2022
MASSACHUSETTS
CLIMATE CHANGE
ASSESSMENT

2022 Massachusetts Climate Change Assessment

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For Public Comment

Executive Office of Energy and Environmental Affairs

Massachusetts Climate Change Assessment

The Massachusetts Climate Change Assessment (Climate Assessment) evaluates the impacts of climate change to the Commonwealth, including human health and safety, natural resources, and public and private assets. The Climate Assessment serves to directly inform the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP).

Aligned with the SHMCAP, the Climate Assessment evaluates 37 climate impacts across five sectors: Human, Infrastructure, Natural Environment, Governance, and Economy; and seven regions of the Commonwealth.

This executive summary (Volume I) provides an overview of the methods and highlights statewide findings of the Climate Assessment by sector. Further details on methods, climate projections, and statewide results can be found in Volume II of this report. Volume III reports impacts at the regional level.

The project consultant team is led by Industrial Economics (IEc) and includes Eastern Research Group, Consensus Building Institute, and Woods Hole Group, in addition to independent subject matter experts from Massachusetts-based universities.

Identifying Impacts of Climate Change

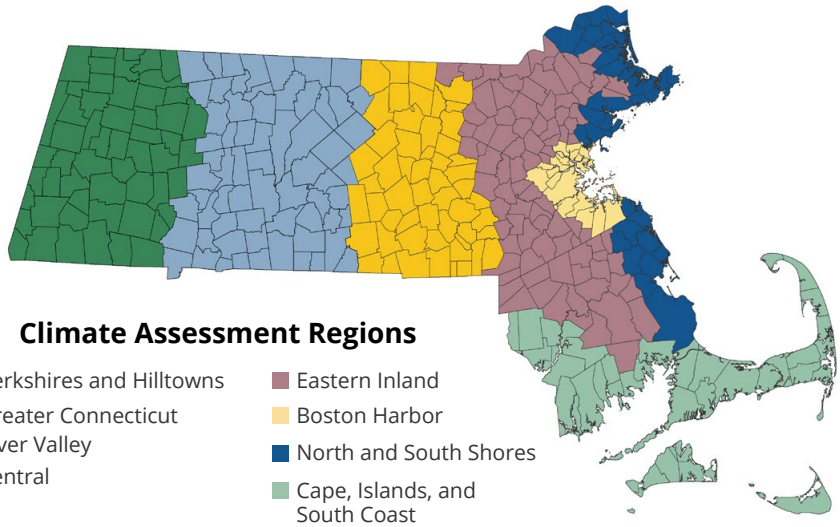
This Climate Assessment identifies the impacts from climate stressors (temperature, precipitation, sea level rise, etc.) and climate hazards (extreme heat, flooding, droughts, etc.) across five sectors that require adaptation action most urgently.

Impact Prioritization Process

1. **Synthesize Climate Projections** — Review existing climate projection data and convene an expert review panel.
2. **Identify Impacts** — Consult with state agency staff and the public through a series of workshops.
3. **Build Evidence Base** — Review existing reports and use available data and models to assess impacts.
4. **Calculate Urgency Scores** — Apply urgency ranking framework to identify highest priority impacts by sector.

Impacts Are Assessed Statewide and for Seven Regions

The seven Climate Assessment regions are designed to balance alignment with existing jurisdictions and planning regions with similarities in the challenges of climate change faced.



Climate Assessment Regions

- Berkshires and Hilltowns
- Greater Connecticut River Valley
- Central
- Eastern Inland
- Boston Harbor
- North and South Shores
- Cape, Islands, and South Coast

Impacts Are Assessed Across Five Sectors

HUMAN
Impacts to people's health, welfare, and safety

INFRASTRUCTURE
Impacts to buildings and transportation systems, and how we get our electricity and water

NATURAL ENVIRONMENT
Impacts to ecosystems and natural resources, and how plants and animals can thrive here

GOVERNANCE
Impacts to state and local government owned facilities, government finances, and demand on government services

ECONOMY
Impacts to people's ability to work and make a living, due to damages to infrastructure, our natural environment, or people's health, and people's ability to find affordably priced housing

1 **Synthesize Climate Projections**

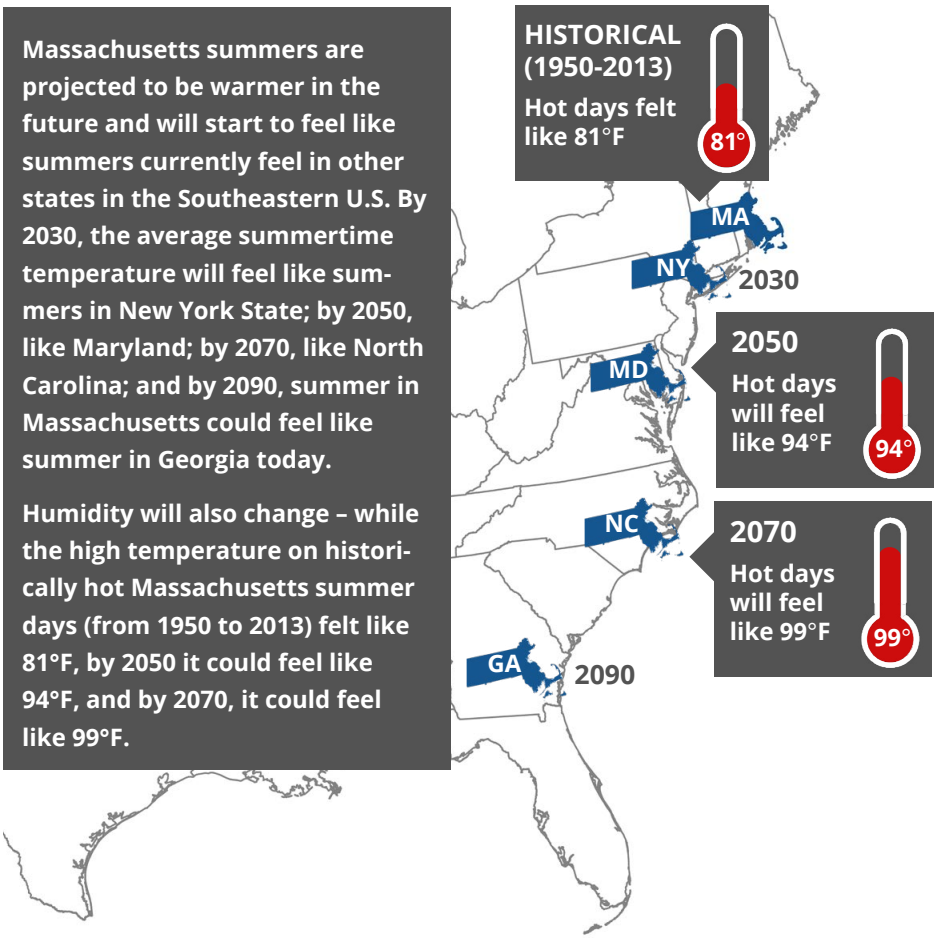
How Could Climate Hazards Change in Massachusetts?

The best climate science for Massachusetts continues to stress three findings: temperatures have gone up over the years and will continue to increase; there could be both fewer rainy days and more intense rainstorms; and sea levels will rise and combine with more powerful coastal storms.

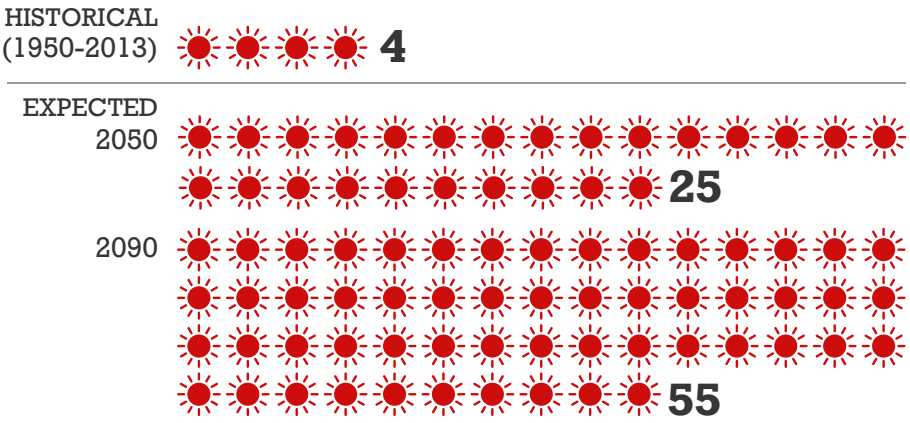
The latest climate science for Massachusetts was synthesized and applied to estimate impacts to human populations, and natural, and infrastructure assets. Key climate hazards include warmer temperatures and more heat waves (as shown in the figures on this page) that are connected to human health, droughts, agriculture yields, and a need for infrastructure repairs. Other projected changes include more frequent seasonal droughts affecting water supply and agriculture; more intense days of high rainfall, increasing flooding; more intense and frequent coastal storms that cause power outages, injuries and deaths, and damaged infrastructure; and gradual sea-level rise, which changes ecosystems and the coastal built environment.

Chapter 3 of this Assessment details a climate future for Massachusetts if greenhouse gas emissions increase at current rates – but meeting Massachusetts' Net-Zero Emissions by 2050 goal will contribute to lessening of all these impacts of climate change.

Change in Average Summertime Temperatures for Massachusetts



Number of Days Per Year Over 90°F - Inland Areas



Data shown above is for inland areas. Coastal areas would see about 25 percent fewer days per year with maximum temperatures above 90°F.

2 **Identify Impacts**

Stakeholder Impacts: What Impacts of Climate Change Are Relevant to Massachusetts?

The set of climate impacts evaluated by the project consulting team in this Climate Assessment were identified through conversations with state agency staff, local and federal government partners, non-profit and community group representatives, and public stakeholders.

Project Consulting Team: The project team is led by Industrial Economics (IEc) and includes Eastern Research Group, Consensus Building Institute, and Woods Hole Group, in addition to independent subject matter experts from Massachusetts-based universities.

Project Working Group: The Project Working Group included state, local, and federal agency representatives as well as other experts from non-profits and community organizations. Project Working Group members assisted in the development of the list of 37 impacts, provided data sources to evaluate the impacts, and reviewed the urgency rankings and underlying analyses. In addition, an expert Climate Science Panel, consisting of Massachusetts academics with deep climate science and impact assessment backgrounds, provided critical input to the use of climate projection data used in the Climate Assessment.

Public Stakeholders: Public stakeholder engagement occurred in three waves over the course of the Climate Assessment. In each wave, stakeholders were asked to answer a key question to inform the Assessment. A team of ten community liaisons from across the state encouraged participation in the public conversations. Input from these conversations resulted in additional impacts added to the Climate Assessment and refinement of urgency scores based on evidence relayed from stakeholders. More information on the Stakeholder Engagement process can be found in Appendix D.

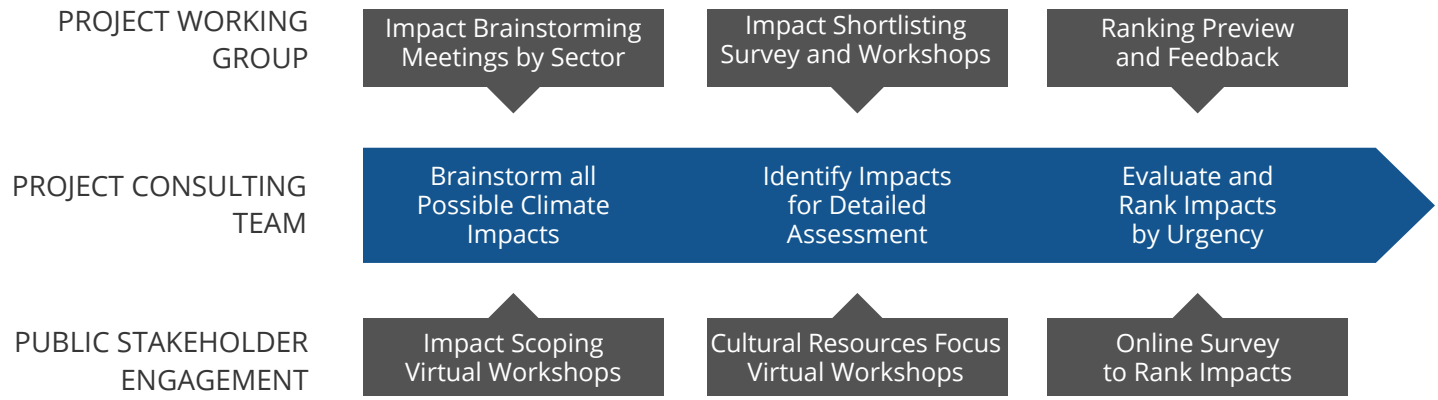
Lived Experience from Residents

"These impacts have already begun to affect me as well as my community."

"I worry about the world my adult children and young grandchildren will live in as the crisis worsens."

"COVID showed us the importance of our publicly accessible natural resource areas and the investment that we need to steward and care for them - especially as climate change impacts forest health, invasive species distribution, etc."

Stakeholder Inputs to the Urgency Ranking Process



3 **Build Evidence Base**

What Do We Know About Climate Impacts in Massachusetts?




Impact urgency rankings are built on an evidence base primarily sourced from existing reports, available models and data, and on the ground experience of state agency staff, non-profit and community groups, and public stakeholders. The assessments consider qualitative and quantitative information on both economic and physical outcomes.

Referenced Reports and Models: The impact assessments draw on available reports, literature, data, models, and damage functions. Examples of models utilized in this Climate Assessment include:

- Massachusetts Coast Flood Risk Model (MC-FRM) – a customized coastal flood risk tool that integrates changes in sea-level, tropical storm activity, and "sunny-day flooding"
- Sea Level Affecting Marshes Model (SLAMM) modeling completed for MA Office of Coastal Zone Management in 2016
- Metropolitan Area Planning Council (MAPC) Land Surface Temperature modeling
- The Stochastic Weather Generator and the Scaled IDF Curve Dataset, which are outputs of EEA's Massachusetts Climate and Hydrologic Risk Project (Phase 1)
- The Benefits and Mapping Analysis Program (BenMAP) for air pollution and pollen analyses
- A broad range of other health, infrastructure, and natural resource impact models developed by the USEPA for the Framework for Estimating Damages and Impacts (FrEDI)
- Published academic literature, white papers, and reports that project impacts of climate change in Massachusetts

4 **Calculate Urgency Scores**

Urgency Ranking Process

Each impact is assigned an urgency score, to assist in prioritizing adaptation action within each sector. Scores are assigned based on three components:

Magnitude of Consequence

How large of a climate effect do we expect from this impact?
Consequence scores are built from an evidence base of quantified physical and economic impacts (e.g., projected acres of marsh lost, number of buildings flooded, changes in revenue, cost of illness) and qualitative measures, specified for each sector. The level of concern stakeholders hold for each impact also factors into the magnitude of consequence rating for emerging risks where evidence is lacking in the literature but lived experiences of residents shared with the Project Assessment team during stakeholder engagement provide evidence for higher levels of consequence.

Disproportionality of Exposure

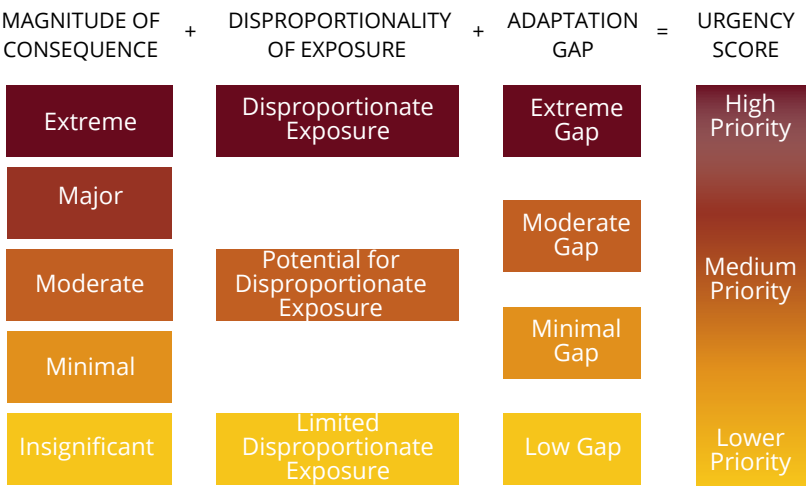
Will populations living in environmental justice areas be affected more than the rest of the population?
Disproportionality scores evaluate whether populations living in environmental justice (EJ) areas are disproportionately exposed to the impact. Following the Commonwealth's 2021 Environmental Justice Policy, EJ areas are defined on the basis of minority population, low median household income, and English language isolation. A measure of disproportionality is calculated by comparing average magnitude of consequences in EJ areas to all other areas in the Commonwealth. Some impacts rely on qualitative assessments of disproportionality.

Need for Effective Adaptation

Are we currently doing enough to adapt to this impact or are there gaps in effective adaptation actions? How soon is action needed?
The adaptation gap score takes stock of the actions currently underway to address each impact and identifies any time pressures for the need to adapt soon (either because near-term impacts are significant or because addressing long-term impacts will take a long time). Adaptation scores are assigned based on the gap between current action and available solutions, and the urgency of the need to act now versus waiting for future adaptation planning efforts.

Urgency Scores Are Used to Rank Impacts in Each Sector

Each impact is given a score for each component described above and the scores are averaged together to produce a final urgency score used to prioritize impacts within each sector. Using this framework, the impacts receiving the highest urgency score (or the highest priority impacts for adaptation actions) are those that have large projected effects due to climate change, disproportionately affect populations living in EJ areas, and for which adaptation actions are needed soon and current actions do not do enough to mitigate the risks.



Most Urgent Impacts by Sector Across the Commonwealth

The impacts below represent the most urgent impacts per sector statewide identified through the urgency ranking process. Volume II of this report provides detailed results for the top three impacts per sector; details on the remaining impacts can be found in Appendix B of Volume II.

Human

Health and Cognitive Effects from Extreme Heat, including premature death and learning loss.

Health Effects from Degraded Air Quality, including childhood asthma cases and premature death due to the climate impact on particulate matter and ozone air quality.

Emergency Service Response Delays and Evacuation Disruptions from extreme storms, leading to injuries, loss of life, and requiring health, safety, and traffic first responders.

Infrastructure

Damage to Inland Buildings from heavy rainfall and overwhelmed drainage systems.

Damage to Electric Transmission and Utility Distribution Infrastructure associated with heat stress and extreme events.

Damage to Rails and Loss of Rail/ Transit Service, including flooding and track buckling during high heat events.

Natural Environment

Freshwater Ecosystem Degradation due to warming waters, drought, and increased runoff.

Coastal Wetland Degradation from sea level rise and storm surge.

Marine Ecosystem Degradation because of warming, particularly in the Gulf of Maine, and ocean acidification.

Governance

Reduction in State and Municipal Revenues, including a reduced property tax base due to coastal and inland flood risk.

Increase in Costs of Responding to Climate Migration, including planning for abrupt changes in local populations.

Increase in Demand for State and Municipal Government Services, including emergency response, food assistance, and state-sponsored health care.

Economy

Reduced Ability to Work, particularly for outdoor workers during extreme heat, as well as commute delays due to damaged infrastructure.

Decrease in Marine Fisheries and Aquaculture Productivity from changing ocean temperatures and acidification, which leads to decreased catch and revenues and impacts on related industries.

Reduction in the Availability of Affordably Priced Housing from direct damage (e.g. flooding) and the scarcity caused by increased demand.

Regional Findings

Priority impacts by region may differ from statewide priorities based on the specific hazards, natural and built environments, and demographics of the region. More details on regional results can be found in the Regional Report (Volume III) of this Climate Assessment.

Selected Unique Impacts of Concern by Region

The impacts below represent some of the unique priority impacts by region, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top two impact regionally. Where multiple impacts meet these criteria, priority is given to impacts that appear in the top two by sector in only one region. See Volume III for the full list of most urgent impacts by region.

Berkshires and Hilltowns

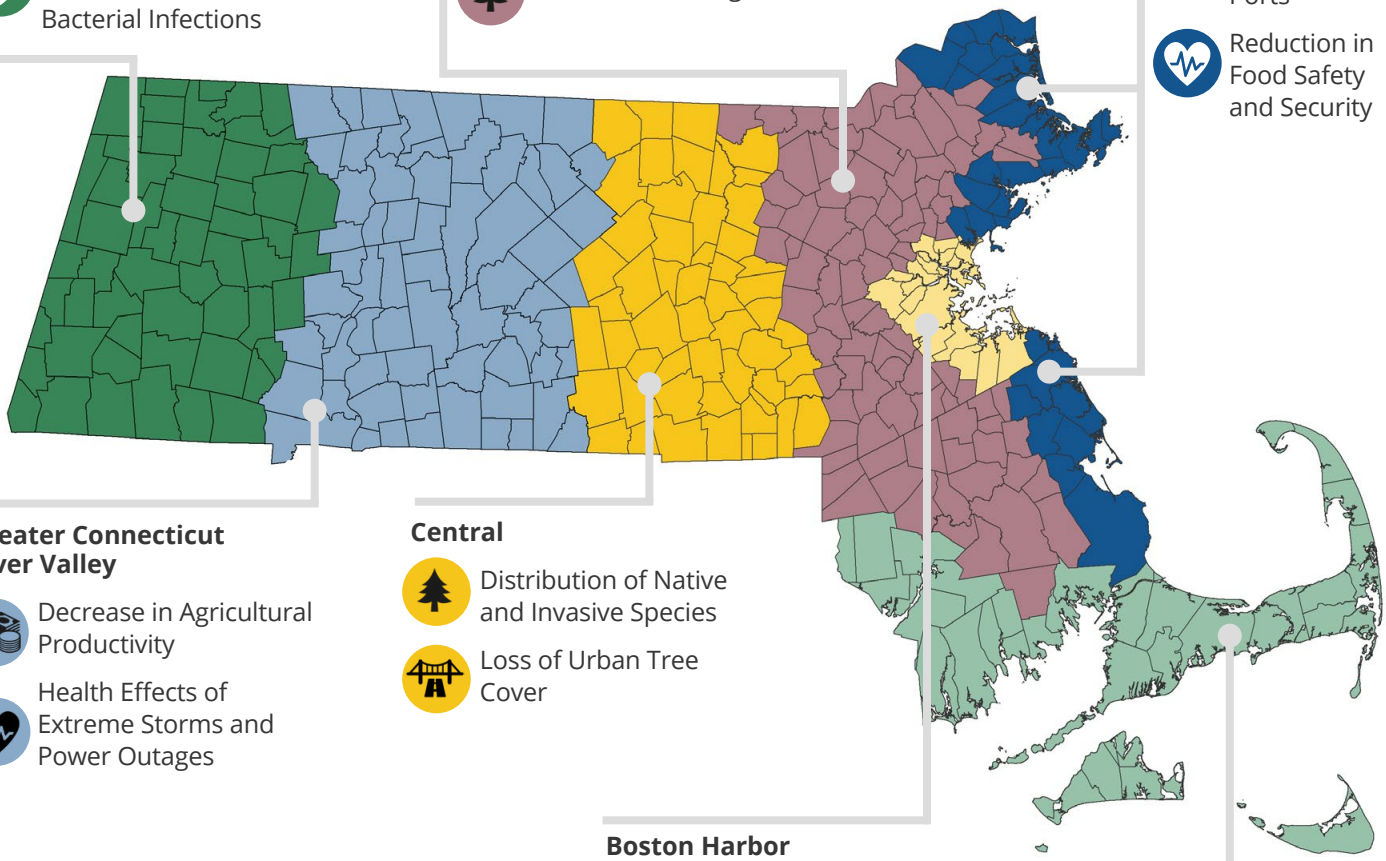
- Tourist Attractions and Recreation Amenities
- Increase in Vector Borne Diseases Incidence and Bacterial Infections

Eastern Inland

- Reduction in Food Safety and Security
- Forest Health Degradation

North and South Shores

- Damage to Coastal Buildings and Ports
- Reduction in Food Safety and Security



Greater Connecticut River Valley

- Decrease in Agricultural Productivity
- Health Effects of Extreme Storms and Power Outages

Central

- Distribution of Native and Invasive Species
- Loss of Urban Tree Cover

Boston Harbor

- Economic Losses from Commercial Structure Damage and Business Interruptions
- Loss of Urban Tree Cover

Cape, Islands, and South Coast

- Reduction in Clean Water Supply
- Coastal Erosion

Statewide Sector Summaries

This Climate Assessment considers impacts across five sectors which represent major categories of projected impacts of climate change with common groupings of exposed assets, individuals, or resources, and that generally fall under the responsibility of similar state agencies. By sector, the pages that follow first present the three most urgent impacts followed by a summary of all evaluated impacts.

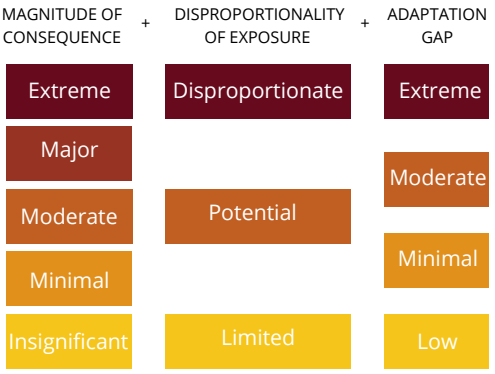
A NOTE ON THE USE OF SECTORS

Sectors are a helpful organizational structure and allow for the prioritization across impacts with similar types of effects. However, it is important to note that the effects of climate change do not fall neatly within the defined sectors, and there are many interactions between impacts both within and across sectors. To the extent possible, these interactions are noted in the Climate Assessment in order to help draw these connections that may not be seen in the quantitative sectoral analysis.

HUMAN SECTOR

IMPACTS TO PEOPLE'S HEALTH, WELFARE, AND SAFETY

Many of the most urgent impacts in the Human Sector have disproportionate exposure, meaning the incremental health effects of climate change will layer on existing disproportionate burdens for populations living in Environmental Justice block groups.



Three Most Urgent Impacts

Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.

Extreme Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Over 400 additional deaths per year are anticipated by 2090. EJ block groups defined on the basis of linguistically isolated households are 28% more likely to experience extreme heat mortality.

Health Effects from Degraded Air Quality	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., premature loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality.

Major Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Results in over 100 additional asthma diagnoses annually by 2030; over 900 additional asthma cases and 200 deaths by 2090. Black and African American individuals are 40% more likely to live in areas with the highest projected increases in childhood asthma diagnoses.

Emergency Service Response Delays and Evacuation Disruptions	Extreme storms cause delays in response time, potentially leading to loss of life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.

Major Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Effects from flooding roads could delay access to emergency health and first responder services, especially hospitals, emergency medical services, fire and law enforcement response, leading to a doubling of effects on mortality and morbidity by 2050. All classifications of EJ block groups will experience greater impacts than the rest of the Commonwealth.

HUMAN SECTOR
IMPACTS TO PEOPLE'S HEALTH, WELFARE, AND SAFETY

Full List of Impacts by Urgency Ranking

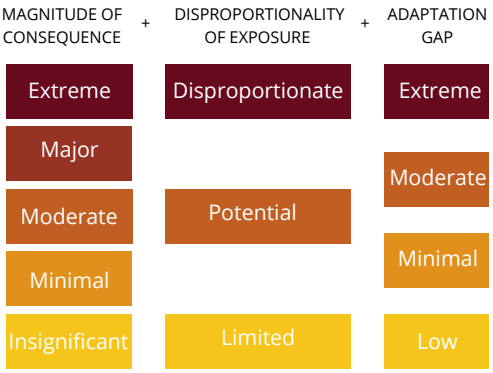
Detailed assessments for the most urgent impacts can be found in Chapter 4 of Volume II. Details for the remaining impacts can be found in Appendix B.

IMPACT	DESCRIPTION	MAGNITUDE	DISPROPORTIONATE EXPOSURE	ADAPTATION GAP
Health and Cognitive Effects from Extreme Heat (MOST URGENT)	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Extreme	Disproportionate	Moderate
Health Effects from Degraded Air Quality (MOST URGENT)	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., premature loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality.	Major	Disproportionate	Moderate
Emergency Service Response Delays and Evacuation Disruptions (MOST URGENT)	Extreme storms cause delays in response time, potentially leading to loss of life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.	Major	Disproportionate	Moderate
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamination. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Moderate	Disproportionate	Moderate
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health.	Major	Potential	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons and increases in exposure to mold spores.	Moderate	Potential	Moderate
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Moderate	Potential	Moderate
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Moderate	Potential	Moderate
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Major	Limited	Moderate

INFRASTRUCTURE SECTOR

IMPACTS TO BUILDINGS AND TRANSPORTATION SYSTEMS, AND HOW WE GET OUR ELECTRICITY AND WATER

Flooding (coastal and inland) is a major threat to infrastructure, but drought, freeze-thaw cycles, high heat and wind are also of concern. Because of infrastructure lifespans and planning horizons, adaptation action is often needed near term.



Three Most Urgent Impacts

Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).

Major Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Inland residential property damage increases 4% over baseline by 2050. Low income and linguistically isolated populations are 24% and 39% more likely to live in areas with the highest projected damages, respectively.

Damage to Electric Transmission and Utility Distribution Infrastructure	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.

Major Level of Consequence + Potential for Disproportionate Exposure + Extreme Adaptation Gap

Repair costs for electric transmission and utility distribution infrastructure alone are projected to increase by $87 million per year by 2050. Impacts from forced outages could fall disproportionately on low-income populations with poor access to backup power sources.

Damage to Rails and Loss of Rail/Transit Service	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.

Moderate Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Additional rail repair costs from extreme temperature effects alone could reach $6 million per year by 2050 and $35 million per year by 2090. EJ block groups defined on the basis of minority population have 24% higher exposure to rail maintenance costs than the rest of the Commonwealth.

INFRASTRUCTURE SECTOR

IMPACTS TO BUILDINGS AND TRANSPORTATION SYSTEMS, AND HOW WE GET OUR ELECTRICITY AND WATER

Full List of Impacts by Urgency Ranking

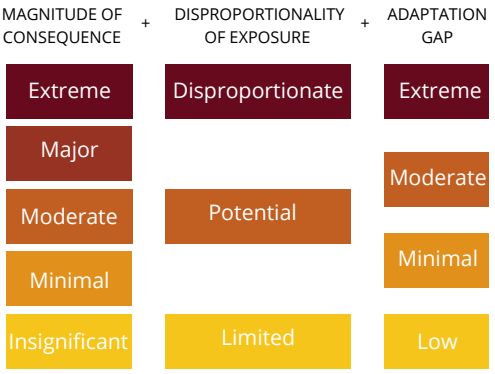
Detailed assessments for the most urgent impacts can be found in Chapter 4 of Volume II. Details for the remaining impacts can be found in Appendix B.

IMPACT	DESCRIPTION	MAGNITUDE	DISPROPORTIONATE EXPOSURE	ADAPTATION GAP
Damage to Inland Buildings (MOST URGENT)	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Major	Disproportionate	Moderate
Damage to Electric Transmission and Utility Distribution Infrastructure (MOST URGENT)	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.	Major	Potential	Extreme
Damage to Rails and Loss of Rail/Transit Service (MOST URGENT)	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.	Moderate	Disproportionate	Moderate
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including mitigating heat island effects, pollution removal, etc.	Moderate	Disproportionate	Minimal
Damage to Coastal Buildings and Ports	Sea level rise, coastal erosion, and storm surge, as well as high wind events from tropical and extra-tropical storms, will cause increased damage to coastal structures, land, and related infrastructure such as ports and marinas.	Extreme	Limited	Moderate
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns and saltwater intrusion can lead to impaired surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.	Major	Potential	Minimal
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Major	Limited	Moderate
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Moderate	Limited	Minimal
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of High or Significant Hazard dams, causing flooding of downstream areas.	Minimal	Limited	Minimal

NATURAL ENVIRONMENT SECTOR

IMPACTS TO ECOSYSTEMS AND NATURAL RESOURCES, AND HOW PLANTS AND ANIMALS CAN THRIVE HERE

A changing climate will permanently alter habitats in the Commonwealth, resulting in disruption during transition and loss of native ecosystems. Impacts in the Natural Environment Sector are interrelated and often have connections to impacts in other sectors.



Three Most Urgent Impacts

Freshwater Ecosystem Degradation

Rising temperature and changing precipitation patterns (which will exacerbate nutrient and non-point source loadings) lead to a reduction in ambient water quality and quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.

Extreme Level of Consequence + Potential for Disproportionate Exposure + Extreme Adaptation Gap

The majority of coldwater fisheries across the Commonwealth are expected to change guild to warmwater fisheries. Harmful algal blooms threaten freshwater reservoirs and can disrupt native ecosystems.

Coastal Wetland Degradation

Sea level rise leads to habitat shifts and possible loss of saltmarshes and important ecosystem services.

Extreme Level of Consequence + Potential for Disproportionate Exposure + Moderate Adaptation Gap

Along the coast, 77% of high marshes (infrequently flooded wetlands) are projected to convert to low marshes (frequently flooded wetlands) by 2070.

Marine Ecosystem Degradation

Changing sea surface temperatures, ocean acidification, and water quality issues from increased runoff nearshore alter habitat conditions in marine environments (including submerged aquatic vegetation) leading to changing marine species distribution.

Extreme Level of Consequence + Potential for Disproportionate Exposure + Moderate Adaptation Gap

Sea surface temperature in the Gulf of Maine is expected to rise by 5 to 10 degrees Fahrenheit by 2100, significantly altering current habitat conditions. Ocean acidification is also a concern for marine ecosystems.

NATURAL ENVIRONMENT SECTOR

IMPACTS TO ECOSYSTEMS AND NATURAL RESOURCES, AND HOW PLANTS AND ANIMALS CAN THRIVE HERE

Full List of Impacts by Urgency Ranking

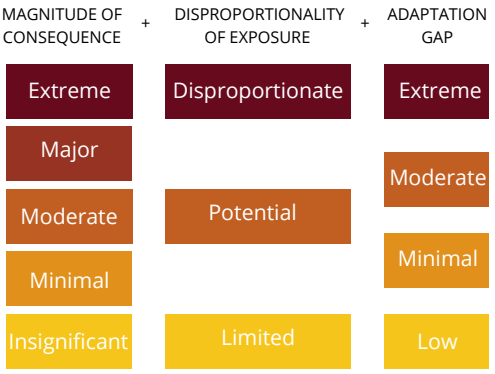
Detailed assessments for the most urgent impacts can be found in Chapter 4 of Volume II. Details for the remaining impacts can be found in Appendix B.

IMPACT	DESCRIPTION	MAGNITUDE	DISPROPORTIONATE EXPOSURE	ADAPTATION GAP
Freshwater Ecosystem Degradation (MOST URGENT)	Rising temperature and changing precipitation patterns (which will exacerbate nutrient and non-point source loadings) lead to a reduction in ambient water quality and quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.	Extreme	Potential	Extreme
Coastal Wetland Degradation (MOST URGENT)	Sea level rise leads to habitat shifts and possible loss of saltmarshes and important ecosystem services.	Extreme	Potential	Moderate
Marine Ecosystem Degradation (MOST URGENT)	Changing sea surface temperatures, ocean acidification, and water quality issues from increased runoff nearshore alter habitat conditions in marine environments (including submerged aquatic vegetation) leading to changing marine species distribution.	Extreme	Potential	Moderate
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency to shocks) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Major	Potential	Moderate
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders potentially causing losses in native biodiversity and loss of culturally important species.	Major	Potential	Moderate
Coastal Erosion	Climate change, and particularly sea level rise, are expected to increase coastal erosion, particularly in areas not protected by wetlands (e.g., dunes, banks, beaches), which has consequences for water quality, land use, and habitat quality.	Major	Potential	Moderate
Soil Erosion	Increase in extreme precipitation could result in increased erosion and potential loss in vegetation, particularly along riverbanks but also in forests and in a number of landscapes.	Minimal	Potential	Moderate

GOVERNANCE SECTOR

IMPACTS TO STATE AND LOCAL GOVERNMENT OWNED FACILITIES, GOVERNMENT FINANCES, AND DEMAND ON GOVERNMENT SERVICES

State and local governments will face growing demand for the essential services they already provide as climate change increases need due to exacerbating stressors in all sectors. Small municipalities with limited tax bases may be disproportionately burdened.



Three Most Urgent Impacts

Reduction in State and Municipal Revenues

State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and income and sales tax losses associated with business interruptions or effects on industrial activities.

Major Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Massachusetts municipalities could experience an annual property tax revenue loss of more than $100 million by 2090 in coastal communities alone (1.4% of current annual property taxes in 89 coastal communities). These losses disproportionately affect many municipalities with a higher proportion of population in EJ block groups than the statewide proportion. Additional revenue losses could result from inland flooding risks (property tax), reduced ability to work (income tax), or on reduced industry production (sales and income tax).

Increase in Costs of Responding to Climate Migration

Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).

Major Level of Consequence + Potential for Disproportionate Exposure + Extreme Adaptation Gap

The relative lack of exposure to most climate hazards, particularly in the western part of the Commonwealth, may make Massachusetts cities and towns attractive locations for in-state or other U.S. and international climate migrants.

Increase in Demand for State and Municipal Government Services

Climate change is a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.

Major Level of Consequence + Potential for Disproportionate Exposure + Moderate Adaptation Gap

The demand for MassHealth, food security support, and emergency response could be most significantly affected by climate impacts in the Commonwealth. Any lapses in these services would disproportionally affect vulnerable populations.

GOVERNANCE SECTOR

IMPACTS TO STATE AND LOCAL GOVERNMENT OWNED FACILITIES, GOVERNMENT FINANCES, AND DEMAND ON GOVERNMENT SERVICES

Full List of Impacts by Urgency Ranking

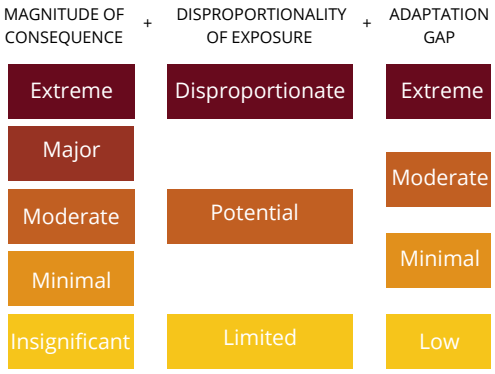
Detailed assessments for the most urgent impacts can be found in Chapter 4 of Volume II. Details for the remaining impacts can be found in Appendix B.

IMPACT	DESCRIPTION	MAGNITUDE	DISPROPORTIONATE EXPOSURE	ADAPTATION GAP
Reduction in State and Municipal Revenues (MOST URGENT)	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and income and sales tax losses associated with business interruptions or effects on industrial activities.	Major	Disproportionate	Moderate
Increase in Costs of Responding to Climate Migration (MOST URGENT)	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration. Generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Major	Potential	Extreme
Increase in Demand for State and Municipal Government Services (MOST URGENT)	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Damage to Coastal State and Municipal Buildings and Land	Risk to vulnerable state and municipally owned structures and other property from coastal flooding, wind, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Major	Limited	Moderate
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Minimal	Potential	Minimal
Damage to Inland State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Minimal

ECONOMY SECTOR

IMPACTS TO PEOPLE'S ABILITY TO WORK AND MAKE A LIVING, DUE TO DAMAGES TO INFRASTRUCTURE, OUR NATURAL ENVIRONMENT, OR PEOPLE'S HEALTH, AND PEOPLE'S ABILITY TO FIND AFFORDABLY PRICED HOUSING

Extreme events, dangerous heat, and transportation delays will all affect business and people's ability to work, earn a living, and make a home. Less productive fisheries and changing agricultural yields cause indirect impacts throughout the Commonwealth's economy. Increased risk of flooding, climate-driven relocation, and stronger building standards put pressure on housing supply and demand, impacting housing affordability.



Three Most Urgent Impacts

Reduced Ability to Work

More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects. Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity. Impacts are felt most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home.

Extreme Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Workers in Massachusetts could lose over 10 million hours of work and associated wages per year by 2090 due to high heat conditions. Minority workers make up a disproportionate share of the labor force for the most at-risk industries.

Decrease in Marine Fisheries and Aquaculture Productivity

Changes in water temperature regimes and acidification in the marine environment change fish habitat and alter commercial landings and revenue, including effects on related industries and threats to the Blue Economy.

Major Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

Changing species distributions result in a decrease in marine industry revenue of nearly $70 million per year by 2090. Populations with low income live in areas with disproportionately large decreases in marine fishery landings.

Reduction in the Availability of Affordably Priced Housing

An increase in demand for affordably priced housing and a decrease in supply worsens the scarcity of affordable housing further exacerbating the known inequities in access to affordable and healthy housing. Demand for affordably priced housing can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resiliency to threats from climate change.

Major Level of Consequence + Disproportionate Exposure + Moderate Adaptation Gap

By 2030 up to 6,500 households in block groups with the lowest average structure value could experience a substantial increase in expected annual damage from flooding, increasing to 36,000 households by 2090.

ECONOMY SECTOR

IMPACTS TO PEOPLE'S ABILITY TO WORK AND MAKE A LIVING, DUE TO DAMAGES TO INFRASTRUCTURE, OUR NATURAL ENVIRONMENT, OR PEOPLE'S HEALTH, AND PEOPLE'S ABILITY TO FIND AFFORDABLY PRICED HOUSING

Full List of Impacts by Urgency Ranking

Detailed assessments for the most urgent impacts can be found in Chapter 4 of Volume II. Details for the remaining impacts can be found in Appendix B.

IMPACT	DESCRIPTION	MAGNITUDE	DISPROPORTIONATE EXPOSURE	ADAPTATION GAP
Reduced Ability to Work (MOST URGENT)	More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects. Weather disruptions to transportation and ability to work may also lead to lost wages and productivity. Impacts are felt most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home.	Extreme	Disproportionate	Moderate
Decrease in Marine Fisheries and Aquaculture Productivity (MOST URGENT)	Changes in water temperature regimes and acidification in the marine environment change fish habitat and alter commercial landings and revenue, including effects on related industries and threats to the Blue Economy.	Major	Disproportionate	Moderate
Reduction in the Availability of Affordably Priced Housing (MOST URGENT)	An increase in demand for affordably priced housing and a decrease in supply worsens the scarcity of affordable housing further exacerbating the known inequities in access to affordable and healthy housing. Demand for affordably priced housing can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resiliency to threats from climate change.	Major	Disproportionate	Moderate
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Extreme	Potential	Moderate
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing), recreational fishing, beach visits (i.e., reduction in beach width due to sea level rise and coastal erosion), and tourism related to vulnerable historical landmarks.	Moderate	Disproportionate	Moderate
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, saltwater intrusion, and others.	Major	Potential	Moderate