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Work Assignment 1-14

Climate Change Vulnerabilities Scoping Report: Risks to Clean Water Act Goals in Northeast Sub-regions

Prepared for:

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1 Purpose

The purpose of this scoping study is to raise awareness of risks to the U.S. Environmental Protection Agency (EPA) Clean Water Act goals associated with climate change and indicate where more analysis might be needed. This study reviewed and analyzed existing information to create a risk-based climate change vulnerability assessment to inform those managing coastal watersheds in sub-regions in the Northeast Study Area. The study examined climate change risks to sub-regions, including estuaries and coastal watersheds, for six study regions within the Northeast (NE) Study Area:

1. Southern Maine concentrating on the Casco Bay Area
2. New Hampshire
3. Massachusetts Bay and environs
4. Buzzards Bay
5. Rhode Island
6. Long Island Sound (Connecticut and New York)

The vulnerability assessment produced separate consequence/probability (C/P) matrices for each of the six NE sub-regions based on each of the four risk identification checklists (pollution control; habitat; fish, wildlife, and plants; recreation and public water supplies) and two time periods (2050 and 2100) for a total of 48 C/P matrices.

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, the same approach was applied to focus on sub-regions and define differences in climate change risk at this finer scale as it compares to the NE Study Area, summarized in Table 1. Expert knowledge and judgment supplemented by a review of the information in the specified sources were applied to an analysis of all four risk identification checklists (pollution control; habitat; fish, wildlife, and plants; recreation and public water supplies) of EPA (2014). Each checklist contains two to three Clean Water Act goals that may be affected by seven listed climate change stressors. Each checklist contains approximately 30 items that were assessed by individuals with relevant regional expertise in pollution control, habitats, biota, and water supplies. The experts made judgments as to the consequence (severity of impact) and likelihood (probability of occurrence) based on the 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 C/P matrix was prepared for each checklist for both 2050 and 2100 and vetted by the team of experts to ensure logical consistency and consensus on the ratings of the matrices.

Table 1. Summary of Checklists, EPA Goals, Stressors, and Time Frames within Study Scope

Potential Climate Change Risks (Checklist)	Clean Water Act Goals	Climate Change Stressors	Time Frames (Years)
Pollution Control	• Controlling point sources of pollution and cleaning up pollution • Controlling nonpoint sources of pollution	• Warmer summers • Warmer winters • Warmer water • Increasing drought • Increasing storminess • Sea level rise • Ocean acidification	• 2050 • 2100
Habitat	• Restoring and protecting physical and hydrologic features • Constructing reefs to promote fish and shellfish	• Warmer summers • Warmer winters • Warmer water • Increasing drought • Increasing storminess • Sea level rise • Ocean acidification	• 2050 • 2100
Fish, Wildlife, and Plants	• Protecting and propagating fish, shellfish, and wildlife • Controlling nonnative and invasive species • Maintaining biological integrity and reintroducing native species	• Warmer summers • Warmer winters • Warmer water • Increasing drought • Increasing storminess • Sea level rise • Ocean acidification	• 2050 • 2100
Recreation and Public Water Supplies	• Restoring and maintaining recreational activities, in and on the water • Protecting public water supplies	• Warmer summers • Warmer winters • Warmer water • Increasing drought • Increasing storminess • Sea level rise • Ocean acidification	• 2050 • 2100

3 Sources of Information Used

For each sub-region, the results of the Northeast analysis (Climate Change Vulnerabilities Scoping Report: Risks to Clean Water Act Goals in Northeast) was compared with the respective state climate change reports. Per EPA direction, information was not sought outside of these sources:

Adaptation Subcommittee to the Governor's Steering Committee on Climate Change. 2010. The Impacts of Climate change on Connecticut Agriculture, Infrastructure, Natural Resources, and Public Health. http://www.ct.gov/deep/lib/deep/climatechange/impactsofclimatechange.pdf.

Executive Office of Energy and Environmental Affairs and the Adaptation Advisory Committee. 2011. Chapter 2: Changing Climate and Its Impact. Massachusetts Climate change Adaptation Report. (http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf).

New York State Climate Action Council. 2010. Climate Action Plan Interim Report. (http://www.dec.ny.gov/docs/administration_pdf/irpart1.pdf).

Rhode Island Climate Change Commission. 2012. Adapting to Climate Change in the Ocean State: A Starting Point: 2012 Progress Report. (http://www.rilin.state.ri.us/Reports/Climate%20Change%20Commission%20Prog%20Report%20Final%2011%2015%2012%20final%202.pdf.)

Wake, C., E. Burakowski, K. Hayhoe, C. Watson, E. Douglas, J. VanDorn, V. Naik, C. Keating. 2009. Climate change in the Casco Bay Watershed: Past, Present, Future. Casco Bay Estuary Partnership. (http://www.seagrant.umaine.edu/files/chg/Climate_Change_in_Casco_Bay.pdf).

Wake, C., E. Burakowski, P. Wilkinson, K. Hayhoe, A. Stoner, C. Keeley, J. LaBranche. 2014. Climate Change in Southern New Hampshire: Past, Present, and Future. Climate Solutions New England. (http://nhblog.stormsmart.org/links-to-resources-for-adaptation-to-climate-change/).

Wake, C., E. Burakowski, K. Hayhoe, A. Stoner, C. Watson, and W. Douglas. 2011. Climate Change in the Piscataqua/Great Bay Region: Past, Present, Future. Carbon Solutions New England, Great Bay Stewards, and University of New Hampshire. http://nhblog.stormsmart.org/links-to-resources-for-adaptation-to-climate-change/

4 Interpreting Findings

Professional judgment is useful for analysis where complex problems exist for which empirical estimation is not feasible, as well as detailed research is unavailable. Professional judgment as applied in this NE Study area meant: (1) persons involved in making the judgment had scientific and / or engineering credentials and academic and or professional experience necessary to support a claim of “expert”; (2) persons involved in making the judgment had through knowledge of the relevant literature essential for interpretation of facts; and (3) concurrence existed among more than one expert to provide scientifically-valid and defendable conclusions.

The experts who contributed to the NE sub-region study Area vulnerability analysis 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.

Siva Sangameswaran, Ph.D., P.E., C.F.M. (Dewberry). A Senior Water Resources Engineer, Dr. Sangameswaran has extensive knowledge and experience solving complex engineering problems and environmental issues using context sensitive modeling and sustainable, natural systems based

approaches. His expertise includes 1-D and 2-D hydrodynamic modeling; hydraulic and hydrologic modeling; coastal engineering and wave modeling; and sediment transport modeling in riverine and coastal systems. He has experience with stream restoration; drainage design for flood protection; green infrastructure design; and TMDL development.

Kaveh Zomorodi, Ph.D., P.E., C.F.M. (Dewberry). A Senior Hydrologist and Water Resources Engineer, Dr. Zomorodi has over 27 years of work experience in academic and consulting engineering work dealing with surface water hydrology and hydraulics, groundwater, water resources planning and management and hazard mitigation. Dr. Zomorodi has published over 45 technical papers in various journals and conference proceedings and numerous R&D and project reports. Consulting and research work experience includes hydrological studies and modeling; floodplain modeling; benefit-cost analysis of hazard mitigation; modeling the impact of climate change on design peak discharges and coastal design flood elevations; highway hydraulic modeling and bridge scour analysis; management and operation of water resources networks; groundwater modeling and management; and artificial groundwater recharge.

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.

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 (Dewberry). 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.

Krista Rand, M.S. Civil Engineering, E.I.T., C.F.M. (Dewberry). Ms. Rand is projects of national significance related to water resources and climate change, especially riverine flooding and transportation systems. Certified Floodplain Manager (2012 – 2014). Expertise include hydrology and hydraulics, climate vulnerability assessments, natural hazard mitigation and climate change adaptation, transportation systems, and natural resources management and policy.

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 were, per EPA direction, categorized as low consequence and low probability. For certain impacts, although there was insufficient quantitative data in the literature, based on expert judgment a medium "M" rating, rather than a low "L" rating was assigned. Only coral reef impacts were not evaluated because there are no coral reefs in the sub-regions.

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 for the ranking of pollution control and recreation and public water supplies.

- 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
- 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

- 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 was 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 versus 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.

In some cases a state report suggests that a risk has a different likelihood or a different consequence than was assigned in the Northeast (NE) analysis. For such cases, the following rules were applied by the experts.

- The results of the NE analysis were given greater weight than state reports with respect to likelihood.
- The state reports were given greater weight with respect to consequence.
- If the NE analysis and a state analysis differed greatly in what they suggested about a risk, then the differences were reconciled in this report with an indication of how the differences were resolved. Reconciliation is understood to mean revising the C/P matrices based on specified weighting of sources of data and, when appropriate and known, providing an explanation for the observed differences between the overall NE analysis and a given sub-region.

A number of the sub-regional sources are limited in their discussion of consequences. The consequence values from the NE analysis were used when the sub-region sources did not discuss consequences for impacts.

The assumption of "as is" conditions meant that although an expert might be aware that cities, and counties are planning and constructing infrastructure with futuristic goals, the tangible benefits of proposed measures were not considered. Highlighting these risks in the absence of following through on plans will better inform stakeholders (planners and decision makers) of the potential risk (consequence in particular) in the absence of adoption of proposed measures.

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.

[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. Battelle's team developed a simplified tool directly to meet the needs of this project. This spreadsheet tool enabled the assignment of individual and combined risk category ranking after the expert(s) assigns the literature and judgement based consequence and likelihood ranks. This tool helped expedite and standardize the analysis and ranking process. Experts of interrelated disciplines (for example pollution control, habitat, and wetlands) discussed and finalized rankings to ensure consistency in rankings due to a mutually impacting stressor.]

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.

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5 Results

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

5.1 Southern Maine Pollution Control

The risks to EPA goals associated with pollution control in the southern Maine sub-region by 2050 are shown in the matrix in Figure 2. The potential inadequacy of flood control facilities allowing flooding impacts appear to be the highest risk by 2050 to EPA goals associated with pollution control, which is consistent with the NE Study Area. There is less risk than in the NE Study Area associated with sewer pipes inflows and infiltration, contaminated sites flooding, and thermal discharge limit concerns.

Likelihood of Occurrence	Low	Medium	High
High	1. Warmer Water - Greater algae growth may occur 2. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters 3. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Warmer Water - Water may hold less dissolved oxygen	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate
Medium	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 3. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 4. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 5. Warmer Summers - Wildfires may lead to soil erosion 6. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 7. Warmer Water - Warmer temperatures may increase toxicity of pollutants 8. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 9. Warmer Water - Higher surface temperatures may lead to stratification	1. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 2. Increasing Storminess - Combined sewer overflows may increase 3. Increasing Storminess - High rainfall may cause septic systems to fail 4. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 5. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 6. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 7. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 8. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 9. Warmer Water - Parasites, bacteria may have greater survival or transmission	1. Increasing Storminess - Treatment plants may go offline during intense floods 2. Increasing Storminess - Streams may see greater erosion and scour 3. Increasing Storminess - Urban areas may be subject to more floods
Low			
	Consequence of Impact		

Figure 2. Southern Maine 2050 Pollution Control 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 pollution control in the southern Maine sub-region by 2100 are shown in the matrix in Figure 3. The high risks for pollution control identified in 2050 are expected to continue to be the high risks in 2100. No additional high risk impacts are expected in 2100 than in 2050.

Likelihood of Occurrence	Consequence of Impact: Low	Consequence of Impact: Medium	Consequence of Impact: High
High	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 3. Warmer Water - Greater algae growth may occur 4. Warmer Winters - Loss of melting winter snows may reduce spring or 5. Longer growing season can lead to more lawn maintenance with fertilizers and pesticides 5. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 2. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 3. Warmer Water - Water may hold less dissolved oxygen	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 3. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution
Medium	1. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 2. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 3. Warmer Summers - Wildfires may lead to soil erosion 4. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 5. Warmer Water - Warmer temperatures may increase toxicity of pollutants 6. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 7. Warmer Water - Higher surface temperatures may lead to stratification	1. Increasing Storminess - Combined sewer overflows may increase 2. Increasing Storminess - High rainfall may cause septic systems to fail 3. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 4. Warmer Water - Parasites, bacteria may have greater survival or transmission	1. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 2. Increasing Storminess - Treatment plants may go offline during intense floods 3. Increasing Storminess - Streams may see greater erosion and scour 4. Increasing Storminess - Urban areas may be subject to more floods
Low			

Figure 3. Southern Maine 2100 Pollution Control Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.2 Southern Maine Habitat

The risks to EPA goals associated with habitat in the southern Maine sub-region by 2050 are shown in the matrix in Figure 4. Habitat damage or loss caused by sea level rise and warmer water, supplemented by increasing turbidity and sedimentation from increased storms, are the high risk concerns by 2050 and are similar to those in the NE Study Area.

Likelihood of Occurrence	Low	Medium	High
	High	1. Warmer Winters - Warmer winters may lead to less snow, more rain may change the runoff / infiltration balance; base flow in streams may change	1. Increasing Drought - An increase in long-term and seasonal short term drought may decrease base flows in streams 2. Increasing Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 3. Increasing Drought - Stream water may become warmer 4. Increasing Storminess - Barrier Islands affected 5. Increasing Storminess - Dunes and beaches damaged 6. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 7. Warmer Water - Coastal lagoons (salt ponds) will warm	1. Increasing Storminess - Coastal habitats will change 2. Increasing Storminess - Coastal overwash or island breaching may occur 3. Increasing Storminess - Salt marshes will be inundated 4. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 5. Sea Level Rise - Higher salinity may kill targeted species 6. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 7. Warmer Water - Warmer water may promote invasive species or disease 8. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease 9. Warmer Water - Warmer water is likely to lead to an expansion of invasive species 10. Warmer Water - Warmer waters may both increase and decrease populations of commercially and recreationally important fish and shellfish
	Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Summers - Warmer summers may lead to greater electricity demand may affect operation decisions at hydropower dams 3. Warmer Summers - Warmer summers may result in the switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Storminess - Increased density stratification due to runoff may lead to more severe hypoxia 2. Increasing Storminess - Turbidity of surface waters may increase 3. Warmer Summers - Warmer summers are expected to result in higher temperatures which may lead to greater evaporation and lower groundwater tables 4. Warmer Water - Desired fish may no longer be present 5. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification	1. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 2. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 3. Sea Level Rise - Tidal influence may move farther upstream 4. Warmer Water - Hypoxia will become more common and widespread 5. Warmer Water - Warmer water may result in a loss of SAV habitat
	Low	1. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 2. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 3. Ocean Acidification - Long Term shellfish sustainability may be an open question 4. Warmer Winters - A spring runoff pulse may disappear along with the snow	1. Increasing Storminess - Lower pH for NPS pollution may affect target species 2. Ocean Acidification - Fish may be adversely affected during development stages 3. Sea Level Rise - Light may not penetrate through deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 4. Southern Maine 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 habitat in the southern Maine sub-region by 2100 are shown in the matrix in Figure 5. Habitat damage or loss caused by sea level rise and warmer water, supplemented by increasing turbidity, sedimentation, and flooding from increased storms, are the high risk concerns by 2100 and are similar to those in the NE Study Area.

Likelihood of Occurrence				
	High		1. Increasing Drought - An increase in long-term and seasonal short term drought may decrease base flows in streams 2. Increasing Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 3. Increasing Drought - Stream water may become warmer 4. Increasing Storminess - Barrier Islands affected 5. Increasing Storminess - Dunes and beaches damaged 6. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 7. Increasing Storminess - Turbidity of surface waters may increase 8. Warmer Summers - Warmer summers are expected to result in higher temperatures which may lead to greater evaporation and lower groundwater tables 9. Warmer Summers - Warmer summers may lead to greater electricity demand may affect operation decisions at hydropower dams 10. Warmer Summers - Warmer summers may result in the switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 11. Warmer Water - Coastal lagoons (salt ponds) will warm 12. Warmer Winters - Warmer winters may lead to less snow, more rain may change the runoff / infiltration balance; base flow in streams may change	1. Increasing Storminess - Coastal habitats will change 2. Increasing Storminess - Coastal overwash or island breaching may occur 3. Increasing Storminess - Salt marshes will be inundated 4. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 5. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 6. Sea Level Rise - Higher salinity may kill targeted species 7. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 8. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 9. Sea Level Rise - Tidal influence may move farther upstream 10. Warmer Water - Hypoxia will become more common and widespread 11. Warmer Water - Warmer water may promote invasive species or disease 12. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease 13. Warmer Water - Warmer water is likely to lead to an expansion of invasive species 14. Warmer Water - Warmer waters may both increase and decrease populations of commercially and recreationally important fish and shellfish
	Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Winters - A spring runoff pulse may disappear along with the snow 3. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 4. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Increasing Storminess - Increased density stratification due to runoff may lead to more severe hypoxia 4. Increasing Storminess - Lower pH for NPS pollution may affect target species 5. Ocean Acidification - Fish may be adversely affected during development stages 6. Ocean Acidification - Long term shellfish sustainability may be an open question 7. Warmer Water - Desired fish may no longer be present 8. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification	1. Warmer Water - Warmer water may result in a loss of SAV habitat
	Low		1. Sea Level Rise - Light may not penetrate through deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 5. Southern Maine 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 Southern Maine Fish, Wildlife and Plants

The risks to EPA goals associated with fish, wildlife and plants in the southern Maine sub-region by 2050 are shown in the matrix in Figure 6. These results are similar to those observed for habitat loss with damage caused by sea level rise, warmer weather, and warmer water, supplemented by increasing turbidity and sedimentation from increased storms, as the high risk concerns by 2050. These are also similar to those observed for the NE Study Area in 2050.

Likelihood of Occurrence				
	High		1. Warmer Summers - Species may need to consume more water as temperature rises 2. Warmer Water - Heat may stress immobile biota 3. Warmer Water - Warmer water will impact the coastal food web base 4. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 5. Warmer Water - Warmer water will result in a shift of pelagic community structure	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) 2. Sea Level Rise - Greater coastal wetland losses may occur 3. Warmer Water - Dissolved oxygen capacity of water may drop 4. Warmer Water - Habitat may become unsuitably warm, for a species or its food 5. Warmer Water - Newly invasive species may appear 6. Warmer Water - Parasites and diseases are enhanced by warmer water 7. Warmer Summers - Species that won't tolerate warmer summers may die or migrate; biota at the southern limit of their range may disappear from ecosystems 8. Warmer Water - Nuisance species will invade from more southern waters 9. Warmer Winters - Invasive species may move into places that used to be too cold 10. Warmer Winters - Pests may survive winters that used to kill them
	Medium		1. Increasing Drought - Species may not tolerate a new drought regime 2.Warmer Summers - Essential food sources may die off or disappear, affecting the food web 3. Warmer Water - Hypoxia will become more common and widespread 4. Warmer Winters - Food supplies and bird migrations may be mistimed 5. Warmer Winters - Some plants may need a "setting" cold temperature 6. Warmer Winters - Species that once migrated through may stop and stay 7. Warmer Winters - Species that used to migrate away may stay all winter 8. Warmer Winters - Warmer winters may result in a shift in the structure of winter fish community	1. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 2. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 3. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 4. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat)
	Low		1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer summers - Species may be weakened by heat and become out- competed	1. Sea Level Rise - Light may not penetrate through the full depth of deeper water 2. Warmer Winters - A longer growing season may lead to an extra reproductive cycle	
			Low	Medium	High
			Consequence of Impact		

Figure 6. Southern Maine 2050 Fish, Wildlife, and Plant 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 fish, wildlife and plants in the southern Maine sub-region by 2100 are shown in the matrix in Figure 7. The high risk concerns by 2100 are similar to those in 2050 and in the NE Study Area by 2100.

Likelihood of Occurrence				
	High		1. Increasing Drought - Species may not tolerate a new drought regime 2. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 3. Warmer Summers - Species may need to consume more water as temperature rises 4. Warmer Summers - Species that won't tolerate warmer summers may die or migrate; biota at the southern limit of their range may disappear from ecosystems 5. Warmer Water - Heat may stress immobile biota 6. Warmer Water - Hypoxia will become more common and widespread 7. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 8. Warmer Water - Warmer water will impact the coastal food web base 9. Warmer Water - Warmer water will result in a shift of pelagic community structure 10. Warmer Winters - Food supplies and bird migrations may be mistimed 11. Warmer Winters - Some plants may need a "setting" cold temperature	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat 2. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 3. Sea Level Rise - Greater coastal wetland losses may occur 4. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat) 5. Warmer Water - Dissolved oxygen capacity of water may drop 6. Warmer Water - Habitat may become unsuitably warm, for a species or its food 7. Warmer Water - Newly invasive species may appear 8. Warmer Water - Nuisance species will invade from more southern waters 9. Warmer Water - Parasites and diseases re enhanced by warmer water 10. Warmer Winters - Invasive species may move into places that used to be too cold 11. Warmer Winters - Pests may survive winters that used to kill them
	Medium	1. Warmer Summers - Species may be weakened by heat and become out- competed	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer Winters - A longer growing season may lead to an extra reproductive cycle 6. Warmer Winters - Species that once migrated through may stop and stay 7. Warmer Winters - Species that used to migrate away may stay all winter 8. Warmer Winters - Warmer winters may result in a shift in the structure of winter fish community	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species
	Low		1. Sea Level Rise - Light may not penetrate through the full depth of deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 7. Southern Maine 2100 Fish, Wildlife, and Plant Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.4 Southern Maine Recreation and Public Water Supplies

The risks to EPA goals associated with recreation and public water supplies in southern Maine by 2050 are shown in the matrix in Figure 8. Consistent with the risks identified for the NE Study Area in 2050, no high risk impacts were identified.

Likelihood of Occurrence				
	High	1. Sea Level Rise - Clearance under bridges may decrease 2. Warmer Water - Harmful algal blooms may be more likely		
	Medium	1. Increasing Storminess - Greater NPS pollution may impair recreation 2. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 3. Ocean Acidification - Recreational shellfish harvesting may be lost 4. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 5. Warmer Summers - Warmer temperatures may drive greater water demand 6. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 7. Warmer Water - Jellyfish may be more common 8. Warmer Water - Fishing seasons and fish may become misaligned 9. Warmer Water - Desired recreational fish may no longer be present 10. Warmer Water - Invasive plants may clog creeks and waterways 11. Warmer Water - Increased growth of algae and microbes may affect drinking water quality 12. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 3. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation	
	Low	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 3. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 4. Increasing Drought - Groundwater tables may drop 5. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 6. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 7. Increasing Drought - Maintaining passing flows at diversions may be difficult 8. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 9. More people using water for recreation may raise the potential for pathogen exposure 10. Warmer Water - Changes in treatment processes may be required 11. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 2. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 8. Southern Maine 2050 Recreation and Water Supply 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 recreation and public water supplies in the southern Maine sub-region by 2100 are shown in the matrix in Figure 9. By 2100 a number of high risk impacts are expected. Most are consistent with those expected by 2100 in the NE Study Area. Storms are expected to have a high risk (rather than medium risk in the NE Study Area). Jellyfish and algae are not expected to be as high a risk for southern Maine as in the overall NE Study Area.

Likelihood of Occurrence		Low	Medium	High
	High	1. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 2. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 3. Warmer Water - Harmful algal blooms may be more likely 4. Warmer Water - Jellyfish may be more common 5. Warmer Water - Increased growth of algae and microbes may affect drinking water quality	1. Increasing Storminess - Greater NPS pollution may impair recreation 2. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 3. Ocean Acidification - Recreational shellfish harvesting may be lost 4. Sea Level Rise - Clearance under bridges may decrease 5. Warmer Summers - Warmer temperatures may drive greater water demand 6. Warmer Water - Fishing seasons and fish may become misaligned 7. Warmer Water - Desired recreational fish may no longer be present 8. Warmer Water - Invasive plants may clog creeks and waterways 9. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 3. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation
	Medium	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 3. Increasing Drought - Groundwater tables may drop 4. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 5. Increasing Drought - Maintaining passing flows at diversions may be difficult 6. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 7. Warmer Water - Changes in treatment processes may be required 8. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 2. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 3. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 4. Sea Level Rise - Sea level may push salt fronts upstream past water diversion	1. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities
	Low			
		Low	Medium	High
		Consequence of Impact		

Figure 9. Southern Maine 2100 Recreation and Water Supply Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.5 New Hampshire Pollution Control

The risks to EPA goals associated with pollution control in the New Hampshire sub-region by 2050 are shown in the matrix in Figure 10. The potential inadequacy of flood control facilities allowing flooding impacts to treatment infrastructure and plants as well as urban areas appear to be the highest risks by 2050 to EPA goals associated with pollution control and is consistent with risks in the NE Study Area. There is less risk than in the NE Study Area associated with sewer pipes inflows and infiltration, contaminated sites flooding, and thermal discharge limit concerns.

Likelihood of Occurrence	Consequence of Impact: Low	Consequence of Impact: Medium	Consequence of Impact: High
High	1. Warmer Water - Greater algae growth may occur 2. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides 3. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters 4. Warmer Water - Water may hold less dissolved oxygen		1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate
Medium	1. Increasing Storminess - Combined sewer overflows may increase 2. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 3. Increasing Drought - Critical-low-flow criteria for discharging may not be met 4. Increasing Storminess - High rainfall may cause septic systems to fail 5. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 6. Warmer Water - Higher surface temperatures may lead to stratification 7. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 8. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 9. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 10. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 11. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 12. Warmer Water - Warmer temperatures may increase toxicity of pollutants 13. Warmer Summers - Wildfires may lead to soil erosion	1. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 2. Warmer Water - Parasites, bacteria may have greater survival or transmission 3. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 4. Increasing Storminess - Streams may see greater erosion and scour 5. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels	1. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 2. Increasing Storminess - Treatment plants may go offline during intense floods 3. Increasing Storminess - Urban areas may be subject to more floods
Low			

Figure 10. New Hampshire 2050 Pollution Control 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 pollution control in the New Hampshire sub-region by 2100 are shown in the matrix in Figure 11. The high risks for pollution control identified in 2050 are expected to continue to be the high risks in 2100. Additional high risk impacts are expected including eutrophication, and discharge limitations.

Likelihood of Occurrence	Low	Medium	High
High	1. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides 2. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters 3. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 4. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Warmer Water - Greater algae growth may occur 3. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 4. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 5. Warmer Water - Water may hold less dissolved oxygen	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Sea Level Rise - Treatment infrastructure may be susceptible to flooding
Medium	1. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 2. Increasing Storminess - High rainfall may cause septic systems to fail 3. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 4. Warmer Water - Higher surface temperatures may lead to stratification 5. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 6. Warmer Water - Warmer temperatures may increase toxicity of pollutants 7. Warmer Summers - Wildfires may lead to soil erosion	1. Increasing Storminess - Combined sewer overflows may increase 2. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 3. Warmer Water - Parasites, bacteria may have greater survival or transmission 4. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 5. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 6. Increasing Storminess - Streams may see greater erosion and scour	1. Increasing Storminess - Treatment plants may go offline during intense floods 2. Increasing Storminess - Urban areas may be subject to more floods
Low			
	Consequence of Impact		

Figure 11. New Hampshire 2100 Pollution Control Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.6 New Hampshire Habitat

The risks to EPA goals associated with habitat in the New Hampshire sub-region by 2050 are shown in the matrix in Figure 12. Habitat damage or loss caused by sea level rise and warmer water, supplemented by increasing turbidity and sedimentation from increased storms, are the high risk concerns by 2050 and are similar to those in the NE Study Area.

Likelihood of Occurrence	Low	Medium	High
High	1. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change	1. Increasing Drought - An increase in long-term and seasonal short term drought may decrease base flows in streams 2. Increasing Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 3. Increasing Drought - Stream water may become warmer 4. Increasing Storminess - Barrier Islands affected 5. Increasing Storminess - Dunes and beaches damaged 6. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 7. Warmer Water - Coastal lagoons (salt ponds) will warm	1. Increasing Storminess - Coastal habitats will change 2. Increasing Storminess - Coastal overwash or island breaching may occur 3. Increasing Storminess - Salt marshes will be inundated 4. Sea Level Rise - Higher salinity may kill targeted species 5. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and Salt marshes 6. Warmer Water - Warmer water may promote invasive species or disease 7. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease 8. Warmer Water - Warmer water is likely to lead to an expansion of invasive species 9. Warmer Water - Warmer waters may both increase and decrease populations of commercially and recreationally important fish and shellfish
Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Summers - Greater electricity demand may affect operation decisions at hydropower dams 3. Warmer Summers - Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Storminess - Increased density stratification due to runoff may lead to more severe hypoxia 2. Increasing Storminess - Turbidity of surface waters may increase 3. Warmer Summers - Higher temperatures may lead to greater evaporation and lower groundwater tables 4. Warmer Water - Desired fish may no longer be present 5. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification	1. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 2. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 3. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 4. Sea Level Rise - Tidal influence may move farther upstream 5. Warmer Water - Hypoxia will become more common and widespread 6. Warmer Water - Warmer water may result in the loss of SAV habitat
Low	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Increasing Storminess - Lower pH for NPS pollution may affect target species 4. Ocean Acidification - Long term shellfish sustainability may be an open question 5. Warmer Winters - A spring runoff pulse may disappear along with the snow	1. Ocean Acidification - Fish may be adversely affected during development stages 2. Sea Level Rise - Light may not penetrate through deeper water	
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 12. New Hampshire 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 habitat in the New Hampshire sub-region by 2100 are shown in the matrix in Figure 13. Habitat damage or loss caused by sea level rise and warmer water, supplemented by increasing turbidity, sedimentation, and flooding from increased storms, are the high risk concerns by 2100 and are similar to those in the NE Study Area.

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 Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 3. Increasing Drought - Stream water may become warmer 4. Increasing Storminess - Barrier Islands affected 5. Increasing Storminess - Dunes and beaches damaged 6. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 7. Increasing Storminess - Turbidity of surface waters may increase 8. Warmer Summers - Greater electricity demand may affect operation decisions at hydropower dams 9. Warmer Summers - Higher temperatures may lead to greater evaporation and lower groundwater tables 10. Warmer Summers - Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 11. Warmer Water - Coastal lagoons (salt ponds) will warm 12. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change	1. Increasing Storminess - Coastal habitats will change 2. Increasing Storminess - Coastal overwash or island breaching may occur 3. Increasing Storminess - Salt marshes will be inundated 4. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 5. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 6. Sea Level Rise - Higher salinity may kill targeted species 7. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 8. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 9. Sea Level Rise - Tidal influence may move farther upstream 10. Warmer Water - Hypoxia will become more common and widespread 11. Warmer Water - Warmer water may promote invasive species or disease 12. Warmer Water - Warmer water is likely to increase incidence of marine and estuarine disease 13. Warmer Water - Warmer water is likely to lead to an expansion of invasive species 14. Warmer Water - Warmer waters may both increase and decrease populations of commercially and recreationally important fish and shellfish
	Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Winters - A spring runoff pulse may disappear along with the snow 3. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 4. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Increasing Storminess - Increased density stratification due to runoff may lead to more severe hypoxia 4. Ocean Acidification - Fish may be adversely affected during development stages 5. Ocean Acidification - Long term shellfish sustainability may be an open question 6. Warmer Water - Desired fish may no longer be present 7. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification	1. Warmer Water - Warmer water may result in the loss of SAV habitat
	Low		1. Increasing Storminess - Lower pH for NPS pollution may affect target species 2. Sea Level Rise - Light may not penetrate through deeper water	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 13. New Hampshire 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 New Hampshire Fish, Wildlife and Plants

The risks to EPA goals associated with fish, wildlife and plants in the New Hampshire sub-region by 2050 are shown in the matrix in Figure 14. These results are similar to those observed for habitat loss with damage caused by sea level rise, warmer weather, and warmer water, supplemented by increasing turbidity and sedimentation from increased storms, are the high risk concerns by 2050. These are also similar to those observed for the NE Study Area in 2050.

Likelihood of Occurrence		Low	Medium	High
	High		1. Warmer Water - Warmer water will impact the coastal food web base 2. Warmer Water - Heat may stress immobile biota 3. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 4. Warmer Water - Warmer water will result in a shift of pelagic community structure	1. Warmer Summers - Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems) 2. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat 3. Sea Level Rise - Greater coastal wetland losses may occur 4. Warmer Water - Dissolved oxygen capacity of water may drop 5. Warmer Water - Habitat may become unsuitably warm, for a species or its food 6. Warmer Water - Newly invasive species may appear 7. Warmer Water - Nuisance species will invade from more southern waters 8. Warmer Water - Parasites and diseases are enhanced by warmer water 9. Warmer Winters - Invasive species may move into places that used to be too cold 10. Warmer Winters - Pests may survive winters that used to kill them
	Medium		1. Increasing Drought - Species may not tolerate a new drought regime 2. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 3. Warmer Summers - Species may need to consume more water as temperature rises 4. Warmer Water - Hypoxia will become more common and widespread 5. Warmer Winters - Food supplies and bird migrations may be mistimed 6. Warmer Winters - Some plants may need a "setting" cold temperature 7. Warmer Winters - Species that once migrated through may stop and stay 8. Warmer Winters - Species that used to migrate away may stay all winter 9. Warmer Winters - Warmer winters may result in a shift in the structure of winter fish community	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 3. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 4. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat)
	Low	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer Summers - Species may be weakened by heat and become out- competed	1. Sea Level Rise - Light may not penetrate through the full depth of deeper water 2. Warmer Winters - A longer growing season may lead to an extra reproductive cycle	
		Consequence of Impact		

Figure 14. New Hampshire 2050 Fish, Wildlife, and Plant 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 fish, wildlife and plants in the New Hampshire sub-region by 2100 are shown in the matrix in Figure 15. The high risk concerns by 2100 are similar to those in the NE Study Area by 2100.

Likelihood of Occurrence				
	High		1. Increasing Drought - Species may not tolerate a new drought regime 2. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 3. Warmer Summers - Species may need to consume more water as temperature rises 4. Warmer Summers - Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 5. Warmer Water - Heat may stress immobile biota 6. Warmer Water - Hypoxia will become more common and widespread 7. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 8. Warmer Water - Warmer water will impact the coastal food web base 9. Warmer Water - Warmer water will result in a shift of pelagic community structure 10. Warmer Winters - Food supplies and bird migrations may be mistimed 11. Warmer Winters - Some plants may need a "setting" cold temperature	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) 2. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 3. Sea Level Rise - Greater coastal wetland losses may occur 4. Warmer Water - Dissolved oxygen capacity of water may drop 5. Warmer Water - Habitat may become unsuitably warm, for a species or its food 6. Warmer Water - Newly invasive species may appear 7. Warmer Water - Nuisance species will invade from more southern waters 8. Warmer Water - Parasites and diseases are enhanced by warmer water 9. Warmer Winters - Invasive species may move into places that used to be too cold 10.Warmer Winters - Pests may survive winters that used to kill them
	Medium	1. Warmer Summers - Species may be weakened by heat and become out- competed	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer Winters - A longer growing season may lead to an extra reproductive cycle 6. Warmer Winters - Species that once migrated through may stop and stay 7. Warmer Winters - Species that used to migrate away may stay all winter 8. Warmer Winters - Warmer winters may result in a shift in the structure of winter fish community	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 3. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat)
	Low		1. Sea Level Rise - Light may not penetrate through the full depth of deeper water	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 15. New Hampshire 2100 Fish, Wildlife, and Plant Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.8 New Hampshire Recreation and Public Water Supplies

The risks to EPA goals associated with recreation and public water supplies in New Hampshire by 2050 are shown in the matrix in Figure 16. Consistent with the risks identified for the NE Study Area in 2050, no high risk impacts were identified.

Likelihood of Occurrence	Low	Medium	High
High	1. Sea Level Rise - Clearance under bridges may decrease 2. Warmer Water - Harmful algal blooms may be more likely		
Medium	1. Increasing Storminess - Greater NPS pollution may impair recreation 2. Increasing Storminess - Water infrastructure may be vulnerable to flooding 3. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 4. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 5. Ocean Acidification - Recreational shellfish harvesting may be lost 6. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 7. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 8. Warmer Summers - Warmer temperatures may drive greater water demand 9. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 10. Warmer Water - Jellyfish may be more common 11. Warmer Water - Fishing seasons and fish may become misaligned 12. Warmer Water - Desired recreational fish may no longer be present 13. Warmer Water - Invasive plants may clog creeks and waterways 14. Warmer Water - Increased growth of algae and microbes may affect drinking water quality 15. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear		
Low	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 3. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 4. Increasing Drought - Groundwater tables may drop 5. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 6. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 7. Increasing Drought - Maintaining passing flows at diversions may be difficult 8. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 9. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 10. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 11. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 12. Warmer Water - Changes in treatment processes may be required 13. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure		
	Consequence of Impact		

Figure 16. New Hampshire 2050 Recreation and Water Supply 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 recreation and public water supplies in the New Hampshire sub-region by 2100 are shown in the matrix in Figure 17. By 2100 a number of high risk impacts are expected. Most are consistent with those expected by 2100 in the NE Study Area. Jellyfish, loss of recreational shellfish harvesting, and degraded eco-tourism are only a medium risk for New Hampshire compared to a high risk for the overall NE Study Area.

Likelihood of Occurrence		Low	Medium	High
	High	1. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 2. Ocean Acidification - Recreational shellfish harvesting may be lost 3. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 4. Warmer Water - Jellyfish may be more common 5. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear	1. Increasing Storminess - Greater NPS pollution may impair recreation 2. Increasing Storminess - Water infrastructure may be vulnerable to flooding 3. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 4. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 5. Sea Level Rise - Clearance under bridges may decrease 6. Warmer Summers - Warmer temperatures may drive greater water demand 7. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 8. Warmer Water - Harmful algal blooms may be more likely 9. Warmer Water - Fishing seasons and fish may become misaligned 10. Warmer Water - Desired recreational fish may no longer be present 11. Warmer Water - Invasive plants may clog creeks and waterways 12. Warmer Water - Increased growth of algae and microbes may affect drinking water quality	
	Medium	1. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 2. Increasing Drought - Groundwater tables may drop 3. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 4. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 5. Increasing Drought - Maintaining passing flows at diversions may be difficult 6. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 7. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 8. Warmer Water - Changes in treatment processes may be required 9. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 3. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 4. Sea Level Rise - Sea level may push salt fronts upstream past water diversion	
	Low			
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 17. New Hampshire ion 2100 Recreation and Water Supply Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.9 Massachusetts Bay and Environs Pollution Control

The risks to EPA goals associated with pollution control in the Massachusetts Bay and environs sub-region by 2050 are shown in the matrix in Figure 18. The potential inadequacy of flood control facilities, eutrophication and hypoxia, and reduced flow concentrating pollutant levels are the highest risks by 2050 to EPA goals associated with pollution control. While these are high risks in the NE Study Area, there is less risk than in the NE Study Area associated with sewer pipes inflows and infiltration, contaminated sites flooding, and flooding of treatment plants and infrastructure, and thermal discharge limit concerns.

Likelihood of Occurrence	Low	Medium	High
High	1. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Warmer Water - Water may hold less dissolved oxygen 3. Warmer Water - Greater algae growth may occur 4. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters	
Medium	1. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 2. Warmer Summers - Wildfires may lead to soil erosion 3. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 4. Warmer Water - Higher surface temperatures may lead to stratification	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 3. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 4. Increasing Storminess - Combined sewer overflows may increase 5. Increasing Storminess - Treatment plants may go offline during intense floods 6. Increasing Storminess - Streams may see greater erosion and scour 7. Increasing Storminess - Urban areas may be subject to more floods 8. Increasing Storminess - High rainfall may cause septic systems to fail 9. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 10. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 11. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 12. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 13. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 14. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 15. Warmer Water - Warmer temperatures may increase toxicity of pollutants 16. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 17. Warmer Water - Parasites, bacteria may have greater survival or transmission	
Low			
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 18. Massachusetts Bay and Environs 2050 Pollution Control 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 pollution control in the Massachusetts Bay and environs sub-region by 2100 are shown in the matrix in Figure 19. The high risks for pollution control identified in 2050 are expected to continue to be the high risks in 2100. Additional high risk impacts are associated with high water levels and flooding that impacts treatment plants and infrastructure, urban area flooding, and combined sewer overflows. Increasing pollutants and concentration of pollutants, as well as problems from low flows are also high risks.

Likelihood of Occurrence	Low	Medium	High
High		1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 3. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 4. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters 5. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 3. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 4. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 5. Warmer Water - Water may hold less dissolved oxygen 6. Warmer Water - Greater algae growth may occur
Medium	1. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 2. Warmer Water - Higher surface temperatures may lead to stratification	1. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 2. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 3. Increasing Storminess - Treatment plants may go offline during intense floods 4. Increasing Storminess - Streams may see greater erosion and scour 5. Increasing Storminess - High rainfall may cause septic systems to fail 6. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 7. Warmer Summers - Wildfires may lead to soil erosion 8. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 9. Warmer Water - Warmer temperatures may increase toxicity of pollutants 10. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 11. Warmer Water - Parasites, bacteria may have greater survival or transmission	1. Increasing Storminess - Combined sewer overflows may increase 2. Increasing Storminess - Urban areas may be subject to more floods
Low			
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 19. Massachusetts Bay and Environs 2100 Pollution Control Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.10 Massachusetts Bay and Environs Habitat

The risks to EPA goals associated with habitat in the Massachusetts Bay and environs sub-region by 2050 are shown in the matrix in Figure 20. Habitat damage or loss caused by sea level rise and warmer water, supplemented by increasing turbidity and sedimentation from increased storms, are the high risk concerns by 2050 and are similar to those in the NE Study Area.

Likelihood of Occurrence	Low	Medium	High
High		1. Increasing Drought - Base flow in streams may decrease 2. Increasing Drought - Groundwater tables may drop 3. Increasing Drought - Stream water may become warmer 4 .Increasing Storminess - Stronger storms may cause more intense flooding and runoff 5. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase 6. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change	1. Increasing Storminess - Coastal overwash or island breaching may occur 2. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 3. Sea Level Rise - Ability of tidal marsh to migrate landward 4. Sea Level Rise - Higher salinity may kill targeted species 5. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 6. Warmer Water - Warmer water may promote invasive species or disease
Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Summers - Greater electricity demand may affect operation decisions at hydropower dams 3. Warmer Summers - Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Storminess - Turbidity of surface waters may increase 2. Warmer Summers - Higher temperatures may lead to greater evaporation and lower groundwater tables 3. Warmer Water - Desired fish may no longer be present 4. Warmer Water - Warmer Water may lead to greater likelihood of stratification	1. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 2. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 3. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 4. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 5. Sea Level Rise - Tidal influence may move farther upstream
Low	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Ocean Acidification - Long term shellfish sustainability may be an open question 4. Warmer Winters - A spring runoff pulse may disappear along with the snow	1. Increasing Storminess - Lower pH for NPS pollution may affect target species 2. Ocean Acidification - Fish may be adversely affected during development stages 3. Sea Level Rise - Light may not penetrate through deeper water	
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 20. Massachusetts Bay and Environs 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 habitat in the Massachusetts Bay and environs sub-region by 2100 are shown in the matrix in Figure 21. Habitat damage or loss caused by sea level rise and warmer water, supplemented by increasing turbidity, sedimentation, and flooding from increased storms, are the high risk concerns by 2100 and are similar to those in the NE Study Area. Other high risk impacts are associated with warmer weather and ocean acidification.

Likelihood of Occurrence				
	High		1. Increasing Drought - Base flow in streams may decrease 2. Increasing Drought - Stream water may become warmer 3. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase 4. Increasing Storminess - Turbidity of surface waters may increase 5. Warmer Summers - Greater electricity demand may affect operation decisions at hydropower dams 6. Warmer Summers - Higher temperatures may lead to greater evaporation and lower groundwater tables 7. Warmer Summers - Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 8. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change	1. Increasing Drought - Groundwater tables may drop 2. Increasing Storminess - Coastal overwash or island breaching may occur 3. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 4. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 5. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 6. Sea Level Rise - Ability of tidal marsh to migrate landward 7. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 8. Sea Level Rise - Higher salinity may kill targeted species 9. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 10. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 11. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 12. Sea Level Rise - Tidal influence may move farther upstream 13. Warmer Water - Warmer water may promote invasive species or disease
	Medium	1. Warmer Winters - A spring runoff pulse may disappear along with the snow 2. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 3. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 4. Increasing Storminess - Lower pH for NPS pollution may affect target species 5. Ocean Acidification - Long term shellfish sustainability may be an open question 6. Warmer Water - Desired fish may no longer be present 7. Warmer Water - Warmer Water may lead to greater likelihood of stratification	1. Ocean Acidification - Fish may be adversely affected during development stages
	Low		1. Sea Level Rise - Light may not penetrate through deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 21. Massachusetts Bay and Environs 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.11 Massachusetts Bay and Environs Fish, Wildlife and Plants

The risks to EPA goals associated with fish, wildlife and plants in the Massachusetts Bay and environs by 2050 are shown in the matrix in Figure 22. These are similar to those observed for the overall NE Study Area in 2050. Most stressors, except ocean acidification, are expected to create some high risk impacts by 2050.

Likelihood of Occurrence				
	High		1. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 2. Warmer Water - Heat may stress immobile biota 3 .Warmer Summers - Species may need to consume more water as temperature rises 4. Warmer Summers - Species that won't tolerate Warmer Summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 5. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat 2. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 3. Sea Level Rise - Ability of tidal marsh to migrate landward 4. Sea Level Rise - Greater coastal wetland losses may occur 5. Warmer Water - Dissolved oxygen capacity of water may drop 6. Warmer Water - Habitat may become unsuitably warm, for a species or its food 7. Warmer Water - Newly invasive species may appear 8. Warmer Water - Parasites and diseases are enhanced by Warmer Water 9. Warmer Winters - Invasive species may move into places that used to be too cold 10. Warmer Winters - Pests may survive winters that used to kill them
	Medium		1. Increasing Drought - Species may not tolerate a new drought regime 2. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 3. Warmer Winters - Food supplies and bird migrations may be mistimed 4. Warmer Winters - Some plants may need a "setting" cold temperature 5. Warmer Winters - Species that once migrated through may stop and stay 6. Warmer Winters - Species that used to migrate away may stay all winter	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 2. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 3. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 4. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat)
	Low	1 .Warmer Summers - Species may be weakened by heat and become out- competed	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 3. Ocean Acidification - The effect of Ocean Acidification on calcifying plankton may lead to cascading effects in the food chain 4. Sea Level Rise - Light may not penetrate through the full depth of deeper water 5. Warmer Winters - A longer growing season may lead to an extra reproductive cycle	1. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 22. Massachusetts Bay and Environs 2050 Fish, Wildlife, and Plant 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 fish, wildlife and plants in the Massachusetts Bay and environs sub-region by 2100 are shown in the matrix in Figure 23. The high risk concerns by 2100 are similar to those in 2050 and in the NE Study Area by 2100.

Likelihood of Occurrence				
	High		1. Increasing Drought - Species may not tolerate a new drought regime 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 3. Warmer Water - Heat may stress immobile biota 4. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 5. Warmer Summers - Species may need to consume more water as temperature rises 6. Warmer Summers - Species that won't tolerate Warmer Summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 7. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 8. Warmer Winters - Food supplies and bird migrations may be mistimed 9. Warmer Winters - Some plants may need a "setting" cold temperature	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat 2. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 3. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 4. Sea Level Rise - Ability of tidal marsh to migrate landward 5. Sea Level Rise - Greater coastal wetland losses may occur 6. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 7. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat) 8. Warmer Water - Dissolved oxygen capacity of water may drop 9. Warmer Water - Habitat may become unsuitably warm, for a species or its food 10. Warmer Water - Newly invasive species may appear 11. Warmer Water - Parasites and diseases are enhanced by Warmer Water 12. Warmer Winters - Invasive species may move into places that used to be too cold 13. Warmer Winters - Pests may survive winters that used to kill them
	Medium	1. Warmer Summers - Species may be weakened by heat and become out-competed	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of Ocean Acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer Winters - A longer growing season may lead to an extra reproductive cycle 6. Warmer Winters - Species that once migrated through may stop and stay 7. Warmer Winters - Species that used to migrate away may stay all winter	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated
	Low		1. Sea Level Rise - Light may not penetrate through the full depth of deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 23. Massachusetts Bay and Environs 2100 Fish, Wildlife, and Plant Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.12 Massachusetts Bay and Environs Recreation and Public Water Supplies

The risks to EPA goals associated with recreation and public water supplies in Massachusetts Bay and environs by 2050 are shown in the matrix in Figure 24. Consistent with the risks identified for the NE Study Area in 2050, no high risk impacts were identified.

Likelihood of Occurrence	Low	Medium	High
High	1. Sea Level Rise - Clearance under bridges may decrease 2. Warmer Water - Harmful algal blooms may be more likely		
Medium	1. Increasing Storminess - Greater NPS pollution may impair recreation 2. Increasing Storminess - Water infrastructure may be vulnerable to flooding 3. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 4. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 5. Ocean Acidification - Recreational shellfish harvesting may be lost 6. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 7. Warmer Summers - Warmer temperatures may drive greater water demand 8. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 9. Warmer Water - Jellyfish may be more common 10. Warmer Water - Invasive plants may clog creeks and waterways 11. Warmer Water - Increased growth of algae and microbes may affect drinking water quality	1. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 2. Warmer Water - Fishing seasons and fish may become misaligned 3. Warmer Water - Desired recreational fish may no longer be present 4. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear	
Low	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 3. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 4. Increasing Drought - Groundwater tables may drop 5. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 6. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 7. Increasing Drought - Maintaining passing flows at diversions may be difficult 8. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 9. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 10. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 11. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 12. Warmer Water - Changes in treatment processes may be required 13. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure		
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 24. Massachusetts Bay and Environs 2050 Recreation and Water Supply 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 recreation and public water supplies in the Massachusetts Bay and environ sub-region by 2100 are shown in the matrix in Figure 25. By 2100 a number of high risk impacts are expected. Most are consistent with those expected by 2100 in the NE Study Area. Storms are expected to have a high risk (rather than medium risk in the NE Study Area). Jellyfish, algae, and invasive plants are not expected to be as high a risk for the Massachusetts Bay and environs as in the overall NE Study Area. A number of other impacts that are high risk in the NE Study Area are only expected to be medium risk in Massachusetts Bay by 2100, e.g., clearance under bridges, NPS pollution, eco-tourism impacts, and loss of recreational shellfish harvesting.

Likelihood of Occurrence	Low	Medium	High
High	1. Sea Level Rise - Clearance under bridges may decrease 2. Increasing Storminess - Greater NPS pollution may impair recreation 3. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 4. Ocean Acidification - Recreational shellfish harvesting may be lost 5. Warmer Summers - Warmer temperatures may drive greater water demand 6. Warmer Water - Harmful algal blooms may be more likely 7. Warmer Water - Jellyfish may be more common 8. Warmer Water - Invasive plants may clog creeks and waterways 9. Warmer Water - Increased growth of algae and microbes may affect drinking water quality	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 3. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 4. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase	1. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 2. Warmer Water - Fishing seasons and fish may become misaligned 3. Warmer Water - Desired recreational fish may no longer be present 4. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear
Medium	1. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 2. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 3. Increasing Drought - Maintaining passing flows at diversions may be difficult 4. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 5. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 6. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 7. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 8. Warmer Water - Changes in treatment processes may be required 9. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Groundwater tables may drop 3. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 4. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater	
Low			
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 25. Massachusetts Bay and Environs 2100 Recreation and Water Supply Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.13 Buzzards Bay Pollution Control

The risks to EPA goals associated with pollution control in the Buzzards Bay sub-region by 2050 are shown in the matrix in Figure 26. The potential inadequacy of flood control facilities, potential for treatment plants to go offline, and eutrophication appear to be the highest risks by 2050 to EPA goals associated with pollution control. These are consistent with risks in the overall NE Study Area. There is less risk than in the NE Study Area associated with, for example, sewer pipes inflows and infiltration, contaminated sites flooding, and thermal discharge limit concerns.

Likelihood of Occurrence	Low	Medium	High
High	1. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Warmer Water - Water may hold less dissolved oxygen 3. Warmer Water - Greater algae growth may occur 4. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters	
Medium	1. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 2. Warmer Summers - Wildfires may lead to soil erosion 3. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution)	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 3. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 4. Increasing Storminess - Combined sewer overflows may increase 5. Increasing Storminess - Streams may see greater erosion and scour 6. Increasing Storminess - Urban areas may be subject to more floods 7. Increasing Storminess - High rainfall may cause septic systems to fail 8. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 9. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 10. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 11. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 12. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 13. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 14. Warmer Water - Warmer temperatures may increase toxicity of pollutants 15. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 16. Warmer Water - Higher surface temperatures may lead to stratification 17. Warmer Water - Parasites, bacteria may have greater survival or transmission	1. Increasing Storminess - Treatment plants may go offline during intense floods
Low			
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 26. Buzzards Bay 2050 Pollution Control 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 pollution control in the Buzzards Bay sub-region by 2100 are shown in the matrix in Figure 27. The high risks for pollution control identified in 2050 are expected to continue to be the high risks in 2100. Additional high risk impacts are expected in 2100 including flooding of urban areas and infrastructure; increased pollution concentrations; sewage entering seawater; and impacts on discharge. These are consistent with NE Study Area risks identified for 2100.

Likelihood of Occurrence		Consequence of Impact: Low	Consequence of Impact: Medium	Consequence of Impact: High
	High		1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 3. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 4. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 5. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 6. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 7. Warmer Water - Water may hold less dissolved oxygen 8. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters 9. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Warmer Water - Greater algae growth may occur
	Medium	1. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 2. Warmer Summers - Wildfires may lead to soil erosion	1. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 2. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 3. Increasing Storminess - Streams may see greater erosion and scour 4. Increasing Storminess - High rainfall may cause septic systems to fail 5. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 6. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 7. Warmer Water - Warmer temperatures may increase toxicity of pollutants 8. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 9. Warmer Water - Higher surface temperatures may lead to stratification 10. Warmer Water - Parasites, bacteria may have greater survival or transmission	1. Increasing Storminess - Combined sewer overflows may increase 2. Increasing Storminess - Treatment plants may go offline during intense floods 3. Increasing Storminess - Urban areas may be subject to more floods
	Low			

Figure 27. Buzzards Bay 2100 Pollution Control Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.14 Buzzards Bay Habitat

The risks to EPA goals associated with habitat in the Buzzards Bay sub-region by 2050 are shown in the matrix in Figure 28. High risks of habitat damage or loss are associated with several stressors: sea level rise; increasing storms; increasing drought; and warmer water. These are consistent with high risks in the overall NE Study Area. No high risk concerns associated with ocean acidification or warmer summers or winters were identified for 2050. This is also consistent with the overall NE Study Area.

Likelihood of Occurrence		Low	Medium	High
	High		1. Increasing Drought - Base flow in streams may decrease 2. Increasing Drought - Groundwater tables may drop 3. Increasing Drought - Stream water may become warmer 4. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 5. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase	1. Increasing Storminess - Coastal overwash or island breaching may occur 2. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 3. Sea Level Rise - Ability of tidal marsh to migrate landward 4. Sea Level Rise - Higher salinity may kill targeted species 5. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 6. Warmer Water - Warmer water may promote invasive species or disease
	Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Summers - Greater electricity demand may affect operation decisions at hydropower dams 3. Warmer Summers - Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change 6. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Storminess - Turbidity of surface waters may increase 2. Warmer Summers - Higher temperatures may lead to greater evaporation and lower groundwater tables 3. Warmer Water - Desired fish may no longer be present 4. Warmer Water - Warmer water may lead to greater likelihood of stratification	1. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 2. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 3. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 4. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 5. Sea Level Rise - Tidal influence may move farther upstream
	Low	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Warmer Winters - A spring runoff pulse may disappear along with the snow	1. Increasing Storminess - Lower pH for NPS pollution may affect target species 2. Ocean Acidification - Fish may be adversely affected during development stages 3. Ocean Acidification - Long term shellfish sustainability may be an open question 4. Sea Level Rise - Light may not penetrate through deeper water	
			Consequence of Impact	

Figure 28. Buzzards Bay 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 habitat in the Buzzards Bay sub-region by 2100 are shown in the matrix in Figure 29. The high risk concerns are consistent with those in the overall NE Study Area.

Likelihood of Occurrence				
	High		1. Increasing Drought - Base flow in streams may decrease 2. Increasing Drought - Stream water may become warmer 3. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase 4. Increasing Storminess - Turbidity of surface waters may increase 5. Warmer Summers - Higher temperatures may lead to greater evaporation and lower groundwater tables 6. Warmer Summers - Switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 7. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change	1. Increasing Drought - Groundwater tables may drop 2. Increasing Storminess - Coastal overwash or island breaching may occur 3. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 4. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 5. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 6. Sea Level Rise - Ability of tidal marsh to migrate landward 7. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 8. Sea Level Rise - Higher salinity may kill targeted species 9. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 10. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 11. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 12. Sea Level Rise - Tidal influence may move farther upstream 13. Warmer Water - Warmer water may promote invasive species or disease
	Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Summers - Greater electricity demand may affect operation decisions at hydropower dams 3. Warmer Winters - A spring runoff pulse may disappear along with the snow 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Increasing Storminess - Lower pH for NPS pollution may affect target species 4. Ocean Acidification - Long term shellfish sustainability may be an open question 5. Ocean Acidification - Fish may be adversely affected during development stages 6. Warmer Water - Desired fish may no longer be present 7. Warmer Water - Warmer water may lead to greater likelihood of stratification	
	Low		1. Sea Level Rise - Light may not penetrate through deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 29. Buzzards Bay 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.15 Buzzards Bay Fish, Wildlife and Plants

The risks to EPA goals associated with fish, wildlife and plants in the Buzzards Bay sub-region by 2050 are shown in the matrix in Figure 30. These results are also similar to those observed for the overall NE Study Area in 2050. Most stressors, except ocean acidification, are expected to create some high risk impacts by 2050.

Likelihood of Occurrence				
	High		1. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 2. Warmer Summers - Species may need to consume more water as temperature rises 3. Warmer Summers - Species that won't tolerate Warmer Summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 4. Warmer Water - Heat may stress immobile biota 5. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) 2. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 3 .Sea Level Rise - Ability of tidal marsh to migrate landward 4. Sea Level Rise - Greater coastal wetland losses may occur 5. Warmer Water - Dissolved oxygen capacity of water may drop 6. Warmer Water - Habitat may become unsuitably warm, for a species or its food 7. Warmer Water - Newly invasive species may appear 8. Warmer Water - Parasites and diseases are enhanced by warmer water 9. Warmer Winters - Invasive species may move into places that used to be too cold 10. Warmer Winters - Pests may survive winters that used to kill them
	Medium		1. Increasing Drought - Species may not tolerate a new drought regime 2. Sea Level Rise - Light may not penetrate through the full depth of deeper water 3. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 4. Warmer Winters - Food supplies and bird migrations may be mistimed 5. Warmer Winters - Some plants may need a "setting" cold temperature 6. Warmer Winters - Species that once migrated through may stop and stay 7. Warmer Winters - Species that used to migrate away may stay all winter	1. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 2. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 3. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 4. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat)
	Low		1. Warmer Summers - Species may be weakened by heat and become out-competed 2. Ocean Acidification - Corrosive waters may impact shellfish development 3. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 4. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish	1. Warmer Winters - A longer growing season may lead to an extra reproductive cycle 2. Ocean Acidification - The effect of Ocean Acidification on calcifying plankton may lead to cascading effects in the food chain	
		Low	Medium	High
		Consequence of Impact		

Figure 30. Buzzards Bay 2050 Fish, Wildlife, and Plant 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 fish, wildlife and plants in the Buzzards Bay sub-region by 2100 are shown in the matrix in Figure 31. The high risk concerns by 2100 are similar to those in the NE Study Area by 2100.

Likelihood of Occurrence				
	High		1. Increasing Drought - Species may not tolerate a new drought regime 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 3. Warmer Water - Heat may stress immobile biota 4. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 5. Warmer Summers - Species may need to consume more water as temperature rises 6. Warmer Summers - Species that won't tolerate Warmer Summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 7. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 8. Warmer Winters - Food supplies and bird migrations may be mistimed 9. Warmer Winters - Some plants may need a "setting" cold temperature	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) 2. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 3. Sea Level Rise - Ability of tidal marsh elevation to match rate of Sea Level Rise 4. Sea Level Rise - Ability of tidal marsh to migrate landward 5. Sea Level Rise - Greater coastal wetland losses may occur 6. Sea Level Rise - Salinization of non-tidal freshwater coastal marshes 7. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat) 8. Warmer Water - Dissolved oxygen capacity of water may drop 9. Warmer Water - Habitat may become unsuitably warm, for a species or its food 10. Warmer Water - Newly invasive species may appear 11. Warmer Water - Parasites and diseases are enhanced by warmer water 12. Warmer Winters - Invasive species may move into places that used to be too cold 13. Warmer Winters - Pests may survive winters that used to kill them
	Medium	1. Warmer Summers - Species may be weakened by heat and become out-competed	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of Ocean Acidification on calcifying plankton may lead to cascading effects in the food chain 5. Sea Level Rise - Light may not penetrate through the full depth of deeper water 6. Warmer Winters - A longer growing season may lead to an extra reproductive cycle 7. Warmer Winters - Species that once migrated through may stop and stay 8. Warmer Winters - Species that used to migrate away may stay all winter	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated
	Low			
		Low	Medium	High
		Consequence of Impact		

Figure 31. Buzzards Bay 2100 Fish, Wildlife, and Plant Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.16 Buzzards Bay Recreation and Public Water Supplies

The risks to EPA goals associated with recreation and public water supplies in the Buzzards Bay sub-region by 2050 are shown in the matrix in Figure 32. While no high risk impacts were identified for the overall NE Study Area in 2050, coastal erosion and inundation, groundwater and water supplies, and fishing are at high risk by 2050 in the Buzzards Bay sub-region.

Likelihood of Occurrence	Low	Medium	High
High	1. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 2. Increasing Storminess - Greater NPS pollution may impair recreation 3. Increasing Storminess - Water infrastructure may be vulnerable to flooding 4. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 5. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 6. Sea Level Rise - Clearance under bridges may decrease 7. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 8. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 9. Warmer Summers - Warmer temperatures may drive greater water demand 10. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 11. Warmer Water - Harmful algal blooms may be more likely 12. Warmer Water - Jellyfish may be more common 13. Warmer Water - Invasive plants may clog creeks and waterways 14. Warmer Water - Changes in treatment processes may be required 15. Warmer Water - Increased growth of algae and microbes may affect drinking water quality 16. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure 17. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation	1. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 2. Warmer Water - Fishing seasons and fish may become misaligned 3. Warmer Water - Desired recreational fish may no longer be present 4. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear	
Medium	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 3. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 4. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 5. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 6. Increasing Drought - Maintaining passing flows at diversions may be difficult 7. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 8. Ocean Acidification - Recreational shellfish harvesting may be lost 9. Increasing Drought - Groundwater tables may drop		
Low			
	Consequence of Impact		

Figure 32. Buzzards Bay 2050 Recreation and Water Supply 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 recreation and public water supplies in the Buzzards Bay sub-region by 2100 are shown in the matrix in Figure 33. By 2100 a number of high risk impacts are expected. Most high risk impacts are consistent with those expected by 2100 in the overall NE Study Area. Groundwater tables are of greater concern than in the overall NE Study Area, whereas undesirable biota, loss of shellfish harvesting, and eco-tourism, and NPS pollution are only medium level concerns for Buzzards Bay, but high risk for the overall region.

Likelihood of Occurrence	Low	Medium	High
High	1. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 2. Increasing Storminess - Greater NPS pollution may impair recreation 3. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 4. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 5. Ocean Acidification - Recreational shellfish harvesting may be lost 6. Sea Level Rise - Clearance under bridges may decrease 7. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 8. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 9. Warmer Summers - Warmer temperatures may drive greater water demand 10. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 11. Warmer Water - Harmful algal blooms may be more likely 12. Warmer Water - Jellyfish may be more common 13. Warmer Water - Invasive plants may clog creeks and waterways 14. Warmer Water - Changes in treatment processes may be required 15. Warmer Water - Increased growth of algae and microbes may affect drinking water quality 16. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 3. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation	1. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 2. Warmer Water - Fishing seasons and fish may become misaligned 3. Warmer Water - Desired recreational fish may no longer be present 4. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear
Medium	1. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 2. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 3. Increasing Drought - Maintaining passing flows at diversions may be difficult	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 3. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater	1. Increasing Drought - Groundwater tables may drop
Low			
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 33. Buzzards Bay 2100 Recreation and Water Supply Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.17 Rhode Island Pollution Control

The risks to EPA goals associated with pollution control in the Rhode Island sub-region by 2050 are shown in the matrix in Figure 34. The potential inadequacy of flood control facilities, potential for treatment plants to go offline, and eutrophication appear to be the highest risks by 2050 to EPA goals associated with pollution control. Concerns with inadequate flood control facilities and higher water leading to treatment infrastructure and plant failures are consistent with risks in the overall NE Study Area. There is less risk than in the NE Study Area associated with, for example, sewer pipes inflows and infiltration, contaminated sites flooding, and thermal discharge limit concerns. There is high risk of algae growth, compared to a medium risk for the overall NE Study Area.

Likelihood of Occurrence				
	High	1. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides 2. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Warmer Water - Greater algae growth may occur 3. Warmer Water - Water may hold less dissolved oxygen	
	Medium	1. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 2. Warmer Water - Higher surface temperatures may lead to stratification 3. Sea Level Rise - Sewage may mix with seawater in combined sewer systems	1. Increasing Storminess - Combined sewer overflows may increase 2. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 3. Increasing Drought - Critical-low-flow criteria for discharging may not be met 4. Increasing Storminess - High rainfall may cause septic systems to fail 5. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 6. Warmer Water - Parasites, bacteria may have greater survival or transmission 7. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 8. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 9. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 10. Increasing Storminess - Streams may see greater erosion and scour 11. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 12. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 13. Increasing Storminess - Urban areas may be subject to more floods 14. Warmer Water - Warmer temperatures may increase toxicity of pollutants 15. Warmer Summers - Wildfires may lead to soil erosion	1. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 2. Increasing Storminess - Treatment plants may go offline during intense floods 3. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels
	Low			
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 34. Rhode Island 2050 Pollution Control 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 pollution control in the Rhode Island sub-region by 2100 are shown in the matrix in Figure 35. The high risks for pollution control identified in 2050 are expected to continue to be the high risks in 2100. Additional high risk impacts are expected in 2100 including sewer pipes inflows and infiltration, and contaminated sites flooding. These are consistent with NE Study Area risks identified for 2100. In the Rhode Island sub-region, there is a high risk for stream erosion and scour, compared to medium risk for the overall NE Study Area in 2100.

Likelihood of Occurrence	Low	Medium	High
High	1. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides 2. Sea Level Rise - Sewage may mix with seawater in combined sewer systems	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Warmer Water - Greater algae growth may occur 3. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters 4. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 5. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 6. Warmer Water - Water may hold less dissolved oxygen	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 3. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels
Medium	1. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters	1. Increasing Storminess - Combined sewer overflows may increase 2. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 3. Increasing Storminess - High rainfall may cause septic systems to fail 4. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 5. Warmer Water - Higher surface temperatures may lead to stratification 6. Warmer Water - Parasites, bacteria may have greater survival or transmission 7. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 8. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 9. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 10. Increasing Storminess - Urban areas may be subject to more floods 11. Warmer Water - Warmer temperatures may increase toxicity of pollutants 12. Warmer Summers - Wildfires may lead to soil erosion	1. Increasing Storminess - Streams may see greater erosion and scour 2. Increasing Storminess - Treatment plants may go offline during intense floods
Low			
	Low	**Medium**	**High**
	Consequence of Impact		

Figure 35. Rhode Island 2100 Pollution Control Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.18 Rhode Island Habitat

The risks to EPA goals associated with habitat in the Rhode Island sub-region by 2050 are shown in the matrix in Figure 36. High risks of habitat damage or loss are associated with several stressors: sea level rise; increasing storms; increasing drought; and warmer water. These are consistent with high risks in the overall NE Study Area. No high risk concerns associated with ocean acidification or warmer summers or winters were identified for 2050. This is also consistent with the overall NE Study Area.

Likelihood of Occurrence		Low	Medium	High
	High	1. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change	1. Increasing Drought - An increase in long-term and seasonal short term drought may decrease base flows in streams 2. Increasing Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 3. Increasing Drought - Stream water may become warmer 4. Increasing Storminess - Barrier Islands affected 5. Increasing Storminess - Coastal habitats will change 6. Increasing Storminess - Dunes and beaches damaged 7. Increasing Storminess - Salt marshes will be inundated 8. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 9. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase 10. Warmer Water - Coastal lagoons (salt ponds) will warm	1. Increasing Storminess - Coastal overwash or island breaching may occur 2. Sea Level Rise - Higher salinity may kill targeted species 3. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 4. Warmer Water - Warmer water may promote invasive species or disease 5. Warmer Water - Warmer water is likely to increase incidence of marine and estuarine disease 6. Warmer Water - Warmer water is likely to lead to an expansion of invasive species 7. Warmer Water - Warmer waters may both increase and decrease populations of commercially and recreationally important fish and shellfish 8. Warmer Winters - Nuisance species will invade from more southern waters
	Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Summers - Warmer summers may lead to greater electricity demand may affect operation decisions at hydropower dams 3. Warmer Summers - Warmer summers may result in the switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Storminess - Turbidity of surface waters may increase 2. Warmer Summers - Warmer summers are expected to result in higher temperatures which may lead to greater evaporation and lower groundwater tables 3. Warmer Water - Desired fish may no longer be present 4. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification	1. Increased Storminess - Stream erosion may lead to high turbidity and greater sedimentation 2. Increasing Storminess - Increased density stratification due to runoff may lead to more severe hypoxia 3. Sea Level Rise - Beaches will shrink 4. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 5. Sea Level Rise - Coastal habitats will change 6. Sea Level Rise - Offshore Islands and barrier beaches affected 7. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 8. Sea Level Rise - Tidal influence may move farther upstream 9. Warmer Water - Submerged aquatic vegetation will die off 10. Warmer Water - Hypoxia will become more common and widespread
	Low	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Increased Storminess - Lower pH for NPS pollution may affect target species 4. Ocean Acidification - Long term shellfish sustainability may be an open question 5. Warmer Winters - A spring runoff pulse may disappear along with the snow	1. Ocean Acidification - Fish may be adversely affected during development stages 2. Sea Level Rise - Light may not penetrate through deeper water	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 36. Rhode Island 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 habitat in the Rhode Island sub-region by 2100 are shown in the matrix in Figure 37. The high risk concerns are generally consistent with those in the overall NE Study Area. The impact of ocean acidification on fish development is a medium risk for Rhode Island, but a low risk for the overall NE Study Area.

Likelihood of Occurrence	High		1. Increasing Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 2. Increasing Drought - Stream water may become warmer 3. Increasing Storminess - The number of storms reaching an intensity that causes problems may increase 4. Increasing Storminess - Turbidity of surface waters may increase 5. Warmer Summers - Warmer summers are expected to result in higher temperatures which may lead to greater evaporation and lower groundwater tables 6. Warmer Summers - Warmer summers may lead to greater electricity demand may affect operation decisions at hydropower dams 7. Warmer Summers - Warmer summers may result in the switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 8. Warmer Water - Coastal lagoons (salt ponds) will warm 9. Warmer winters may lead to less snow, more rain may change the runoff/infiltration balance; base flow in streams may change	1. Increasing Drought - An increase in long-term and seasonal short term drought may decrease base flows in streams 2. Increased Storminess - Stream erosion may lead to high turbidity and greater sedimentation 3. Increasing Storminess - Barrier Islands affected 4. Increasing Storminess - Coastal habitats will change 5. Increasing Storminess - Coastal overwash or island breaching may occur 6. Increasing Storminess - Dunes and beaches damaged 7. Increasing Storminess - Increased density stratification due to runoff may lead to more severe hypoxia 8. Increasing Storminess - Salt marshes will be inundated 9. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 10. Sea Level Rise - Beaches will shrink 11. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 12. Sea Level Rise - Coastal habitats will change 13. Sea Level Rise - Higher salinity may kill targeted species 14. Sea Level Rise - Offshore Islands and barrier beaches affected 15. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 16. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 17. Sea Level Rise - Tidal influence may move farther upstream 18. Warmer Water - Warmer water may promote invasive species or disease 19. Warmer Water - Warmer water is likely to Increase incidence of marine and estuarine disease 20. Warmer Water - Warmer water is likely to lead to an expansion of invasive species 21. Warmer Water - Warmer waters may both increase and decrease populations of commercially and recreationally important fish and shellfish 22. Warmer Winters - Nuisance species will invade from more southern waters
Likelihood of Occurrence	Medium	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Increased Storminess - Lower pH for NPS pollution may affect target species 3. Warmer Winters - A spring runoff pulse may disappear along with the snow 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Ocean Acidification - Long term shellfish sustainability may be an open question 4. Ocean Acidification - Fish may be adversely affected during development stages 5. Warmer Water - Desired fish may no longer be present 6. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification	1. Warmer Water - Hypoxia will become more common and widespread 2. Warmer Water - Submerged aquatic vegetation will die off
	Low		1. Sea Level Rise - Light may not penetrate through deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 37. Rhode Island 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.19 Rhode Island Fish, Wildlife and Plants

The risks to EPA goals associated with fish, wildlife and plants in the Rhode Island sub-region by 2050 are shown in the matrix in Figure 38. These results are also similar to those observed for the overall NE Study Area in 2050. All stressors are expected to create some high risk impacts by 2050.

Likelihood of Occurrence				
	High	1. Warmer Summers - Species may need to consume more water as temperature rises	1. Warmer Summers - Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 2 .Warmer Water - Habitat may become unsuitably warm, for a species or its food 3. Warmer Water - Heat may stress immobile biota 4. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 5. Warmer Water - Warmer water will impact the coastal food web base 6. Warmer Winters - Warmer winters may result in a shift in the structure of winter fish community	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) 2. Sea Level Rise - Greater coastal wetland losses may occur 3. Warmer Water - Diseases common to fish, shellfish and marine plants in southern waters will move northward 4. Warmer Water - Dissolved oxygen capacity of water may drop 5. Warmer Water - Fish and shellfish species and abundance will shift northward 6. Warmer Water - Newly invasive species may appear 7. Warmer Water - Nuisance species will invade from more southern waters 8. Warmer Water - Parasites and diseases are enhanced by warmer water 9. Warmer Water - Warmer water will result in a shift of pelagic community structure 10. Warmer Winters - Invasive species may move into places that used to be too cold 11. Warmer Winters - Pests may survive winters that used to kill them
	Medium		1. Increasing Drought - Species may not tolerate a new drought regime 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 3. Ocean Acidification - Adverse effect on metabolism of pelagic species 4. Ocean Acidification - Adverse effects on shell formation 5. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 6. Warmer Water - Hypoxia will become more common and widespread 7. Warmer Winters - Food supplies and bird migrations may be mistimed 8. Warmer Winters - Some plants may need a "setting" cold temperature 9. Warmer Winters - Species that once migrated through may stop and stay 10. Warmer Winters - Species that used to migrate away may stay all winter	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 2. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 3. Ocean Acidification - Impacts on larval development 4. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat)
	Low	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer Summers - Species may be weakened by heat and become out- competed 6. Warmer Water - Marine Mammals will shift northward	1. Sea Level Rise - Light may not penetrate through the full depth of deeper water 2. Warmer Winters - A longer growing season may lead to an extra reproductive cycle	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 38. Rhode Island 2050 Fish, Wildlife, and Plant 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 fish, wildlife and plants in the Rhode Island sub-region by 2100 are shown in the matrix in Figure 39. The high risk concerns by 2100 are similar to those in 2050 and in the NE Study Area by 2100.

Likelihood of Occurrence				
	High		1. Increasing Drought - Species may not tolerate a new drought regime 2. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 3. Warmer Summers - Species may need to consume more water as temperature rises 4. Warmer Summers - Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 5. Warmer Water - Habitat may become unsuitably warm, for a species or its food 6. Warmer Water - Heat may stress immobile biota 7. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 8. Warmer Water - Warmer water will impact the coastal food web base 9. Warmer Winters - Food supplies and bird migrations may be mistimed 10. Warmer Winters - Warmer winters may result in a shift in the structure of winter fish community 11. Warmer Winters - Some plants may need a "setting" cold temperature	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 3. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 4. Sea Level Rise - Greater coastal wetland losses may occur 5. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat) 6. Warmer Water - Diseases common to fish, shellfish and marine plants in southern waters will move northward 7. Warmer Water - Dissolved oxygen capacity of water may drop 8. Warmer Water - Fish and shellfish species and abundance will shift northward 9. Warmer Water - Hypoxia will become more common and widespread 10. Warmer Water - Newly invasive species may appear 11. Warmer Water - Nuisance species will invade from more southern waters 12. Warmer Water - Parasites and diseases are enhanced by warmer water 13. Warmer Water - Warmer water will result in a shift of pelagic community structure 14. Warmer Winters - Invasive species may move into places that used to be too cold 15. Warmer Winters - Pests may survive winters that used to kill them
	Medium	1. Warmer Summers - Species may be weakened by heat and become out-competed	1. Ocean Acidification - Adverse effect on metabolism of pelagic species 2. Ocean Acidification - Adverse effects on shell formation 3. Ocean Acidification - Corrosive waters may impact shellfish development 4. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 5. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 6. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 7. Warmer Water - Marine Mammals will shift northward 8. Warmer Winters - A longer growing season may lead to an extra reproductive cycle 9. Warmer Winters - Species that once migrated through may stop and stay 10. Warmer Winters - Species that used to migrate away may stay all winter	1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated 2. Ocean Acidification - Impacts on larval development
	Low		1. Sea Level Rise - Light may not penetrate through the full depth of deeper water	
		Low	Medium	High
		Consequence of Impact		

Figure 39. Rhode Island 2100 Fish, Wildlife, and Plant Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.20 Rhode Island Recreation and Public Water Supplies

The risks to EPA goals associated with recreation and public water supplies in the Rhode Island sub-region by 2050 are shown in the matrix in Figure 40. While no high risk impacts were identified for the overall NE Study Area in 2050, coastal erosion and inundation impacts on water infrastructure and beaches, saltwater intrusion in to groundwater, bridge clearances, loss of recreational fish, and increase in jellyfish are high risk concerns by 2050 in the Rhode Island sub-region.

Likelihood of Occurrence		Low	Medium	High
	High	1. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 2. Increasing Storminess - Greater NPS pollution may impair recreation 3. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 4. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 5. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 6. Warmer Summers - Warmer temperatures may drive greater water demand 7. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 8. Warmer Water - Harmful algal blooms may be more likely 9. Warmer Water - Fishing seasons and fish may become misaligned 10. Warmer Water - Invasive plants may clog creeks and waterways 11. Warmer Water - Changes in treatment processes may be required 12. Warmer Water - Increased growth of algae and microbes may affect drinking water quality 13. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear 14. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 3. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 4. Sea Level Rise - Clearance under bridges may decrease 5. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 6. Warmer Water - Jellyfish may be more common 7. Warmer Water - Desired recreational fish may no longer be present	
	Medium	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 3. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 4. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 5. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 6. Increasing Drought - Maintaining passing flows at diversions may be difficult 7. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 8. Ocean Acidification - Recreational shellfish harvesting may be lost	1. Increasing Drought - Groundwater tables may drop	
	Low			
		Low	Medium	High
		Consequence of Impact		

Figure 40. Rhode Island 2050 Recreation and Water Supply 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 recreation and public water supplies in the Rhode Island sub-region by 2100 are shown in the matrix in Figure 41. By 2100 a number of high risk impacts are expected. Most high risk impacts are consistent with those expected by 2100 in the overall NE Study Area. Drop in groundwater tables is a high risk for Rhode Island, but only a medium risk in the overall NE Study Area, whereas warmer temperatures driving greater water demand is only a medium risk for Rhode Island, but a high risk for the overall NE Study Area.

Likelihood of Occurrence	Low	Medium	High
High	1. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 2. Warmer Summers - Warmer temperatures may drive greater water demand 3. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 4. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear 5. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 2. Increasing Storminess - Greater NPS pollution may impair recreation 3. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 4. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 5. Ocean Acidification - Recreational shellfish harvesting may be lost 6. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 7. Warmer Water - Harmful algal blooms may be more likely 8. Warmer Water - Fishing seasons and fish may become misaligned 9. Warmer Water - Invasive plants may clog creeks and waterways 10. Warmer Water - Changes in treatment processes may be required 11. Warmer Water - Increased growth of algae and microbes may affect drinking water quality	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 3. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 4. Sea Level Rise - Clearance under bridges may decrease 5. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 6. Warmer Water - Jellyfish may be more common 7. Warmer Water - Desired recreational fish may no longer be present
Medium	1. Increasing Drought - Freshwater flows in streams may not support recreational uses 2. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 3. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 4. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 5. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 6. Increasing Drought - Maintaining passing flows at diversions may be difficult		1. Increasing Drought - Groundwater tables may drop
Low			
	Consequence of Impact		

Figure 41. Rhode Island 2100 Recreation and Water Supply Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.21 Long Island Sound (Connecticut and New York) Pollution Control

The risks to EPA goals associated with pollution control in the Long Island Sound (Connecticut and New York) sub-region by 2050 are shown in the matrix in Figure 42. The potential inadequacy of flood control facilities, potential for treatment plants to go offline, flooding of treatment infrastructure and urban areas, and eutrophication appear to be the highest risks by 2050 to EPA goals associated with pollution control. Concerns with inadequate flood control facilities and higher water leading to treatment infrastructure and plant failures are consistent with risks in the overall NE Study Area. There is less risk than in the NE Study Area associated with, for example, sewer pipes inflows and infiltration, contaminated sites flooding, and thermal discharge limit concerns. There is high risk of greater algae growth, compared to a medium risk for the overall NE Study Area.

Likelihood of Occurrence		Low	Medium	High
	High	1. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Warmer Water - Greater algae growth may occur 3. Warmer Water - Water may hold less dissolved oxygen 4. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters	
	Medium	1. Increasing Storminess - Streams may see greater erosion and scour 2. Increasing Storminess - Urban areas may be subject to more floods 3. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 4. Warmer Water - Warmer temperatures may increase toxicity of pollutants	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 3. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 4. Increasing Storminess - Combined sewer overflows may increase 5. Increasing Storminess - High rainfall may cause septic systems to fail 6. Increasing Storminess - Treatment plants may go offline during intense floods 7. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 8. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 9. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 10. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 11. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 12. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels 13. Warmer Summers - Wildfires may lead to soil erosion 14. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 15. Warmer Water - Higher surface temperatures may lead to stratification 16. Warmer Water - Parasites, bacteria may have greater survival or transmission 17. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution)	
	Low			
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 42. Long Island Sound (Connecticut and New York) 2050 Pollution Control 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 pollution control in the Long Island Sound (Connecticut and New York) sub-region by 2100 are shown in the matrix in Figure 43. The high risks for pollution control identified in 2100 are similar to those for the overall NE Study Area. Additional high risk impacts are expected in the Long Island Sound (Connecticut and New York) in 2100 including sewer pipes inflows and infiltration, contaminated sites flooding, sewage mixing with seawater, additional pollution, and greater concerns with parasites and bacteria.

Likelihood of Occurrence		Low	Medium	High
	High	1. Sea Level Rise - Sewer pipes may have more inflow (floods) or infiltration (higher water table) 2. Warmer Winters - Longer growing season can lead to more lawn maintenance with fertilizers and pesticides	1. Increasing Drought - Critical-low-flow criteria for discharging may not be met 2. Sea Level Rise - Sewage may mix with seawater in combined sewer systems 3. Sea Level Rise - Tidal flooding may extend to new areas, leading to additional sources of pollution 4. Warmer Water - Greater algae growth may occur 5. Warmer Water - Water may hold less dissolved oxygen 6. Warmer Winters - Loss of melting winter snows may reduce spring or summer flow volume and raise pollutant concentration in receiving waters	1. Increasing Storminess - Flood control facilities (e.g., detention basins, manure management) may be inadequate 2. Sea Level Rise - Treatment infrastructure may be susceptible to flooding 3. Sea Level Rise - Treatment plants may not be able to discharge via gravity at higher water levels
	Medium	1. Increasing Storminess - Streams may see greater erosion and scour	1. Increasing Drought - Pollutant concentrations may increase if sources stay the same and flow diminishes 2. Increasing Drought - Pollution sources may build up on land, followed by high-intensity flushes 3. Increasing Storminess - High rainfall may cause septic systems to fail 4. Increasing Storminess - Urban areas may be subject to more floods 5. Ocean Acidification - Decomposing organic matter releases carbon dioxide, which may exacerbate the ocean acidification problem in coastal waters 6. Sea Level Rise - Contaminated sites may flood or have shoreline erosion 7. Warmer Summers - Wildfires may lead to soil erosion 8. Warmer Water - Higher solubility may lead to higher concentrations of pollutants 9. Warmer Water - Higher surface temperatures may lead to stratification 10. Warmer Water - Temperature criteria for discharges may be exceeded (thermal pollution) 11. Warmer Water - Warmer temperatures may increase toxicity of pollutants	1. Increasing Storminess - Combined sewer overflows may increase 2. Increasing Storminess - Treatment plants may go offline during intense floods 3. Warmer Water - Parasites, bacteria may have greater survival or transmission
	Low			
		Low	Medium	High
		Consequence of Impact		

Figure 43. Long Island Sound (Connecticut and New York) 2100 Pollution Control Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.22 Long Island Sound (Connecticut and New York) Habitat

The risks to EPA goals associated with habitat in the Long Island Sound (Connecticut and New York) sub-region by 2050 are shown in the matrix in Figure 44. High risks of habitat damage or loss are associated with several stressors: sea level rise; increasing storms; increasing drought; warmer water, and warmer winters. Except for warmer winters impacting base flow (medium risk in the overall region), these high risks are consistent with high risks in the overall NE Study Area. No high risk concerns associated with ocean acidification were identified for 2050. This is consistent with the overall NE Study Area.

Likelihood of Occurrence				
	High		1. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 2. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 3. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 4. Sea Level Rise - Tidal influence may move farther upstream	1. Increasing Storminess - Coastal overwash or island breaching may occur 2. Sea Level Rise - Higher salinity may kill targeted species 3. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 4. Warmer Water - Warmer water may promote invasive species or disease
	Medium	1. Increasing Storminess - Lower pH for NPS pollution may affect target species 2. Ocean Acidification - Fish may be adversely affected during development stages	1. Increasing Storminess - Turbidity of surface waters may increase 2. Warmer Summers - Warmer summers are expected to result in higher temperatures which may lead to greater evaporation and lower groundwater tables 3. Warmer Water - Desired fish may no longer be present 4. Warmer Water - Warmer water is likely to lead to greater likelihood of stratification	1. Increasing Drought - An increase in long-term and seasonal short term drought may decrease base flows in streams 2. Increasing Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 3. Increasing Drought - Stream water may become warmer 4. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 5. Increasing Storminess - The number of storms reaching an intensity that causes problems are expected to increase 6.Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change
	Low	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 3. Ocean Acidification - Long term shellfish sustainability may be an open question 4. Sea Level Rise - Light may not penetrate through deeper water 5. Warmer Winters - A spring runoff pulse may disappear along with the snow	1. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 2. Warmer Summers - Warmer summers may lead to greater electricity demand may affect operation decisions at hydropower dams 3. Warmer Summers - Warmer summers may result in the switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 44. Long Island Sound (Connecticut and New York) 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 habitat in the Long Island (Connecticut and New York) sub-region by 2100 are shown in the matrix in Figure 45. The high risk concerns are generally consistent with those in the overall NE Study Area. The impact of ocean acidification on fish development is a high risk for Long Island (Connecticut and New York), but a medium risk for the overall NE Study Area.

Likelihood of Occurrence	Low	Medium	High
High		1. Increasing Drought - New water supply reservoirs may affect the integrity of freshwater streams 2. Ocean Acidification - Fish may be adversely affected during development stages	1. Increasing Drought - An increase in long-term and seasonal short term drought may decrease base flows in streams 2. Increasing Storminess - Coastal overwash or island breaching may occur 3. Increasing Storminess - Stream erosion may lead to high turbidity and greater sedimentation 4. Sea Level Rise - Bulkheads, sea walls and revetments may become more widespread 5. Sea Level Rise - Higher salinity may kill targeted species 6. Sea Level Rise - Saline water may move farther upstream and freshwater habitat may become brackish 7. Sea Level Rise - Shoreline erosion may lead to loss of beaches, wetlands and salt marshes 8. Sea Level Rise - Tidal influence may move farther upstream 9. Warmer Water - Warmer water may promote invasive species or disease
Medium		1. Increasing Storminess - Lower pH for NPS pollution may affect target species 2. Ocean Acidification - Long term shellfish sustainability may be an open question 3. Warmer Water - Desired fish may no longer be present	1. Increasing Drought - An increase in long-term and seasonal short term drought may cause groundwater tables to drop 2. Increasing Drought - Stream water may become warmer 3. Increasing Storminess - Stronger storms may cause more intense flooding and runoff 4. Increasing Storminess - The number of storms reaching an intensity that causes problems are expected to increase 5. Increasing Storminess - Turbidity of surface waters may increase 6. Warmer Summers - Warmer summers are expected to result in higher temperatures which may lead to greater evaporation and lower groundwater tables 7. Warmer Summers - Warmer summers may result in the switching between surface and groundwater sources for public water supplies may affect the integrity of water bodies 8. Warming of water may lead to increased stratification which in turn may affect the larval transport 9. Warmer Winters - A spring runoff pulse may disappear along with the snow 10. Warmer Winters - Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change
Low	1. Sea Level Rise - Light may not penetrate through deeper water	1. Increasing Drought - Increased human use of groundwater during drought may reduce stream baseflow 2. Increasing Storminess - Increased intensity of precipitation may yield less infiltration 3. Warmer Summers - Warmer summers may lead to greater electricity demand may affect operation decisions at hydropower dams 4. Warmer Winters - Marshes and beaches may erode from loss of protecting ice 5. Warmer Winters - Rivers may no longer freeze; a spring thaw would be obsolete	

Consequence of Impact

Figure 45. Long Island Sound (Connecticut and New York) 2100 Habitat Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.23 Long Island Sound (Connecticut and New York) Fish, Wildlife and Plants

The risks to EPA goals associated with fish, wildlife and plants in the Long Island (Connecticut and New York) sub-region by 2050 are shown in the matrix in Figure 46. These results are also similar to those observed for the overall NE Study Area in 2050. All stressors except ocean acidification are expected to create some high risk impacts by 2050.

Likelihood of Occurrence				
	High		1. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 2. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) 2. Sea Level Rise - Greater coastal wetland losses may occur 3. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat) 4. Warmer Water - Dissolved oxygen capacity of water may drop 5. Warmer Water - Habitat may become unsuitably warm, for a species or its food 6. Warmer Water - Newly invasive species may appear 7. Warmer Water - Parasites and diseases are enhanced by warmer water 8. Warmer Winters - Invasive species may move into places that used to be too cold 9. Warmer Winters - Pests may survive winters that used to kill them
	Medium	1. Sea Level Rise - Light may not penetrate through the full depth of deeper water 2. Warmer Winters - A longer growing season may lead to an extra reproductive cycle	1. Increasing Drought - Species may not tolerate a new drought regime 2. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 3. Warmer Winters - Some plants may need a “setting” cold temperature 4. Warmer winters - Food supplies and bird migrations may be mistimed 5. Warmer Winters - Species that once migrated through may stop and stay 6. Warmer Winters - Species that used to migrate away may stay all winter 7. Warmer Summers - Essential food sources may die off or disappear, affecting the food web	1 .Warmer Summers - Species that won’t tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 2. Warmer Water - Heat may stress immobile biota 3. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature
	Low	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer Summers - Species may be weakened by heat and become out- competed		1. Warmer Summers - Species may need to consume more water as temperature rises
		Low	Medium	High
		Consequence of Impact		

Figure 46. Long Island Sound (Connecticut and New York) 2050 Fish, Wildlife, and Plant 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 fish, wildlife and plants in the Long Island (Connecticut and New York) sub-region by 2100 are shown in the matrix in Figure 47. The high risk concerns by 2100 are similar to those in the NE Study Area by 2100.

Likelihood of Occurrence				
	High		1. Increasing Drought - Native habitat may be affected if freshwater flow in streams is diminished or eliminated	1. Increasing Drought - Changing freshwater inputs may affect salinity distribution in estuaries (especially of interest with regard to shellfish habitat) 2. Increasing Storminess - Greater soil erosion may increase turbidity and decrease water clarity 3. Increasing Storminess - Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species 4. Sea Level Rise - Greater coastal wetland losses may occur 5. Sea Level Rise - Sea level may push saltier water farther upstream (especially of interest with regard to shellfish habitat) 6. Warmer Water - Dissolved oxygen capacity of water may drop 7. Warmer Water - Habitat may become unsuitably warm, for a species or its food 8. Warmer Water - Newly invasive species may appear 9. Warmer Water - Parasites and diseases are enhanced by warmer water 10. Warmer Winters - Invasive species may move into places that used to be too cold 11. Warmer Winters - Pests may survive winters that used to kill them
	Medium	1. Sea Level Rise - Light may not penetrate through the full depth of deeper water	1. Ocean Acidification - Corrosive waters may impact shellfish development 2. Ocean Acidification - Fish may be adversely affected during development stages by changes to water chemistry 3. Ocean Acidification - Shellfish predators may not survive the disappearance of shellfish 4. Ocean Acidification - The effect of ocean acidification on calcifying plankton may lead to cascading effects in the food chain 5. Warmer Winters - Species that once migrated through may stop and stay 6. Warmer Winters - Species that used to migrate away may stay all winter	1. Increasing Drought - Species may not tolerate a new drought regime 2. Warmer Water - Heat may stress immobile biota 3. Warmer Summers - Species that won't tolerate warmer summers may die/migrate; biota at the southern limit of their range may disappear from ecosystems 4. Warmer Summers - Essential food sources may die off or disappear, affecting the food web 5. Warmer Summers - Species may need to consume more water as temperature rises 6. Warmer Water - Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature 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 - Some plants may need a "setting" cold temperature
	Low		1. Warmer Summers - Species may be weakened by heat and become out-competed	
		Low	Medium	High
		Consequence of Impact		

Figure 47. Long Island Sound (Connecticut and New York) 2100 Fish, Wildlife, and Plant Vulnerability Assessment where impacts in green cells have low risk, yellow cells have medium risk, and red cells have high risk.

5.24 Long Island Sound (Connecticut and New York) Recreation and Public Water Supplies

The risks to EPA goals associated with recreation and public water supplies in the Long Island (Connecticut and New York) sub-region by 2050 are shown in the matrix in Figure 48. While no high risk impacts were identified for the overall NE Study Area in 2050, coastal erosion and inundation impacts on water infrastructure and coasts, saltwater intrusion in to groundwater, and salt fronts past water diversion are high risk concerns by 2050 in the Long Island (Connecticut and New York) sub-region.

Likelihood of Occurrence	Low	Medium	High
High	1. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 2. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 3. Increasing Storminess - Greater NPS pollution may impair recreation 4. Sea Level Rise - Clearance under bridges may decrease 5. Warmer Summers - Warmer temperatures may drive greater water demand 6. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 7. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 8. Warmer Water - Changes in treatment processes may be required 9. Warmer Water - Increased growth of algae and microbes may affect drinking water quality 10. Warmer Water - Harmful algal blooms may be more likely 11. Warmer Water - Jellyfish may be more common 12. Warmer Water - Fishing seasons and fish may become misaligned 13. Warmer Water - Invasive plants may clog creeks and waterways 14. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear 15. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 3. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 4. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 5. Warmer Water - Desired recreational fish may no longer be present	1. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion
Medium	1. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 2. Increasing Drought - Groundwater tables may drop 3. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 4. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 5. Increasing Drought - Maintaining passing flows at diversions may be difficult 6. Increasing Drought - Freshwater flows in streams may not support recreational uses 7. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish 8. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 9. Ocean Acidification - Recreational shellfish harvesting may be lost		
Low			
	Consequence of Impact		

Figure 48. Long Island Sound (Connecticut and New York) 2050 Recreation and Water Supply 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 recreation and public water supplies in the Long Island (Connecticut and New York) sub-region by 2100 are shown in the matrix in Figure 49. By 2100 a number of high risk impacts are expected. Most high risk impacts are consistent with those expected by 2100 in the overall NE Study Area. Salt fronts past water diversion are high risk concerns by 2050 in the Long Island (Connecticut and New York) sub-region, medium risk in the overall NE Study Area. Increased water demand, evaporation losses, and harmful algal blooms, are medium risk in the Long Island (Connecticut and New York) sub-region, high risk in the overall NE Study Area.

Likelihood of Occurrence		Low	Medium	High
	High	1. Warmer Water - Jellyfish may be more common 2. Warmer Winters - Cold places may see more freeze/thaw cycles that can affect infrastructure	1. Increasing Storminess - Flood waters may raise downstream turbidity and affect water quality 2. Increasing Storminess - More frequent or more intense storms may decrease recreational opportunities 3. Increasing Storminess - Greater NPS pollution may impair recreation 4. Ocean Acidification - Eco-tourism resource or attractions (e.g., birding, diving, fishing) may be degraded 5. Ocean Acidification - Recreational shellfish harvesting may be lost 6. Sea Level Rise - Clearance under bridges may decrease 7. Warmer Summers - Warmer temperatures may drive greater water demand 8. Warmer Summers - Evaporation losses from reservoirs and groundwater may increase 9. Warmer Summers - More people using water for recreation may raise the potential for pathogen exposure 10. Warmer Water - Changes in treatment processes may be required 11. Warmer Water - Increased growth of algae and microbes may affect drinking water quality 12. Warmer Water - Harmful algal blooms may be more likely 13. Warmer Water - Fishing seasons and fish may become misaligned 14. Warmer Water - Invasive plants may clog creeks and waterways 15. Warmer Winters - Summer water supplies that depend on winter snow pack may disappear	1. Increasing Storminess - Water infrastructure may be vulnerable to flooding 2. Sea Level Rise - Water infrastructure may be vulnerable to inundation or erosion 3. Sea Level Rise - Sea level may push salt fronts upstream past water diversion 4. Sea Level Rise - Saltwater intrusion into groundwater may be more likely 5. Sea Level Rise - Beaches or public access sites may be lost to coastal erosion or inundation 6. Warmer Water - Desired recreational fish may no longer be present
	Medium	1. Increasing Drought - Lower freshwater flows may not keep saltwater downstream of intakes 2. Increasing Drought - Maintaining passing flows at diversions may be difficult 3. Increasing Drought - Increased estuary salinity may drive away targeted recreational fish	1. Increasing Drought - Groundwater tables may drop 2. Increasing Drought - Coastal aquifers may be salinized from insufficient freshwater input 3. Increasing Drought - Coastal aquifers may be salinized from higher demand on groundwater 4. Increasing Drought - Freshwater flows in streams may not support recreational uses	
	Low			
		Low	**Medium**	**High**
		Consequence of Impact		

Figure 49. Long Island Sound (Connecticut and New York) 2100 Recreation and Water Supply 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 six sub-regions, including estuaries and coastal watersheds:

1. Southern Maine concentrating on the Casco Bay Area
2. New Hampshire
3. Massachusetts Bay and environs
4. Buzzards Bay
5. Rhode Island
6. Long Island Sound (Connecticut and New York)

C/P matrices for four EPA goal areas (pollution control; habitat; fish, wildlife, and plants; recreation and public water supplies) 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 become substantially greater for all EPA goals by 2100.

The high risk climate change impacts for the sub-region 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, 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. Quantitative data on the extent to which predicted climate change stressors will result in specific levels of impact by 2050 and 2100. 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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