Generally the young would be completely fledged by September 1. Piping plover chicks are somewhat unusual in that they must leave the nest shortly after hatching in order to begin foraging for food. Since the chicks are flightless, suitable feeding areas must be located within a reasonable walking distance of the nest site. Feeding areas include the wet portion of the beach, wrack lines, moist washover areas, and shorelines and flats associated with coastal lagoons and ponds. If the vegetation is too dense, the chicks may be deterred from reaching the feeding areas. The wave overwash that occurs during storms can be beneficial by creating low moist feeding areas and by keeping the vegetation from becoming too dense.

The expected increase in the rate of sea level rise and storm activity over the next 50 to 100 years is virtually certain to affect piping plover habitat within Delaware and more broadly across the Atlantic Coast range. The effects are likely to be variable spatially and temporally. The habitat in some areas may be improved where wave overwash increases and inlets form and close naturally. Some new habitat will likely be created to replace what is lost where the shoreline can respond by receding unimpeded. However, some areas could reach a point at which storms and higher sea levels could directly reduce breeding success by repeatedly flooding nests. The presence of human development may prevent new habitat from being created as the shoreline recedes. The implementation of shoreline stabilization measures to protect development or human infrastructure could also adversely affect plover habitat.

There is a recognized need to improve understanding of threats from sea-level rise and increased storm activity to Atlantic Coast piping plovers. A research team led by Sarah Karpanty at Virginia Tech, under contract with the North Atlantic Landscape Conservation Cooperative, is developing a model for predicting how piping plover breeding habitat will change as a result of sea level rise and altered storminess. The model will be also used to develop habitat conservation recommendations and measures to preserve the resilience of piping plover habitat. This three-year project is expected to be completed in 2014.

Seabeach Amaranth (*Amarantus pumilus*)

Seabeach amaranth is a federally listed annual plant that occurs on Delaware's ocean beaches. It was listed as a threatened species in 1993 after it had been extirpated from much of its historic range which included nine states from Massachusetts to South Carolina. It was considered to be extirpated in Delaware for 125 years until it was rediscovered in 2000. Since then it has been present every year. While the number of plants can vary greatly year to year, a fairly typical population would be on the order of 25 plants. In recent years it has been occupying sites within Cape Henlopen State Park and Delaware Seashore State Park, although earlier it was also found within Fenwick Island State Park. The State regularly monitors these areas to determine the plant's presence and restricts public access into the areas where it grows.

Seabeach amaranth is restricted to open sandy portions of ocean beaches within the relatively narrow zone between the high tide line and the toe of the primary dune. It favors barrier island beaches, especially the lower foredunes and upper strands of non-eroding beaches and overwash flats at the accreting ends. It is as annual plant which has a relatively long germination period that may begin as early as April and extend at least thru July. In Delaware the plants are usually first observed in July. They exhibit low sprawling growth that progresses from a small unbranched sprig into a much branched clump that often reaches 30 cm in diameter. The clumps are generally widely scattered. Seed production begins in July or August, reaches a peak in September, and then declines until senescence in early winter. The seeds are dispersed mainly by water and wind and are believed to remain viable for long periods. As a result, the plant has a high dispersal ability that allows it to colonize habitat as it becomes available. Seabeach amaranth is considered to be a "fugitive" species that is intolerant of competition and does not occur on well vegetated sites. It tends to trap sand, creating habitat for other dune plants which will eventually outcompete it. Despite its habit of colonizing relatively low elevation areas on the beach, it is intolerant of even occasional flooding during its primary growing season (June to September). Storm tides and/or beach erosion cause substantial mortality. Storms that occur earlier in the growing season are especially damaging because they limit seed production which this annual plant depends upon for producing the next generation. Because of these natural vulnerabilities, there can be large population fluctuations, even to the point where the plants vanish for years before reappearing.

Seabeach amaranth appears to need extensive areas of dynamic naturally functioning barrier island that allow it to move within the coastal landscape in response to changing conditions. This permits populations that are periodically eliminated from an area by natural forces to be reestablished, once the conditions become suitable, by seeds transported from neighboring areas. Habitat fragmentation can be a significant problem because it inhibits reestablishment after episodes of natural depopulation. Where the dynamic landscape is altered by installation of shoreline stabilization structures or by construction of vegetated dunes, the habitat usually becomes unsuitable. Recreational development and public use of beaches typically renders them unsuitable as habitat. Based on its life history and ecology, it appears that seabeach amaranth will be vulnerable to impact from the increases in the rate of sea level rise and storm activity that are expected to occur over the coming decades. While it has survived in this dynamic environment for thousands of years, its current populations are more reduced and fragmented than historically, making it less resilient.

Rufa Red Knot (*Calidris canutus rufa*)

The rufa red knot (hereafter referred to as red knot) is a shorebird subspecies that was recently (September 30, 2013) proposed to be listed as threatened under the federal Endangered Species Act. The Delaware Bay shoreline is known to be a major stopover site for these birds during their northward migration in the spring. They perform an unusually long distance migration from their primary wintering areas in southern South America to their breeding areas in the Canadian Arctic. While they normally feed primarily on small bivalves, their spring migration has evolved so that the Delaware Bay area has become their primary stopover location due to the extraordinary abundance of horseshoe crab eggs. This food source is considered to be a key factor that allows them to gain sufficient body condition to complete the migration and accomplish their breeding activity. The reduced availability of horseshoe crabs eggs at the Delaware Bay stopover site due to commercial harvest of the crabs is believed to be a primary cause for the decline of the red knot population that was observed in the early 2000s. This decline in the population was an important factor in the decision to propose that the species be given threatened status.

In Delaware during the spring migration, the birds are heavily concentrated along the shoreline reach between Broadkill Beach and Bombay Hook National Wildlife Refuge. Large numbers typically arrive in mid-May and depart by the end of the first week in June. Most of their time is spent feeding on horseshoe crab eggs which are available on the intertidal beaches, although they also make comparatively limited use of the exposed mud flats and pans within the adjacent marshes and impoundments for roosting. They are relatively uncommon along Delaware Bay during the southward fall migration, which peaks in August, and along the Delaware ocean coast during both spring and fall migration periods.

The beach habitat that these birds are dependent upon may be substantially affected by acceleration of the rate of sea level rise and associated increased storm activity. The beaches have historically been resilient and, except where constrained by man-made structures, have responded to sea level rise by migrating landward. However the amount of sand in this system is rather limited and the beaches are relatively thin and narrow so it is unclear how well they will be maintained as the erosion rate increases. Even for those beaches that are able to persist, an increase in the rate of shoreline recession could change their character in a way that would reduce the amount of horseshoe crab spawning. For example, the crabs are known to avoid spawning on beaches that exist simply as a thin layer of sand over peat. The potential for increased shoreline armoring or other structural stabilization to protect human infrastructure as the shoreline recedes closer to developed areas is another related threat to the birds' important beach habitat.

Waterbird Nesting Colonies and Concentration Areas

Delaware Waterbird Nesting Colonies

Since 2009, 11 water bird nesting colonies (> 10 nesting pairs) have been reported form Delaware. Eight of them are located in a landscape position where they are vulnerable to the effects of sea level rise and erosion. The non-vulnerable colonies are inland wooded sites used by great blue herons. Seven of the vulnerable colonies are located within the coastal bays region (Indian River Bay and Rehoboth Bay). One colony is located on Pea Patch Island, located in the upper reach of Delaware Bay. Eleven species use these colony sites and they include various herons, egrets, glossy ibis, and common and Forster's terns.

Four of the colonies are located on islands. Three of these are small eroding islands with limited life expectancy, which are favored by terns (ground nesters) and some herons depending on the vegetative condition. Remote islands are preferred colony sites for many species because of their isolation and reduced level of mammalian predation. These quality sites are scarce in Delaware and are likely to become even more so as they are subject to erosion and inundation by sea level rise.

Most of the colonies are rather small, typically supporting less than 100 breeding pairs. The one notable exception is Pea Patch Island which has been the site of a major nesting colony for wading birds since the early 1970s. Once touted as the largest heronry on the East Coast, the number of breeding pairs has declined from a high of approximately 12,000 in 1993 to 3,886 in 2000. While no direct population counts have been made since 2000 in order to avoid disturbing the nesting activity, indirect measures such as counts of birds coming and going seems to indicate that there has been some further decline. The site is used by eight species including: great blue heron, little blue heron, black-crowned night heron, yellow-crowned night heron, great egret, snowy egret, cattle egret, and glossy ibis.

Pea Patch Island is approximately 300 acres in size, and is owned and managed by the State of Delaware. The heronry is located on the northern end, while the southern portion is occupied by Fort Delaware, a Civil War fort that is open to the public during the spring and summer. The colony consists of two major habitat types, upland and wetland. The upland portion is vegetated with deciduous shrubs and trees, while the wetland portion is vegetated by dense *Phragmites*. The use of these habitats has varied over time and among the species, as dense nesting activity affects the vegetation through phytotoxic effects of the bird excrement and the physical stress of large numbers of nests. The Pea Patch Island colony, like many of the other colonies in Delaware, is vulnerable to erosion and sea level rise.

Delaware Bay Shorebird Stopover Area

The shoreline bordering the lower 80 km (50 miles) of the Delaware Bay is the site of the second largest spring concentration of migrating shorebirds in the Western Hemisphere. Its importance on an international scale was formally recognized in 1985 when it was the first site dedicated as part of the Western Hemisphere Shorebird Reserve Network. Upwards of 1,000,000 shorebirds utilize this area in May and June when they interrupt their northward migration to feed and replenish their energy reserves prior to continuing their migration to their arctic and subarctic breeding grounds. Commonly occurring species include: ruddy turnstones, semipalmated sandpipers, red knots, sanderlings, dunlins, and dowitchers. These shorebirds are long distance migrants and arrive at Delaware Bay in a thin and exhausted condition after traveling from their wintering grounds in Central and South America. They have a limited amount of time during which they must feed heavily to regain weight lost during the migration and to attain sufficient body condition to complete their migration and accomplish their breeding activity.

On the Delaware side of the bay the birds congregate on the bayfront region extending from Cape Henlopen to the vicinity of Woodland Beach. The wide tidal marshes and narrow beaches are the primary habitats. The highest densities of birds occur on the beaches, but large numbers also utilize the marshes especially as high tides limit beach feeding. A primary reason that these birds are attracted to this area is the abundance of horseshoe crab eggs which provide a vital food source. Delaware Bay has the largest population of horseshoe crabs on the East Coast. The horseshoe crabs deposit their eggs in nests on the beach in the spring, and the birds arrive there at about the same time.

The beach and marsh habitats that the birds depend on are quite vulnerable to impact from sea-level rise and storm induced erosion. The ongoing conversion of marsh to open water is expected to accelerate substantially as sea level rise promotes marsh drowning as well as edge erosion. The beaches have historically been more resilient and, except where constrained by man-made structures, have responded to sea level rise by migrating landward. Their resilience will be severely tested as the rate of sea level rise increases, especially in those areas where the presence of human development interferes with their landward migration. Even if beaches remain present, there could be changes in their character which could affect bird use by affecting the horseshoe crab spawning.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

Prime Hook National Wildlife Refuge

Prime Hook NWR is located in the outer Coastal Plain, along the southwestern shore of the Delaware Bay, in Delaware. Eighty percent of the 10,144-acre refuge consists of coastal marshes and associated estuarine and freshwater creek drainages. The remaining 20 percent is composed of upland habitats. The refuge's wide coastal marshes are separated from Delaware Bay by a narrow sandy coastal barrier that extends for approximately 9.6 miles. The broad wave fetch establishes a longshore drift system but the sand supply is rather limited so the accumulation of sand along the shoreline is confined to a relatively narrow formation. The refuge includes approximately 3 miles of the barrier beach between Primehook Beach and Slaughter Beach, but a substantial portion (approximately 6.6.miles) is occupied by three isolated beachfront residential communities (Slaughter Beach, Primehook Beach, and Broadkill Beach).

The wooded habitats are also an important component of the refuge. They are utilized by a wide variety of breeding land birds and are critical stopover habitat for migrating birds as well. The forested habitat also supports a small population of the Delmarva Peninsula fox squirrel (*Sciurus* *niger cinerus*), a federally listed endangered species. The refuge provides substantial public recreational and educational activities including fishing, hunting, canoeing/kayaking, trail walking, and wildlife observation. While the refuge does not normally conduct surveys of annual visitation, a special survey in 2004 found a total visitation of 120,414 persons of which 37 percent were travelers from out of the state.

While approximately 2,300 acres of the refuge's coastal marsh habitat consists of salt marsh that is open to tidal flooding, the largest fraction of the habitat (approximately 4,200 acres) has been intensively managed as two freshwater impounded marshes. The control of water level and salinity allowed growth of annual seed producing plants that are particularly attractive for waterfowl. This intensive management had been highly successful, and during the peak fall migration more than 80,000 ducks and 100,000 snow geese were recorded using the refuge.

However, in recent years the refuge has been heavily impacted by storms. The key impact involved the ridge of higher elevation coastal barrier along Delaware Bay that has functioned as a dike for the two freshwater impoundments located in Units 2 and 3 of the Refuge. From the late 1980s to about 2005, the dune system needed to be reconfigured several times by the refuge and the state in order to maintain its integrity and prevent overwash of saline estuarine water into the freshwater impoundments. Despite these efforts, a series of storms starting with tropical storm Ernesto in 2006 and continuing to Hurricane Sandy in 2012, overwashed the beach barrier at the Unit 2 impoundment, creating a widening breach in the dune system. Attempts to close the breach were unsuccessful and saltwater began to regularly enter the formerly freshwater impoundment. The saline water killed the freshwater vegetation and riparian forests along Prime Hook Creek and Slaughter Creek and resulted in the conversion of much of the marsh to open water. In addition to substantially degrading the ability of the area to support waterfowl and shorebirds, the presence of this new expanse of open water has created problems for the community of Primehook Beach including frequent flooding of the community's access road which crosses the refuge. Residents of the community have been strongly advocating that the refuge close the breach and take steps to restore the area. The management capability of Unit 3 has also been diminished since the two impoundments are interconnected.

The refuge manager has concluded that the Unit 2 impoundment cannot be restored to a freshwater condition on a sustainable basis. They are developing plans to rehabilitate the area by converting it to tidal salt marsh. This will be a complicated effort, in part due to the existing road infrastructure which restricts tidal flow. Depending on the results of a sediment transport study, it may also be necessary to import a substantial volume of substrate material to raise the bottom up to an appropriate intertidal elevation. The managers also envision that the water control structures on the Unit 3 impoundment will need to be removed to allow it to develop into a natural tidal marsh system. The progress of saltmarsh restoration in Unit 2 will directly affect the future management decisions for Unit 3. However, they are hopeful that by controlling the increase in tidal floodwater so that it is gradual, it should be possible to reduce the reoccurrence of the problems that occurred in Unit 2 where the extensive rapid death of salt-sensitive plants resulted in sediment loss, erosion, and conversion to open water. The shift from intensively managed freshwater impoundments to natural salt and brackish marsh will likely result in a reduction in waterfowl numbers, but the estuarine tidal marsh habitat will be more sustainable and resilient. The managers are optimistic that Unit 3, which receives freshwater discharge from

Prime Hook Creek, can be converted into a natural tidal system that produces a high quality and diverse waterfowl habitat.

Over the longer period from 50 to 100 years in the future, the combined effects of sea level rise and storms are expected to have profound effects on the refuge. A 2009 study used the Sea Level Affecting Marshes Model version 5 (SLAMM 5) and high resolution elevation data (15 cm vertical accuracy) to predict changes in the land cover types at the Refuge. The model looked at sea level rise scenarios of 0.5 and 1.0 meters by the year 2100. This region experiences a relatively high amount of sea level rise because of land subsidence. For example a eustatic sea level rise of 0.387 meters in 100 years translates to a total change in sea level of 0.5 meters for the Prime Hook region when local land subsidence is considered. In addition to the amount of sea level rise, the SLAMM model must make a number of other important assumptions regarding factors such as: the frequency of major dune overwash events; the rate of marsh vertical accretion; erosion rates for the marsh and the other land covers; and the locally propagated inland tide range (currently dampened because of the circuitous route that the tide takes before entering the refuge, but would rise if a more direct connection to Delaware Bay was established). Thus, the specific model results should be viewed with a high degree of uncertainty. Nevertheless, the model can give a general idea of what future changes may occur. Under all of the model scenarios, by the year 2050 at least half of the upland area will be converted to wetland cover types. The validity of this outcome is supported by recent surveys showing that the refuge already contains 125 to 150 acres of dead, dying, or stressed woodland habitat due to saltwater intrusion. The loss of a substantial portion of the upland area has important habitat consequences and would likely extensively impact the refuge’s infrastructure (e.g., visitor center, staff offices, equipment storage buildings, roads, boat ramps, trails, etc.). Not surprisingly, the model also indicates that marsh will migrate inland and there will be a substantial increase in the amount of open water and tidal mud flat.

The refuge’s Comprehensive Conservation Plan was approved in March 2013 to guide management decisions for the next 15 years. It includes numerous strategies and monitoring plans to help the refuge adapt to the effects of climate change and sea level rise. The plan to abandon intensive freshwater impoundment management in favor of restoration of natural salt marsh is a major change of management direction. The refuge is also planning to import sand to enhance beach/dune habitat and to provide a marsh platform immediately behind the restored dunes to fortify the beach/barrier complex. However, artificial dune stabilization will be minimized since barrier island shorelines are dependent upon transgression and storm overwash processes to build and maintain shoreline elevation and width, as well as providing sediment input to the coastal marshes to help them keep up with rising sea levels.

Monitoring and data collection are an integral part of the management and sea level adaptation strategy for this dynamic system. A few of the key components include:

1) Conducting regular shoreline position and topography surveys along the full length of the refuge coastline consistent with National Park Service protocols (Northeast Coastal and Barrier Network-Geomorphological Monitoring Protocol). This monitoring will be coordinated with other coastal refuges to foster sharing of standardized monitoring data.
2) Establishing several tide gauges.
3) Establishing a program for making marsh surface elevation table measurements. Also expand efforts to use real time kinematic surveys and underwater sonar technology (less

precise than surface elevation table measurements, but can be conducted on a broader geographical scale) to monitor elevation throughout the wetland complex.

4) Implementing water quality, salinity, and sediment monitoring to inform decisions about wetland response to management and restoration.
5) In partnership with the Delaware DNREC Coastal Program and Atkins-Global Engineering, Inc., developing a model to predict the hydrodynamic response of the wetland complex under a wide variety of different management and restoration scenarios.

The monitoring information will be a critical element for the refuge to make the best management decisions to respond to the challenges resulting from climate change and sea level rise.

In May 2013 the refuge received $20 million in Hurricane Sandy Disaster Relief appropriations to repair the beach/dune system and to create a marsh platform on the back side of the dunes. In October 2013 another $19.8 million was received to restore the marsh behind the repaired dunes. This will entail building up the marsh elevation, removing water control structures, and creating channels in the marsh to manage how the water flows.

Bombay Hook National Wildlife Refuge

Bombay Hook National Wildlife Refuge is located in Delaware along the western shore of Delaware Bay approximately 36 miles from the mouth. It encompasses approximately 16,250 acres that extend for 8 miles along Delaware Bay. Eighty percent of the refuge consists of tidal salt marsh and associated mud flats and tidal creeks. The remaining portion consists of a mix of forest, freshwater impoundments, scrub/shrub swamps, and fields. The refuge was originally established as a sanctuary for migratory waterfowl, but subsequent management objectives were expanded to include a broader diversity of migratory birds including migrating songbirds, shorebirds, and wading birds. More than 300 species of birds have been recorded at the refuge and it is recognized as one of America's 100 "Important Bird Areas" by the American Bird Conservancy. The refuge receives about 170,000 visitors per year. Its facilities include a visitor center, nature store, three observation towers, 12-mile auto tour, five walking trails, and three observation towers. It also operates a public hunting program.

The refuge's expansive tidal marshes are particularly notable because of their pristine and unditched condition. In addition to their habitat value, they provide a buffer between Delaware Bay and the managed impoundments and public use areas. The marsh edge has been experiencing a long-term high rate of erosion. Over the last century it has receded at a rate of approximately 10 feet per year. Except at the south end where there are some small intermittent pocket beaches, the marsh edge is mostly a peat scarp and the presence of littoral drift material, which might provide some protection, is negligible. Sea level rise is considered to be the underlying cause of the erosion. In recent years a few areas have experienced a noticeable loss of interior marsh which has been converted to mud flat. From a habitat point of view, on the scale observed so far, this has not been a great concern because the flats provide good habitat especially for shorebirds. However, one of the areas where this marsh loss is occurring lies adjacent to the Shearness impoundment. The so called Mother's Day Storm in 2008 caused a breach in the impoundment dike in this area, although it was quickly repaired and fortified.

The cause of the interior marsh loss is unclear. Initially, it was thought that the loss might have been caused by the feeding activity of the large numbers of snow geese that have been increasingly wintering at the refuge. However, further investigation showed that the loss in some areas actually began before large numbers of the snow geese were using the refuge. Surface elevation tables have been installed to record changes in marsh surface elevation, but not enough data is available to draw any conclusions. Further studies are also contemplated to examine sediment and hydrodynamic processes. The refuge has had some preliminary discussions with the Army Corps of Engineers regarding the possible use of dredged material for restoring eroding marshes, but no specific actions are being pursued. The Sea-Level Affecting Marshes Model Version 6 was used in 2010 to investigate the susceptibility of the marsh to sea level rise over the longer term. The model results indicated that the marshes at the refuge are fairly resilient to rates of eustatic sea level rise up to one meter by 2100. However, some expert commenters pointed out that there were some questions on the accuracy of the Light Detection and Ranging (LiDAR) elevation data that was used as a model input and on the ability of the model to accurately capture the changes in the interior marsh.

NEW JERSEY

Federally Listed Threatened and Endangered Species

Piping Plover (*Charadrius melodus*)

Piping plover, a federally listed threatened species, nests on suitable beaches at a number of locations. In recent years the state's nesting population has generally been just over 100 breeding pairs. Some of the most important areas that were used in 2013 were Sandy Hook (43 pairs), Little Beach Island (23 pairs), and the North Brigantine Natural Area (6 pairs). Small numbers may utilize beaches at Monmouth Beach, Belmar, Spring Lake, and Sea Girt along the northern portion of the state's coast, and near Holgate, Longport, Ocean City, Corson's Inlet State Park, Strathmore, Townsend's Inlet, Avalon, Stone Harbor Point, Hereford Inlet, Two-mile Beach, Cape May City, and Cape May Meadows in the southern portion of the state.

The Atlantic Coast piping plover breeding population nests on suitable beaches located from North Carolina north to the western coast of Newfoundland. Wide flat, sparsely vegetated barrier beach habitats are particularly favored. These habitats include abundant moist sediment areas that are associated with dune blowouts, washover areas, sand spits, unstabilized and recently closed inlets, ephemeral pools, and sparsely vegetated dunes. Locations suitable for breeding are also limited because these ground nesting birds are especially sensitive to human related disturbance and predation. The nesting ecology can vary depending on the location and habitat. In New Jersey the birds begin arriving in mid-March to set up territories and perform courtship behavior. Egg laying begins mid-April and hatching takes place from mid-May to mid-July. The birds may renest one or more times if their nest is lost prior to hatching. Generally the young would be completely fledged by September 1. Piping plover chicks are unusual in that they must leave the nest shortly after hatching in order to begin foraging for food. Since the chicks are flightless, suitable feeding areas must be located within a reasonable walking distance of the nest site. Feeding areas include the wet portion of the beach, wrack lines, moist washover areas, and shorelines and flats associated with coastal lagoons and ponds. In some areas if the vegetation is too dense, the chicks may be deterred from reaching the feeding areas. Wave overwash that occurs during storms can be beneficial by creating low moist feeding areas and by keeping the vegetation from becoming too dense.

The expected increase in the rate of sea level rise and storm activity over the next 50 to 100 years is virtually certain to affect piping plover habitat within New Jersey and more broadly across the Atlantic Coast range. The effects are likely to be variable spatially and temporally. The habitat in some areas may be improved where wave overwash increases and inlets form and close naturally. Some new habitat will likely be created to replace what is lost where the shoreline can respond by receding unimpeded. However, some areas could reach a point at which storms and higher sea levels could directly reduce breeding success by repeatedly flooding nests. Another problem may occur in areas where the presence of human development prevents new habitat from being created as the shoreline recedes. The implementation of shoreline stabilization measures to protect development or human infrastructure could also adversely affect plover habitat.

The U.S. Fish and Wildlife Service recognizes the need to improve understanding of threats from sea level rise and increased storm activity to Atlantic Coast piping plovers. Accordingly, the North Atlantic Landscape Conservation Cooperative has provided funding for a collaborative project to develop a model for predicting how piping plover breeding habitat will change as a result of sea level rise and altered storminess. The model will be also used to develop habitat conservation recommendations and measures to preserve the resilience of piping plover habitat. The results of the first phase of the project were recently published (Gieder et al. 2014).

Seabeach Amaranth (*Amaranthus pumilus*)

Seabeach amaranth is a federally listed annual plant that occurs on the New Jersey ocean beaches. It was listed as a threatened species in 1993 after it had been extirpated from much of its historic range which encompassed nine states from Massachusetts to South Carolina. It was reported to be a common inhabitant of the New Jersey beaches in the late 1800s, but its abundance declined dramatically shortly thereafter. It was not reported from 1913 until 2000 when it was rediscovered at some Monmouth County beaches where a sand replenishment operation had recently been conducted. A comprehensive survey in 2001 found 5,813 plants with occurrences from all four coastal counties, although all but 69 were in the Monmouth Beach/Sandy Hook area. In recent years its primary presence has been at the Sandy Hook beaches, although smaller numbers of plants may occur on a less consistent basis at a variety of other locations such as Ocean City where 28 plants were reported in 2012. The reason for its reappearance in New Jersey after such a long absence is unclear although it followed a general pattern of recolonizing sites in other mid-Atlantic states where it had been absent for many years (New York in 1990, Maryland in1998, Delaware in 2000, and Virginia in 2002).

Seabeach amaranth is restricted to open sandy portions of ocean beaches within the relatively narrow zone between the high tide line and the toe of the primary dune. It favors barrier island beaches, especially the lower foredunes and upper strands of non-eroding beaches and overwash flats at the accreting ends. It is an annual plant which has a relatively long germination period that may begin as early as April and extend at least thru July. The plants exhibit low sprawling growth that progresses from a small unbranched sprig into a much branched clump that often reaches 30 cm in diameter. The clumps are generally widely scattered. Seed production begins in July or August, reaches a peak in September, and then declines until senescence in early winter. The seeds are dispersed mainly by water and wind and are believed to remain viable for long periods. As a result, the plant has a high dispersal ability that allows it to colonize habitat as it becomes available. Seabeach amaranth is considered to be a "fugitive" species that is intolerant of competition and does not occur on well vegetated sites. It tends to trap sand, creating habitat for other dune plants which will eventually outcompete it. Despite its habit of colonizing relatively low elevation areas on the beach, it is intolerant of even occasional flooding during its primary growing season (June to September). Storm tides and/or beach erosion cause substantial mortality. Storms that occur earlier in the growing season are especially damaging because they limit seed production which this annual plant depends upon for producing the next generation. Because of these natural vulnerabilities, there can be large population fluctuations, even to the point where the plants vanish for years before reappearing.

Seabeach amaranth appears to need extensive areas of dynamic naturally functioning barrier island that allow it to move within the coastal landscape in response to changing conditions. This permits populations that are periodically eliminated from an area by natural forces to be reestablished, once the conditions become suitable, by seeds transported from neighboring areas. Habitat fragmentation can be a significant problem because it inhibits reestablishment after episodes of natural depopulation. Where the dynamic landscape is altered by installation of shoreline stabilization structures or by construction of vegetated dunes, the habitat usually becomes unsuitable. Recreational development and public use of beaches typically renders them unsuitable as habitat. Based on its life history and ecology, it appears that seabeach amaranth will be vulnerable to impact from the increases in the rate of sea level rise and storm activity that are expected to occur over the coming decades. While it has survived in this dynamic environment for thousands of years, its current populations are more reduced and fragmented than historically, making it less resilient.

Northeastern Beach Tiger Beetle (*Cicindela dorsalis dorsalis*)

The northeastern beach tiger beetle is a beach dwelling flying insect that was historically abundant along coastal beaches from Cape Cod, Massachusetts to central New Jersey. It was federally listed as a threatened species in 1990 after becoming extirpated from Connecticut, Rhode Island, New York and New Jersey. An effort to reestablish the species in New Jersey was begun in 1994 by releasing larvae obtained from the Chesapeake Bay populations at two sites at Sandy Hook. Five more releases of larvae were made during the years up to 2006. Initially, the results were encouraging as the larvae were observed to develop into an adult population. However, the population underwent a decline beginning in 2001. By 2007 only two adult beetles were observed and none were found during the 2008 surveys. The status of this population is currently considered to be uncertain.

The adult beetles are only present on the beach from June to September when they mate and lay their eggs in shallow burrows. The adults may disperse over distances up to at least 7 kilometers. The eggs hatch into larvae which take up residence in burrows located between the intertidal zone and the base of the dunes. The larvae pass through three stages before they pupate and emerge as adults. The larval stage generally lasts about 2 years but can be less depending on the available prey base. The larvae are predators which position themselves at the burrow entrance where they can capture passing prey such as small amphipods. In the early fall the larvae typically relocate their burrow to a position higher on the beach in an apparent effort to reduce their vulnerability to the effects of winter storms. They plug the entrance and retreat down into the burrow when not actively seeking prey and during winter hibernation.

The extirpation of this species from most of its range resulted primarily from destruction and disturbance of natural beach habitat associated with shoreline developments, stabilization structures, and high recreational use. Shoreline alterations that directly or indirectly affect the character of the beach (i.e., width, profile, grain size, and vegetation) are a particular concern. In addition to the anthropogenic threats, this species is vulnerable to severe storms and beach erosion.

Rufa Red Knot (*Calidris canutus rufa*)

The rufa red knot (hereafter referred to as red knot) is a shorebird subspecies that was recently (September 30, 2013) proposed to be federally listed as threatened under the Endangered Species Act. The Delaware Bay shoreline is known to be a major stopover site for these birds during their northward migration in the spring. They are known for their unusually long distance migration from their primary wintering areas in southern South America to their breeding areas in the Canadian Arctic. However, some birds do not migrate southward beyond the United States and utilize wintering areas along the coastlines bordering the Gulf of Mexico and the southeast states from Florida to North Carolina. While they normally feed primarily on small bivalves, their spring migration has evolved so that the Delaware Bay area has become their primary stopover location because of the extraordinary abundance of horseshoe crab eggs. This rich food source is considered to be a key factor that allows them to gain sufficient body condition to complete the migration and accomplish their breeding activity. The reduced availability of horseshoe crabs eggs at the Delaware Bay stopover site due to commercial harvest of the crabs is believed to be a primary cause for the decline of the red knot population that was observed in the early 2000s. This decline in the population was an important factor in the decision to propose that the species be given threatened status.

In New Jersey during the spring migration, the birds are heavily concentrated along the shoreline reach between Cape May and Fortescue. Large numbers typically arrive in mid-May and depart by the end of the first week in June. Most of their time is spent feeding on horseshoe crab eggs which are abundant on the intertidal beaches, although they also make comparatively limited use of the exposed mud flats and pans within the adjacent marshes and impoundments for roosting. They are uncommon along Delaware Bay during the southward fall migration, which peaks in August. Small numbers are regularly observed on the New Jersey ocean coastal beaches during both spring and fall migration periods.

The Delaware Bay beach habitat that these birds are dependent upon during their spring stopover may be substantially affected by increased erosion produced by sea level rise and increased storm activity. The beaches have historically been resilient and, except where constrained by man-made structures, have responded to sea level rise by migrating landward. However the amount of sand in this system is rather limited and the beaches are relatively thin and narrow so it is unclear how well they will be maintained as the erosion rate increases. Even for those beaches that are able to persist, an increase in the rate of shoreline recession could change their character in a way that would reduce the amount of horseshoe crab spawning. For example, the horseshoe crabs are known to avoid spawning on beaches that exist simply as a thin layer of sand over peat. The potential for increased shoreline armoring or other structural stabilization to protect human infrastructure as the shoreline recedes closer to developed areas is another related threat to the birds' important beach habitat.

Waterbird Nesting Colonies and Concentration Areas

Numerous waterbird nesting colonies occur in New Jersey, particularly in the coastal region between Barnegat Bay and Cape May. They are notably absent from the Delaware Bay shoreline. The New Jersey colonies which are vulnerable to the effects of sea level rise, storm surge, and erosion are composed of up to eight species of long-legged wading birds (snowy egret, great egret, cattle egret, glossy ibis, black-crowned night heron, little blue heron, tricolored heron, and yellow-crowned night heron), four tern species (common, Forster's, least, and gull-billed), three gull species (laughing, herring, and great black-backed), and black skimmer. Great blue heron colonies also occur, but they are usually located in more inland forested areas. Most of the species in New Jersey utilize colony sites on low marshy islands in the coastal bays and on certain undeveloped barrier island beaches especially near inlets in areas where human related disturbance is low. Some colonies are located on islands and hummocks created by deposition of dredged material. For most species suitable colony sites are scarce and successful colony sites are typically used repeatedly for a number of years. One notable exception is the laughing gull which nests in large colonies on marsh islands and switches sites often. Most species will continue to use a successful colony site unless there is a change in the habitat conditions or a change in the larger regional population. Colonies may be abandoned for a variety of factors including increased predation pressure, human disturbance, and changes in the vegetation. In wading bird colonies the phytotoxic effects of the birds' excrement over time may alter the vegetation forcing them to find a new site. Climatic influences such as abnormally cold temperatures, storms, and floods may force the birds to renest which prolongs the nesting season and results in substantial yearly variation in reproductive success. If the rate of sea level rise increases and the coast is subjected to more stormy conditions, erosion and flooding will likely greatly limit the availability of suitable colony sites and cause a substantial reduction in reproductive success.

Delaware Bay Shorebird Stopover Area

The shoreline bordering the lower 80 km (50 miles) of the Delaware Bay is the site of the second largest spring concentration of migrating shorebirds in the Western Hemisphere. Its importance on an international scale was formally recognized in 1985 when it was the first site dedicated as part of the Western Hemisphere Shorebird Reserve Network. Upwards of 1,000,000 shorebirds utilize this area in May and early June when they interrupt their northward migration to feed and replenish their energy reserves prior to continuing their migration to their arctic and subarctic breeding grounds. The most common species include ruddy turnstone, semipalmated sandpiper, red knot, sanderling, dunlin, and short billed dowitcher. Fourteen other species regularly use the Delaware Bay shoreline during their spring and fall migration. Most of these shorebirds are long distance migrants that arrive at Delaware Bay in a thin and exhausted condition after traveling from their wintering grounds in Central and South America. They have a limited amount of time during which they must feed heavily to regain weight lost during the migration and to attain sufficient body condition to complete their migration and accomplish their breeding activity.

On the New Jersey side of the bay the birds congregate on the region extending from Cape May to the vicinity of the Cohansey River. The wide tidal marshes and narrow beaches are the primary habitats. The highest densities of birds occur on the beaches, but large numbers also utilize the marshes especially as high tides limit beach feeding. A primary reason that these birds are attracted to this area is the abundance of horseshoe crab eggs which provide a vital food source. Delaware Bay has the largest population of horseshoe crabs on the East Coast. The horseshoe crabs deposit their eggs in nests on the beach in the spring, and the birds arrive there at about the same time. In order to limit human disturbance to these dense aggregations of shorebirds, the state closes many of the beach areas to pedestrian traffic from May 7 to June 7.

The beach and marsh habitats that the birds depend on are quite vulnerable to impact from sea level rise and storm induced erosion. Hurricane Sandy caused significant debris accumulation and beach erosion that was expected to threaten the success of the horseshoe crab spawn that the shorebirds depend on. As a result, several nongovernmental environmental organizations led an emergency beach restoration effort that included trucking in 32,000 cubic yards of sand for placement at five sites covering more than a mile of the New Jersey Bay shoreline. The ongoing conversion of marsh to open water is expected to accelerate substantially as sea level rise promotes marsh drowning as well as edge erosion. The beaches have historically been more resilient and, except where constrained by man-made structures, have responded to sea level rise by migrating landward. Their resilience will be severely tested as the rate of sea level rise increases, especially in those areas where the presence of human development interferes with their landward migration. Even if beaches remain present, there could be changes in their character which could affect bird use by affecting the horseshoe crab spawning. As the shoreline recedes closer to developed areas, there is also increased potential for shoreline armoring or other structural stabilization projects that would adversely affect the beach habitat.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

E.B Forsythe National Wildlife Refuge

The Forsythe National Wildlife Refuge encompasses approximately 47,000 acres in two divisions (Brigantine Division and Barnegat Division) that are distributed in a patchwork along more than 50 miles of the coast in Atlantic, Burlington, and Ocean Counties. Approximately 82 percent of the refuge consists of wetlands, of which 78 percent is salt marsh interspersed with shallow coves and bays. The wetlands include three large impoundments of freshwater and brackish marsh habitat totaling approximately 1,490 acres. The impoundments allow intensive water level management to enhance the habitat value for waterfowl, shorebirds, and wading birds. The remaining 18 percent of the refuge is upland, of which approximately 5,000 acres are forested, and 2,000 acres are a mix of grasslands, beaches and dunes. The refuge includes two undeveloped barrier island beaches, the Holgate Unit, which consists of the lower 3.5-mile end of Long Beach Island, and Little Beach Island. Little Beach Island is an important nesting area for the federally threatened piping plover with 23 nesting pairs using the area in 2013. Both of these coastal barrier areas, along with a pristine section of saltmarsh on the West side of Great Bay, have been designated a National Wilderness Area.

The refuge provides substantial public recreational and educational activities including fishing, hunting, canoeing/kayaking, trail walking, wildlife observation, and environmental education programs. The facilities include a visitor center and 8-mile long wildlife drive. The annual visitation exceeds 200,000.

Sea level rise and the potential for increased storm surges will create a number of challenges for this low-lying coastal refuge. The barrier beaches at Holgate and Little Beach Island have been experiencing migration at substantial rates. Holgate has steadily moved westward (about 200 meters over the last 20 years) and has grown southward about 1.25 miles in that time. The pattern at Little Beach Island is different with its shoreline advancing due to growth of the sand spit over the northern portion of the island. During storms beachfront sand is washed to the backside where it buries salt marsh. While periodic overwashes are beneficial to beach-nesting birds, the response of this dynamic system to the expected increase in the rate of sea level rise and/or increased storm conditions is uncertain. There is a potential for these barriers to reach a tipping point that would be followed by a dramatic change in habitat condition.

Actions that are taken to reduce beach erosion on the developed beaches adjacent to the refuge could have important negative consequences for the refuge. The implementation of structural stabilization measures is a major concern. For example, the southernmost groin on Long Beach Island has caused severe erosion along the northern edge of Holgate. Since the problems associated with structural shoreline stabilization on barrier islands are now better recognized, beach replenishment has become a preferred alternative to offset beach erosion. However, beach replenishment also has the potential to cause adverse environmental effects and the refuge managers are concerned that some of the borrow sites that are being considered to provide sand for a currently proposed project are located in a position where the dredging could affect the sand transport dynamics of Holgate and/or Little Beach Island. These types of conflicts may become more common as accelerated sea level rise creates an even greater need for sand to offset beach erosion.

In recent years, storm surge and salt water inundation has been causing a significant die-off on the forested areas along the refuge’s marsh/forest interface. While it is possible that salt marsh will advance into these impacted forested areas, a more likely outcome is that *Phragmites*, an undesirable invasive species, will become established and cause a sharp decline in habitat value (Smith 2013).

The storm surge accompanying Hurricane Sandy seriously damaged the refuge’s impoundments and the popular wildlife drive. The wildlife drive had to be closed to public use for several months while repairs were underway.

Another problem associated with storm surge is debris accumulation on the marsh. During Hurricane Sandy the tidal surge transported massive quantities of debris onto the refuge. Debris, if not removed in a timely manner, would kill marsh vegetation. Over time this could weaken the marsh’s ability to accrete enough material to maintain its elevation at a level that can keep up with sea level rise. Debris removal is difficult, time consuming, and expensive. The debris from Sandy included fuel tanks that had to be assessed for the presence of hazardous waste. The clean-up operations themselves run the risk of causing soil compaction, damage to vegetation, and disturbance to wildlife.

While the most of the marsh areas have not exhibited obvious problems from erosion or waterlogging, significant loss of salt meadow cordgrass marsh is occurring at the historic salt hay farm sites. There is concern that accelerated sea level rise could result in important changes to the marshes and other low lying habitats. A 2012 study (Warren Pinnacle Consulting, Inc. 2012) commissioned by the refuge utilized the Sea-Level Affecting Marshes Model version 6 (SLAMM 6) to estimate the effects on the refuge under five different sea level ride (SLR) scenarios (increases of 0.39 m, 0.69 m, 1.0 m, 1.5 m, and 2.0 m between 1990 and 2100). The model included an adjustment for local SLR since tide gauge records indicate that the historical

SLR rate for the region (3.95 mm/year) is significantly higher than the global average (1.7 mm/year for the last century). High accuracy elevation data was obtained from a LiDAR survey conducted in 2011. The model assumed marsh accretion rates of 3.75 mm/year and 2.5 mm/year for irregularly flooded and regularly flooded marshes respectively based on values previously measured on the refuge. The model simulations indicated that the refuge will be substantially affected under all scenarios. The irregularly-flooded marsh decreases by 66% under the 0.39 m scenario and 97% under the 0.69 m scenario. These losses are balanced by gains in regularly-flooded marsh. Under the higher rates of SLR, the marshes are predicted to largely convert to open water or tidal flat. Freshwater swamp would be reduced by 23% under the 0.69 m scenario and 44% under the 1.5 m scenario. The refuge's developed uplands would be reduced by 11% under the 0.69 m scenario and by 23% under the 1.5 m scenario. The model predictions involve significant uncertainties, but nevertheless indicate that substantial change is likely. The refuge managers are using the study results and other observed trends in marine transgression, marsh migration, and coastal forest retreat to assess long-term planning needs such as adjusting the acquisition boundary so that the refuge will be in the best possible position to provide vital habitat for wildlife throughout the next century.

Cape May National Wildlife Refuge

The Cape May National Wildlife Refuge encompasses approximately 11,800 acres within the Cape May Peninsula. It is divided into three main divisions: Great Cedar Swamp Division, Delaware Bay Division, and the Two-Mile Beach Unit. The Great Cedar Swamp Division includes approximately 6,000 acres of primarily moist woodlands and thickets located in the Peninsula's interior. This Division receives limited tidal flow on the north end from Great Egg Harbor and on the south end from Dennis Creek. The Delaware Bay Division includes approximately 5,000 acres of mixed wooded uplands, tidal marsh, and beach habitat that extends for 5 miles along the Delaware Bay shoreline. The Two-Mile Beach Unit consists of approximately 800 acres bordering a 0.7-mile long section of ocean fronting beach just north of the Cape May Inlet. The beach and tidal marsh of the Delaware Bay Division are heavily used by shorebirds which congregate there during their spring migration. The Delaware Bay shoreline is internationally recognized as a major shorebird stopover area. The birds are particularly attracted to this area because of the intense horseshoe crab spawning which takes place on the beach. The horseshoe crab eggs provide an especially rich and available food source for the shorebirds. The Two-Mile Beach Unit is also important to shorebirds which stop here in large numbers during their spring and fall migrations. This Unit has also recently been discovered as one of the most important stopover sites for piping plover in New Jersey with up to 20 birds observed here per day. In addition to the abundant shorebirds, the Cape May Peninsula's configuration and strategic location act to concentrate large numbers of songbirds, raptors, and woodcock as these birds funnel down to Cape May Point during the fall migration.

Sea level rise, worsening erosion, and possible increased stormy conditions are likely to produce substantial changes in the refuge's habitats. The salt marsh along the Delaware Bay shoreline is already being lost to erosion at rates up to 3 meters per years (Smith 2013). The forest at the salt marsh-forest interface is also being lost as a result of increasing salt water inundation. As the forest dies back, the wetland species that colonize tend to be dominated by the invasive nonnative form of *Phragmites australis*, which has low habitat value. The beach has been resilient up to now, but the Delaware Bay beach in particular could become more vulnerable in the future. Hurricane Sandy eroded many of the refuge's bay beaches down to the peat layers. Because of the importance of these beaches to horseshoe crab spawning and shorebirds, several nongovernmental conservation organizations led an effort to restore the beaches in several eroded areas including refuge beaches by removing debris and trucking in 32,000 cubic yards of sand. The effort was successfully completed just in time for the horseshoe crab spawning season. The higher sea levels that are expected to occur in the future, combined with more frequent storms, could result in more extensive and persistent beach erosion.

The ocean beach at the Two-Mile Beach Unit is larger and more resilient, especially if it is allowed to slowly migrate landward. However, shoreline stabilization efforts that are undertaken at adjacent developed shorelines and inlets could put the refuge's beach at greater risk. The refuge managers have already refused a request by the Army Corps of Engineers to dredge sand from within the Unit boundary to replenish the beach at the U.S. Coast Guard property on the south side of the Cape May Inlet because of the potential for adverse effects on the refuge beach. However, beach sand cannot be retained at any one location for very long because waves and currents continually transport it along the shoreline and between offshore and onshore locations. Even if the refuge can continue to exert control over sand removal activity within its boundaries, its beaches could easily be affected by artificial sand redistribution or structural shoreline modifications on the neighboring coastal areas. As the sea level rises, the need for beach replenishment material or other shoreline stabilization measures to maintain developed coastal areas will increase, as will the potential for conflict.

In order to gain some insight into the potential effects of sea level rise on the refuge, the U.S. Fish and Wildlife Service contracted the application of the Sea-Level Affecting Marshes Model version 6 (SLAMM 6) (Warren Pinnacle Consulting, Inc. 2011). The model predicts changes in tidal marsh area and other low lying habitat types due to sea level rise by simulating five primary processes: inundation, erosion, accretion, overwash, and saturation. The model was run using five SLR scenarios covering the period from 1990 to 2100: 0.39 m, 0.69 m, 1.0 m, 1.5 m, and 2.0 m. Tide gage data indicates that historic rate of SLR in the Cape May area is approximately 4.0 mm/year, which is substantially higher than the global (eustatic) rate (1.7 mm/year for the last century). The higher rate at Cape May, which is believed to be due to land subsidence, is factored into the analysis. The model used land elevations from a 2008 statewide LiDAR survey. The model assumed that the tidal marshes would be able to raise their elevation (through sediment and organic matter accretion) at a rate of 3.75 mm/year based on measurements made at Forsythe NWR.

It should be recognized that the model's individual predictions have a significant degree of uncertainty. Therefore, it is prudent to examine general trends for a variety of scenarios rather than placing too much reliance on individual predictions. The model predicts that there will be substantial impacts on the wetlands by 2100 for all but the lowest SLR scenario. Irregularly flooded salt marsh, which currently comprises the third largest habitat type on the refuge at 17%, is the most vulnerable habitat type with a 68% loss under the 0.69 m scenario and 94% loss under the 1.5 m scenario. This marsh type would generally be converted into regularly flooded marsh, although considerable conversion to open water occurs with the highest SLR scenario (2.0 m). Nontidal swamp, which comprises the dominant habitat cover type at 50%, would be reduced by 26% under the 0.69 m scenario and by 44% under the 1.5 m scenario. Developed dry land, which include the land where the refuge offices, visitor contact station, and maintenance buildings are situated, would be diminished by 35% under the 0.69 m scenario and by 47% under the 1.5 m scenario. The refuge managers are using the study results in conjunction with other climate projections and observed trends in habitat evolution to evaluate long-term planning needs so that the refuge will be able to continue to provide important habitat for wildlife.

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NEW YORK

Federally Listed Threatened and Endangered Species

Roseate Tern (*Sterna dougallii dougallii*)

The roseate tern is a federally listed coastal marine species that has a major nesting colony at Great Gull Island located at the eastern end of Long Island Sound between Plum Island and Fishers Island. It is the largest colony in the Northeast with approximately 1,500 nesting pairs in recent years. Sporadic breeding also occurs at several areas around Long Island including Cartwright Shoals in Gardiners Bay, Lanes Island in Shinnecock Bay, Carters Island and New Made Island in Moriches Bay, Goose Flat in Great South Bay, and "The Grouts" in Babylon. The Northeast population, which is federally listed as endangered, currently has breeding sites distributed between Long Island and Nova Scotia, although formerly its breeding range extended to Virginia.

Roseate terns arrive on the breeding grounds in late April or early May. In the Northeast they are invariably found nesting with common terns. Roseates are believed to benefit from the common tern's aggressive defense of colony sites against predators. The nest is a shallow scrape that is sometimes lined with pieces of grass and other debris. The nests may occur on a wide variety of substrates including sand, shell, gravel, rock, and vegetation. In contrast with common terns which usually make their nests in exposed sites, roseates usually prefer to conceal their nests under some sort of cover such as clumps of vegetation, rocks, or driftwood. Egg laying begins during the third or fourth week of May, but the birds may continue to lay new or replacement clutches until the middle of July. Incubation takes 23-24 days and the chicks fledge 25-28 days after hatching. Roseate terns feed on small fish that are captured by plunge-diving. In the Northeast sand lance is the primary prey. The young remain dependent on the adults for food for several weeks after fledging which reflects the highly specialized fishing technique that the young must learn. In late July the adults and fledglings typically begin moving to staging areas from which they make foraging flights to feeding areas. The eastern end of Long Island is known to be an important staging area, as is Cape Cod, Massachusetts. A few weeks later, usually by mid- to late-September, roseates begin their southward migration to the north coast of South America.

Preferred colony sites for Northeast population are located on smaller islands with sandy, gravelly, or rocky substrates, although smaller colonies occur on long barrier islands especially near the ends. Expected increases in sea level rise, erosion, and storminess could adversely affect many colonies. For example, the Gardiners Island/Cartwright Point area on Long Island, which supported about 150 to 250 breeding pairs in the early 2000s, has been largely abandoned due at least in part to erosion and excessive overwash. The vulnerability of the important Great Gull Island colony is of particular interest. The colony was re-established in the late 1950s after the American Museum of Natural History (AMNH) took control of the island in 1949 to preserve potential breeding habitat for terns being displaced by development on Long Island's beaches. The 17-acre island had been the site of a U.S. Army coastal defense system that was taken out of service after World War II. Since 1969 the AMNH has been conducting an intensive monitoring study of the colony. Research scientists and volunteers live on the island from April through August conducting research and management activities such as bird banding and vegetation control. In addition to roseate terns, the island also supports a major colony of common terns (estimated at 9,500 pairs). While the common terns nest mostly in the island's interior, the roseates mostly nest along the perimeter amongst the rocks that were placed there long ago for erosion protection. This perimeter habitat is vulnerable to sea level rise and storm activity. Hurricane Sandy partially breached the rock perimeter in two places and a section on the east side eroded away. While most of the roseate nesting habitat remains intact, funds are being sought to repair the damage and prevent further deterioration.

Piping Plover *Charadrius melodus*)

The federally threatened piping plover nests on Long Island beaches bordering the Atlantic Ocean, Peconic Bay and Long Island Sound and on some bay islands within these watersheds. The south shore barrier islands and Atlantic Ocean beaches in Southampton and East Hampton support about 60% of the Long Island piping plover population, whereas, the Peconic Bay and Long Island Sounds together support about 40% of the island-wide population. Piping plover breeding areas that support more than 10 pairs of plovers include Arverne (Rockaway Island), Breezy Point Gateway National Recreational Area (Rockaway Island), Breezy Point Cooperative (Rockaway Island), Nickerson Beach (Long Beach Island), Jones Beach State Park (Jones Island), Cedar Beach, Babylon (Jones Island), Democrat Point (Fire Island), Fire Island Wilderness Area (Fire Island), West Hampton Dunes (Westhampton Island), Tiana Beach (Westhampton Island), and Southampton Village Beach (Southampton Atlantic Ocean beaches).

The Atlantic Coast piping plover population typically nests on coastal beaches, sandspits at the end of barrier islands, gently sloping foredunes, blowout areas behind primary dunes, and in overwash-created bare sand areas cut into or between dunes. In the central portions of their Atlantic Coast range (including NY-NJ), they may also nest on beaches that have been artificially augmented through beach nourishment projects. Nests are usually found in areas with little or no vegetation. Overwash habitats, bayside flats, unstabilized and recently closed inlets, ephemeral pools (areas on the beach where sea and/or rain water pool during storm overwashes and rains), and moist, sparsely vegetated barrier flats are especially important to piping plover productivity and carrying capacity in the New York. These are dynamic habitats, constantly being reshaped by the forces of nature, are a necessary component of the species ability to survive and recover in the wild.

Much of the plover's historic habitat along the Atlantic Coast has already been destroyed or permanently degraded by inlet stabilization activities, development, and human use. The construction of houses and commercial buildings on and adjacent to barrier beaches directly removes plover habitat and results in increased human disturbance. Additional disturbance comes in the form of recreational use of beach habitats. While legal restrictions on coastal development may slow the future pace of physical habitat destruction, the trend in habitat availability for this species is inexorably downward. Furthermore, habitat availability for the species is compromised by the ever increasing human access to, and recreational use of, these coastal habitats. The decrease in habitat availability, especially with regard to the dynamic nature of these coastal areas, may force birds to nest in suboptimal habitats, the effects of which could manifest itself in poor future reproductive success. It has been noted that a decline in habitat quality and quantity may prompt within-site movements and thus may increase competition for space leading to displacement of some individuals. As high quality habitat continues to decrease, and as low quality of remaining habitat persists, it is unlikely that new immigrants would be attracted to a site (Cohen et al. 2006).

Accelerating sea level rise and increased storm activity pose substantial threats to Atlantic Coast piping plover due to the potential for changes in their barrier island breeding habitats. These climatic changes are expected to promote increased erosion, island overwash, inlet formation, and in some cases dramatic shifts in barrier evolution (Gutierrez et al. 2007). However, the magnitude of the response may be highly variable depending on the barrier geomorphology. Piping plover habitat may benefit from increased overwash and inlet formation up to a point, but could be harmed if conditions lead to excessive nest flooding. Piping plover habitat could also be adversely affected if shoreline stabilization projects, which could potentially disrupt barrier island sediment movement, were implemented to combat the increasing erosion.

A study by Seavey et al. (2011) assessed the threat of sea level rise to piping plover breeding habitat on the barrier island system of Suffolk County, N.Y., which is located along the southern coast of Long Island. The study developed a generalized linear model to predict plover breeding habitat under four SLR scenarios (0.38 m, 0.47 m, 0.5 m, and 1.5 m over the next 100 years). The study also examined the risk of storm-induced flooding of plover habitat by pairing the 1.5 m SLR with three types of storms: a 5-yr storm surge event (1.65 m) and category-two and -three hurricanes. The study predicted that where the breeding areas had the room to migrate upslope and inland, the breeding habitat could actually increase. However, where this movement was impeded by development, the available habitat was projected to decrease by 5-12% depending on the SLR scenario. Under the 1.5 m scenario large storms would flood almost the entire breeding area.

The U.S. Fish and Wildlife Service recognizes the need to develop better models to predict how sea level rise and development will affect plover nesting habitat. Toward that end the U.S. Fish and Wildlife Service is providing funding through the North Atlantic Landscape Conservation Cooperative for a collaborative project led by Sarah Karpanty of Virginia Tech to develop a modelling approach to better assess the threat from sea level rise and inform related conservation recommendations. Results from the first phase of this project, which focused on predicting nest presence using barrier island features, were recently published (Gieder et al. 2014).

Seabeach Amaranth (*Amaranthus pumilus*)

Seabeach amaranth is a federally listed threatened plant that is found along the south shore Atlantic Ocean beaches from Rockaway Island east to Montauk Point. In 2012, the Long Island population of this plant was about 750 plants, distributed from Breezy Point in Queens to East Hampton town beaches. This represents a significant reduction from 2003 when over 190,000 plants were observed on Long Island south shore beaches. Seabeach amaranth (family Amaranthaceae) is an annual plant native to the barrier island beaches of the Atlantic Coast, from Massachusetts to South Carolina.

The species' primary habitat typically consists of flats originally created by overwash events at accreting ends of barrier islands and lower foredunes and upper strands of non-eroding beaches.

In New York, the habitat of seabeach amaranth is also characterized by barrier islands exposed to high wave energy, low tidal energy, frequent overwash, and breaching by hurricanes with resulting formation of new inlets (Weakley and Bucher 1992). Seabeach amaranth is never found on beaches where the foredune is scarped by undermining water at high storm tides. Occasionally, small, temporary populations are established in secondary habitats, such as blowouts in foredunes, and in sand or shell dredge spoil or in beach nourishment material.

Seabeach amaranth does not occur on well-vegetated beaches, particularly where perennials have become strongly established (Weakley and Bucher 1992). A dynamic, early successional "pioneer" species, seabeach amaranth is also termed as "fugitive" because its populations are constantly shifting to newly disturbed areas. The plant is eliminated from existing habitats by competition and erosion and colonizes newly-formed habitats by dispersal and (probably) long-lived seed banks. The same physical forces (*e.g.*, storms and extreme high tides) that create the plant's very specific and ephemeral coastal habitat also destroy it. Existing habitats are eroded away but new habitats are created by island overwash and breaching in areas where natural processes are allowed to proceed. Therefore, seabeach amaranth requires extensive areas of barrier island beaches and inlets, functioning in a relatively natural and dynamic manner. Such conditions allow the plant to move around in the landscape, occupying suitable habitats as they are formed.

Based on its life history and ecology, it appears that sea beach amaranth will be vulnerable to impact from the increases in the rate of sea level rise and storm activity that are expected to occur over the next several decades. While it has survived in this dynamic environment for thousands of years, its current populations and habitat are more reduced and fragmented, making it less resilient.

Rufa Red Knot (*Calidris canutus rufa*)

The rufa red knot (hereafter called red knot) is a shorebird subspecies which has been recently (September 30, 2013) proposed for listing as threatened under the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*). The red knot utilizes barrier beaches, bay shorelines, tidal flats, and wetland margins as foraging areas primarily along the south shore of on Long Island. Details on the distribution and abundance of red knots is still being evaluated, however, the Service is aware of the following distribution of red knots on Long Island. Concentration areas are around the major inlet and bay beaches, including associated wetland complexes and tidal flats. The greatest use is in Jamaica Bay area, but the other major inlets on the south shore also represent important habitats and concentration areas for this species. These dynamic beach foraging and resting habitats should be relatively resilient to the effects of sea level rise and moderately increased storm activity.

Waterbird Nesting Colonies

New York contains numerous waterbird nesting colonies which are distributed in three main areas: the New York Harbor area including Jamaica Bay and the western section of Long Island Sound between Queens and the Bronx; the Long Island south shore barrier islands and bay systems; and Long Island Sound and Peconic Bay. New York City Audubon (www.nycaudubon.org) has been conducting surveys of the New York Harbor waterbird colonies for a number of years. Their 2010 survey identified nine colonies of mixed species long-legged wading birds located on nine islands. These species, hereafter collectively referred to as waders, included black-crowned night heron, great egret, snowy egret, glossy ibis, yellow-crowned night heron, little blue heron, tricolored heron, cattle egret, and green heron. Several of the islands also supported nesting colonies of herring gull, great black-backed gull, and double-crested cormorant. Hoffman Island, located in lower New York Bay, had the largest wader colony with 624 nests observed. Other large wader colonies were located at Canarsie Pol in Jamaica Bay (497 nests), and at South Brother Island in the western section of Long Island Sound (456 nests). Several others island sites that hosted wader colonies in the past remain intact but are currently unoccupied. Colonially nesting birds periodically move to alternative sites as a result of human disturbance, predation, or other factors. Therefore, it is important that suitable sites remain available for the birds to colonize or recolonize when colony abandonment occurs. Many of these urban island colony sites have been armored to prevent erosion and should be relatively resistant to alteration from sea level rise and increased storm activity. However, several island colony sites in Jamaica Bay have been experiencing significant erosion. Approximately 155 acres of island marsh and hummock habitat at five locations were restored by the Army Corps of Engineers between 2006 and 2012 using dredged material placement and vegetation planting. This restored habitat should provide wildlife benefits for the next few decades, but long-term vulnerability to sea level rise and erosion remains a concern.

The Long Island south shore bay systems and barrier island from Hempstead Bay to Shinnecock Bay provide important feeding and breeding habitat for common terns and least terns. Major colonies of these species occur at Breezy Point in Queens, Silver Point in Hempstead, the bay island wetlands in Hempstead, Babylon, Islip, Brookhaven, and Southampton. Bay islands, such as Warners Island West in Shinnecock Bay, John Boyle Island in Great South Bay, and the Hempstead Bay islands also contain important breeding sites for green heron, black-crowned night heron, herring gull, and other species. These low-lying islands will be vulnerable to the effects of accelerating sea level rise and increased storm activity.

The Long Island Sound and Peconic Bay systems are critical waterbird breeding and feeding areas. The numerous bays, creeks, and islands provide habitat for these species. Major waterbird breeding colonies can be found from Gardiners Island in the east to North Brother Island in western Long Island Sound. Great Gull Island off Orient Point is the site of a major common tern and roseate tern colony. Nearby Plum Island, which is administrated by the U.S. Department of Homeland Security, contains a rookery of black-crowned night heron and great egret. This area also includes Fishers Island which supports a variety of waterbird colonies. Because of their larger size and/or armored shorelines these colony sites are relatively less vulnerable to the erosion and flooding associated with sea level rise and increased storm activity.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

A number of refuges that are part of the Long Island National Wildlife Refuge Complex, including Oyster Bay, Conscience Bay, Elizabeth A. Morton, Amagansett, Wertheim, Sayville, and Target Rock National Wildlife Refuges and the Lido Beach Wildlife Management Area were heavily impacted by Hurricane Sandy. Most of the impacts occurred as a result of solid waste deposition in the marsh, fallen trees, eroded and damaged roads impassable throughout the complex, and trails littered with debris from the storm surge. Some dune erosion was evident at Amagansett National Wildlife Refuge. Overall, extensive amounts of debris and hazardous materials accumulated within an environmentally sensitive area with limited access over a 6.5 mile stretch of coastline. A wildlife observation platform was also damaged.

E.A. Morton National Wildlife Refuge

E. A. Morton National Wildlife Refuge separates Little Peconic Bay from Noyack Bay. The north-south axis of the peninsula between Long Island's two forks also makes the refuge an important migration corridor for a variety of birds. The peninsula consists of 3 miles of undeveloped shoreline; one of the few shorelines without armoring or development that remain in the area. The tip of the Neck has steep, heavily eroded bluffs approaching 50 feet. Habitats are varied and include: sandy and rocky beaches; salt and freshwater marshes; brackish and freshwater ponds; lagoons; tidal flats; old fields; and oak and cedar forests.

Piping plovers arrive at the refuge between mid-March and early April. The heaviest use of the refuge by plovers occurs in July. In addition to the nesting adults and their young, adults and fledglings from other areas forage and loaf there. Terns are highly visible species at the refuge in late spring and early summer. The most common species include the common tern, least tern, and roseate tern. The peninsula at the refuge is a favorite loafing site and staging area for terns, while the surrounding bays provide excellent foraging habitat for all tern species.

Conscience National Wildlife Refuge

This small refuge is a 60-acre mix of woodlands, grasslands, and saltmarsh. Wading birds and osprey are common on the refuge during the spring and summer.

Amagansett National Wildlife Refuge

Amagansett National Wildlife Refuge is located in Amagansett on the south shore of eastern Long Island. This 36-acre refuge consists of barrier beach, dune, and scrub oak habitats. It has a unique double dune system, a habitat type that has been lost on much of Long Island due to development. The coastal location of this refuge makes it a prime stopover for migrating raptors, shorebirds, and songbirds. The roseate tern and piping plover use Amagansett for resting, feeding, and nesting. Management efforts focus on protecting native strand communities, providing habitat for threatened and endangered species, migratory birds, and other wildlife, and controlling non-native species.

Seatuck National Wildlife Refuge

This 196-acre refuge consists of grasslands, woodlands, and salt and freshwater marshes bordering Champlain Creek and Great South Bay, in Islip, New York. Seatuck is maintained for habitat diversity and actively managed for migratory birds, such as nesting osprey and purple martins, migrating raptors, waterfowl, and shorebirds.

Wertheim National Wildlife Refuge

The refuge is located in the southern core of the Central Pine Barrens region of Long Island and includes the Carmans River. At the southern terminus of the Carmans River there are extensive saltmarsh wetlands.

Oyster Bay National Wildlife Refuge

Oyster Bay National Wildlife Refuge on the north shore of Long Island consists of high quality marine habitats that support a variety of aquatic-dependent wildlife. The refuge's waters and marshes surround Sagamore Hill National Historic Site. Subtidal habitats are abundant with marine invertebrates, shellfish, and fish. Oyster Bay NWR is one of the few bay bottom refuges owned and managed by the U.S. Fish and Wildlife Service. Bay bottom comprises 78% of the refuge; unconsolidated shoreline is 3%; saltmarsh cordgrass (*Spartina alterniflora*) fringe along the shore accounts for 5%; another 5% includes high marsh habitat with salt meadow hay and saltgrass (*S. patens*/*Distichlis spicata*) at the west end of the harbor; and an estuarine stream bed, approximately 9%, makes up the remainder. The refuge is located off of the Long Island Sound in a sheltered water body.

The refuge supports large numbers of waterbirds including double-crested cormorants, Forster's and common terns, wading birds, and shorebirds. The most common waterbird on the refuge is the double-crested cormorant. They are seen year-round on the refuge, but the numbers are highest from April through October. Great cormorants occur at a low level during the winter months. Other waterbirds which use the refuge include common loon, red-throated loon, horned grebe, pied-billed grebe, American coot, belted kingfisher, great blue heron, black-crowned night heron, green heron, great egret, and snowy egret. Heron numbers peak in August.

Gulls are common on the refuge. Herring gulls are most common in winter and decline during the warmer months. Great black-backed gulls are present year-round but occur in lower numbers than herring gulls. Ring-billed gulls are more common in the winter months, but their numbers are lower than herring gulls. Laughing gulls and Bonaparte's gulls use the refuge in summer and winter, respectively. Terns use Oyster Bay NWR from May through October. Common and least tern use is heaviest from May through August. Forster's terns are present on the refuge in good numbers during September and October. Seven species of shorebirds are commonly observed. The most common shorebirds include black-bellied plover, dunlin, greater yellowlegs, and least and spotted sandpipers.

Target Rock National Wildlife Refuge

The Target Rock National Wildlife Refuge is located on the north shore of Long Island, 25 miles east of New York City. This 80-acre refuge is composed of mature oak-hickory forest, a half-mile rocky beach, a brackish pond, and several vernal ponds. The land and waters support a variety of songbirds (particularly warblers during spring migration), mammals, shorebirds, fish, reptiles, and amphibians. New York state endangered and federally protected piping plover, along with New York State threatened least tern, and common tern depend on the refuge's rocky shore for foraging and rearing young.

More than 200 bird species have been documented at the Target Rock NWR, with more than 50 breeding species. The refuge provides suitable habitats for many forest, wetland, and beach-dependent species and is an important stopover for many migrants. A variety of marine wildlife use the waters adjacent to the Target Rock NWR, and the shoreline supports a marine rocky intertidal community. Marine mammals, particularly the harbor seal, and leatherback and Kemp’s ridley turtles, use the coastline for feeding and loafing.

Common loons, red-throated loons, great cormorants, and horned grebes are common in winter off the refuge's beach. During the summer, double-crested cormorants are easily observed. Among the six species of long-legged waders present, those commonly documented on the refuge include great blue herons, snowy egrets, and great egrets.

Four species of gulls are present on the refuge, while sandpipers also make use of the rocky beach and brackish pond. The most common shorebird species include greater yellowlegs, black-bellied plover, semipalmated plover, spotted sandpiper, and willet. Common and least terns are observed from May through September.

Piping plovers forage on the refuge beach and nest on the adjacent beach approximately 1/4-mile away from the refuge. New York State threatened least and common terns also forage along the refuge's shore. There are nesting colonies of these birds, as well as piping plover, directly across from the refuge at Eaton's Neck, Northport and at Caumsett State Park, Lloyd Harbor.

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CONNECTICUT

Federally Listed Threatened and Endangered Species

Piping Plover (*Charadrius melodus*)

Piping plovers are small, sand-colored shorebirds approximately seven inches long (18 cm) with a wing span of approximately 15 inches (38 cm). The piping plover was listed as federally threatened and endangered on January 10, 1986. Three distinct populations were identified: Atlantic Coast (threatened), Great Lakes (endangered), and Northern Great Plains (threatened). Protection of all three populations of this species under the Endangered Species Act (ESA) reflects its precarious status range-wide. The Atlantic Coast population breeds on coastal beaches from Newfoundland to North Carolina (and occasionally in South Carolina), and winters along the Atlantic Coast from North Carolina southward, along the Gulf Coast, and in the Caribbean. In 1996, the Service approved a revised recovery plan for the Atlantic Coast piping plover population.

Piping plovers begin returning to their Atlantic Coast nesting beaches in early March. They nest above the high tide line on coastal beaches, sandflats at the ends of sandspits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes. In the central portion of their Atlantic Coast range, they have also been known to nest on beaches that have been artificially augmented thru beach nourishment projects. By early April, males begin to establish and defend territories and court females. Clutch size is generally four eggs, and eggs are usually incubated for 27-30 days before hatching. As a rule, piping plovers fledge only a single brood per season, but may re-nest several times if previous nests are lost.

Plover foods consist of invertebrates such as marine worms, fly larvae, beetles, crustaceans, and mollusks. Feeding areas include intertidal portions of ocean beaches, washover areas, mudflats, sandflats, wrack lines, and shorelines of coastal ponds, lagoons or salt marshes. Feeding activities of both adults and chicks occur during all hours of the day and night. Feeding territories are generally contiguous to nesting territories, although adults may forage on the opposite side of small coastal inlets or on nearby bayside intertidal flats (e.g., Cohen 2005).

Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the species' decline. Beaches throughout the plover’s range are affected by federal and non-federal actions, including inlet management, beach nourishment, dune construction, and dune stabilization. Shoreline stabilization has interfered with natural coastal processes by precluding formation of newly-forming inlets, overwash zones, and accreting beach habitats that would create or revitalize piping plover nesting and foraging habitats (USFWS 2005).

Disturbance by humans and pets often reduces the functional suitability of habitat and causes direct and indirect mortality of eggs and chicks. Recreational use of piping plover beaches includes pedestrian and vehicular activities. Pedestrian and non-motorized recreational activities can be a source of both direct mortality and harassment of piping plovers. Pedestrians may disrupt plovers during territory establishment, courting, egg-laying, and chick rearing. Intense pedestrian use of plover beaches may also prevent chicks from foraging, separate chicks from adults, and increase chicks' vulnerability to predation. Unmanaged off-road vehicle use will degrade plover nesting and foraging habitat or may crush chicks and occasionally adults. Predation has been identified as a major factor limiting piping plover reproductive success at many Atlantic Coast sites. Predators of piping plover eggs and chicks include foxes, skunks, raccoons, rats, opossums, crows, gulls, grackles, hawks and falcons, domestic dogs and cats, and ghost crabs (USFWS 1996).

Since listing under the ESA, the Atlantic Coast population estimate has increased 239%, from approximately 790 pairs to an estimated 1,890 pairs in 2007 (USFWS 2008 Population increases since 1989 have been highest in New England (242%), followed by New York-New Jersey (84%). Most growth in the Southern (DE-MD-VA-NC) recovery unit (67%) has occurred since 2003, while the Atlantic Canada population fluctuates from year to year with increases often quickly eroded in subsequent years (USFWS 2008).

While population growth is heartening, periodic rapid declines in populations at the level of the individual recovery unit raise concerns about the long-term risk of extirpation faced by the Atlantic Coast population. Pressure on Atlantic Coast beach habitat from development, human disturbance, and predation is widespread and unrelenting. The recovery of the Atlantic Coast piping plover population is occurring in the context of extremely intensive annual management that is implemented on almost all plover beaches, in both the United States and Atlantic Canada (USFWS 1996; RENEW 2003, 2004).

Piping plovers nest along numerous beaches throughout Connecticut. In 2012, there were 51 pairs of nesting piping plover which fledged a total of 60 chicks. The most productive beaches of 2012 were Sandy Point/Morse Point in West Haven, Griswold Point in Old Lyme, and Bluff Point/Mumford Cove in Groton. At Sandy Point/Morse Point, 8 piping plover pairs produced 12 fledglings. At Griswold Point, 8 pairs of piping plover produced 8 fledglings, and at the Bluff Point/Mumford Cove site, 8 pairs of piping plovers produced 11 fledglings. Eight pairs of piping plovers attempted to nest on Long Beach but none were successful.

Some of the barrier beaches in Connecticut that are susceptible to storm surges and provide significant habitat for piping plover are the Long Beach/Pleasure Beach Complex and the Sandy Point/Morse Point Complex. Stratford's Long Beach, together with Bridgeport's Pleasure Beach make up a 2-mile long barrier beach that shelters the Great Meadows Marsh Unit of the Stewart B. McKinney National Wildlife Refuge. Long Beach and Pleasure Beach total 80 acres in size and represent 20% of Connecticut's undeveloped barrier beaches. Together they contain a rich set of sand dunes, tidal wetlands and sand flats. As a barrier beach, it constantly changes as a result of coastal processes, such as erosion, overwash during storms, dune movement, and inlet formation and migration. Sandy Point/Morse Point make up a 60 acre site that includes barrier beach, tidal creek, and marsh which provide excellent habitat for waterbirds. This is one of the most significant nesting locations for piping plover and also one of the most important least tern colonies in the state. This area receives significant usage by migrating shorebirds, which roost on the sand spit and sandbars at high tide and forage on the tidal flats at lower tides. In addition, it is one of the primary stopover areas for red knot in Connecticut.

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Roseate Tern (*Sterna dougallii dougallii*)

The roseate tern is a medium-sized, black-capped sea tern about 15 inches long (38 cm) and weighs about 4 ounces (Gochfeld et al. 1998). Its plumage superficially resembles that of the common tern (*Sterna hirundo*), among which, it invariably nests in the Northeast. On November 2, 1987, the Service determined the population that nests in the Northeast to be endangered, and the population that nests in the Caribbean to be threatened.

Historically, the breeding range of roseate terns extended from Atlantic Canada south to Virginia and North Carolina. In recent decades, the breeding range has contracted and the population has become concentrated in Massachusetts and New York, with smaller colonies in Connecticut, New Hampshire, and Maine. Birds breed from Long Island, New York, east and north to Nova Scotia and Quebec (Iles Madeleines). However, at present, less than 5% of the northeastern North American population nests in Canada (Environment Canada 2006). Approximately 87% of the endangered North Atlantic roseate population nests on just three colonies in Buzzards Bay, Massachusetts (Bird, Ram and Penikese Islands), and one colony off Long Island, New York (Great Gull Island) (RTRT 2007).

In spring, roseates make a long distance, northward migration traveling over open ocean. The terns arrive at Nantucket and
Martha’s Vineyard Islands “in large flocks”, and then disperse to nesting colonies northward and

westward (Gochfeld et al. 1998). Adult roseates arrive at nesting colony sites in late April to early May. Generally, courtship occurs at the breeding colonies and in the surrounding intertidal area (Nisbet 1981; Gochfeld et al. 1998). Roseate terns begin egg laying in mid-to-late May. Typically, two eggs are laid and the incubation period lasts 23 days. Young tern chicks are fed small fish by both adults and grow rapidly. Re-nesting is common if the first clutch of eggs is lost.

The roseate tern is a marine bird, usually breeding on small islands, but occasionally on sand spits and dunes at the ends of barrier beaches. All recorded nesting in the Northeast is within colonies of common terns. Within these mixed colonies, roseate terns usually select the more densely vegetated areas (Burger and Gochfeld 1988; Gochfeld et al. 1998) or other areas that provide dense cover. Roseate terns also nest under rocks, sometimes deep within crevices of rock riprap placed to protect island slopes from erosion. They readily adopt artificial sites such as wooden nest boxes or partially-buried automobile tires (Spendelow 1982, 1994).

Beginning in July and by mid-August, most terns have completed nesting and leave colony sites for pre-migratory staging areas. In August and September, staging birds are reported in large flocks with other species of terns at inlets and islands from Long Island, New York to Maine (Viet and Petersen 1993; Shealer and Kress 1994). From mid-August to mid-September, it is thought that most roseate terns have aggregated in coastal areas of Massachusetts, especially along outer Cape Cod. About 20 post-breeding staging areas have been identified around Cape Cod; South Beach and the Monomoy Islands appear to be among the most important locations for roseates prior to fall migration (Gochfeld et al. 1998). Young-of-the-year roseate terns remain dependent on their parent(s) for at least six weeks after fledging and may remain dependent on parental feeding until after arrival in the winter quarters (Nisbet 1981).

During the breeding season, roseate terns forage over shallow coastal waters, sometimes near the colony and at other times at distances of over 20 miles (32 km) (Heinemann 1992). Roseates tend to concentrate in places where prey fish are brought close to the surface by the vertical movement of water. Hence, they usually forage over shallow bays, tidal inlets and channels, tiderips, and sandbars over which tidal currents run rapidly (Nisbet 1981; Duffy 1986; Safina 1990;Heinemann 1992; Casey, Kilpatrick and Lima, unpubi. data, 1996 USFWS). . Roseate terns forage mainly by plunge-diving and by contact-dipping or surface dipping over shallow sandbars, reefs, or schools of predatory fish (Gochfeld et al. 1998). Gochfeld et al. (1998) also report that they tend to fly into the wind, hover, and dive from a height of 3.3 - 20 ft (1-6 meters), but up to 40 ft (12 meters) at times.

Roseate terns feed almost exclusively on small, schooling marine fish. In the northeastern United States, they show a preference for sand eels (also called sand lance) (*Ammodytes spp.*). Also taken are various small fish, including bay anchovy (*Anchoa spp*.), juvenile herring (*ciupea spp.*), Atlantic menhaden (*Brevoortia tyannus*), Atlantic mackerel (*Scomber scombrus*), Atlantic silversides (*Menidia menidia*), juvenile bluefish (*Pomatomus saltatrix*), and white hake (*Urophycis tenuis*) (Gochfeld et al. 1998).

The numbers of roseate terns nesting in the Northeast were greatly reduced in the 19th century by commercial hunting for the millinery trade. With the cessation of market hunting, the population recovered, and by the 1930s, there were about 8,500 pairs. However, encroachment onto their nesting islands by increasing populations of gulls, and combined with habitat loss reduced numbers to a low of about 2,500 pairs in 1977.

While roseates are now known to nest at about 20 different sites, they remain vulnerable because only small numbers of pairs occur at most colonies. In 2007, only 6 nesting colonies supported more than 100 pairs (4 had >200 pairs), and more than 90% of the total population in the Northeast breeds on just five islands. Concentrated at so few nesting sites, the endangered northeast population of the roseate tern is susceptible to stochastic events, including erosion of nesting habitat, storms, and over-washing of nests, prey food shortages, predation, oil spills, and human disturbance. In addition, the roseate tern breeding population remains numerically and geographically reduced from historic levels.

Falkner Island contains the only roseate tern colony in the state. Historically, the population numbered in the thousands. In addition, the island currently hosts more than 95 percent of Connecticut's common terns (over 2,500 pairs) and large numbers of landbirds and shorebirds during spring and fall migration. The 5-acre island, part of the Steward B. McKinney National Wildlife Refuge, is located approximately 3 miles off the coast of Guilford, Connecticut.

The north spit section of the island, where approximately two-thirds of all roseate tern nests are located, was reduced to one-third its size due to Hurricane Sandy. As a result of this habitat loss, fewer breeding pairs nested in 2013. Roseate tern pairs went from approximately 45 pairs to 26 pairs after Hurricane Sandy. It is possible that without this habitat, the terns may abandon the island or use less desirable habitat. This could result in a reduced production rate or loss of the colony. The southern tip of the island suffered erosion as well. The significance of the southern tip is as nesting habitat for common terns and other shorebirds such as American oystercatcher. In addition, it helps to protect the rest of the island from storms.

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Waterbird Nesting Colonies

Connecticut’s offshore islands provide an important refuge for colonial-nesting herons and beach and island ground-nesting birds from predators that feed on nestlings and eggs. They are considered an imperiled community in Connecticut as they are subject to development pressures and the potentially damaging effects of heavy recreational use. Offshore Islands are limited geographically and are potentially vulnerable to rising sea levels and storm surges.

Colonies ranged in size from a few pairs to up to 284 pairs. These colonies are located on Charles Island, Cockenoe Island, Duck Island, Great Captains Island, Ram Island, and Tuxis Island. These islands are some of the most important waterbird colonies that are vulnerable to storm damage. For example, Charles Island has been hard hit by recent storms and the wading bird colony declined significantly as a result of storm-related changes to the habitat.

Colonial waterbirds are concentrated into a usually small number of sites during the nesting season. Many of these sites are experiencing loss of high quality nesting habitat due to sea level rise and increased storm events. Loss of high quality habitat can lead to overcrowding of nesting colonies. It can also force movement of nesting birds to less desirable nesting areas where there may be increased levels of human disturbance and predation resulting in lower productivity of hatchlings. The extensive recreational, commercial, and industrial development along the U.S. coast has placed waterbird colonies at increasing risk to their survival, especially in the Northeast. Threats to colonial nesting waterbirds include sea level rise and more frequent storm surges. Other significant threats include human disturbance, predation, habitat degradation, and contaminants. Recreational use of bird-nesting islands and beaches during spring and summer breeding season is detrimental to disturbance-sensitive species such as plovers, terns, and wading birds. Nesting populations of colonial waterbirds and piping plovers on sand or gravel beaches are especially vulnerable during the nesting season (April to August) to human-caused disturbances such as trampling or destruction of nests. Predation is a major problem in waterbird colonies. On beaches, mammalian predators such as foxes, skunks, raccoons, rats, dogs, and cats are a major problem; islands, although generally free from mammalian predation, may be subject to predation by gulls, crows, other birds, and insects. Degradation of nesting and foraging habitat is a major threat to both island-nesting and beach-nesting species. Increased vegetation and succession on some islands may reduce their suitability for nesting by terns and gulls. Competition for nesting sites and predation by gulls results in loss of tern nesting habitat. Contaminants continue to be a major threat to waterbirds.

Colonial waterbirds are concentrated into a usually small number of sites during the nesting season, which makes protection of these sites a high priority. Attempts to stabilize and control erosion on beaches often result in a loss of natural diversity of beaches and decreased habitat suitability for nesting and feeding birds. Erosion control projects should be done in a way that recognizes the dynamic nature of these habitats.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

Stewart B. McKinney National Wildlife Refuge

Stewart B. McKinney National Wildlife Refuge is located on the Connecticut shore along, and on islands within, Long Island Sound, the second largest estuary in the United States. The refuge spans 70 miles of the Connecticut Coast and includes diverse barrier beach (141.0 acres), tidal salt marsh (470.6 acres), grassland, shrubland, and near shore woodland habitats. The refuge is composed of 11 units, 3 on the Connecticut shore and 8 islands in Long Island Sound. The refuge provides important resting, feeding, and nesting habitat for many species of wading birds, waterfowl, songbirds, shorebirds, and terns, including the endangered roseate tern and the threatened piping plover. While some of the island units are quite small, each provides important protected habitat along New England's densely developed South Coast. Much of the refuge is also available seasonally for compatible, wildlife-dependent public use.

The Falkner Island Unit is a 5-acre parcel located approximately 3 miles off the coast of Guilford, Connecticut. The island terrain rises steeply on all sides from a rocky beach to an upland area of grasses, shrubs, and early successional tree species (Steeves et al. 2012). Approximately 65% of the island is barren and 35% is vegetated (Center for Land Use Education & Research, University of Connecticut, 2006). A revetment that extends along the entire east shore and the northern tip was constructed in 2000 to help stop erosion. The highest area of the island rises to a maximum elevation of 40 feet above sea level. Falkner Island contains the only colony of the federally endangered roseate tern colony in the state. In addition, the island currently hosts more than 95 percent of Connecticut's common terns (over 2,500 pairs). The north spit section of the island, where approximately two-thirds of all roseate tern nests are located, was reduced to one-third its size due to Hurricane Sandy. As a result of this habitat loss, roseate tern pairs dropped from approximately 45 pairs to 26 pairs. The southern tip of the island suffered erosion as well. The significance of the southern tip is as nesting habitat for common terns and other shorebirds such as American oystercatcher. In addition, it helps to protect the rest of the island from storms.

Milford Point Unit is a 22-acre beach peninsula located next to the Wheeler Marsh Wildlife Management Area. Its diverse mix of habitats provides over 50 species of waterfowl, shorebirds and wading birds a safe haven in which to feed and rest during their long spring and fall migrations. Milford Point is a historic piping plover nesting area. In 2012, four pairs of piping plovers nested but only two chicks fledged due to tidal inundation and disturbance by humans and predators.

Outer Island is a 5-acre parcel located off the coast of Branford, Connecticut and it is the southernmost of the Thimble Islands. The island is composed of granite outcroppings, boulder and cobble beaches in the intertidal zone, and small salt marshes that provide habitat for both migrating and nesting birds. The island was donated to the U.S. Fish and Wildlife Service to protect its natural resources and to provide access for education and research. The island is the refuge's primary facility for environmental education. Structures on the island damaged by Hurricane Sandy include an education building and seawalls.

The Norwalk Island Unit is located approximately 40 miles east of New York City. It includes four islands: Chimon (68 acres), Goose (4 acres), Sheffield (51 acres) and Peach (3 acres). Both Chimon and Sheffield Island contain refuge facilities that are susceptible to damage from coastal storms. As late as the 1980s, Chimon Island once held one of the largest wading bird colonies in Long Island Sound. The loss of the colony is suspected to be predation. However, ideal habitat remains on the island and it is a goal of the refuge to reestablish a successful wading bird colony following the implementation of a predator control program.

The Calf Island Unit is a 33-acre parcel located south of Byram Harbor, approximately 3,000 feet from the mainland. Calf Island provides roosting and foraging habitat for the waterbird colony at Great Captain's Island, a designated Important Bird Area located 1 mile from Calf Island. Great Captain's Island is the site of the largest wading bird rookery in Connecticut, with approximately 300 nesting pairs of great egrets, snowy egrets, and black-crowned night-herons. Wading birds frequently utilize the Calf Island salt marsh for feeding and tall trees for roosting. The eastern part of Calf Island has been recently impacted due to coastal storms, resulting in loss of forest habitat occupied by raptors. Stuctures on Calf Island include a pavilion, a bathroom, living quarters and a shed, some of which were damaged by Hurricane Sandy.

The Milford Point unit, Great Meadows unit, and Salt Meadows unit display varying degrees of vulnerability to sea level rise and increased storm activity. The Milford Point unit, a barrier beach at the mouth of the Housatonic River, provides protected nesting beaches for the threatened Piping Plover, as well as a protected resting and feeding stop in migration for over 50 species of waterfowl, shorebirds, and wading birds. The Great Meadows unit, which includes the largest unditched saltwater high marsh remaining in Connecticut, provides nesting and feeding habitat for over 270 species of birds and is an important wintering area for the American Black Duck. The 400-acre Salt Meadows unit includes marsh, grassland, forest and shrubland habitats. The variety of upland habitats on the Salt Meadows unit provides both feeding resources for coastal birds and an important migratory stop for a diversity of landbirds

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RHODE ISLAND

Federally Listed Threatened and Endangered Species

Piping Plover (*Charadrius melodus*)

The barrier beaches of Rhode Island contain several nesting areas for piping plover, a shorebird that is federally listed as threatened on the Atlantic Coast. The Atlantic Coast plover population breeds on coastal beaches from Newfoundland to North Carolina (and occasionally in South Carolina), and winters along the Atlantic Coast from North Carolina southward, along the Gulf Coast, and in the Caribbean. In 2013, there were 92 piping plover nests at 13 sites in Rhode Island. A total of 90 chicks were fledged. The highest number of nesting pairs were at Maschaug Beach (Westerly) with 17 pairs, Ninigret Beach (Charlestown) with 16 pairs, Weekapaug (Westerly) and Moonstone Beach (South Kingstown) with 15 pairs each, and Briggs Beach (Little Compton) with 8 pairs. Piping plovers begin returning to the Rhode Island nesting areas in March. Nest sites are typically located well above the high tide line on coastal beaches, sandflats at the ends of sandspits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes. Nesting has also been known to occur on beaches that have been artificially enlarged as a result of beach nourishment projects. By early April, males begin to establish and defend territories and court females. Clutch size is generally four eggs, and eggs are usually incubated for 27-30 days before hatching. As a rule, piping plovers fledge only a single brood per season, but may re-nest several times if previous nests are lost.

Shortly after hatching the flightless chicks must leave the nest and travel to foraging areas such as intertidal portions of ocean beaches, washover areas, mudflats, sandflats, wrack lines, and shorelines of coastal ponds, lagoons or salt marshes. Plover foods consist of invertebrates such as marine worms, fly larvae, beetles, crustaceans, and mollusks. It is crucial that the flightless chicks are able to reach quality foraging areas which are frequently on the bay side of the barrier island. Sparsely vegetated areas are generally required for nesting in part because dense vegetation would impede the movement of the chicks. It takes about 25-35 days before the chicks are able to fly.

Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the species' decline. Beaches throughout the plover's range are affected by coastal management actions such as inlet management, installation of structural erosion control measures, beach nourishment, and dune construction. Shoreline stabilization efforts have often interfered with natural coastal processes and precluded formation of newly-forming inlets, overwash zones, and accreting beach habitats that are necessary for maintaining piping plover breeding habitat. Disturbance by humans and pets is another problem that reduces the functional suitability of habitat. As a ground nester, piping plover are also quite vulnerable to a variety of ground-based and aerial predators.

Plover habitat located on coastal barrier islands or spits will be certainly be affected by sea level rise and increased stormy conditions. These dynamic geomorphic features can experience major changes in ecology as a result of severe storms. As the rise in sea level accelerates, storm activity will likely cause barrier islands to experience more beach and dune erosion, more overwash, more frequent island breaching, and more rapid landward migration. These types of changes could be beneficial to piping plover by perpetuating sparsely vegetated areas and discouraging ground-based predators. However, since overwash during the nesting season could cause nest flooding, the outcome would depend on where the balance was struck. In addition, if changes in a barrier island threatened neighboring developed areas, the human response could prove detrimental to plovers.

Waterbird Nesting Colonies

Rhode Island's offshore islands provide an important refuge for a variety of colonial nesting bird species including various terns, egrets, gulls, and herons as well as double crested cormorant, black skimmer, glossy ibis, and American oystercatcher. Colonial waterbirds are concentrated into a usually small number of sites during the nesting season. Some of these sites, such as Dyer and Spar Islands are experiencing the loss of nesting habitat due to sea level rise and increased storm events. Loss of high quality habitat can lead to overcrowding of nesting colonies. It can also force movement of nesting birds to less desirable nesting areas where there may be increased levels of human disturbance and predation resulting in lower productivity of hatchlings.

Colonial nesting waterbirds are important components of coastal ecosystems in the United States. Threats to colonial nesting waterbirds include sea level rise and more frequent storm surges. Other significant threats include human disturbance, predation, habitat degradation, and contaminants. Colonies surveyed in 2013 in Rhode Island ranged in size from a few pairs to up to 722 pairs. Some of these colonies are located on Dyer and Spar Islands, both of which are vulnerable to storm damage. For example, Dyer is a low island that historically provided common tern breeding habitat. Dyer has been negatively impacted by sea level rise, storm surges, and erosion which have caused complete washovers as well as the disappearance of shoals.

Attempts to stabilize and control erosion on beaches may result in a loss of natural diversity of beaches and decreased habitat suitability for nesting and feeding birds. Erosion control projects initiated to stabilize and control erosion on these islands should be done in a way that recognizes the dynamic nature of these habitats in order to avoid the loss of natural diversity of these islands.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

Rhode Island Complex

The Rhode Island National Wildlife Refuge Complex comprises five national wildlife refuges. They are the Block Island National Wildlife Refuge on Block Island in the town of New Shoreham; Ninigret National Wildlife Refuge in the town of Charlestown; John H. Chafee National Wildlife Refuge in the towns of South Kingstown and Narragansett; Sachuest Point

National Wildlife Refuge in the town of Middletown; and Trustom Pond National Wildlife Refuge in the town of South Kingstown.

The piping plover is the only federally listed endangered or threatened species that currently breeds on refuge lands within the Rhode Island National Wildlife Refuge Complex. Piping plover nest on the beaches of Trustom Pond NWR, Ninigret NWR, and Sachuest Point NWR. Trustom Pond NWR and Ninigret NWR also host least tern nesting colonies, and Trustom Pond NWR serves as a fall migration staging area for roseate terns.

Saltmarsh sparrows nest on Ninigret NWR, John H. Chafee NWR, and Sachuest Point NWR. The saltmarsh habitat where saltmarsh sparrows nest at Ninigret NWR is immediately north of the barrier beach. This area is primarily low marsh habitat and therefore susceptible to inundation with rapid sea level rise.

The Rhode Island NWR Complex was recently awarded Hurricane Sandy mitigation funds to conduct resiliency planning and restoration projects on refuge lands. At the John H. Chafee NWR there is a proposal to restore and improve over 200 acres of salt marsh. Most of the protective marsh shoreline has been eroded by boat wakes, wind-driven waves, and poor water quality. Sediment loading in the Narrow River from nearby beach replenishment has made the river's channel shallow and has resulted in eroded marsh banks. Additionally, prolonged ponding of water on the marsh surface is drowning salt marsh vegetation, preventing sediment from accumulating at rates that will match sea level rise. Due to a lack of potential salt marsh migration corridors, there is a pressing need to restore and rebuild these marshes so that they may continue to provide benefits to trust species and local communities.

The refuge proposes to dredge portions of the Narrow River to restore natural channels, and spread dredge materials to increase the elevation of salt marshes, help restore shorelines, and create tidal flats critically important to shorebirds and estuarine habitat. The dredging design will include maintenance dredging areas to help capture excess beach sediment and maintain the restoration long-term. Natural materials such as core logs and oyster shells will be installed to create "living salt marsh shorelines" rather than completely relying on engineered materials. Small ditches called runnels will be created on the marsh surface where marsh vegetation is drowning.

The 100-acre Sachuest NWR salt marsh suffers from restricted tidal flow due to an undersized road culvert that drains across nearby Third Beach, a nesting site for the piping plover. This culvert provides the only outlet for the Maidford River and the only source of tidal flow for the marsh. During high tides and storm events the outlet frequently becomes blocked with sand, trapping water on the marsh for days and causing nest failure of breeding saltmarsh sparrows, death of native marsh vegetation, and reduced water quality to the extent that adjacent beach closures become necessary. To address these issues, the refuge proposes to replace the undersized culvert at the mouth of the Maidford River and at Third beach with water control structures better suited to handle natural flow regimes as well as storm surges and flooding, within the framework of rising sea levels.

Native maritime shrub land habitat provides a natural storm buffer that protects homes, schools, and transportation networks. Shrub land buffers represent an ideal area for salt marshes to migrate inland. The refuge proposes to restore and create a total of 10 miles of shrub habitat in salt marsh buffer zones. The project will take place within the Chafee NWR, Sachuest NWR, and Ninigret NWR.

MASSACHUSETTS

Federally Listed Threatened and Endangered Species

Piping Plover (*Charadrius melodus*)

Piping plovers are small, sand-colored shorebirds approximately seven inches long (18 cm) with a wing span of approximately 15 inches (38 cm). The piping plover was listed as federally threatened and endangered (ESA) on January 10, 1986. Three distinct populations were identified: Atlantic Coast (threatened), Great Lakes (endangered), and Northern Great Plains (threatened). Protection of all three populations of this species under the Endangered Species Act reflects its precarious status range-wide. The Atlantic Coast population breeds on coastal beaches from Newfoundland to North Carolina (and occasionally in South Carolina), and winters along the Atlantic Coast from North Carolina southward, along the Gulf Coast, and in the Caribbean. In 1996, the Service approved a revised recovery plan for the Atlantic Coast piping plover population.

Piping plovers begin returning to their Atlantic Coast nesting beaches in early March. They nest above the high tide line on coastal beaches, sandflats at the ends of sandspits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes. In the central portion of their Atlantic Coast range, they have also been known to nest on beaches that have been augmented thru beach nourishment projects. By early April, males begin to establish and defend territories and court females. Clutch size is generally four eggs, and eggs are usually incubated for 27-30 days before hatching. As a rule, piping plovers fledge only a single brood per season, but may re-nest several times if previous nests are lost.

Plover foods consist of invertebrates such as marine worms, fly larvae, beetles, crustaceans, and mollusks. Feeding areas include intertidal portions of ocean beaches, washover areas, mudflats, sandflats, wrack lines, and shorelines of coastal ponds, lagoons or salt marshes. Feeding activities of both adults and chicks occur during all hours of the day and night. Feeding territories are generally contiguous to nesting territories, although adults may forage on the opposite side of small coastal inlets or on nearby bayside intertidal flats (e.g., Cohen 2005).

Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the species' decline. Beaches throughout the plover’s range are affected by federal and non-federal actions, including inlet management, beach nourishment, dune construction, and dune stabilization. Shoreline stabilization has interfered with natural coastal processes by precluding formation of newly-forming inlets, overwash zones, and accreting beach habitats that would create or maintain piping plover nesting and foraging habitats (USFWS 2005).

Disturbance by humans and pets often reduces the functional suitability of habitat and causes direct and indirect mortality of eggs and chicks. Recreational use of piping plover beaches includes pedestrian and vehicular activities. Pedestrian and non-motorized recreational activities can be a source of both direct mortality and harassment of piping plovers. Pedestrians may disrupt plovers during territory establishment, courting, egg-laying, and chick rearing. Intense pedestrian use of plover beaches may also prevent chicks from foraging, separate chicks from adults, and increase chicks' vulnerability to predation. Unmanaged off-road vehicle use will degrade plover nesting and foraging habitat or may crush chicks and occasionally adults. Predation has been identified as a major factor limiting piping plover reproductive success at many Atlantic Coast sites. Predators of piping plover eggs and chicks include foxes, skunks, raccoons, rats, opossums, crows, gulls, grackles, hawks and falcons, domestic dogs and cats, and ghost crabs (USFWS 1996).

Since listing under the ESA, the Atlantic Coast population estimate has increased 239%, from approximately 790 pairs to an estimated 1,890 pairs in 2007 (USFWS 2008). Population increases since 1989 have been highest in New England (242%), followed by New York-New Jersey (84%). Most growth in the Southern (DE-MD-VA-NC) recovery unit (67%) has occurred since 2003, while the Atlantic Canada population fluctuates from year to year with increases often quickly eroded in subsequent years (USFWS 2008).

While population growth is heartening, periodic rapid declines in populations at the level of the individual recovery unit raise concerns about the long-term risk of extirpation faced by the Atlantic Coast population. Pressure on Atlantic Coast beach habitat from development, human disturbance, and predation is widespread and unrelenting. The recovery of the Atlantic Coast piping plover population is occurring in the context of extremely intensive annual management that is implemented on almost all plover beaches, in both the United States and Atlantic Canada (USFWS 1996; RENEW 2003, 2004)

Piping plovers nest on the beaches throughout the State of Massachusetts. In 2011, observers reported breeding piping plovers at 145 sites. They nest above the high tide line on coastal beaches, sandflats at the ends of sandspits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes and washover areas cut into or between dunes. They may also nest on areas where suitable dredge material has been deposited (USFWS 1996). Their nest sites are shallow scraped depressions and contain little or no vegetation. Piping plovers feed on invertebrates in areas of mudflats, sandflats, wrack lines, and intertidal portions of ocean beaches. They arrive in late March to nest. Birds that lose their nests and young may renest into early July.

In 2011, the estimated total number of breeding pairs for the entire season was 655 pairs which fledged 757 chicks. Two regions contained 61% of the total breeding pairs in the state in 2011: the Lower Cape (39%) and the Upper Cape (22%). Individual sites with the largest numbers of pairs were South Beach, Chatham (55 pairs), Sandy Neck, Barnstable (43 pairs), South Monomoy Island, Chatham (41 pairs), Crane Beach, Ipswich (35 pairs), Nauset Spit, Orleans (24 pairs), Race Point-South, Provincetown/Truro (22 pairs), Plymouth Long Beach, Plymouth (20 pairs), North Beach Island, Chatham (16 pairs), and Parker River National Wildlife Refuge, Newbury and Rowley (13 pairs) (Melvin 2011).

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Roseate Tern (*Sterna dougallii dougallii*)

The roseate tern is a medium-sized, black-capped sea tern [about 15 inches long (38 cm) and weighs about 4 ounces (Gochfeld et al. 1998). Its plumage superficially resembles that of the common tern (*Sterna hirundo*), among which, it invariably nests in the Northeast. On November 2, 1987, the Service determined the population that nests in the Northeast to be endangered, and the population that nests in the Caribbean to be threatened.

Historically, the breeding range of roseate terns extended from Atlantic Canada south to Virginia and North Carolina. In recent decades, the breeding range has contracted and the population has become concentrated in Massachusetts and New York, with smaller colonies in Connecticut, New Hampshire and Maine. Birds breed from Long Island, New York, east and north to Nova Scotia and Quebec (Iles Madeleines). However, at present, less than 5% of the northeastern North American population nests in Canada (Environment Canada 2006). Approximately 87% of the endangered North Atlantic roseate population nests on just three colonies in Buzzards Bay, Massachusetts (Bird, Ram and Penikese Islands), and one colony off Long Island, New York (Great Gull Island) (RTRT 2007).

In spring, roseates make a long distance, northward migration traveling over open ocean. The terns arrive at Nantucket and Martha's Vineyard Islands "in large flocks", and then disperse to nesting colonies northward and westward (Gochfeld et al. 1998). Adult roseates arrive at nesting colony sites in late April to early May. Generally, courtship occurs at the breeding colonies and in the surrounding intertidal area (Nisbet 1981; Gochfeld et al. 1998). Roseate terns begin egglaying in mid-to-late May. Typically, two eggs are laid and the incubation period lasts 23 days. Young tern chicks are fed small fish by both adults and grow rapidly. Re-nesting is common if the first clutch of eggs is lost.

The roseate tern is a marine bird, usually breeding on small islands, but occasionally on sand spits and dunes at the ends of barrier beaches. All recorded nesting in the Northeast is within colonies of common terns. Within these mixed colonies, roseate terns usually select the more densely vegetated areas (Burger and Gochfeld 1988; Gochfeld et al. 1998) or other areas that provide dense cover. Roseate terns also nest under rocks, sometimes deep within crevices of rock riprap placed to protect island slopes from erosion. They readily adopt artificial sites such as wooden nest boxes or partially-buried automobile tires (Spendelow 1982).

Beginning in July and by mid-August, most terns have completed nesting and leave colony sites for pre-migratory staging areas. In August and September, staging birds are reported in large flocks with other species of terns at inlets and islands from Long Island, New York to Maine (Viet and Petersen 1993; Shealer and Kress 1994). From mid-August to mid-September, it is thought that most roseate terns have aggregated in coastal areas of Massachusetts, especially along outer Cape Cod. About 20 post-breeding staging areas have been identified around Cape Cod; South Beach and the Monomoy Islands appear to be among the most important locations for roseates prior to fall migration (Gochfeld et al. 1998). Young-of-the-year roseate terns remain dependent on their parent(s) for at least six weeks after fledging and may remain dependent on parental feeding until after arrival in the winter quarters (Nisbet 1981).

During the breeding season, roseate terns forage over shallow coastal waters, sometimes near the colony and at other times at distances of over 20 miles (32 km) (Heinemann 1992). Roseates tend to concentrate in places where prey fish are brought close to the surface by the vertical movement of water. Hence, they usually forage over shallow bays, tidal inlets and channels, tiderips and sandbars over which tidal currents run rapidly (Nisbet 1981; Duffy 1986; Safina 1990; Heinemann 1992; Casey, Kilpatrick and Lima, unpubi. data, 1996 USFWS Roseate terns forage mainly by plunge-diving and by contact-dipping or surface dipping over shallow sandbars, reefs or schools of predatory fish (Gochfeld et al. 1998). Gochfeld et al. (1998) also report that they tend to fly into the wind, hover and dive from a height of 3.3 - 20 ft (1-6 meters), but up to 40 ft (12 meters) at times.

Roseate terns feed almost exclusively on small, schooling marine fish. In the northeastern United States, they show a preference for sand eels (also called sand lance) (*Ammodytes spp.*). Also taken are various small fish, including bay anchovy (*Anchoa spp*.), juvenile herring (*ciupea spp.*), Atlantic menhaden (*Brevoortia tyannus*), Atlantic mackerel (*Scomber scombrus*), Atlantic silversides (*Menidia menidia*), juvenile bluefish (*Pomatomus saltatrix*), and white hake (*Urophycis tenuis*) (Gochfeld et al. 1998).

The numbers of roseate terns nesting in the Northeast were greatly reduced in the 19th century by commercial hunting for the millinery trade. With the cessation of market hunting, the population recovered, and by the 1930s, there were about 8,500 pairs. However, encroachment onto their nesting islands by increasing populations of gulls, and combined with habitat loss reduced numbers to a low of about 2,500 pairs in 1977.

While roseates are now known to nest at about 20 different sites, they remain vulnerable because only small numbers of pairs occur at most colonies. In 2007, only six nesting colonies supported more than 100 pairs (four had >200pairs), and more than 90% of the total population in the Northeast breeds on just five islands. Concentrated at so few nesting sites, the endangered northeast population of the roseate tern is susceptible to stochastic events, including erosion of nesting habitat, storms and over-washing of nests, prey food shortages, predation, oil spills, and human disturbance. In addition, the roseate tern breeding population remains numerically and geographically reduced from historic levels.

In Massachusetts most of the major nesting islands for roseate terns are in Buzzards Bay at Bird, Ram, and Penikese Islands. Another key site is Monomoy National Wildlife Refuge off Cape Cod, which supports the largest common tern colony on the Atlantic Coast. Although recent numbers of nesting roseates have decreased at Monomoy, it remains a high quality site that may rebound in the future.

Preliminary numbers indicate that roseates were confirmed to have nested at four sites in Massachusetts in 2013. The largest colony was at Bird Island with 772 pairs. The second largest colony was at Ram Island with 535 pairs. Other nesting sites included Minimoy Island with 6 pairs, South Monomoy Island with 8 pairs and Norton Beach with 35 pairs (Mostello communication 2013).

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Northeastern Beach Tiger Beetle

In August of 1990, the northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*) was listed by the Service as threatened. This tiger beetle occurred historically "in great swarms" on beaches along the Atlantic Coast, from Cape Cod to central New Jersey, and along Chesapeake Bay beaches in Maryland and Virginia (USFWS 1994). Currently in New England, northeastern beach tiger beetles are restricted to beaches in Martha's Vineyard and Chatham, Massachusetts.

The northeastern beach tiger beetle recovery plan establishes four Geographic Recovery Areas (GRA) and the status and goals for each area. Monomoy National Wildlife Refuge is currently one of only two occupied sites in GRA 1 (coastal Massachusetts and islands) sustaining a population of northeastern beach tiger beetles; the other site is located at Squibnocket Beach on Martha's Vineyard. Both of these sites contain large populations (peak count greater than 500); however, the refuge is the only site that is considered permanently protected (USFWS 2009).

The northeastern beach tiger beetle has been identified as an indicator species for healthy beach communities and its presence reflects positively on the ecological value of the habitats where it can be found. The habitat that is most preferable to this species is healthy, wild beach ecosystems that are highly dynamic, subject to natural erosion and accretion processes, and undisturbed by heavy human use (USFWS 1994).

Adults tend to be concentrated in wider sections of beach, and occur in smaller numbers or may even be absent from nearby areas of narrow beach (USFWS 1994). Larvae occur in a relatively narrow band of the upper intertidal to high drift zone, but may relocate their burrows throughout development to adapt to environmental and seasonal changes in the beach ecosystem. Adult beetles generally emerge from their sandy burrows in July and August. The larval stage of this beetle lasts approximately 2 years and each population consist of two cohorts: adults that emerge in odd years and adults that emerge in even years.

Threats to the northeastern beach tiger beetle include destruction and disturbance of natural beach habitat from shoreline developments, beach stabilization projects, and high recreational use. Additionally, the proximity of the larval burrows to the high-tide line increases their chance of being washed away by severe storms.

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Waterbird Nesting Colonies

Massachusetts supports significant populations and habitats of colonial nesting marine birds and wading birds including the federally listed roseate tern. Massachusetts also contains some of the most important shorebird migration habitat along the Atlantic Coast. There are significant breeding colonies of common and least terns, laughing gulls, American oystercatchers, black-crowned night-herons, and snowy egrets. Many of these colonies occur on sites that are experiencing effects from storms and rising sea levels.

In 2012, more than 140 sites with histories of nesting were surveyed for the presence of coastal waterbirds. Numbers ranged from a few nesting pairs up to over 7,000 pairs. Hundreds of nests on at least 42 sites were overwashed during a severe northeast storm in June and therefore not included in the census. Some of the largest colony sites were at South Monomoy Island, Ram Island, Bird Island, Plymouth Beach, and Norton Beach.

Colonial waterbirds are concentrated into a usually small number of sites during the nesting season. Many of these sites are experiencing loss of high quality nesting habitat due to sea level rise and increased storm events. Loss of high quality habitat can lead to overcrowding of nesting colonies. It can also force movement of nesting birds to less desirable nesting areas where there may be increased levels of human disturbance and predation resulting in lower productivity of hatchlings.

Colonial nesting waterbirds are important components of coastal ecosystems in the United States. The extensive recreational, commercial, and industrial development along the U.S. coast have placed waterbird colonies at increasing risk to their survival, especially in the Northeast. Threats to colonial nesting waterbirds include sea level rise and more frequent storm surges. Other significant threats include human disturbance, predation, habitat degradation, and contaminants. Recreational use of bird-nesting islands and beaches during spring and summer breeding season is detrimental to disturbance-sensitive species such as plovers, terns, and wading birds. Nesting populations of colonial waterbirds and piping plovers on sand or gravel beaches are especially vulnerable during the nesting season (April to August) to human-caused disturbances such as trampling or destruction of nests. Predation is a major problem in waterbird colonies. On beaches, mammalian predators such as foxes, skunks, raccoons, rats, dogs, and cats are a major problem; islands, although generally free from mammalian predation, may be subject to predation by gulls, crows, other birds, and insects. Degradation of nesting and foraging habitat is a major threat to both island-nesting and beach-nesting species. Increased vegetation and succession on some islands may reduce their suitability for nesting by terns and gulls. Competition for nesting sites and predation by gulls results in loss of tern nesting habitat. Contaminants continue to be a major threat to waterbirds.

Colonial waterbirds are concentrated into a usually small number of sites during the nesting season, which makes protection of these sites a high priority. Attempts to stabilize and control erosion on beaches often result in a loss of natural diversity of beaches and decreased habitat suitability for nesting and feeding birds. Erosion control projects should be done in a way that recognizes the dynamic nature of these habitats. The State of Massachusetts has initiated projects to restore tern nesting habitat, which is being lost due to erosion and sea level rise, at Bird and Ram Islands. These islands lie just a few feet above sea level. At both sites, eroded areas will be filled with sand and gravel to create suitable tern nesting habitat. At Bird Island, a deteriorating seawall will be rebuilt to better protect the upland habitat.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

Monomoy National Wildlife Refuge

Monomoy National Wildlife Refuge (NWR) is one of eight refuges that comprise the Eastern Massachusetts NWR Complex, which is headquartered in Sudbury, Massachusetts. Monomoy NWR stretches for 8 miles off the elbow of Cape Cod in the Town of Chatham, Barnstable County, Massachusetts. Much of the following discussion is drawn from the Draft Monomoy National Wildlife Refuge Comprehensive Conservation Plan (USFWS 2013).

The refuge was established in 1944 as a sanctuary for birds with an emphasis on threatened, endangered, and migratory birds. The refuge includes South Monomoy, North Monomoy Island, Minimoy Island, 40 acres on Morris Island where the headquarters and visitor contact station are located, and all waters within the Declaration of Taking. Nearly half of the refuge, including most of refuge land above the mean low water mark is designated as a wilderness area; currently the only wilderness area in southern New England. The refuge is also designated as a Western Hemisphere Shorebird Reserve Network Regional site, an Important Bird Area, and a Marine Protected Area. The decommissioned Monomoy Point Lighthouse and keeper’s house on South Monomoy are listed on the National Register of Historic Places. The barrier islands are part of a dynamic coastal zone, characterized by an ever-changing landscape. Salt and freshwater marshes, dunes, and ponds provide nesting, resting, and feeding habitat for migratory birds. Years of accretion on the eastern shoreline of South Monomoy, where Nauset/South Beach connected in 2006 and where a breach subsequently occurred in 2013 after frequent overwashing, has altered the eastern boundary of the refuge.

Natural habitats are dominated by intertidal sandflats, open sand, grassland-covered dunes, and salt marsh, interspersed with shrublands representative of coastal ecosystems. The majority of Monomoy's vegetation cover types are shaped by the dynamic tidal processes and shifting sands associated with barrier beach habitats. The remaining 40 percent is comprised of upland shrubland and forest with woody shrubs and small trees.

Monomoy NWR's beaches and salt marshes provide important spawning and nursery habitat for horseshoe crabs, and the refuge is one of the most important areas for horseshoe crabs in the State. About 12 percent of the State's piping plover population nests on Monomoy NWR and South Beach combined. Monomoy NWR is an important nesting site for roseate terns. The refuge has hosted one of the largest common tern colonies along the Atlantic seaboard in most years since 1999, and the largest laughing gull colony in Massachusetts in most years since 2001. The potential for a large roseate tern colony at Monomoy NWR is great, given the large common tern colony, which has similar nesting requirements. Monomoy NWR has become increasingly important stopover and molting area for the rufa red knot and Monomoy NWR also serves as an introduction site for the federally threatened northeastern beach tiger beetle.

The Morris Island portion consists of 40 acres, connected to the mainland by a causeway, and is home to the refuge's headquarters and visitor contact station. This management unit includes beach, dunes, and salt marsh habitats that support a variety of flora and fauna, including migratory birds, horseshoe crabs, fish, mammals, reptiles, and amphibians. Four to 5 acres of intertidal salt marsh occur on the south end of the island, and American beach grass is the dominant dune vegetation. In addition, 12 upland acres are forested with woody shrubs and small trees, including northern bayberry, beach plum, pitch pine, scrub oak, and eastern red cedar. The east side of Morris Island includes a slowly eroding coastal embankment rising close to 50 feet above a narrowing beach. That eroding refuge beach is impassable during mid-high tide, but extends southward until joining the more moderately sloping Morris Point, which encompasses intertidal flats, salt marsh, dunes, and beach. The Morris Island Interpretive Trail, popular with refuge visitors, follows this refuge beach corridor and loops through the different Morris Island habitats described above. The Morris Island portion of the refuge is situated on outwash plain deposits. Ongoing erosion of the east side of the island, which rises up close to 50 feet from a narrow beach to the refuge's headquarters site, has removed most of the beach, and only a narrow strip of beach remains at high tide. The southern portion of Morris Island slopes down moderately to mixed pine forest, dunes, intertidal salt marsh, and beach and an adjoining dredge material sand spit.

North Monomoy Island is an estimated 1.3 miles long and 0.4 miles wide and consists of beach, dunes, intertidal salt marsh, and (sand and mud) flats. North Monomoy Island provides habitat for spawning horseshoe crabs, nesting habitat for saltmarsh sparrows, and nesting and staging areas for shorebirds, terns, and wading birds.

South Monomoy is roughly tear-shaped, about 6 miles long and 1.3 miles wide at the southern end and is characterized by sand and mudflats, sandy beaches, extensive dunes, salt marsh, and freshwater ponds and wetlands. Small salt marsh patches occur on the northwest and southwest sides, consisting primarily of saltmarsh cordgrass, saltmarsh hay, saltgrass, and black grass. The freshwater ponds and marshes, which cover more than 150 acres on South Monomoy, host cattail, pond lilies, and common reed.

As a result of ongoing, natural coastal beach migration processes typical of this area, adjacent Nauset/South Beach accreted sufficiently to connect to the northeast tip of South Monomoy in 2006, creating a land bridge from the island to mainland Cape Cod. Sand is now accreting on the ocean side, widening the seaward side of the 2006 connection, while salt marsh forms on the interior side of the connection.

In early February 2013, a break in South Beach occurred in areas that had been eroding for several years. The South Beach “thumb” adhering to South Monomoy, while changing almost daily in size and shape, was estimated as 674 acres in June 2013. The winter storms that created the 2013 break also overwashed the majority of this residual “thumb.” That overwashing buried what had been dune and some salt marsh vegetation under sand, and lowered dunes while filling in the interdunal swales. The area is now generally lower and flatter than before the break, dominated by the bare sands of numerous overwash fans separated by patches of dune, some saltmarsh vegetation abutting the intertidal flats of the old Southway channel, and approximately 3 miles of sandy beaches along the Atlantic Ocean.

A small island, Minimoy, is located west of the northern tip of South Monomoy. This eroding island is currently estimated to be 0.25 miles long and 0.36 miles wide, and is also characterized by sandy beaches and dunes, as well as a growing salt marsh on the east side. This management unit provides habitat for thousands of nesting and migrating birds, including shorebirds and terns. From 2003 to 2008, Minimoy Island hosted between 10 and 43 pairs of roseate terns. Erosion of the western side of Minimoy Island in recent years resulted in less habitat for roseate terns, until virtually no suitable habitat was available by 2009. Beginning in 2009, refuge staff attempted to attract roseate terns back to the main common tern nesting colony on South Monomoy by placing nesting structures, decoys, and a sound system in suitable habitat. In 2009, no roseate terns nested on the refuge, but in 2010, roseate terns returned to the nesting area on South Monomoy. Minimoy Island continues to erode as a result of storm surge and sea level rise. There have been discussions between the U.S. Army Corps of Engineers (Corps) and the town of Chatham to place dredge material on the intertidal flats that protect Minimoy. However, a feasibility study determined that it was the most costly alternative and therefore was not chosen.

Monomoy NWR is part of a dynamic coastal area where erosion and accretion processes have always been present. Sea level rise is one of the most potentially serious consequences of climate change for coastal ecosystems like Monomoy NWR. If sea level continues to rise, this could have serious impacts on coastal barriers and islands like Monomoy and South Beach. It would not only affect the overall size of the refuge, but also the available habitat for species that rely on coastal ecosystems. Losses in coastal land area would result in a decrease in feeding, resting, and breeding habitat for many coastal wildlife species.

There is an existing federal navigation project at the entrance to Stage Harbor in Chatham. In an effort to find options to reduce the vulnerability of the refuge to storm surges, as well as to improve available nesting habitat for piping plover and other high priority avian species, refuge staff and the Corps are engaging in discussions regarding the placement of some of the dredged material on non-wilderness portions of the refuge and adjoining conservation partners.

Parker River National Wildlife Refuge

Parker River National Wildlife Refuge was established in 1941 to provide feeding, resting, and nesting habitat for migratory birds. It is located within the towns of Newbury, Rowley, and Ipswich, while the refuge headquarters is located within the city of Newburyport, Massachusetts. This 4,727-acre refuge includes sand dunes, saltmarsh, freshwater marsh, glacial upland, and more than 6 miles of ocean beach along the eastern side of Plum Island. The most abundant habitat on the refuge is its 3,000+ acres of salt marsh, one of the most productive ecosystems in nature. Parker River provides pristine coastal habitat more than 300 species of resident and migratory birds, as well as a large variety of mammals, insects, fish, reptiles, and amphibians. The refuge also provides breeding habitat for the federally threatened piping plover.

In addition to its mission of wildlife conservation, the refuge provides a variety of excellent wildlife-dependent recreational activities, including surf fishing, wildlife observation and photography, a variety of interpretive programs, and seasonal waterfowl and deer hunting opportunities. A large visitor center – complete with a classroom and auditorium – supports many of these public uses.

Parker River Refuge also administers Thacher Island National Wildlife Refuge, an unstaffed satellite refuge off the coast of Rockport, Massachusetts. Thacher Island Refuge encompasses the northern 22 acres of the 52-acre island. It was established in 1972 to provide feeding, resting, and nesting habitat for migratory birds and is currently managed to protect migratory birds, endangered species, and other wildlife and their habitats.

The refuge receives approximately 250,000 visitors per year primarily during the warmer months, May through October. It is considered one of the finest birding areas in the nation with more than 350 species recorded. The refuge occupies in part, the southern three-fourths of Plum Island, an 8-mile barrier island. Located along the Atlantic Flyway, the refuge is of vital stopover significance to waterfowl, shorebirds, and songbirds during pre- and post-breeding migratory periods.

There are about 10 miles of piping plover and least tern nesting habitat on Plum Island, approximately 6 miles of which are refuge-owned. Plum Island beaches and the surrounding salt marshes are also used as feeding and stop-over area by roseate terns and red knots. Roseate terns are present during the breeding and migration periods and red knots are present during migration, primarily between from July through November. There are also small common tern colonies in the salt marshes in Plum Island Sound. Population numbers average about 200 pairs annually.

Parker River has a high density of salt marsh sparrows. Although this species is not currently federally listed as threatened or endangered, it is a high conservation priority because of its limited breeding distribution, suspected declining population trend, and substantial threats to its coastal high salt marsh habitat. Salt marsh sparrows are obligate salt marsh species that breed from Maine to Virginia. They nest in high marsh close to the marsh surface where there are particularly vulnerable to the increase in flooding events that is likely to occur with sea level rise and increased stormy conditions.

The refuge is a mainly intact barrier island system, and has the capacity to adapt to changes caused by erosion and accretion. However, surrounding anthropogenic changes reduce the resiliency of the system. Man-made structures like jetties at the mouth of the Merrimack River, groins along the beach, dams, and roads all limit and reduce sediment supply and movement in the system which we believe to be sediment-limited already. These anthropogenic stresses further reduce the ability of the system to adapt to tidal storm surges. On the beach, man-made structures reduce movement of sand from the north end of the island to the refuge beach, further narrowing the beach.

The refuge is located directly on a barrier island and therefore it is susceptible to coastal storms and vulnerable to storm surge effects. Infrastructure in jeopardy during storms include boardwalks, observation platforms, a 6.5 mile road, parking lots, a visitor contact station, rest room facilities, and refuge residence and maintenance buildings.

NEW HAMPSHIRE

Federally Listed Threatened and Endangered Species

Piping Plover (*Charadrius melodus*)

Piping plover is a federally listed species that nests in small numbers along certain New Hampshire beaches. The Atlantic Coast population, which breeds on coastal beaches from Newfoundland to North Carolina (and occasionally South Carolina), is listed as threatened. Of the approximately 19 miles of New Hampshire coastline, only 1.8 miles are coastal beach and sand dune systems suitable for piping plover breeding activity. These beaches are located at the Seabrook and Hampton beaches which generally support 5 to 7 breeding pairs each year. Seabrook has the most extensive intact coastal sand dune system in the state. The Hampton beach is primarily flat sand that ends at a seawall.

Piping plovers nest above the high tide line on coastal beaches, sandflats at the ends of sandspits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, sparsely vegetated dunes, and washover areas cut into or between dunes. In the central portions of their Atlantic Coast range they have also been known to nest on beaches that have been augmented through beach nourishment projects. Since the flightless young leave the nest shortly after hatching, suitable feeding areas must be located close to the nest area. Plover foods consist of invertebrates such as marine worms, fly larvae, beetles, crustaceans, and mollusks. Feeding areas include intertidal portions of ocean beaches, washover areas, mudflats, sandflats, wrack lines, and shorelines of coastal ponds, lagoons or salt marshes.

Loss and degradation of habitat due to development and shoreline stabilization have been major contributors to the species' decline. Beaches throughout the plover’s range are affected by federal and non-federal actions, including inlet management, beach nourishment, dune construction, and dune stabilization. Shoreline stabilization has interfered with natural coastal processes by precluding formation of newly-forming inlets, overwash zones, and accreting beaches that would create or maintain piping plover nesting and foraging habitats (USFWS 2005). Disturbance by humans and pets often reduces the functional suitability of habitat and causes direct and indirect mortality of eggs and chicks. Predation is another important factor limiting piping plover reproductive success at many Atlantic Coast sites. Predators of piping plover eggs and chicks include foxes, skunks, raccoons, rats, opossums, crows, gulls, grackles, hawks and falcons, domestic dogs and cats, and ghost crabs (USFWS 1996).

The exposed location and limited extent of suitable plover habitat in New Hampshire indicates that it will quite vulnerable to storm surges. Sea level rise and increased storm activity will likely increase beach and dune erosion and alter pattern of sand deposition. The risk of habitat loss is accentuated by the presence of development in the neighboring areas that will restrict the potential for normal landward migration of the beach as the sea level rises.

Roseate Tern (*Sterna dougallii dougallii*)

The federally endangered roseate tern has a breeding colony on Seavey and White Islands, two small islands connected by a rocky neck exposed at low tide that are located approximately 6 miles off the coast from Rye, New Hampshire within the island group known as Isle of Shoals. A historic colony was abandoned by 1955 due to an increase in gull predation. Roseate terns began nesting there again in 2001 after an intensive tern restoration program was undertaken. Each year biologists are stationed on the island through the entire breeding season (April through August) to deter gull predation and conduct monitoring activities. Roughly 40 to 60 roseate pairs have been nesting at the colony every year since it was re-established, making it was of the larger colonies in the Northeast population. As is invariably the case in the Northeast, the roseate colony is situated within a larger colony of common terns (approximately 2000 to 2500). A few arctic terns (6 to 9) also typically nest there. Since these islands are rocky and stable, they should be less vulnerable to sea level rise than the colonies from Cape Cod westward, most of which are subject to erosion. However, sea level rise and increased stormy conditions could have some effect on the physical habitat conditions depending on the degree. There may also be more subtle effects on colony productivity. For example, gull predation on tern eggs and chicks at Seavey Island appears to be more severe during storms. The rainfall pattern also affects the vegetation growth on this island which in turn affects the habitat quality.

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MAINE

Overview

Half of Maine's 3,500 miles of coastline is made of bedrock, which resists erosion and generally is not affected by rising seas (Chai and Anderson 2009). However, the remaining 50% of the coastline is composed of bluffs, sand beaches, and wetlands, which are very sensitive to rising sea level (Chai and Anderson 2009). Along the Maine coast, the greatest threat of damage from storm surge lies along the beaches and low-lying areas south of Portland.

For this planning report, focus was placed on sensitive biological resources and national wildlife refuge divisions occurring in the southern region of Maine – primarily from the mouth of the Kennebec River south to the Maine – New Hampshire border. This portion of the Maine coast includes important habitat for several federally-listed and state-listed endangered or threatened species, colonial nesting bird species, and species inhabiting salt marshes. Rachel Carson National Wildlife Refuge and several islands within the southern portion of Maine Coastal Islands National Wildlife Refuge occur within this focus area.

National wildlife refuges lying outside of the focus area include the remainder of Maine Coastal Islands National Wildlife Refuge which extends to the Canadian border, and the Edmunds Division of Moosehorn National Wildlife Refuge. The Edmunds Division has frontage on two bays within Cobscook Bay that are important for migrating shorebirds, waterfowl, and bald eagles.

Map polygons of important habitat in the southern coastal Maine focus area were derived from the U.S. Fish and Wildlife Service's Information, Planning, and Conservation System (IPaC, USFWS 2013a) and Maine Essential Habitat Program (MDIFW 2013a).

Federally Listed Threatened and Endangered Species

Piping Plover (*Charadrius melodus*) and State-listed Least Tern (*Sterna antillarum*)

The piping plover, a beach-nesting shorebird, is a federally-listed threatened species and also listed as an endangered species by the state of Maine. The least tern is a state-listed endangered species. In southern Maine, the two species often nest in close association on the same sand beaches.

Piping plover nests in Maine have been monitored annually since 1981 at 27 sites in the state's southern coastal counties - York, Cumberland, and Sagadahoc. The piping plover population in the state has varied widely over the years with the number of nesting pairs ranging from a low of 6 in 1983 to a high of 66 in 2002 (Camuso *et al*. 2013). In 2013, Maine's population of piping plovers was 44 pairs and they used the following beaches for nesting:

Ogunquit Beach, Ogunquit	Old Orchard Beach, Orchard Beach
Wells Beach, Wells	Pine Point Beach, Scarborough
Laudholm, Wells	Scarborough Beach State Park, Scarborough
Crescent Surf Beach, Kennebunk	Ram Island, Cape Elizabeth
Goose Rocks Beach, Kennebunkport	Seawall Beach (Morse Mountain), Phippsburg
Fortunes Rock/Hattie's Beach, Biddeford	Popham Beach State Park, Phippsburg
Hills Beach, Biddeford	Reid State Park, Georgetown
Goosefare Brook, Saco	

Breeding piping plovers typically return to Maine in April (K. O'Brien, USFWS. 2013. Personal communication), but some early individuals may arrive in late March (Wilson *et al*. 1997). Piping plovers nest on coastal beaches above the high tide line, sand flats at the ends of sand spits and barrier islands, gently sloping foredunes, blowout areas behind primary dunes, and washover areas cut into or between dunes (McCollough 2000). Nest sites are relatively flat with substrates ranging from fine sand to mixtures of sand, shells, pebbles, or cobble and commonly occur at sites with little or no vegetation, except for moderately-dense stands of beachgrass (*Ammophila breviligulata*) (McCollough 2000).

Least tern nests in Maine have been monitored annually since 1977 at 13 sites in the state's southern coastal counties - York, Cumberland, and Sagadahoc. Since surveys began in Maine, the lowest estimate of least tern pairs was 39 in 1982 and the highest was 224 in 2013. In 2013, least tern nesting occurred at Crescent Surf (129 pairs), Stratton Island (92 pairs), and Popham Beach (3 pairs).

Least terns return to Maine to nest about the second week in May (Wilson *et al*. 1997). The terns nest in scattered colonies on points and spits of sand beaches characterized by highly dynamic areas of accretion and erosion, sparse vegetation, and coarse sand, gravel, and bits of broken shells (McCollough 1993). The largest least tern colonies in Maine typically reside at Crescent Surf Beach and the second largest colony nests on Stratton Island.

Beach habitat (sand, cobble, gravel, and boulder) in Maine comprises only 2% or approximately 75 miles of the coastline, and the sand beaches favored by nesting piping plovers and least terns account for less than 40 miles of the 75 beach miles. About 50% of Maine's sandy beaches are stabilized with seawalls (Slovinsky 2005). The construction of seawalls, jetties, piers, homes, parking lots, and other structures along Maine's sand beaches has reduced the amount of suitable nesting habitat available to the species by more than 75% (MDIFW 2013b).

Approximately 50% of the Maine piping plover population nests at sites on or near Rachel Carson National Wildlife Refuge, including Crescent Surf Beach, Goosefare Brook, and Marshall Point at Goose Rocks. Nearly all of the Maine least tern population nested at only two locations in 2013 - Crescent Surf Beach (57%) and Stratton Island (42%). During migration, transient plovers and terns could occur on any pocket beach or sandflat along the Maine coast.

Maine's sandy beaches are dynamic habitats whose profile changes over the course of eroding winter storms and developing summer accretions. Recovery of Maine's beaches to winter storms, however, does not appear to be occurring as well as they have in the past (Slovinsky *et al*. 2013). Increased storm frequency and severity are anticipated with climate change (Jacobson *et al*. 2009) and will accelerate beach erosion. Over the next several decades, the "100-year coastal storm" could occur every 2 to 3 years in the Northeast (Frumhoff *et al*. 2006). The incremental loss of sand beach decreases available piping plover and least tern nesting habitat. Development along Maine's southern beaches also limits the likelihood of beach migration inward and the establishment of new nesting habitat. Storm surge can wreak havoc on nesting plovers and terns. Late winter and spring storms may produce significant storm tides that wash out nests; a situation that occurred on the Maine coast in June 2012. Piping plovers and terns may establish new territories and renest after these types of storm events, but if climate change increases the frequency of these storm events, plover nest loss may increase and productivity would decrease (Seavey *et al*. 2011). Plover and tern nesting habitat is often in immediate proximity to developed portions of the Maine coast. Storm surge has the potential to cause significant damage to coastal homes, businesses, and infrastructure. Piping plover and least tern habitat may be further degraded during post storm surge recovery and restoration operations associated with debris removal from damaged structures and other infrastructure demolition and rebuilding.

Roseate Tern (*Sterna dougallii dougallii*)

The roseate tern is a federally-listed and state-listed endangered species. The roseate tern resembles the common tern *S. hirundo* and Arctic tern *S. paradisaea*, with which it nests in mixed species colonies in Maine. In 2013, about 190 pairs of roseate terns nested on 4 Maine coastal islands – Petit Manan, Eastern Egg Rock, Jenny, and Stratton. Historically, roseate terns have also nested on Outer Green, Pond, Seal, and Metinic Islands.

Roseate terns return to Maine's offshore islands to nest in mid-May. The roseate tern nest is a simple scrape on the ground in dense vegetation or under rocks or driftwood (Gochfeld *et al*. 1998). Within the southern Maine focus area, roseate terns have nested on Stratton Island off Prouts Neck at the mouth of the Scarborough River, Jenny Island in eastern Casco Bay south of Cundy's Harbor, and Pond Island at the mouth of the Kennebec River. In 2013, Stratton Island had the largest colony in Maine with 94 pairs. In addition to providing nesting habitat, southern Maine beaches are staging areas for roseate terns prior to their fall migration.

The three islands in southern Maine used by roseate terns for nesting are subject to flooding during storm events with high waves. An increased frequency of significant storms from climate change coupled with sea level rise puts these nesting colonies at further risk, particularly the birds that build their nests at the lower elevations of the islands.

Rufa Red Knot (*Calidris canutus rufa*)

The rufa red knot was proposed for listing as a threatened species under the Endangered Species Act on September 30, 2013. The red knot is a large, long-winged sandpiper with a short bill that travels up to 15,000 km from its Arctic tundra breeding sites to wintering areas in South America

(Harrington 2001). During their southward (mid to late summer) migration from nesting areas in the Arctic, the red knots stop to feed at sandy beaches and mudflats along the entire Maine coast. Red knot feed on invertebrates and small marine mollusks, especially bivalves that are swallowed whole (Harrington 2001). During migration, red knots are observed on the tidal mudflats of Lubec, Steuben, and Harrington in Downeast Maine and along the sand beaches and mudflats of southern Maine. Birds will roost on the offshore ledges Downeast and in the southern part of the state, particularly at Stratton Island (L. Tudor, Maine Department of Inland Fisheries and Wildlife. 2013. Personal communication). The numbers of red knots occurring in Maine during migration may not be large (Niles *et al*. 2007). Reported red knot sighting by birders along the Maine coast during the fall migration, typically involve low numbers (< 5) with occasional reported sightings of 20+ (eBird 2013). Birds are also sporadically sighted in Maine during spring migration, but typically at very low numbers (1 to 5). Potential storm surge impacts to sand beaches along the southern Maine coast (i.e., the focus area) that may be visited by migrating red knots are described in the piping plover and least tern section.

Other Important Species

Saltmarsh Sparrow (*Ammodramus caudacutus*) and Nelson's Sparrow (*A. nelsoni*)

The saltmarsh sparrow and Nelson's sparrow are not listed endangered or threatened species by the state of Maine or the federal government, but they are species of high conservation priority in the northeastern United States with extensive range overlap (Hodgman *et al*. 2002). In Maine, the two sparrow species are listed as Species of Special Concern (MDIFW 2013c). Due to a decreasing population trend, the saltmarsh sparrow is listed as vulnerable on the International Union for Conservation of Nature red list (IUCN 2013).

Population estimates for saltmarsh and Nelson's sparrows in Maine are currently under development and expected within the next year, but numbers are possibly in the range of 7,000 to < 10,000 birds for the saltmarsh sparrow and around 10,000 for the Nelson's sparrow (T. Hodgman, Maine Department of Inland Fisheries and Wildlife. 2013. Personal communication). The state of Maine has identified 27 marshes, all within the focus area, totaling over 16,000 acres that may provide essential habitat for saltmarsh and Nelson's sparrows.

Although often overlooked in discussions of sea-level rise and climate change, both sparrow species would be seriously impacted by storm surge both directly during breeding season and indirectly through loss or degradation of salt marsh habitat (Bayard and Elphick 2011). When storm surges arrive at lower tidal heights, wave erosion attacks the salt marsh edge facing open estuarine waters resulting in horizontal erosion. As water is forced up tidal channels on rising tides, the channels within the marsh have to widen (erode) in order to accommodate the large volume of water. The amount of horizontal erosion that results within salt marshes can be quite significant, particularly if there are several severe storms in any given year. Storm surges that occur during higher tides can result in substantial sheet flow across the salt marsh. Extended sheet flow/flooding conditions put stress on a salt marsh through prolonged saturation of marsh plants' root zone, by compacting the marsh through the added weight of water, by deposition of wrack which can smother plants, and by the conveyance of untreated sewage or other contaminants such as fuel oil, gasoline, and pesticides. When response or management agencies decide to remove wrack or contaminants, the additional traffic on the salt marsh can cause severe trampling and marsh degradation.

Saltmarsh and Nelson's sparrows nest on the surface of the salt marsh often just centimeters above the marsh surface. Normal lunar flooding is key cause of nest failure for these sparrow species (Shriver *et al*. 2007). Storm surges compound the stress these birds face with the normal flooding events of spring tides. When storm surges are added to spring tide flooding, it may result in no successful sparrow fledging for the entire summer. As climate change progresses and severe storms increase along with sea level rise, this becomes an ever real and daunting situation for the two species.

National Wildlife Refuges Vulnerable to Coastal Storm Surges

Rachel Carson National Wildlife Refuge

Rachel Carson National Wildlife Refuge stretches along 50 miles of coastline in York and Cumberland counties in southern Maine. The approximately 5,600-acre refuge has 11 divisions that occur within the municipalities of Cape Elizabeth, Scarborough, Old Orchard Beach, Saco, Biddeford, Kennebunkport, Kennebunk, Wells, Ogunquit, York, and Kittery (USFWS 2007). The dominant habitat types within the refuge are tidal (35%), freshwater wetlands (10%) and uplands (55%). Tidal habitats include beach, dune, dune grassland, river, rocky shore, estuarine, bay, and salt marsh. Freshwater wetland habitat includes cattail marsh, bog, emergent scrub-shrub wetlands, red maple swamps, and floodplain forest. Upland habitat is primarily comprised of mixed oak and pine forest with smaller stands of hemlock, spruce, pitch pine, hickory, and maple mingled with grasslands and shrub thickets.

The refuge's estuaries and tidal rivers provide nursery habitat for many marine fish, passage to upstream spawning areas for anadromous fish, and important feeding and nesting areas for migrating waterfowl, wading birds, and songbirds. Mudflats associated with these waterways support large concentrations of worms, clams, mollusks, and crustaceans that migrating shorebirds and waterfowl depend on to survive.

Rachel Carson NWR divisions lie at the mouth of more than a dozen tidal rivers that drain more than 250 square miles of land. The tidal rivers, streams, and salt marshes are located at critical places in the increasingly developed, fragmented region of southern Maine. These diverse aquatic and upland habitats support breeding, migrating, and wintering birds, and provide essential habitat for federally-listed and state-listed threatened and endangered species, candidate species, and species of management concern including piping plover, roseate tern, red knot, least tern, Nelson's and saltmarsh sparrows, salt marsh tiger beetle (*Cicindela marginata*), and New England cottontail (*Sylvilagus transitionalis*).

The salt marsh tiger beetle is a state-listed Species of Special Concern with limited mobility within its habitat and a restricted range in southern Maine. The beetle has very specific habitat needs in the back dune-mud flat ecotone that occurs on refuge lands and neighboring areas (Ward and Mays 2011). The New England cottontail, a federal candidate species, relies on fringes of coastal shrub thickets in York and Cumberland Counties and is losing habitat to developmental encroachment. Storm surge, sea level rise, and coastal flooding are additive risks to these very vulnerable species that occur on Rachel Carson NWR.

In many instances, salt marshes within refuge divisions are bordered by roadways, residences, businesses, and other areas with impermeable surfaces. Run-off from these areas, particularly during significant rainfall events, may contribute to heavy flows into marshes and decreasing water quality. The refuge has had problems with reduced water quality. Goosefare Brook is considered impaired with heavy metals from industrial stormwater discharge and polluted runoff and in 2013 levels of enterococci bacteria in the brook exceeded EPA safety levels. Storm surge into the refuge's wetlands would only exacerbate water quality issues.

In 2006, the Maine Geological Survey used LIDAR topographic data to project the impact of scenarios involving 1, 2, and 3 foot rises in sea level on the refuge (Slovinsky and Dickson 2006). The simulations suggested changes in marsh composition (high marsh to low marsh), flooding of property and roads, and susceptibility of breach areas to overwash and erosion.

Maine Coastal Islands National Wildlife Refuge

The Maine Coastal Islands National Wildlife Refuge lies within the Gulf of Maine Watershed and stretches along the entire 200 air-miles of the Maine coastline from the border with New Hampshire to Cobscook Bay on the Canadian border (USFWS 2005). The refuge is comprised of five separate refuge units: Cross Island, Petit Manan, Seal Island, Franklin Island, and Pond Island National Wildlife Refuges. Each refuge has separate establishment histories and stated purposes, but they are referred to collectively as the "Maine Coastal Islands National Wildlife Refuge." Seal, Franklin, and Pond islands are single-island refuges. Cross Island Refuge is a 6-island complex, while Petit Manan Refuge includes over 40 islands and 4 mainland divisions, including: Petit Manan Point (2,195 ac), Sawyers Marsh (1,028 ac), Gouldsboro Bay (623 ac) and the Corea Heath (431 ac). Togther, Maine Coastal Islands National Wildlife Refuge encompasses more than 8,000 acres of diverse coastal Maine habitats including forested and non-forested offshore islands, coastal salt marsh, open field, and upland mature spruce-fir forest.

Within the southern coastal Maine focus area of the Planning Aid Report, the refuge has fee title or conservation easements for 6 islands – Duck Island (11 ac), Smuttynose Island (39.9 ac) and Malaga Island (2.5 ac) within the Isles of Shoals, Upper Flag Island (30 ac) and Ram Island (10 ac) within Casco Bay, and Pond Island (10 ac) at the mouth of the Kennebec River. These islands vary in topography from low-lying rocky outcrops with elevations of 10 feet (Malaga) to shrub dominated islands with tall 130 foot cliffs (Upper Flag). In past years, the islands have been used for nesting by great blacked-back gulls (*Larus marinus*), herring gulls (*Larus argentatus*), common eider (*Somateria mollissima*), black-crowned night heron (*Nycticorax nycticorax*), double-crested cormorants (*Phalacrocorax auritus*), common terns, and black guillemot (*Cepphus grylle*).

These islands, as with all exposed offshore Maine islands, are often subject to substantial coastal storms, particularly in winter. Storm surges that occur during the seabird nesting season wash away eggs and nests and flood burrows.

Moosehorn National Wildlife Refuge

Moosehorn NWR is comprised of two divisions – the Baring Division (20,531 ac) and Edmunds Division (8,808 ac). Except for some frontage on the St. Croix River, the Baring Division is an inland parcel. The Edmunds Division, however, has about 18 miles of coastal frontage on Dennys and Whiting Bays, two smaller bays within Cobscook Bay in Downeast Maine (USFWS 2013b). Coastal habitat within the Edmunds Division includes ledge/rocky shoreline (115 ac), tidal flat (60 ac), and saltmarsh (94 ac).

Cobscook Bay is a complex of inlets, bays, tidal creeks, and rivers with tidal fluctuations of up to 24 feet, the greatest in the United States. The strong tides of Cobscook Bay keep water open in winter, vital to wintering waterfowl particularly American black ducks (*Anas rubripes*) along the Atlantic Flyway. Ox Cove and Bellier Cove, two coves where the refuge has frontage in Denny's Bay, are noted as important areas for American black ducks within Cobscook Bay (Daigle 2001). Shorelines within the Edmunds Division with rockweed and gradual slopes provide important brood-rearing habitat for common eiders with their ducklings (Blinn *et al*. 2008).

Cobscook Bay is also one of the most important areas in Maine for fall migrating shorebirds with these populations listed as highly imperiled or of high conservation concern (Clark and Niles 2000). The extensive tidal flats of Cobscook Bay provide internationally significant "staging areas" for more than 20 species of migrating shorebirds including the red knot (highly imperiled and proposed for listing as threatened under the Endangered Species Act), whimbrel (*Numenius phaeopus*, high concern), sanderling (*Calidris alba*, high concern), ruddy turnstone (*Arenaria interpres*, high concern), as well as large numbers of semipalmated plover (*Charadrius semipalmatus*), black-bellied plover (*Pluvialis squatarola*), and semipalmated, least, and white-rumped sandpipers (*Calidris pusilla*, *C. minutilla*, *C. fuscicollis*; Brown *et al*. 2001). Cobscook Bay has had the highest breeding density of bald eagles (*Haliaeetus leucocephalus*) in the state of Maine for at least the past 35 years (C. Todd, Maine Department of Inland Fisheries and Wildlife. 2013. Personal communication).

Since bays may exacerbate the funneling effect of storm surge, coastal habitat within the Edmunds Division of Moosehorn NWR, including the parcel with Cobscook Bay State Park, may experience damage from storm surge.

A study of sea level rise of Moosehorn NWR using the Sea Level Affecting Marshes Model or SLAMM (Clough and Larson 2008) projected a decline in brackish marsh, but an increase in salt marsh, estuarine beach, and transition salt marsh by 2100 (Whitman *et al*. 2010). The high tidal range (approximately 20 feet) at Moosehorn NWR when combined with the significant vertical relief, helped to explain predictions of resilience to sea level rise (Whitman *et al*. 2010).

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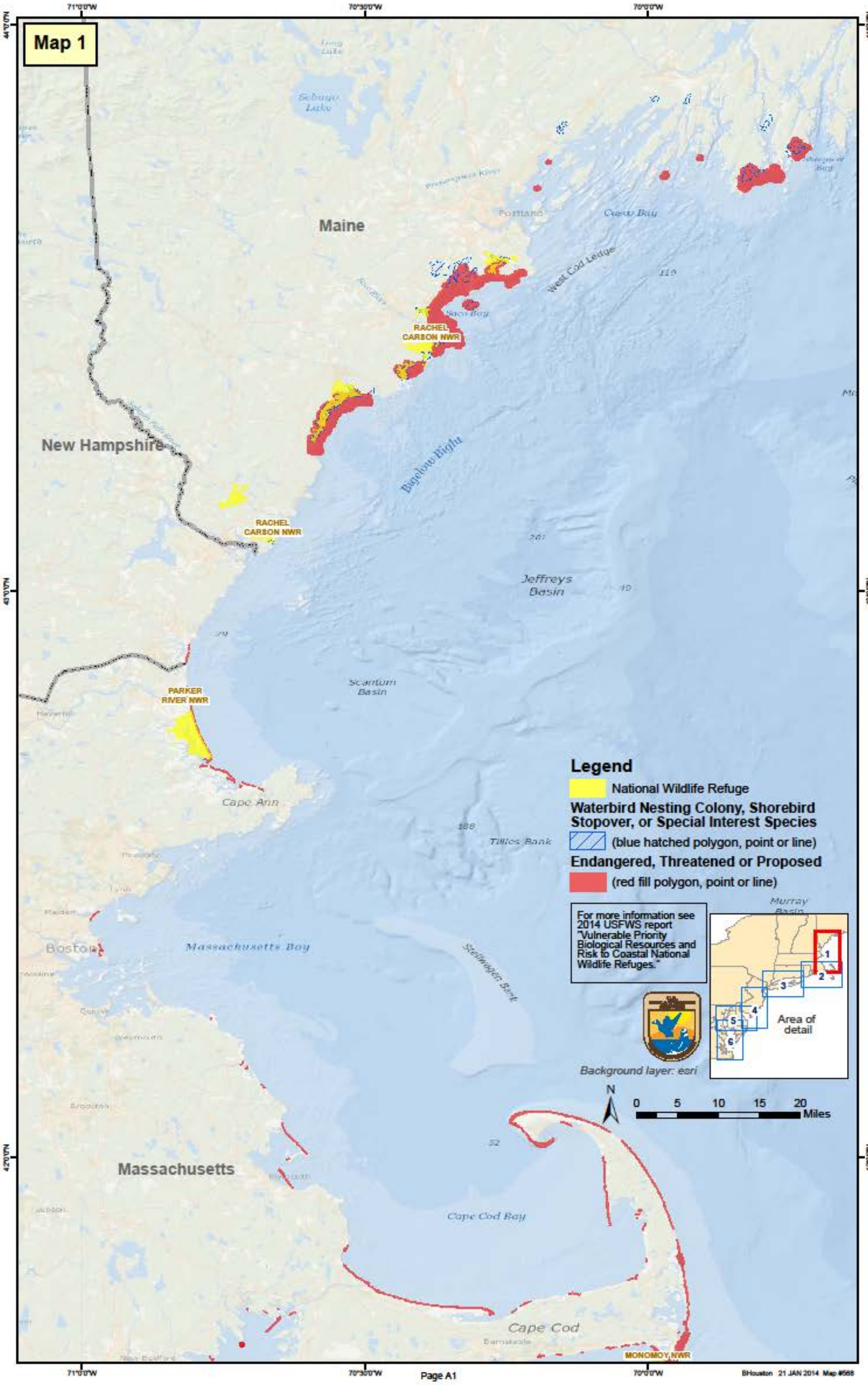
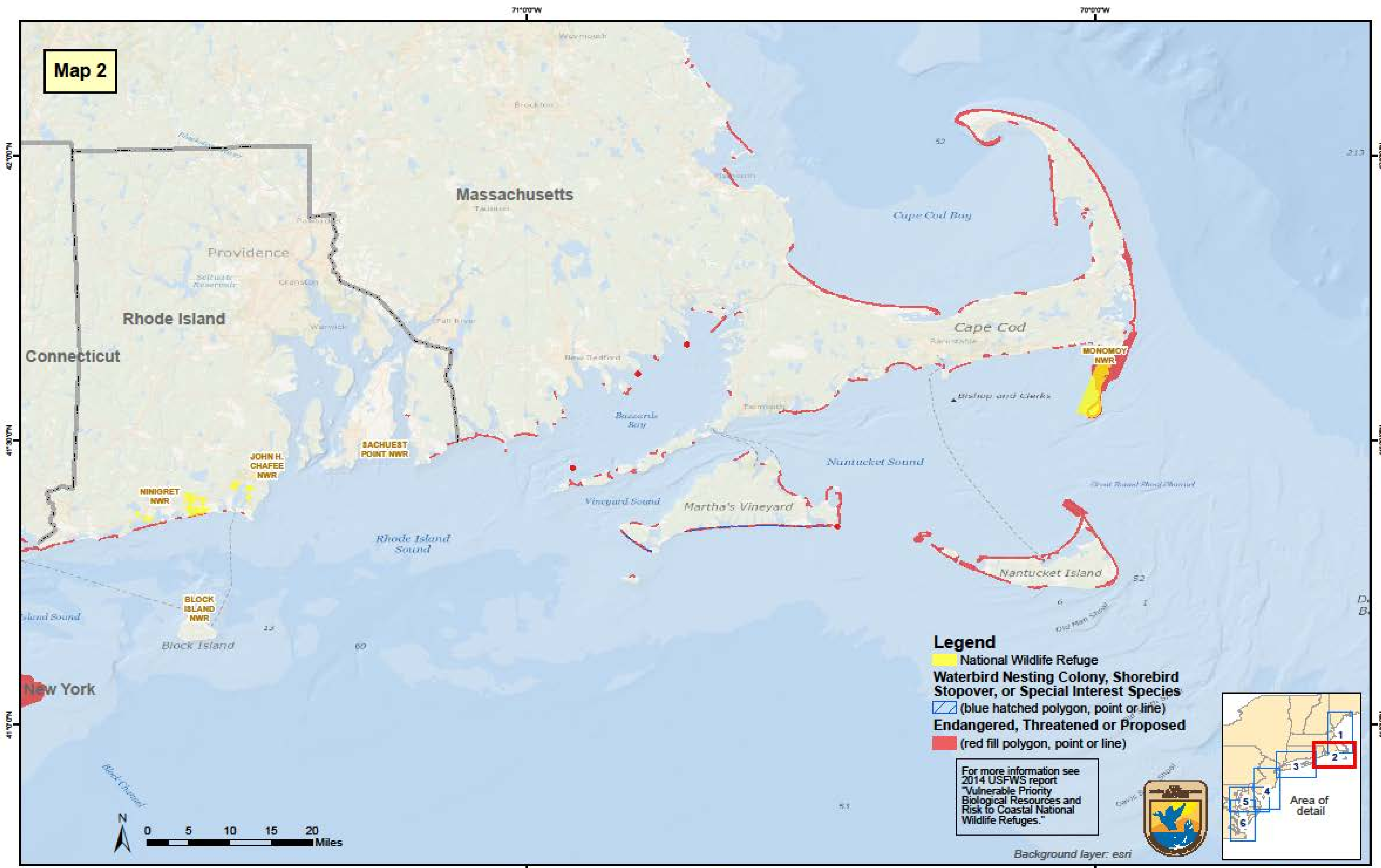
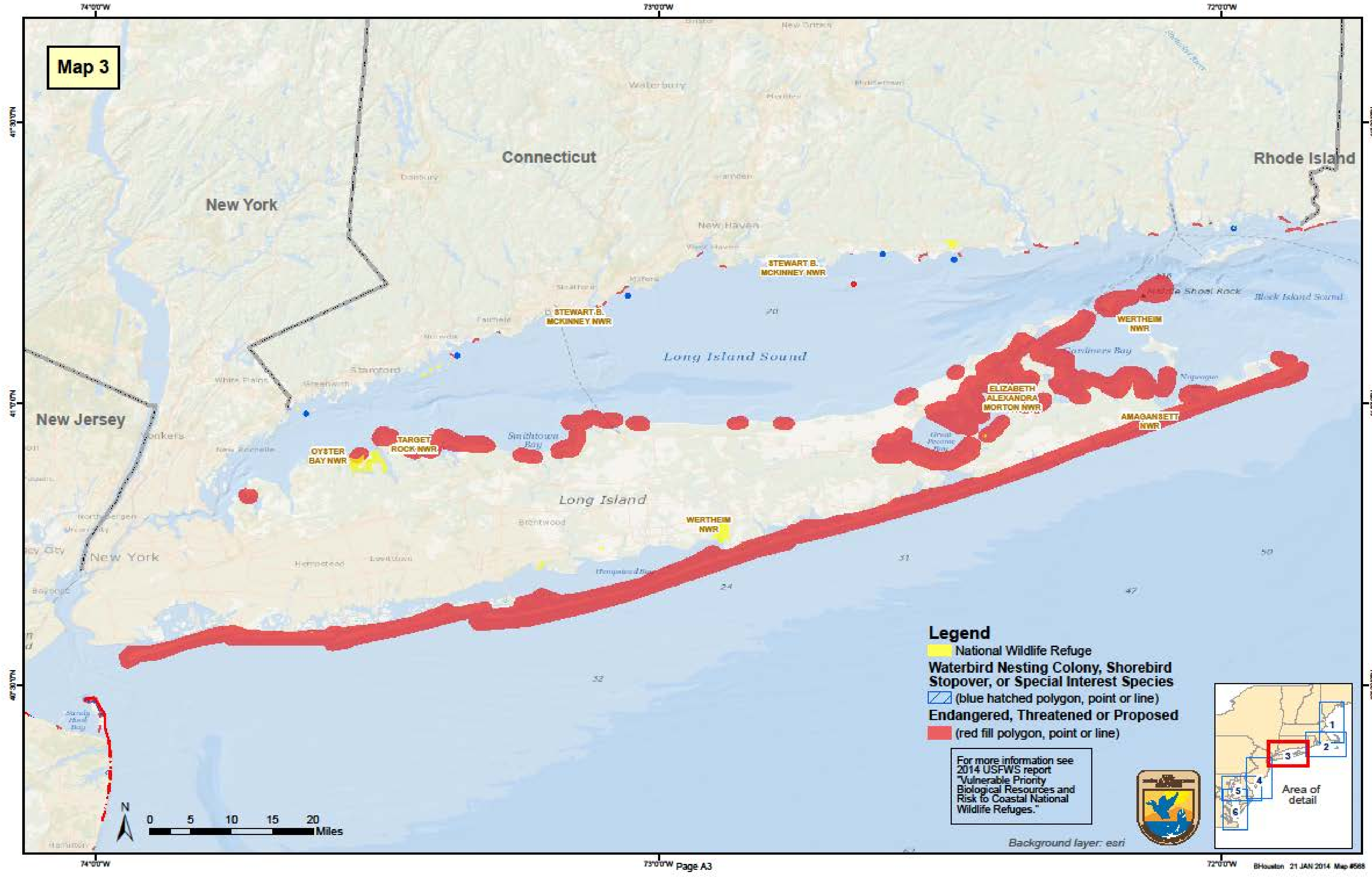
Appendix A.
Maps showing locations of vulnerable biological resources.



Map 1
Maine
New Hampshire
Massachusetts
RACHEL CARSON NWR
RACHEL CARSON NWR
PARKER RIVER NWR
MONOMOY NWR
Bigelow Bight
Jeffreys Basin
Scantum Basin
Cape Ann
Tillies Bank
Massachusetts Bay
Stellwagen Bank
Cape Cod Bay
Cape Cod
Boston
West Cod Ledge
Casco Bay
Saco Bay
Portland
Legend
National Wildlife Refuge
Waterbird Nesting Colony, Shorebird Stopover, or Special Interest Species
(blue hatched polygon, point or line)
Endangered, Threatened or Proposed
(red fill polygon, point or line)
For more information see 2014 USFWS report "Vulnerable Priority Biological Resources and Risk to Coastal National Wildlife Refuges."
Area of detail
Background layer: esri
0 5 10 15 20 Miles
71°0'0"W
70°30'0"W
70°0'0"W
44°0'0"N
43°0'0"N
42°0'0"N
Page A1
BHouston 21 JAN 2014 Map #568


Map 2
Massachusetts
Providence
Rhode Island
Connecticut
New York
Cape Cod Bay
Cape Cod
MONOMOY NWR
Bishop and Clerks
Buzzards Bay
Nantucket Sound
Vineyard Sound
Martha's Vineyard
Nantucket Island
Rhode Island Sound
SACHUEST POINT NWR
JOHN H. CHAFEE NWR
NINIGRET NWR
BLOCK ISLAND NWR
Block Island
Old Man Shoal
Legend
National Wildlife Refuge
Waterbird Nesting Colony, Shorebird Stopover, or Special Interest Species
(blue hatched polygon, point or line)
Endangered, Threatened or Proposed
(red fill polygon, point or line)
For more information see 2014 USFWS report "Vulnerable Priority Biological Resources and Risk to Coastal National Wildlife Refuges."
Background layer: esri
Area of detail
1
2
3
4
5
6
N
0 5 10 15 20 Miles
71°0'0"W
70°0'0"W
BHouston 21 JAN 2014
Page A2



74°0'0"W
73°0'0"W
72°0'0"W
Map 3
Connecticut
New York
Rhode Island
New Jersey
New York
Long Island Sound
Long Island
STEWART B. MCKINNEY NWR
STEWART B. MCKINNEY NWR
WERTHEIM NWR
ELIZABETH ALEXANDRA MORTON NWR
AMAGANSETT NWR
OYSTER BAY NWR
TARGET ROCK NWR
WERTHEIM NWR
Legend
National Wildlife Refuge
Waterbird Nesting Colony, Shorebird Stopover, or Special Interest Species
(blue hatched polygon, point or line)
Endangered, Threatened or Proposed
(red fill polygon, point or line)
For more information see 2014 USFWS report "Vulnerable Priority Biological Resources and Risk to Coastal National Wildlife Refuges."
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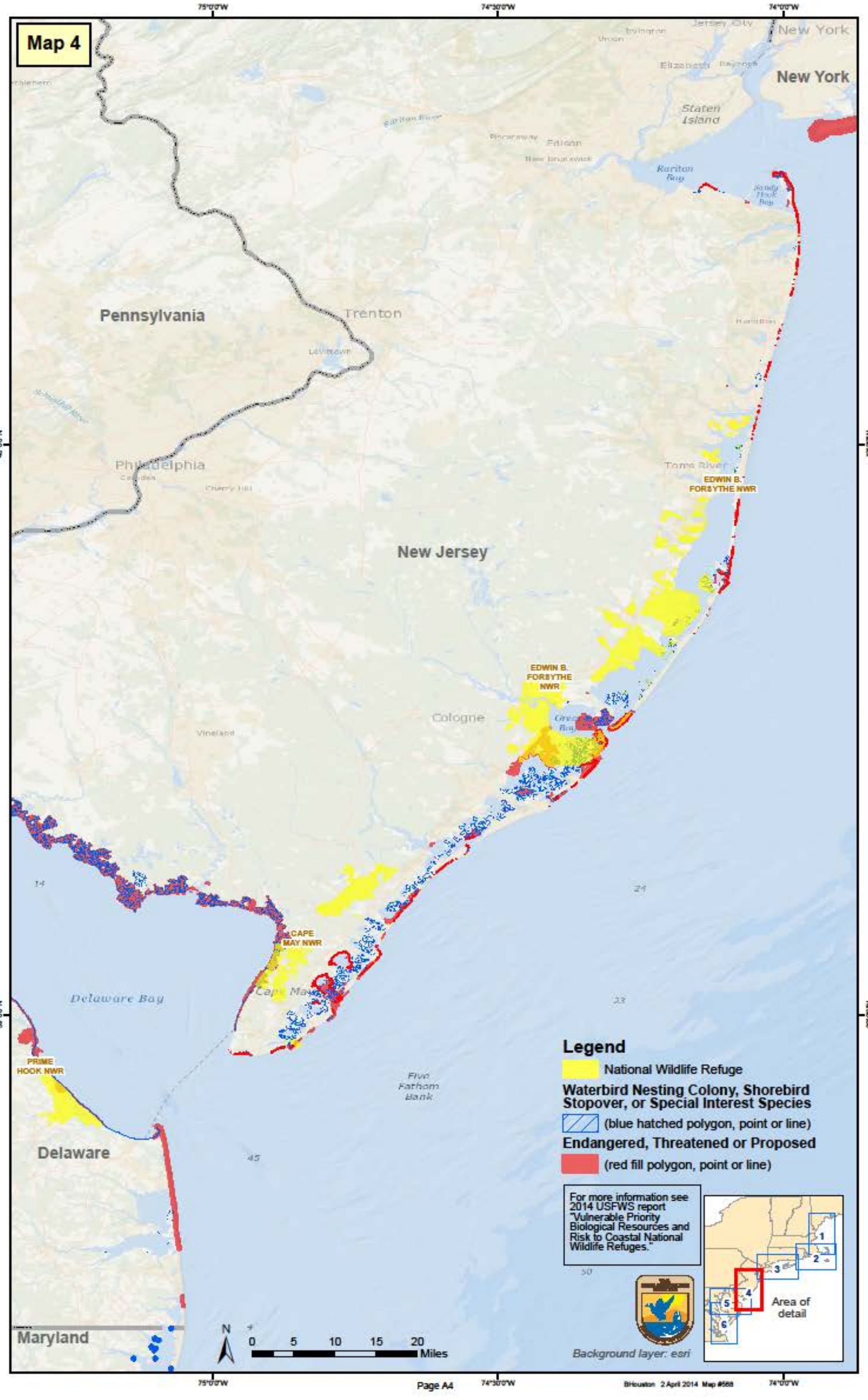
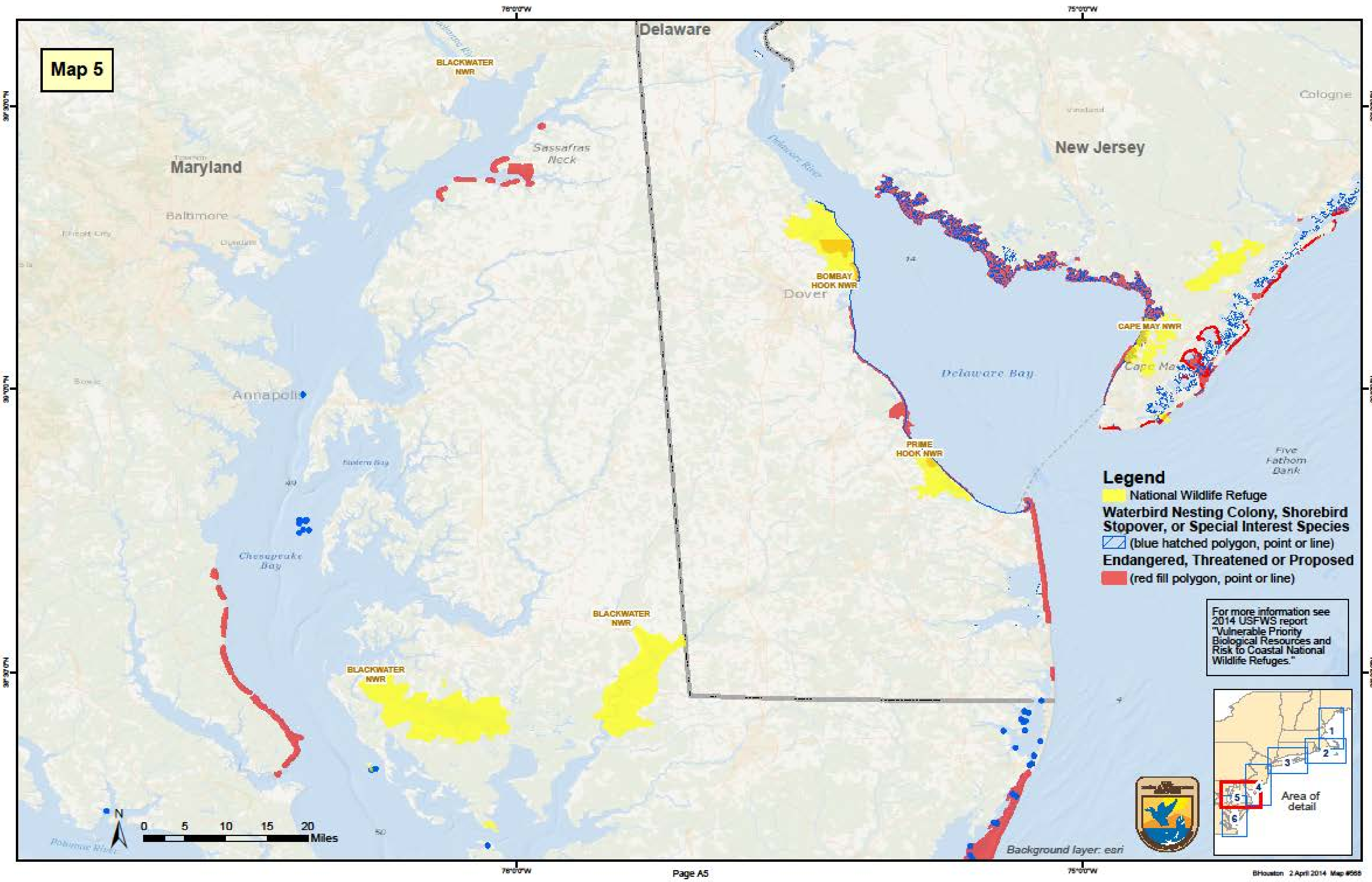
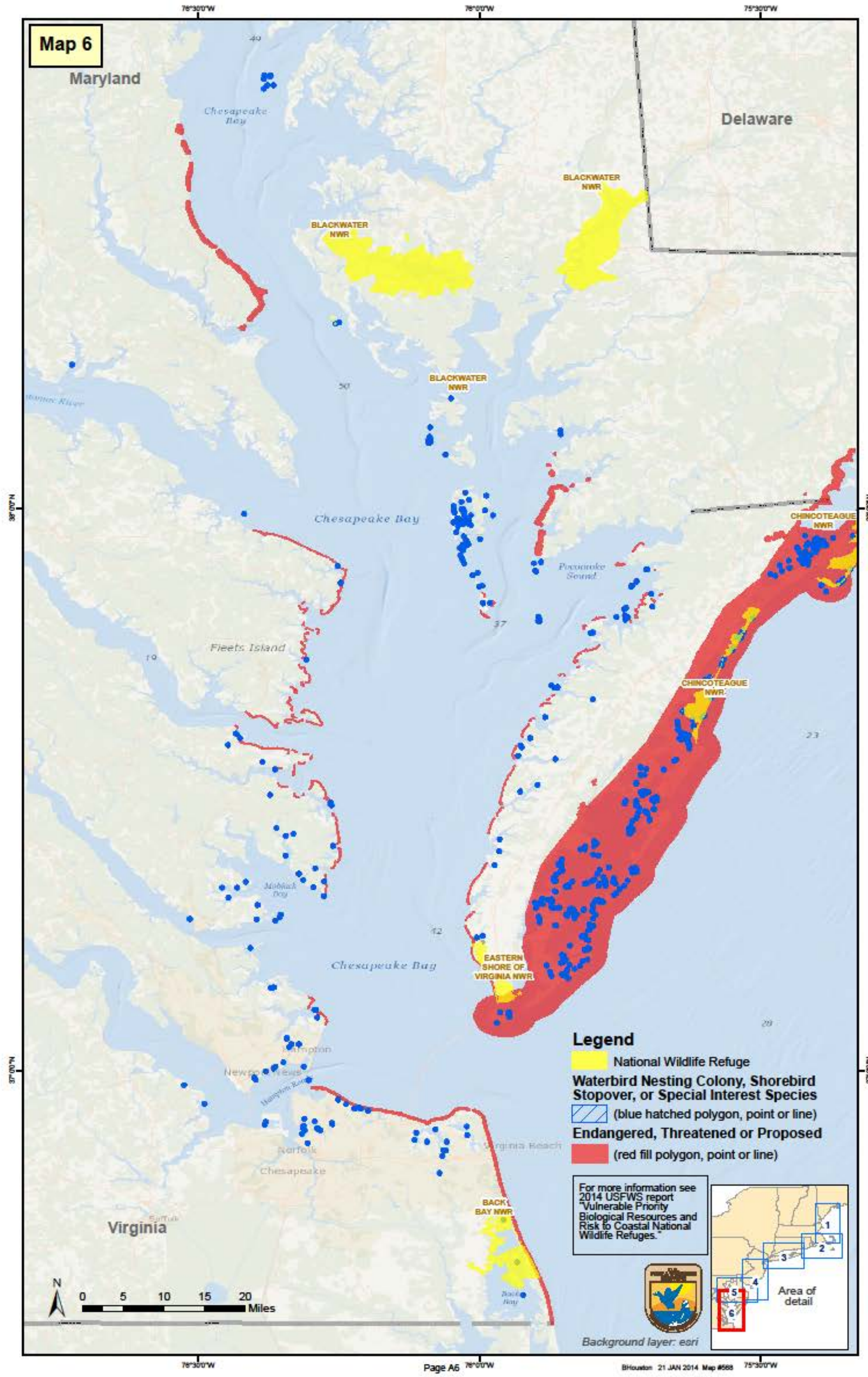
Area of detail
0 5 10 15 20 Miles
N
Page A3
BHouston 21 JAN 2014 Map #566



Map 4
Pennsylvania
New Jersey
New York
Delaware
Maryland
Trenton
Philadelphia
Cologne
Staten Island
Raritan Bay
Toms River
Delaware Bay
EDWIN B. FORSYTHE NWR
CAPE MAY NWR
PRIME HOOK NWR
Five Fathom Bank
Legend
National Wildlife Refuge
Waterbird Nesting Colony, Shorebird Stopover, or Special Interest Species
(blue hatched polygon, point or line)
Endangered, Threatened or Proposed
(red fill polygon, point or line)
For more information see 2014 USFWS report "Vulnerable Priority Biological Resources and Risk to Coastal National Wildlife Refuges."
Area of detail
Background layer: esri
0 5 10 15 20 Miles
75°0'0"W
74°30'0"W
74°0'0"W
40°0'0"N
39°0'0"N
Page A4
BHouston 2 April 2014 Map #568


Map 5
Delaware
Maryland
New Jersey
Baltimore
Annapolis
Dover
Cologne
Sassafras Neck
Chesapeake Bay
Delaware Bay
Delaware River
Cape May
Five Fathom Bank
BLACKWATER NWR
BOMBAY HOOK NWR
PRIME HOOK NWR
CAPE MAY NWR
Legend
National Wildlife Refuge
Waterbird Nesting Colony, Shorebird Stopover, or Special Interest Species
(blue hatched polygon, point or line)
Endangered, Threatened or Proposed
(red fill polygon, point or line)
For more information see 2014 USFWS report "Vulnerable Priority Biological Resources and Risk to Coastal National Wildlife Refuges."
Area of detail
Background layer: esri
0 5 10 15 20 Miles
N
76°0'0"W
75°0'0"W
Page A5



Map 6
Maryland
Delaware
Virginia
Chesapeake Bay
BLACKWATER NWR
BLACKWATER NWR
BLACKWATER NWR
CHINCOTEAGUE NWR
CHINCOTEAGUE NWR
EASTERN SHORE OF VIRGINIA NWR
BACK BAY NWR
Fleets Island
Pocomoke Sound
Chesapeake Bay
Chesapeake Bay
Newport News
Hampton
Norfolk
Chesapeake
Virginia Beach
Legend
National Wildlife Refuge
Waterbird Nesting Colony, Shorebird Stopover, or Special Interest Species
(blue hatched polygon, point or line)
Endangered, Threatened or Proposed
(red fill polygon, point or line)
For more information see 2014 USFWS report "Vulnerable Priority Biological Resources and Risk to Coastal National Wildlife Refuges."
Area of detail
1
2
3
4
5
6
Background layer: esri
0 5 10 15 20 Miles
N
76°30'0"W
76°0'0"W
75°30'0"W
38°0'0"N
37°0'0"N
Page A6
BHouston 21 JAN 2014 Map #566