EPA Contract Number EP-C-14-017

Work Assignment 1-14

Climate Change Vulnerabilities Scoping Report: Risks to Clean Water Act Goals in Habitats of the Northeast

Prepared for:

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January 15, 2016

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1 Purpose

The purpose of this scoping study is to raise awareness of risks to U.S. Environmental Protection Agency (EPA) goals associated with climate change and indicate where more analysis might be needed. This study synthesized and applied existing information to create a risk-based climate change vulnerability assessment to inform those managing coastal and marine habitats in the Northeast (NE) Study Area. The study utilized the analysis previously performed for Task 2, Risks to Clean Water Act goals in the Northeast, as the base from which to synthesize an analysis for eight coastal and marine habitat types in the NE Study Area:

1. Ocean Beach and Dune Ecosystem
2. Coastal Wetlands
3. Submerged Aquatic Vegetation
4. Oyster Reefs
5. Rock Reefs/Rocky Shorelines
6. Shallow Bay Habitat/Bay Islands
7. Terrestrial Upland
8. Floodplains/Riparian

The vulnerability assessment produced separate consequence/probability (C/P) matrices for each of the eight habitat types in the NE Study Area based on the results of the NE Study Area C/P matrices from Task 2, and on sources of information listed in Section 3. It is important to note that no other literature sources were reviewed as part of this study. A total of 16 C/P matrices were developed based on the eight habitat types listed above, and the two future time periods of 2050 and 2100.

2 Scope and Limitations of Study

In a companion study, potential climate change risks to the NE Study Area (Long Island to southern Maine) were identified or inferred from sources specified by the EPA: the National Climate Assessment (NCA) (Melillo et al., 2014) and NOAA (2013). Here, a similar approach, augmented by adopting an understanding of habitat type consistent with *North Atlantic Coast Comprehensive Study* (NACCS) (USACE, 2014), is applied to focus on coastal and marine habitats and define differences in climate change risk at this finer ecosystem scale as it compares to the NE Study Area. Expert knowledge and judgment supplemented by a review of the information in the specified sources were applied to the analysis of the eight habitat types specified (Ocean Beach and Dune Ecosystem; Coastal Wetlands; Submerged Aquatic Vegetation; Oyster Reefs; Rock Reefs/Rocky Shorelines; Shallow Bay Habitat/Bay Islands; Terrestrial Upland; Floodplains/Riparian). The experts made judgments as to the consequence (severity of impact) and likelihood (probability of occurrence) based on the specified sources of information listed in Section 3. It is important to note that no other literature sources were reviewed as part of this study. A consequence/probability (C/P) matrix was prepared for each habitat type and time period (2050 and 2100) and vetted by the team of experts to ensure logical consistency and consensus on the ratings of the matrices.

3 Sources of Information Used

Per direction from EPA, only the following data sources were reviewed and used to inform expert judgment in the development of the C/P matrices. Per EPA direction, information was not sought outside of these sources:

EPA. 2014. Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans. Climate Ready Estuaries, EPA Office of Water (http://www2.epa.gov/sites/production/files/2014-09/documents/being_prepared_workbook_508.pdf).

Melillo, J.M., T. Richmond, and G.W. Yohe, Eds. 2014. Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. (http://nca2014.globalchange.gov/downloads)

NOAA. 2013. NOAA Technical Report NESDIS 142-1, Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 1. Climate of the Northeast U.S. U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), Washington, D.C. (http://www.nesdis.noaa.gov/technical_reports/NOAA_NESDIS_Tech_Report_142-1-Climate_of_the_Northeast_U.S.pdf).

USACE 2014. North Atlantic Coast Comprehensive Study. Department of the Army, U.S. Army Corps of Engineers (USACE), Washington, D.C. (http://www.nad.usace.army.mil/compstudy)

4 Interpreting Findings

Professional judgment is useful for analysis where complex problems exist for which empirical studies are not feasible. Professional judgment as applied in this NE Study Area meant: (1) persons involved in making the judgment had academic credentials and experience necessary to support a claim of “expert”; (2) persons involved in making the judgment had knowledge of the relevant literature; and (3) concurrence existed among more than one expert to provide scientifically-credible answers.
The experts who contributed to the vulnerability analysis of coastal and marine habitat types in the NE Study Area included:

Dr. Kurt Philipp, Ph.D., Marine Sciences (Avatar Environmental). Credentials include being a Professional Wetland Scientist and former Professional Certification Board President. He has over 30 years of experience conducting wetlands investigations, particularly in wetlands restoration and creation, as well as delineation, mapping and the impact of hazardous waste. Dr. Philipp conducted his doctoral graduate research in salt and water relations of tidal marsh plants at the University of Delaware and conducted research in tidal marshes throughout the estuary. He has also provided historical and ecological characterizations in Estuarine Profiles - Delaware National Estuarine Research Reserve, Comprehensive Conservation and Management Plan for Delaware’s Tidal Wetlands, The ecology of freshwater tidal wetlands, History of Delaware and New Jersey salt marsh restoration sites, *Phragmites australis* expansion in Delaware Bay salt marshes, and presentations at conferences such as the Society of Wetland Scientists.

Chuck Dobroski, M.S., Marine Biology (Avatar Environmental). He is a co-founder and Principal of Avatar Environmental, and provides the technical direction and oversight of ecological programs as well as ecological and human health risk assessments for Avatar. He has over 35 years of providing ecological services in marine and estuarine environments for the government and private sector. Activities have included the technical development, management and performance of a diverse array of coastal and estuarine projects throughout the United States as well as overseas. Mr. Dobroski provides consulting support for biological monitoring of marine/estuarine fisheries; marine construction and dredging impacts; ocean outfalls; salt marsh, beach and dune restoration; submerged aquatic vegetation evaluations; intertidal and benthic ecology; blue water biology; and tropical/subtropical ecology. Water/sediment quality and hydrographic investigations in marine and estuarine habitats have included evaluation of thermal plumes using standard techniques as well as remote sensing, tracer studies for ocean outfalls; nutrient chemistry and evaluation, chemical contaminant characterization; and dissolved oxygen reduction in poorly circulating marinas and embayments.

John Licsko, M.Sc., Water Resource Engineering (Avatar Environmental). During his 20-year career, John Licsko has been a technical and management lead for the application and review of hydrologic & hydraulic procedures for floodplain, interior drainage, dam, transportation and stream restoration studies and designs, across the U.S., including New York, New Jersey, Virginia, and Maryland. Currently, he serves as a senior engineer and project manager with Dewberry's joint venture with URS Corporation for the Production and Technical Services contract with FEMA, which includes development of floodplain studies in FEMA Regions II, III, and IV. His work has included the development and review of engineering models, such as HEC-HMS, HEC-RAS (Steady and Unsteady State), XP-SWMM (1D & 2D), EPA SWMM, and FLO-2D in support of flood insurance studies, appeals, and Letter Of Map Change (LOMC) requests. Prior to 2009, John worked within Dewberry's Water Resources Department developing and managing water quality monitoring programs to meet National Pollutant Discharge Elimination System (NPDES) requirements for local municipalities and agencies. John also completed hydrologic and hydraulic models for dam, transportation, and stream restoration projects, primarily in Virginia and Maryland.

Harry Stone, Ph.D. (ecology), M.S. (plant physiology), M.B.A. (Battelle). Dr. Stone is a Senior Research Scientist. He is a Certified Senior Ecologist (Ecological Society of America) with more than 25 years of project management experience. Recent work includes leading a team of experts in the evaluation of models applicable to prediction of algal blooms in Lake Erie on an EPA project and modeling the likelihood of observing pollution intolerant fish communities in the Ohio Interior Low Plateau Ecoregion. Recently for the US Army Corps of Engineers, he provided technical leadership for the evaluation of climate change impacts on ecosystem services in the Ohio River Basin and corresponding adaptation strategies.

4.1 Assumptions and Guidelines

An analysis was performed to elucidate the likelihood of risk using a "future without action" or "business as usual" scenario for two time periods (the years 2050 and 2100). Planned actions were not considered in the risk analysis.

Outcomes that were judged to be zero risk, per EPA direction, were categorized as low consequence and low probability. Only coral reef impacts were not evaluated because there are no coral reefs in the NE Study Area.

The criteria for selecting high, medium, and low risk values were vetted by the team of experts prior to beginning the analysis. Consensus was reached with the team of experts during a teleconference on September 10, 2015 establishing the following orders of magnitude rating guide for assigning risk.
The probability (likelihood) of occurrence was rated using the following guideline:

- If confidence level is “Very High (strong evidence and scientific consensus)” or “High” (moderate evidence from multiple sources, medium consensus) – probability (likelihood) of occurrence is rated “high”.
- If confidence level is “Medium” (suggestive evidence, limited consensus, competing schools of thought) – probability (likelihood) of occurrence is rated “medium”.
- If confidence level is “Low” (inconclusive, limited evidence, disagreement or lack of opinions among experts) – probability (likelihood) of occurrence is rated “low”.

The consequence of impact was rated using the following guideline:

- High if
    - Spatial extent is large and/or
    - More than roughly 1 million people impacted and/or
    - More than roughly $1 billion impact and/or
    - Significant impacts on critical habitat.
- Medium if
    - Spatial extent is place or region and/or
    - More than roughly 10,000 people impacted and/or
    - More than roughly $1 million impact and/or
    - Some critical habitat impacted.
- Low if
    - Spatial extent is one or a few sites and/or
    - Less than roughly 1,000 people impacted and/or
    - Less than roughly $1 million impact.

During the study, it was found that the above quantitative criteria were not directly usable for numerous situations owing to lack of data. For multiple situations, data was not available / complete. To assign a scientifically-informed consequence for the above, engineering judgement was used to assign a rank higher than low, if appropriate, following discussions between the experts of related disciplines.

For this assessment, ecological consequences were rated based the implied effect on the specific Clean Water Goals to be achieved and the severity of the effect:

Habitat:

- Severity - loss of habitat, modification of habitat, or shifting of habitat,
- Sensitivity or ecological importance of habitat,
- Spatial Scale - regional/sub-regional vs local,
- Potential for recovery – permanent loss or temporary loss, restoration possible,
- others

Fish, Wildlife, and Plants:

- Level of biological organization – Community, population, individual (threatened/endangered species)
- Spatial scale of effect regional versus sub-regional versus local
- Effect on survival, maintenance, reproductive capacity of species

- Effect on trophic structure
- Commercial fishery
- Others

All values should be considered approximate order of magnitude, not absolutes.

4.2 Consequence/Probability (C/P) Matrix

The C/P matrix is a risk management tool for sorting risks based on their likelihoods and consequences of the occurrence of a specific impact. The approach used to develop the C/P matrices is found in EPA's *Being Prepared for Climate Change Workbook* – Step 5 (EPA 2014).

After reviewing the specified sources of information, expert judgment was used to assign a likelihood rating and a consequence rating for each potential impact. The potential impact was added to the appropriate cell in the corresponding C/P matrix. Figure 1 provides an example of a C/P matrix with a single impact ("Jellyfish may be more common") added to the matrix. In this example, a medium consequence and a low probability rating [for illustration only] assigns this impact to a "green" cell, i.e. a cell with a low risk. Any combinations of low and medium ratings for consequence and likelihood results in an overall low risk rating. Any combination of medium/medium or low/high ratings for consequence and likelihood results in a "yellow" or overall medium risk rating. Any combination of medium/high or high/high ratings for consequence and likelihood results in a "red" or overall high risk rating.

The experts applied their knowledge and judgment and the existing information specified in the Quality Assurance Project Plan (QAPP) to analyze all four risk identification checklists (pollution control; habitat; fish, wildlife, and plants; recreation and public water supplies) of the NCA. Each checklist contains two to three Clean Water Act goals that may be affected by seven listed climate change stressors. Overall each checklist contains approximately 30 items that were assessed with regard to consequence (severity of impact) and likelihood (probability of occurrence). High/medium/low consequence rating and high/medium/low probability rating was applied to each potential impact in the checklists. Spreadsheets developed by the expert team were used to capture the ratings, sources of information supporting the ratings, and to generate the C/P matrices. These are submitted separately to the EPA.

Probability (Likelihood) of Occurrence	**High**	Yellow (Medium Risk)	Red (High Risk)	Red (High Risk)
	Medium	Green (Low Risk)	Yellow (Medium Risk)	Red (High Risk)
	Low	Green (Low Risk)	*Jellyfish may be more common* Green (Low Risk)	Yellow (Medium Risk)
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 1. Consequence/probability matrix with illustrative example.

[EPA is developing an online tool that can be used in conjunction with *Being Prepared for Climate Change: A Workbook for Developing Risk-Based Adaptation Plans* to generate C/P matrices. The beta version of the tool was considered for use in this study. EPA provided training on the tool to the team of experts. However, because the tool was expected to be unavailable during critical times in the study, the beta version of the tool was not used.].

5 Results

The following sections provide the C/P matrices that were generated as described above.

5.1 Ocean Beach and Dune Ecosystem

The risks to EPA goals associated with the ocean beach and dune ecosystem NE Study Area by 2050 are shown in the matrix in Figure 2. The potential increase in storminess and sea level rise appear to pose the greatest risk to this habitat type by 2050 through an increase in erosion, over washing and inundation. There is less apparent risk associated with an increase in drought conditions and warmer seasons.

Likelihood of Occurrence	Low (Consequence of Impact)	Medium (Consequence of Impact)	High (Consequence of Impact)
High		1. Increasing Storminess - Intense storms and associated storm surge will increase the likelihood of new temporary or permanent inlet development. 2. Increasing Storminess - Storm surge and the resulting beach and dune erosion will result in lowering of beach elevation. 3. Sea Level Rise - Beaches and dunes that currently lie adjacent to developed land will not be able to migrate landward resulting in loss of beach and dune habitat. 4. Sea Level Rise - Beaches and barrier islands may be degraded or lost by increased flooding frequency associated with sea level rise.	1. Increasing Storminess - An increase in intense coastal storms (i.e., nor'easters and hurricanes) may result in significant beach erosion and the reduction, or loss of coastal dunes with associated habitat loss for plants and wildlife. 2. Increasing Storminess - High winds and associated storm surge may result in the breaching or over wash of barrier islands. 3. Sea Level Rise - Barrier beaches will be more susceptible to erosion and overwash, and in some cases, breaching and inlet formation.
Medium		1. Increasing Storminess - Intense storms may result in significant damage or loss of coastal/maritime forest community of the barrier islands. 2. Warmer Summers - Dune or beach species that cannot tolerate warmer summers may die or migrate. Biota at the southern limit of their range may disappear from beach/dune ecosystem. 3. Warmer Summers - Warmer summers may result in the promotion of invasive species and disease.	1. Increasing Storminess - Erosion of beaches and dunes will leave back-bay wetland habitat vulnerable to inundation from winter storms and high tides.
Low	1. Warmer Winters - Marshes and beaches may erode from loss of protecting ice.	1. Increasing Drought - Increased drought may result in the potential degradation or loss of habitat to plant and animal species including migratory birds. 2. Increasing Drought - Increased drought may result in the potential degradation or loss of dune vegetation as well as adverse impact to maritime forest community on barrier islands. 3. Warmer Summers - Essential food sources may die-off or disappear affecting beach and dune ecology. 4. Warmer Winters - Species that once migrated through may stop and stay through winter.	

Figure 2. Ocean Beach and Dune Ecosystem 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with the ocean beach and dune ecosystem NE Study Area by 2100 are shown in the matrix in Figure 3. The high risks identified for this habitat type by 2050 are expected to be present in 2100. There is also an expected shift of low moderate risks identified for 2050 to move into the higher risk categories for 2100.

Likelihood of Occurrence	Low	Medium	High
High		1. Increasing Storminess - Intense storms and associated storm surge will increase the likelihood of new temporary or permanent inlet development.	1. Increasing Storminess - An increase in intense coastal storms (i.e., nor'easters and hurricanes) may result in significant beach erosion and the reduction, or loss of coastal dunes with associated habitat loss for plants and wildlife. 2. Increasing Storminess - Erosion of beaches and dunes will leave back-bay wetland habitat vulnerable to inundation from winter storms and high tides. 3. Increasing Storminess - High winds and associated storm surge may result in the breaching or over wash of barrier islands. 4. Increasing Storminess - Storm surge and the resulting beach and dune erosion will result in lowering of beach elevation. 5. Sea Level Rise - Barrier beaches will be more susceptible to erosion and overwash, and in some cases, breaching and inlet formation. 6. Sea Level Rise - Beaches and dunes that currently lie adjacent to developed land will not be able to migrate landward resulting in loss of beach and dune habitat. 7. Sea Level Rise - Beaches and barrier islands may be degraded or lost by increased flooding frequency associated with sea level rise.
Medium		1. Increasing Storminess - Intense storms may result in significant damage or loss of coastal/maritime forest community of the barrier islands. 2. Warmer Summers - Dune or beach species that cannot tolerate warmer summers may die or migrate. Biota at the southern limit of their range may disappear from beach/dune ecosystem. 3. Warmer Summers - Essential food sources may die-off or disappear affecting beach and dune ecology. 4. Warmer Summers - Warmer summers may result in the promotion of invasive species and disease. 5. Warmer Winters - Species that once migrated through may stop and stay through winter.	
Low	1. Warmer Winters - Marshes and beaches may erode from loss of protecting ice.	1. Increasing Drought - Increased drought may result in the potential degradation or loss of habitat to plant and animal species including migratory birds. 2. Increasing Drought - Increased drought may result in the potential degradation or loss of dune vegetation as well as adverse impact to maritime forest community on barrier islands	
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 3. Ocean Beach and Dune Ecosystem 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.2 Coastal Wetlands

The risks to EPA goals associated with coastal wetland habitat in the NE Study Area by 2050 are shown in the matrix in Figure 4. Habitat damage or loss caused by increasing storminess, sea level rise and warmer water are the high risk concerns by 2050.

Likelihood of Occurrence	High		1. Sea Level Rise - An increase in the rate of sea level rise will result in significant loss of coastal salt marsh habitat. 2. Increasing Storminess - Coastal overwash or barrier island breaching may result in a smothering of back-bay marshes by migrating beach sand and dunes. 3. Increasing Storminess - Increased frequency and intensity of coastal storms will impair coastal wetlands through wind, wave and surge effects. 4. Increasing Storminess - Increased shoreline erosion may lead to loss of coastal wetlands and marshes. 5. Sea Level Rise - An increase in sea-level will lead to greater susceptibility to storm surge. Shoreline erosion is likely to lead to loss of wetlands and salt marshes. 6. Sea Level Rise - As sea level rises, salinity migration farther up the estuary and tidal tributaries is likely to result in an upstream migration of brackish and fresh water wetlands. 7. Sea Level Rise - As sea level rises, salt marshes will migrate inland. The ability to migrate will be affected in locations where man-made structures, e.g., bulkheads, interfere with migration. 8. Sea Level Rise - If the rate of sea level rise increases dramatically, salt marshes may not be able to match the change in vertical elevation and will be lost. 9. Sea Level Rise - In low energy shores with ample sediment supply, intertidal flats may become vegetated as low marsh encroaches seaward. This may increase low marsh at the expense of tidal flats. 10. Sea Level Rise - In some cases where tidal range increases with increased rates of sea-level rise, there may be an overall increase in the acreage of tidal flats. 11. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease. 12. Warmer Winters - Warmer winter temperatures may promote the northern migration of southern species. 13. Warmer Summers - Warmer summer are likely to promote the northern migration of southern invasive species. 14. Warmer Water - Depending on the temperature increase, warmer waters may alter species composition of the coastal wetlands due to exceedance of temperature tolerance. 15. Warmer Winters - Warmer winters may facilitate the survival of invasive species, epizootics, and disease.	1. Sea Level Rise - Bulkheads, sea walls and revetments are likely to become more widespread.

Likelihood of Occurrence		Low	Medium	High
	Medium	1. Warmer Summers - Warmer summers leading to increased temperatures are likely to lead to reduced high marsh moisture and increased salinity because of greater evapotranspiration. 2. Warmer Winters - The alteration in the amplitude and timing of the annual spring freshets may adversely impact freshwater and brackish water wetlands.	1. Warmer Summers - Wetland species that can't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems.	
	Low	1. Ocean Acidification - Changes in surface water pH may affect the viability of certain marsh species. 2. Increased Drought - A decrease in precipitation events may adversely impact coastal wetlands by reducing the supply of sediment necessary to sustain marsh elevation. 3. Increased Drought - A significant decrease in precipitation is likely to result in deceased marsh productivity. 4. Increased Drought - A decrease in precipitation may lead to the oxidation and formation of highly saline marsh soils. Hypersaline conditions on the high marsh will decreasing marsh production and habitat support. 5. Increasing Storminess - Increased nutrient loads from watershed runoff and flooding may increase the vulnerability of tidal marshes. 6. Warmer Waters - Warmer waters may alter the salinity distribution in marshes which may, in turn, alter the species composition due to exceedance of salinity tolerance. 7. Warmer Winters - Marshes and beaches may erode from loss of protecting ice.		
		Low	Medium	High
		Consequence of Impact		

Figure 4. Coastal Wetlands 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with coastal wetland habitat in the NE Study Area by 2100 are shown in the matrix in Figure 5. Habitat damage or loss caused by sea level rise and warmer water continue to be the high risk concerns by 2100.

Likelihood of Occurrence	**High**		1. Sea Level Rise - -An increase in the rate of sea level rise will result in significant loss of coastal salt marsh habitat. 2. Increasing Storminess - Coastal overwash or barrier island breaching may result in a smothering of back-bay marshes by migrating beach sand and dunes. 3. Increasing Storminess - Increased frequency and intensity of coastal storms will impair coastal wetlands through wind, wave and surge effects. 4. Increasing Storminess - Increased shoreline erosion may lead to loss of coastal wetlands and marshes. 5. Sea Level Rise - An increase in sea-level will lead to greater susceptibility to storm surge. Shoreline erosion is likely to lead to loss of wetlands and salt marshes. 6. Sea Level Rise - As sea level rises, salinity migration farther up the estuary and tidal tributaries is likely to result in an upstream migration of brackish and fresh water wetlands. 7. Sea Level Rise - As sea level rises, salt marshes will migrate inland. The ability to migrate will be affected in locations where man-made structures, e.g., bulkheads, interfere with migration. 8. Sea Level Rise - If the rate of sea level rise increases dramatically, salt marshes may not be able to match the change in vertical elevation and will be lost. 9. Sea Level Rise - In low energy shores with ample sediment supply, intertidal flats may become vegetated as low marsh encroaches seaward. This may increase low marsh at the expense of tidal flats. 10. Sea Level Rise - In some cases where tidal range increases with increased rates of sea-level rise, there may be an overall increase in the acreage of tidal flats. 11. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease. 12. Warmer Winters - Warmer winter temperatures may promote the northern migration of southern species. 13. Warmer Summers - Warmer summer are likely to promote the northern migration of southern invasive species. 14. Warmer Summers - Wetland species that can't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems. 15. Warmer Water - Depending on the temperature increase, warmer waters may alter species composition of the	1. Sea Level Rise - Bulkheads, sea walls and revetments are likely to become more widespread.

Likelihood of Occurrence		Low	Medium	High
			coastal wetlands due to exceedance of temperature tolerance. 16. Warmer Winters - Warmer winters may facilitate the survival of invasive species, epizootics, and disease.	
	Medium	1. Warmer Summers - Warmer summers leading to increased temperatures are likely to lead to reduced high marsh moisture and increased salinity because of greater evapotranspiration. 2. Warmer Winters - The alteration in the amplitude and timing of the annual spring freshets may adversely impact freshwater and brackish water wetlands.		
	Low	1. Ocean Acidification - Changes in surface water pH may affect the viability of certain marsh species. 2. Increased Drought - A decrease in precipitation events may adversely impact coastal wetlands by reducing the supply of sediment necessary to sustain marsh elevation. 3. Increased Drought - A significant decrease in precipitation is likely to result in deceased marsh productivity. 4. Increased Drought - A decrease in precipitation may lead to the oxidation and formation of highly saline marsh soils. Hypersaline conditions on the high marsh will decreasing marsh production and habitat support. 5. Increasing Storminess - Increased nutrient loads from watershed runoff and flooding may increase the vulnerability of tidal marshes. 6. Warmer Waters - Warmer waters may alter the salinity distribution in marshes which may, in turn, alter the species composition due to exceedance of salinity tolerance. 7. Warmer Winters - Marshes and beaches may erode from loss of protecting ice.		
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 5. Coastal Wetlands 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.3 Submerged Aquatic Vegetation

The risks to EPA goals associated with submerged aquatic vegetation (SAV) in the NE Study Area by 2050 are shown in the matrix in Figure 6. Habitat damage or loss caused by increasing storminess, sea level rise and warmer water are the high risk concerns by 2050.

Likelihood of Occurrence	Consequence of Impact: Low	Consequence of Impact: Medium	Consequence of Impact: High
High		1. Increasing Storminess -Greater soil erosion will increase turbidity and decrease water clarity. 2. Sea Level Rise - 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. 3. Sea Level Rise - Increased overwash and breaching of barrier islands could negatively impact local SAV populations (e.g., eelgrass) by smothering. As sea level rises, however, the inundation of shorelines could create new SAV habitat. 4. Sea Level Rise - Shifts in salinity regime will affect the distribution of SAV. 5. Warmer Summers - Warmer summers may lead to latitudinal migration of SAV spp. 6. Warmer Winters - Warmer winters may lead to latitudinal expansion of invasive SAV spp.	1. Warmer Summers - Warmer summers may lead to warmer coastal water; possibly exceeding SAV temperature tolerance. 2. Warmer Summers - Warmer summers may result in the latitudinal expansion of invasive species and disease. 3. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine epizootics and disease (eelgrass wasting disease).
Medium	1. Increasing Storminess - Stronger storms will cause more intense flooding and runoff potentially increasing nutrient loads (nitrogen, phosphorus) resulting in eutrophication.	1. Warmer Winters - Warmer winters may result in asynchrony of vegetative growth and bird migrations.	1. Increasing Storminess - Depending on depth of bed, increased wave action may severely damage SAV beds. 2. Warmer Water - Certain species of submerged aquatic vegetation are sensitive to large fluctuations in water temperature. Warmer water may exceed tolerance of some SAV species resulting in the loss of SAV habitat.
Low	1. Ocean Acidification - Increased acidification may exceed the pH tolerance of some SAV species.	1. Increasing Drought - Potential decrease in freshwater runoff could result in salinity changes that could affect the propagation and growth of SAV. 2. Sea Level Rise - Sea level rise may pose significant threats to SAV habitat due to potential implications of increased water depth and reduction in light penetration.	
	Low	**Medium**	**High**
		Consequence of Impact	

Figure 6. Submerged Aquatic Vegetation 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with submerged aquatic vegetation in the NE Study Area by 2100 are shown in the matrix in Figure 7. The high risk concerns by 2100 are similar to those in 2050 while risk concerns previously associated with the lower categories in the 2050 time frame have generally shifted to higher categories.

	Low	Medium	High
		1. Increasing Storminess - Greater soil erosion will increase turbidity and decrease water clarity. 2. Sea Level Rise - 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. 3. Sea Level Rise - Increased overwash and breaching of barrier islands could negatively impact local SAV populations (e.g., eelgrass) by smothering. As sea level rises, however, the inundation of shorelines could create new SAV habitat. 4. Warmer Summers - Warmer summers may lead to latitudinal migration of SAV spp. 5. Warmer Winters - Warmer winters may lead to latitudinal expansion of invasive SAV spp. 6. Warmer Winters - Warmer winters may result in asynchrony of vegetative growth and bird migrations.	1. Increasing Storminess - Depending on depth of bed, increased wave action may severely damage SAV beds. 2. Sea Level Rise - Shifts in salinity regime will affect the distribution of SAV. 3. Warmer Summers - Warmer summers may result in the latitudinal expansion of invasive species and disease. 4. Warmer Summers - Warmer summers may lead to warmer coastal water; possibly exceeding SAV temperature tolerance. 5. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine epizootics and disease (eelgrass wasting disease).
Medium		1. Increasing Drought - Potential decrease in freshwater runoff could result in salinity changes that could affect the propagation and growth of SAV. 2. Increasing Storminess - Stronger storms will cause more intense flooding and runoff potentially increasing nutrient loads (nitrogen, phosphorus) resulting in eutrophication. 3. Ocean Acidification - Increased acidification may exceed the pH tolerance of some SAV species.	1. Warmer Water - Certain species of SAV are sensitive to large fluctuations in water temperature. Warmer water may exceed tolerance of some SAV species resulting in the loss of SAV habitat.
Low		1. Sea Level Rise - Sea Level Rise may pose significant threats to SAV habitat due to potential implications of increased water depth and reduction in light penetration.	
	Consequence of Impact		

Figure 7. Submerged Aquatic Vegetation 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.4 Oyster Reefs

The risks to EPA goals associated with oyster reef habitat in the NE Study Area by 2050 are shown in the matrix in Figure 8. Two high risk impacts associated with increasing drought and warmer water were identified, while the majority of potential impacts to this habitat were identified as medium risks concerns.

Likelihood of Occurrence	High		1. Increasing Drought - Increase in water temperature and decrease flow during periods of drought may lead to harmful algal blooms some of which may be deleterious to oysters (e.g., cyanobacteria). 2. Warmer Water - Warmer water is likely to lead to an expansion of epizootics (MSX, Dermo) and invasive species.	
	Medium	1. Sea Level Rise - Changes in the salinity regime is; likely to change the distribution of shellfish habitat. 2. Warmer Water - Temperature changes could include changes in predator populations and natural food assemblages which could influence shellfish quality and survival.	1. Increasing Drought - Increase in water temperature leading to an increase in areas of hypoxia. 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with potential for smothering nascent reefs or shell substrate required for setting. 3. Increasing Storminess - Habitat conditions for shellfish could be impacted by strong storms and increased frequency of rain events which can result in increased sedimentation. 4. Increasing Storminess - Increase freshwater events can lead to decreases in salinity which could affect the distribution of shellfish. 5. Ocean Acidification - Long Term shellfish sustainability may be an open question. 6. Ocean Acidification - Oysters and other mollusks may be adversely affected during development stages which construct calcareous shells through pH-sensitive calcification processes. 7. Sea Level Rise - An increase in salinity would promote the upstream migration of shellfish epizootics and disease. 8. Sea Level Rise - Sea level rise could reduce the availability of intertidal habitat thereby limiting the available habitat for some species such as oysters and blue mussels. 9. Sea Level Rise - An increase in salinity may affect the growth and propagation of oysters. 10. Warmer Summers - Warm summers will lead to warmer waters that may promote invasive species, epizootics (Dermo, MSX), or disease. 11. Warmer Water - Increased water temperature could affect reproduction and growth of oysters. 12. Warmer Water - increased water temperatures may affect the spawning of oysters which in turn may result in asynchrony between larval development and food supply. 13. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease.	

	Low	1. Increasing Storminess - Increased storminess may exacerbate exposure to pathogens from increased turbidity runoff and partially treated or untreated sewage overflows from storm events. 2. Warmer Water - Increased water temperature may result in dissolved oxygen levels sufficiently low to stress oysters. 3. Warmer Winters - Warmer winters may affect the reproduction and growth of oysters.	1. Increasing Drought - Increase in drought could reduce freshwater inflow and affect the salinity regime which may affect the distribution of the oyster reefs. 2. Warmer Summers - Warm summers will lead to warmer waters that may result in temperature stress to oysters. 3. Warmer Winters - Invasive species, epizootics, and disease previously killed due to cold water may survive.	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 8. Oyster Reef 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with oyster reef habitat in the NE Study Area by 2100 are shown in the matrix in Figure 9. The risks identified for this habitat type by 2100 are similar to those previously identified for 2050.

Likelihood of Occurrence	High		1. Increasing Drought - Increase in water temperature and decrease flow during periods of drought may lead to harmful algal blooms some of which may be deleterious to oysters (e.g., cyanobacteria). 2. Warmer Water - Warmer water is likely to lead to an expansion of epizootics (MSX, Dermo) and invasive species.	
	Medium	1. Sea Level Rise - Changes in the salinity regime is; likely to change the distribution of shellfish habitat. 2. Warmer Water - Temperature changes could include changes in predator populations and natural food assemblages which could influence shellfish quality and survival.	1. Increasing Drought - Increase in water temperature leading to an increase in areas of hypoxia. 2 .Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with potential for smothering nascent reefs or shell substrate required for setting. 3. Increasing Storminess - Habitat conditions for shellfish could be impacted by strong storms and increased frequency of rain events which can result in increased sedimentation. 4. Increasing Storminess - Increase freshwater events can lead to decreases in salinity which could affect the distribution of shellfish. 5. Ocean Acidification - Long Term shellfish sustainability may be an open question. 6. Ocean Acidification - Oysters and other mollusks may be adversely affected during development stages which construct calcareous shells through pH-sensitive calcification processes. 7. Sea Level Rise - An increase in salinity would promote the upstream migration of shellfish epizootics and disease. 8. Sea Level Rise - Sea level rise could reduce the availability of intertidal habitat thereby limiting the available habitat for some species such as oysters and blue mussels. 9. Sea Level Rise - An increase in salinity may affect the growth and propagation of oysters. 10. Warmer Summers - Warm summers will lead to warmer waters that may promote invasive species, epizootics (Dermo, MSX), or disease. 11. Warmer Water - Increased water temperature could affect reproduction and growth of oysters. 12. Warmer Water - increased water temperatures may affect the spawning of oysters which in turn may result in asynchrony between larval development and food supply. 13. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease.	
		pathogens from increased turbidity runoff	and affect the salinity regime which	

		and partially treated or untreated sewage overflows from storm events. 2. Warmer Water - Increased water temperature may result in dissolved oxygen levels sufficiently low to stress oysters. 3. Warmer Winters - Warmer winters may affect the reproduction and growth of oysters.	may affect the distribution of the oyster reefs. 2. Warmer Summers - Warm summers will lead to warmer waters that may result in temperature stress to oysters. 3. Warmer Winters - Invasive species, epizootics, and disease previously killed due to cold water may survive.	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 9. Oyster Reef 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.5 Rock Reefs and Shorelines

The risks to EPA goals associated with rock reef and shoreline habitat in the NE Study Area by 2050 are shown in the matrix in Figure 10. Habitat damage or loss caused by sea level rise and warmer water are the high risk concerns by 2050.

Likelihood of Occurrence	Low (Consequence of Impact)	Medium (Consequence of Impact)	High (Consequence of Impact)
High		1. Sea Level Rise - Littoral zone biota are likely to respond to changing tide heights by shifting vertically where shoreline topography allows it. 2. Sea Level Rise - Loss or compression of intertidal habitat will alter the vertical zonation of the species which utilize this habitat. 3. Sea Level Rise - Rocky shorelines, especially intertidal and shallow water rocky habitat could become totally or partially inundated. Intertidal rock habitat may be lost or compressed and no longer available as intertidal habitat. 4. Warmer Water - Warmer coastal waters may result in a northward shift in rocky intertidal communities of plants and animals at their southern limit. 5. Warmer Water - Warmer waters may result in the colonization of rocky reefs and shorelines by southern species.	
Medium	1. Sea Level Rise - Shallow intertidal pools may become entirely submerged and intertidal habitat lost. 2. Warmer Winters - The ecological benefit of ice scour on rocky shorelines would be lost or reduced.	1. Increasing Storminess - An increase in strength and frequency of wave action may adversely affect associated invertebrates upon which multiple wildlife species forage. 2. Increasing Storminess - An increase in strength and frequency of wave action may adversely affect seaweed growing in rocky intertidal zones. 3. Increasing Storminess - In combination with Sea Level Rise, increased frequency and intensity of wave action, will result in erosion of sedimentary rock bluffs. 4. Ocean Acidification - Lowering of pH in adjacent coastal waters would affect the developmental calcification of shells by larval molluscs that might inhabit rocky shorelines i.e., barnacles, mussels, oysters.	
Low	1. Increasing Drought - Reduced precipitation and increased air temperature may result in stress to upper strata biota. 2. Sea Level Rise - Inundation periods of rock platforms may change altering habitat use. 3. Warmer Summers - Increased air temperatures may affect the survivability of some intertidal species.		

Figure 10. Rock Reefs and Shorelines 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with rock reef and shoreline habitat in the NE Study Region by 2100 are shown in the matrix in Figure 11. The risks identified for this habitat type by 2100 are similar to those previously identified for 2050.

Likelihood of Occurrence	Low (Consequence of Impact)	Medium (Consequence of Impact)	High (Consequence of Impact)
High		1. Sea Level Rise - Littoral zone biota are likely to respond to changing tide heights by shifting vertically where shoreline topography allows it. 2. Sea Level Rise - Loss or compression of intertidal habitat will alter the vertical zonation of the species which utilize this habitat. 3. Sea Level Rise - Rocky shorelines, especially intertidal and shallow water rocky habitat could become totally or partially inundated. Intertidal rock habitat may be lost or compressed and no longer available as intertidal habitat. 4. Warmer Water - Warmer coastal waters may result in a northward shift in rocky intertidal communities of plants and animals at their southern limit. 5. Warmer Water - Warmer waters may result in the colonization of rocky reefs and shorelines by southern species.	
Medium	1. Sea Level Rise - Shallow intertidal pools may become entirely submerged and intertidal habitat lost. 2. Warmer Winters - The ecological benefit of ice scour on rocky shorelines would be lost or reduced.	1. Increasing Storminess - An increase in strength and frequency of wave action may adversely affect associated invertebrates upon which multiple wildlife species forage. 2. Increasing Storminess - An increase in strength and frequency of wave action may adversely affect seaweed growing in rocky intertidal zones. 3. Increasing Storminess - In combination with Sea Level Rise, increased frequency and intensity of wave action, will result in erosion of sedimentary rock bluffs. 4. Ocean Acidification - Lowering of pH in adjacent coastal waters would affect the developmental calcification of shells by larval molluscs that might inhabit rocky shorelines i.e., barnacles, mussels, oysters.	
Low	1. Increasing Drought - Reduced precipitation and increased air temperature may result in stress to upper strata biota. 2. Sea Level Rise - Inundation periods of rock platforms may change altering habitat use. 3. Warmer Summers - Increased air temperatures may affect the survivability of some intertidal species.		

Figure 11. Rock Reefs and Shorelines 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.6 Shallow Bay Habitat/Bay Islands

The risks to EPA goals associated with shallow bay and bay island habitat in the NE Study Area by 2050 are shown in the matrix in Figure 12. Habitat damage or loss caused by sea level rise and warmer water, and ocean acidification are the high risk concerns for this habitat type by 2050.

			1. Increasing Storminess - Increasing overwash and breaching of new inlets could potentially change the physical and environmental characteristics of the bays such as, flushing rates, salinity, light penetration and nutrient dynamics. 2. Increasing Storminess - Increased storminess will result in increased erosion of shallow bay shorelines. 3. Sea Level Rise - Some bay islands may become completely or almost completely submerged. 4. Sea Level Rise - Depth of waters in shallow bay habitat may be expected to increase as the sea rises potentially affecting coastal bay wetlands and shorelines. 5. Sea Level Rise - Hardening of shorelines with bulkheads, sea walls and revetments may become more widespread resulting in the loss of natural shoreline habitats and decreased water quality. 6. Sea Level Rise - Sea Level rise in conjunction with increased tidal amplitude will result in increased erosion of shallow bay shorelines. 7. Sea Level Rise - Sea level rise may change the salinity regime of the inland bays thereby affecting the distribution of salinity-sensitive flora and fauna. 8. Warmer Summers - Increased water temperature may increase areas of hypoxia in shallow embayments. 9. Warmer Summers -Finfish species at the southern end of their distribution may migrate northward. 10. Warmer Water - Desired fish may no longer be present. 11. Warmer Water - Warmer water is likely to lead to an expansion of invasive species, epizootics, and disease. 12. Warmer Water - Warmer water is likely to promote the migration of current fish species northward and immigration of fish from southern regions.	
	Medium	1. Warmer water will decrease oxygen solubility possibly resulting in a decrease in oxygen concentrations in bay waters.	1. Increasing Drought - An increase in long-term and seasonal short-term drought may decrease freshwater flow and affect the salinity distribution in the bays. 2. Increasing Drought - Increased drought may result in waters sufficiently warm to promote areas of hypoxia. 3. Increasing Drought - Increased drought may result in waters sufficiently warm to promote harmful algal blooms.	1. Ocean Acidification - The effect of embayment acidification on calcifying plankton may lead to cascading effects in the food chain. 2. Ocean Acidification - Fish and invertebrates may be adversely affected during developmental stages.

			4. Increasing Storminess - Increased runoff from the surrounding watershed may lead to increased loading of nitrogen and phosphorus to inland bays resulting in eutrophication. 5. Increasing Storminess - Increased storminess may result in increased turbidity and decrease water clarity. 6. Sea Level Rise - Sea level rise may result in drowning of bay wetlands. 7. Warmer Water - Warmer water may result in the loss of SAV habitat. 8. Warmer Winters - Invasive species, epizootics, and disease may survive winters that used to kill them. 9. Warmer Winters - Finfish species that used to migrate may stay all winter.	
	Low	1. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification. 2. Warmer Winters - Increased foraging of plants and animals.		
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 12. Shallow Bay Habitat/Bay Islands 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with shallow bay and bay island habitat in the NE Study Area by 2100 are shown in the matrix in Figure 13. The high risks identified for this habitat type by 2050 are expected to be present in 2100.

	Low	Medium	High
		1. Sea Level Rise - Some bay islands may become completely or almost completely submerged. 2. Sea Level Rise - Depth of waters in shallow bay habitat may be expected to increase as the sea rises potentially affecting coastal bay wetlands and shorelines. 3. Sea Level Rise - Sea level rise may change the salinity regime of the inland bays thereby affecting the distribution of salinity-sensitive flora and fauna. 4. Warmer Summers -Finfish species at the southern end of their distribution may migrate northward. 5. Warmer Water - Desired fish may no longer be present. 6. Warmer Water - Warmer water is likely to lead to an expansion of invasive species, epizootics, and disease. 7. Warmer Winters - Finfish species that used to migrate may stay all winter.	1. Increasing Drought - Increased drought may result in waters sufficiently warm to promote areas of hypoxia. 2. Increasing Storminess - Increasing overwash and breaching of new inlets could potentially change the physical and environmental characteristics of the bays such as, flushing rates, salinity, light penetration and nutrient dynamics. 3. Increasing Storminess - Increased storminess will result in increased erosion of shallow bay shorelines. 4. Sea Level Rise - Hardening of shorelines with bulkheads, sea walls and revetments may become more widespread resulting in the loss of natural shoreline habitats and decreased water quality. 5. Sea Level Rise - Sea Level rise in conjunction with increased tidal amplitude will result in increased erosion of shallow bay shorelines. 6. Warmer Summers - Increased water temperature may increase areas of hypoxia in shallow embayments. 7. Warmer Water - Warmer water is likely to promote the migration of current fish species northward and immigration of fish from southern regions. 8. Warmer Winters - Invasive species, epizootics, and disease may survive winters that used to kill them.
Medium	1. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification. 2. Warmer water will decrease oxygen solubility possibly resulting in a decrease in oxygen concentrations in bay waters.	1. Increasing Drought - An increase in long-term and seasonal short-term drought may decrease freshwater flow and affect the salinity distribution in the bays. 2. Increasing Drought - Increased drought may result in waters sufficiently warm to promote harmful algal blooms. 3. Increasing Storminess - Increased runoff from the surrounding watershed may lead to increased loading of nitrogen and phosphorus to inland bays resulting in eutrophication. 4. Increasing Storminess -Increased storminess may result in increased turbidity and decrease water clarity.	1. Ocean Acidification - The effect of embayment acidification on calcifying plankton may lead to cascading effects in the food chain. 2. Ocean Acidification - Fish and invertebrates may be adversely affected during developmental stages. 3. Sea Level Rise - Sea level rise may result in drowning of bay wetlands. 4. Warmer Water - Warmer water may result in the loss of SAV habitat.
Low	1. Warmer Winters - Increased foraging of plants and animals.		
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 13. Shallow Bay Habitat/Bay Islands 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.7 Terrestrial Upland

The risks to EPA goals associated with terrestrial upland habitat in the NE Study Area by 2050 are shown in the matrix in Figure 14. Three high risk impacts associated with increasing storminess, sea level rise, and warmer summers were identified, while the majority of potential impacts to this habitat were identified as medium risks concerns.

Likelihood of Occurrence		Low	Medium	High
	High		1. Increasing Storminess - Combined with sea level rise, increased flooding will impact adjacent upland habitat. 2. Sea Level Rise - As sea level rises, there will be an encroachment on and flooding of adjacent upland forests. 3. Warmer Summers - Species that won't tolerate warmer summers may migrate. Floral and faunal species at the southern limit of their range may disappear.	
	Medium		1. Increasing Storminess - Severe storms may result in significant tree fall or damage. 2. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase. 3. Warmer Summers - Essential food sources may disappear affecting the food web. 4. Warmer Summers - Some invasive species and disease are expected to expand into the Northeast forests. 5. Warmer Summers - Species may be weakened by heat and become out- competed. 6. Warmer Summers - Species may need to consume more water. 7. Warmer Winters - A longer growing season may lead to an extra reproductive cycle. 8. Warmer Winters - Food supplies and bird migrations may be mistimed. 9. Warmer Winters - Species that used to migrate away may stay all winter. 10. Warmer Winters - Invasive species may move into places that used to be too cold.	
	Low	1. Increasing Drought - Stress from excess heat and decreased water may result in increased susceptibility to disease. 2. Increasing Drought - Stress from excess heat and decreased water may result in vegetative die-off.	1. Increasing Storminess - Increased storm damage will promote and exacerbate the effect of disease.	
		Consequence of Impact		

Figure 14. Terrestrial Upland 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with terrestrial upland habitat in the NE Study Area by 2100 are shown in the matrix in Figure 15. The risk concerns for this habitat type by 2100 are similar to those previously identified for the 2050 timeframe.

Likelihood of Occurrence		Consequence of Impact: Low	Consequence of Impact: Medium	Consequence of Impact: High
	High		1. Increasing Storminess - Combined with sea level rise, increased flooding will impact adjacent upland habitat. 2. Sea Level Rise - As sea level rises, there will be an encroachment on and flooding of adjacent upland forests. 3. Warmer Summers - Species that won't tolerate warmer summers may migrate. Floral and faunal species at the southern limit of their range may disappear.	
	Medium		1. Increasing Storminess - Severe storms may result in significant tree fall or damage. 2. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase. 3. Warmer Summers - Essential food sources may disappear affecting the food web. 4. Warmer Summers - Some invasive species and disease are expected to expand into the Northeast forests. 5. Warmer Summers - Species may be weakened by heat and become out- competed. 6. Warmer Summers - Species may need to consume more water. 7. Warmer Winters - A longer growing season may lead to an extra reproductive cycle. 8. Warmer Winters - Food supplies and bird migrations may be mistimed. 9. Warmer Winters - Species that used to migrate away may stay all winter. 10. Warmer Winters - Invasive species may move into places that used to be too cold.	
	Low	1. Increasing Drought - Stress from excess heat and decreased water may result in increased susceptibility to disease. 2. Increasing Drought - Stress from excess heat and decreased water may result in vegetative die-off.	1. Increasing Storminess - Increased storm damage will promote and exacerbate the effect of disease.	

Figure 15. Terrestrial Upland 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.8 Floodplains/Riparian

The risks to EPA goals associated with floodplain and riparian habitat in the NE Study Area by 2050 are shown in the matrix in Figure 16. Four high risk impacts associated with increasing drought, increasing storminess, sea level rise, and warmer winters were identified, while the majority of potential impacts to this habitat were identified as low and medium risks concerns.

Likelihood of Occurrence		Consequence of Impact: Low	Consequence of Impact: Medium	Consequence of Impact: High
	High		1. Increasing Drought - An increase in long-term and seasonal short-term drought may decrease base flows in streams. 2. Increasing Storminess - Increased frequency and intensity of flooding events will result in erosion of floodplains and riparian habitat. 3. Sea Level Rise - Saline water may move farther upstream and the biological assemblages of floodplain and riparian habitat may change. 4. Warmer Winters - Less snow and more rain may change the runoff/infiltration balance; base flow in streams may change. 5. Sea Level Rise – Bulkheads, sea walls, and revetments may become more widespread along floodplains and riparian areas resulting in loss of habitat.	
	Medium	1. Warmer Summers - As with terrestrial and aquatic habitats, warmer summers may result in a latitudinal shift in species.	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow. 2. Sea Level Rise - May lead to an increase or decrease of floodplains or riparian habitat. 3. Warmer Winters - A spring runoff pulse may disappear along with the snow. 4. Warmer Winters - The absence of snowmelt may lead to a decrease of vernal pool habitat.	
	Low	1. Increasing Storminess - Increased frequency and intensity of flooding events may result in the loss of existing floodplains and the formation of new floodplains. 2. Warmer Summers - Species may need to consume more water as temperature rises. 3. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete.		

Figure 16. Floodplain/Riparian 2050 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

The risks to EPA goals associated with floodplain and riparian habitat in the NE Study Area by 2100 are shown in the matrix in Figure 17. The risk concerns for this habitat type by 2100 are similar to those previously identified for the 2050 timeframe.

Likelihood of Occurrence	Low	Medium	High
High		1. Increasing Drought - An increase in long-term and seasonal short-term drought may decrease base flows in streams. 2. Increasing Storminess - Increased frequency and intensity of flooding events will result in erosion of floodplains and riparian habitat. 3. Sea Level Rise - Saline water may move farther upstream and the biological assemblages of floodplain and riparian habitat may change. 4. Warmer Winters - Less snow and more rain may change the runoff/infiltration balance; base flow in streams may change. 5. Sea Level Rise – Bulkheads, sea walls, and revetments may become more widespread along floodplains and riparian areas resulting in loss of habitat.	
Medium	1. Warmer Summers - As with terrestrial and aquatic habitats, warmer summers may result in a latitudinal shift in species.	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow. 2. Sea Level Rise - May lead to an increase or decrease of floodplains or riparian habitat. 3. Warmer Winters - A spring runoff pulse may disappear along with the snow. 4. Warmer Winters - The absence of snowmelt may lead to a decrease of vernal pool habitat.	
Low	1. Increasing Storminess - Increased frequency and intensity of flooding events may result in the loss of existing floodplains and the formation of new floodplains. 2. Warmer Summers - Species may need to consume more water as temperature rises. 3. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete.		
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 17. Floodplain/Riparian 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

6 Conclusions and Comments

This scoping study provides climate change vulnerability assessments for eight habitat types in the NE Study Area:

1. Ocean Beach and Dune Ecosystem
2. Coastal Wetlands
3. Submerged Aquatic Vegetation
4. Oyster Reefs
5. Rock Reefs/Rocky Shorelines
6. Shallow Bay Habitat/Bay Islands
7. Terrestrial Upland
8. Floodplains/Riparian

C/P matrices for the eight habitat types for 2050 and 2100 indicate that risks to EPA Clean Water Act goals associated with climate change exist in the near term for most EPA goals and remain or generally increase for all EPA goals by 2100.

The high risk climate change impacts for the eight habitat types were generally consistent with the results of the climate change vulnerability assessment for the overall NE Study Area from Long Island, NY to southern Maine.

Because these results represent expert judgment of a very limited number of individuals, the results should be considered preliminary and communicated and used with appropriate disclaimers and due caution. Owing to the nature of data available and reviewed, high levels of uncertainty exist in the complexities of climate change applied to any potential impact, particularly ecological impacts. For example, there is certainty that increased carbon dioxide in the atmosphere will increase the pH of the oceans. The sources reviewed indicated that empirical data from aquaculture and from laboratory experiments show that pH changes negatively impact species of economic interest. What was less certain is the extent of acidification and the impacts over time. The uncertainties were prevalent and enhanced the uncertainty in rank assignment based on spatial extents of the risk item.

The estimation of risk produced in this scoping study can be can be improved by ensuring that the breadth of understanding is available. No small group of experts will possess that breadth of knowledge. A full vetting of the scoping study vulnerability assessment results with a broad range of experts is strongly recommended.

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