Chapter 6. State Agency Vulnerabilities

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Abbreviations

COOP	Continuity of Operations Plan
DCR	Department of Conservation and Recreation
DER	Division of Ecological Restoration
MassWildlife	Division of Fisheries and Wildlife
EOTSS	Executive Office of Technology Services and Security
IT	information technology
LST	Land-surface temperature
MassDOT	Massachusetts Department of Transportation
RMAT	Resilient MA Action Team
SHMCAP	MA State Hazard Mitigation and Climate Adaptation Plan

Definitions

- **State agency adaptive capacity:** The ability of state agencies (including their assets, functions, missions, and services/programs) to adjust or modify their operations, policies, assets, or other functions to reduce damage, disruption, or loss due to exposure from hazards and climate change impacts, both in the short and long term. For example, an agency that requires increased funding in its capital planning process to address increasing risks due to climate change by repairing infrastructure or constructing new infrastructure has built more adaptive capacity in its processes and budgets. Another example is an agency responsible for education services and facilities. If this agency has standards and procedures in place to reduce risks from extreme heat to students, families, employees, and teachers, then this agency will be more adaptable to the increasing number of high-heat days due to climate change.
- **Environmental justice populations:** In the Commonwealth, environmental justice populations (or neighborhoods) have been identified as Census block groups (i.e., divisions of larger Census tracts that are made up of about 600 to 3,000 people) that meet one or more of the following criteria:
    - The annual median household income is not more than 65 percent of the statewide annual median household income.

    - Minorities make up 40 percent or more of the population.
    - At least 25 percent of households identify as speaking English less than "very well."
    - Minorities make up 25 percent or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150 percent of the statewide annual median household income.
- **Exposure:** The extent to which physical and nonphysical assets, functions, population groups, and geographic areas are in direct contact with hazards or their related climate change impacts. Exposure is often determined by examining the number of people or assets that are currently located within a geographic area, the number of people projected to be affected by a hazard, or the magnitude of the climate change impact. For example, measurement of flood extent, depth, and duration in a given area or the number of heat waves experienced by a county are measurements of exposure.
- **Functions:** The programs and services provided to ensure the health, safety, and welfare of Massachusetts communities and environments, such as planning, policy development, regulatory enforcement, research, permitting, grant-making, outreach and education, or stewardship of critical resources.
- **Nonphysical assets:** Power, internet connectivity, transit services, recreation services and programs, public K–12 education, emergency preparedness and response, public health and safety functions and services, waste management, youth programs and foster care services, animal shelter and safety services, cloud-based data, and more that provide critical services to people and environments.
- **Priority populations:** People or communities disproportionately impacted by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond to these hazards. In addition to factors that contribute to environmental justice status (i.e., income, race, and language), other factors like physical ability, access to transportation, health, and age can indicate whether someone or their community will be disproportionately affected by climate change. These factors are driven by underlying contributors such as racial discrimination, economic disparities, or accessibility barriers that create vulnerability. The term priority populations acknowledges that the needs of people with these experiences must take precedence when developing resilience solutions to reduce vulnerability to climate change.
- **Physical assets:** Infrastructure, utilities, buildings, parks and open space, agricultural lands, housing, schools, ports, airports, equipment, natural resources, and other tangible items that are needed by the people and environments in Massachusetts for their health and well-being.
- **Sensitivity:** Sensitivity refers to the impact on a system, service, or asset when exposed to hazards. For example, if a facility is exposed to storm surge, how will its

ability to function be affected? What are its most sensitive components: generators in the basement, salt-sensitive native habitat, elderly residents cared for within the facility, or something else? Sensitivity is often considered within the context of critical thresholds. Determining the threshold at which an agency, specific asset, function, or population group is affected by a hazard and what components cause that sensitivity can help identify the most effective and critical ways to reduce risk. If the critical threshold is not exceeded, even though the asset is exposed, then there are few or no sensitive components affected by the exposure.

- **Vulnerability** occurs when the people, assets, services, and built and natural environments in Massachusetts are likely to experience exposure, will have sensitivity to the exposure, and/or lack adaptive capacity to limit damage, disruption, or loss from the exposure.

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6.1 Introduction and Purpose

The purpose of this state agency vulnerability assessment is to identify areas where the Commonwealth of Massachusetts and its agencies are likely to be most vulnerable to the hazard and climate vulnerabilities and consequences identified in Chapter 5 (Risk Assessment) of the 2023 State Hazard Mitigation and Climate Adaptation Plan (MA SHMCAP). To determine the most critical vulnerabilities of state agencies and their associated physical assets, nonphysical assets, and functions, Massachusetts undertook the following actions:

- Assessed its current and future risk from natural hazards and climate change, as well as associated vulnerabilities, through Chapter 5 (Risk Assessment) and the 2022 Massachusetts Climate Change Assessment (hereafter referred to as the MA Climate Assessment).
- Conducted a survey of state agencies in fall 2022 to identify vulnerability of the physical and nonphysical assets, as well as functions, that they are responsible for. Eighty-five agencies (out of 94 who received the survey) responded. (See Appendix 4.B for the full state agency survey.)
- Reviewed and vetted results with state agencies through their review of draft versions of the chapter and brief presentation at a Resilient MA Action Team (RMAT) meeting.

The sections that follow highlight the overarching and crosscutting vulnerabilities in the Commonwealth, including: (1) physical and nonphysical assets and functions of greatest concern, (2) social vulnerabilities, (3) environmental vulnerabilities, and (4) trends in relation to state agency actions taken to reduce vulnerabilities. This chapter synthesizes information across other key components of the MA SHMCAP—such as Chapter 5 (Risk

Assessment) and Chapter 4 (State Capability and Adaptive Capacity Analysis)—as well as the MA Climate Assessment. Throughout the chapter, the vulnerabilities highlighted correspond to many of the five sectors detailed throughout the MA Climate Assessment, which include the human, infrastructure, natural environment, governance, and economy sectors. This chapter focuses on vulnerabilities to those five sectors in the following ways:

- The chapter discusses the **infrastructure sector** by detailing vulnerabilities of physical assets described by agencies in the survey, in addition to physical asset and infrastructure vulnerabilities identified in Chapter 5 (Risk Assessment) and the MA Climate Assessment.
- Vulnerability of the **human sector** is highlighted in relation to social and health vulnerabilities, as well as how vulnerabilities to state agency nonphysical assets and functions may impact communities these agencies serve.
- **Natural environment sector** vulnerabilities are assessed in relation to how core habitats and other natural areas in the Commonwealth will be impacted by climate hazards. Discussion of natural environment vulnerabilities includes consideration of the important services (e.g., clean water, air, food, natural protection) that the natural environment provides.
- The **governance** and **economy sector** vulnerabilities are interwoven throughout this chapter. The vulnerabilities of state agencies' physical and nonphysical assets and functions described throughout this chapter demonstrate many of the Commonwealth's governance vulnerabilities. Economic vulnerabilities are mentioned throughout the chapter where relevant (and economic risk and vulnerability is discussed in more detail in Chapter 5 [Risk Assessment]).

By highlighting vulnerabilities discussed in the MA Climate Assessment, Chapter 5 (Risk Assessment), Chapter 4 (State Capability and Adaptive Capacity Analysis)—as well as findings highlighted by state agencies in the survey—this chapter provides a foundation for developing strategies and actions to reduce risk. The final section of this chapter summarizes gaps in existing strategies and actions, and more detail regarding the MA SHMCAP strategies and actions can be found in Chapter 7 (State Strategy, Actions, and Implementation Plan).

For the purposes of this plan, the **vulnerability** occurs when the people, assets, services, and built and natural environments in Massachusetts are likely to experience exposure, will have sensitivity to the exposure, and/or lack the adaptive capacity to limit damage, disruption, or losses from the exposure. When assets, communities, environments, and services are exposed, this exposure is consequential if there is an underlying condition that causes damage, disruption, or loss to something critical or valuable. Examples of these types of underlying conditions include underground living spaces that are impacted in a flood, people with underlying health conditions that will be exacerbated during high-heat days, or an industry, community, or government (e.g., Native American Tribes, the commercial fishing industry) that relies on the presence of native species and is affected

when the native species are displaced by invasive species. There are two main types of **assets:**

- **Physical assets** include infrastructure, utilities, buildings, parks and open space, agricultural lands, housing, schools, ports, airports, equipment, natural and cultural resources, and other tangible items that are needed by the people and environments in Massachusetts for their health and well-being.
- **Non-physical assets** capture power, internet connectivity, transit services, recreation services and programs, public K–12 education programs, emergency preparedness and response operations, public health (e.g., healthcare services) and safety functions and services, waste management, youth programs and foster care services, elder and daycare services and programs, career services, animal shelter and safety services, cloud-based data, and more that provide critical services to people and environments.

Additionally, this analysis identifies which functions (with a focus on those of state agencies) are vulnerable to hazard and climate impacts that result in consequences that impede or impair critical functions. **Functions** are defined as the programs and services provided to ensure the health, safety, and welfare of Massachusetts communities and environments, such as planning, policy development, regulatory enforcement, research, permitting, grant-making, outreach and education, or stewardship of critical resources.

In combination with Chapter 5 (Risk Assessment) and Chapter 4 (State Capability and Adaptive Capacity Analysis), the analysis presented in this chapter:

- Helps assess ongoing actions taken by state agencies to reduce vulnerabilities.
- Summarizes existing vulnerabilities (with a focus on state agencies, as well as social and environmental vulnerabilities) that could result in significant consequences to Commonwealth's human, infrastructure, environment, economic, and governance sectors.
- **Supports the identification of specific actions** to include in the hazard mitigation and climate adaptation strategy to help the Commonwealth reduce risks and vulnerabilities identified in Chapter 5 (Risk Assessment) and this chapter.

6.1.1 Physical and Nonphysical Assets and Functions of Concern

6.1.1.1 State Phyiscal and Nonphysical Assets and Functions

Agencies in the Commonwealth are responsible for a variety of physical and nonphysical assets that may be impacted by the hazards described in Chapter 5 (Risk Assessment). Hazards can have consequences in relation to the function of any agency and impair an agency's ability to deliver services and perform critical functions. Agencies surveyed were responsible for a variety of physical and nonphysical assets and functions (see

Appendix 6.A for a list of agencies and associated asset and function responsibilities). Additionally, agencies have experienced a variety of past disruptions and damages to their assets and functions. Understanding the types of disruptions agencies have experienced from hazards and in relation to their assets and functions is critical for determining the potential consequences of future hazards and the vulnerability of assets and functions. These losses also have implications for the Commonwealth and the services that its residents receive. Of the agencies surveyed, about half had experienced previous damage, disruption, or loss due to unplanned events, such as weather-related closures or cessation of functions and emergency repairs. Agencies indicated that disruptions ranged from a few hours to multiple years (e.g., due to the COVID-19 pandemic), with most respondents citing an average disruption of a few days. In relation to specific disruptions experienced, respondents provided examples such as:

- **Losses and damages to physical assets** including limited ability to use buildings, delay in gaining access to agency buildings, minor to major damage to buildings (e.g., collapse of a roof due to the weight of snow and resulting pipe failure and flooding, window damage, water and mold damage from flooding) and equipment (e.g., loss of equipment and associated operations at fish hatcheries, damage to wiring, printer damage), loss of and damage to stored materials (e.g., archived historic items), and destruction and blockages of embankments, culverts, and roads.
- **Losses to non-physical assets** such as loss of network and database functions; disruption of administrative services; temporary loss of communications, internet, and wireless capability; and disrupted emergency response and recovery activities due to detours and impassable roads and bridges.
- **Losses to functions** including cessation or reduced ability of operations and functions, limited ability to complete construction and restoration projects for infrastructure and natural resource assets, inability to hold meetings and trainings, disruption of administrative services, disposal of contaminated records, and diversion of funds to address disruptions.

Table 6-1 below describes the categories of assets and functions and provides the percent of agencies for each asset and function category that have experienced past disruptions and damages. The table also offers examples—drawn from both the 2023 state capability, adaptive capacity, and vulnerability assessment survey and the MA Climate Assessment—of these losses and potential implications for the Commonwealth and its residents. See Appendix 6.A for more details regarding the various assets and functions for which agencies are responsible.

Table 6-1. Agency Responsibilities and Description (N = 85)

Category of Physical and Non-Physical Assets and Functions	Description Examples	Agencies (%) with Damage to Assets and Functions	Examples and Implications to the Commonwealth
Communication	Land line telephone systems, cable systems, cellular telephone antennae, underground communication conduits, and internet and telecommunications provision.	16%	• **Examples:** Disruption to network and agency databases, loss of communications among agency staff, delay in gaining access to buildings, service disruptions due to power failures. • **Implications:** Limited public access to online state services (e.g., customer inquiries, benefits).
Community	Day cares, food banks, grocery stores, senior centers, education and research institutions, youth and elder care, housing, courthouses, research, waste transfer stations, landfills, recycling and reclamation facilities, incinerators, waste collection and transfer, household hazardous waste collection sites, social or transitional services such as unemployment assistance, job placement, job centers, workers' compensation, and paid family/medical leave support.	21%	• **Examples:** Destruction of roof in warehouse and associated flooding, pause in community outreach and disruption of regularly planned events, disruptions to environmental health functions (e.g., licensing and regulatory inspections, childhood lead poisoning prevention surveillance screenings). • **Implications:** Limited ability of community members to access services provided by agencies, backlog of inspection activities, decrease in lead screening, increased prevalence of lead poisoning.
Critical facilities and services	Hospitals and medical facilities, prisons, animal care facilities, medical services, police stations, fire stations, safety and education services, public schools, emergency response services, critical infrastructure support, and workplace safety services.	29%	• **Examples:** Loss of communications among agency staff, disruptions and delays in emergency response services and recovery activities, physical damage to buildings (e.g., veterans housing), relocation of residents. • **Implications:** Impacts (including injuries and potential loss of life) to those accessing critical medical and mental health services

Category of Physical and Non-Physical Assets and Functions	Description Examples	Agencies (%) with Damage to Assets and Functions	Examples and Implications to the Commonwealth
			that are disrupted, potential issues in accessing emergency services and care needed, disruption to housing and shelter.
Hazardous material sites and contaminated lands	Hazardous materials, landfills, cleanup sites, hazardous waste disposal and transfer, and toxic and contaminant reduction.	9%	• **Examples:** Disruption to inspections for hazardous materials and waste sites, disruption of mosquito control operations. • **Implications:** Potential for increase in vector-borne mosquito diseases, backlogs in inspections and administrative functions that could result in potential environmental damage from compromised hazardous material or contaminated land sites.
Ports and maritime	Seaports and marine terminals, shipping and commerce services, seawalls and riprap, docks, and nature-based flood and storm water systems.	7%	• **Examples:** Shellfish harvest closures due to storms, disruption of port operations and businesses, supply chain interruption. • **Implications:** Decreased fish harvest and lost wages to fishers, decreased seafood product availability for local consumers, lost wages for port workers, supply chain disruption that impacts local and regional commerce, interruption of recreational activity.
Recreation, open space, natural areas, and working lands	Park and recreation facilities, designated open space, cultural and historic resources, bike/pedestrian trails, natural areas, agricultural and working lands, natural and working lands resource management, natural and working lands regulations and programs, recreational opportunities,	16%	• **Examples:** Damage to coastal areas from flooding and storm events, fish mortality in the wild and in hatcheries, impacts to construction for restoration projects, cessation of environmental monitoring. • **Implications:** Limited access to natural areas for anglers, hunters, nature enthusiasts, recreational boaters, and the general public;

Category of Physical and Non-Physical Assets and Functions	Description Examples	Agencies (%) with Damage to Assets and Functions	Examples and Implications to the Commonwealth
	wildlife habitat, and wildland-urban interface buffer provision.		decreased catch and lost wages for fishers; decreased seafood product availability for local customers.
Transportation and mobility	Local streets and roads, state highways, bus shelters, bus and train stations, bridges and tunnels, railroads and freight lines, transit services such as bus or light rail, ferry and boating services, movement of goods, bike/pedestrian routes, and airports.	15%	• **Examples:** Blown motors on railcars, damage to tracks and switches from snow and ice buildup, buckling tracks, damage to bus and rail stations, limited access to and damage to roads and evacuation routes. • **Implications:** Cessation of transportation service and inability to provide reliable public transportation, with particular impacts for individuals with no alternate forms of transportation.
Utilities and infrastructure	Reservoirs, dams, industrial and sanitary sewer systems, flood control infrastructure, stormwater systems, power utilities, fuel and natural gas pipelines, oil refineries, power provision, flood control, and drinking water provision.	13%	• **Examples:** Disruption, removal, reconstruction, and replacement of infrastructure; damage to and blockages of culverts and bridges; damage to electric transmission and utility distribution infrastructure. • **Implications:** Power outages and service delays, disrupted fish passage, interruption in utility services due to delays in construction and repair, economic losses due to power outages and business closure, potential food contamination from lack of refrigeration.
Other	Office equipment and supplies, consumer support services, geospatial data collection and distribution, library and cultural assets, legal databases,	9%	• **Examples:** Interrupted response time to consumer inquiries, increased need for death and management services, disrupted ability to file needed documents and reports.

Category of Physical and Non-Physical Assets and Functions	Description Examples	Agencies (%) with Damage to Assets and Functions	Examples and Implications to the Commonwealth
	land leases, disability accommodations and services, program approval, and more.		• **Implications:** Limited access to hearing rooms and accommodation support, delays in proceedings or document filings, difficulties for injured workers to receive needed benefits and compensation.

The MA Climate Assessment also detailed impacts to physical assets from hazards, with a focus on impacts to the infrastructure sector. The three most urgent impacts to infrastructure that the assessment identified were (1) damage to inland buildings from flooding, (2) damage to electric transmission and utility distribution infrastructure due to heat stress and extreme events, and (3) damage to rails and loss of rail and transit service due to extreme temperature events, storms, and sea level rise. Key findings related to these three most urgent impacts include:

- **Inland residential properties will become more vulnerable to hazards**, with projected property damage increasing 44 percent over baseline by 2050. These impacts will be more severe for low-income and linguistically isolated populations, who are respectively 24 percent and 39 percent more likely to live in areas that will be most impacted by hazards.
- **Electric transmission and utility distribution physical assets** will be vulnerable to increased damage and repair costs, with projected increases from $46 million per year in 2030 to $87 million per year by 2050.
- **Physical assets in the rail system are likely to experience increased damage** from exposure to extreme temperatures, with potential repair costs of $6 million per year by 2050 and $35 million per year by 2090.

Drawing on the data from the MA Climate Assessment, Chapter 5 (Risk Assessment) details the potential impacts of all hazards addressed to the infrastructure sector. Table 6-2 below summarizes these hazard-specific infrastructure vulnerabilities. (See Chapter 5 for more details, including specific physical assets that may be at risk.) These findings highlight a few key themes in relation to physical infrastructure vulnerabilities:

- **Geography.** Coastal counties like Barnstable, Plymouth, and Suffolk experience more vulnerability due to exposure to all hazards, including unique exposure to coastal hazards. All hazards are projected to increase in intensity, and some in frequency, due to climate change (e.g., sea level rise, coastal storms and surge, coastal erosion and flooding, hurricanes and tropical cyclones). Inland counties like Hampshire and Worcester are at risk from hazards such as tornadoes, extreme weather, wildfire, and drought, and some inland counties lack redundancy, resources, and capacity to address the risks efficiently. The MA Climate Assessment also detailed the most urgent infrastructure vulnerabilities and impacts to various regions, outlined below:
    - **Berkshires and Hilltowns Region** infrastructure will be most vulnerable to hazards related to changes in precipitation, which puts many inland buildings at risk due to exposure and vulnerability to inland flooding and associated groundwater rise. Electric transmission and distribution infrastructure, as well as clean water supply (particularly since many communities rely on groundwater supply), are projected to be most exposed and vulnerable to flooding impacts, and clean water supply could also be impacted by precipitation decreases and drought.

The electric transmission and utility distribution infrastructure will also be very vulnerable to failure associated with heat stress and extreme heat events.

- **Greater Connecticut River Valley Region** infrastructure is highly vulnerable to inland flooding, with inland buildings and the electric transmission and distribution infrastructure likely to be most at risk. Extreme temperature, severe weather events, and wildfire activity may also put electric transmission and distribution lines, poles, towers, and transformers at risk.
- **Central Region** infrastructure that is likely to be most vulnerable to hazards includes urban tree cover (from extreme heat, drought, and increased pests) and electric transmission and distribution infrastructure (due to extreme heat and associated heat stress). Roads and transportation infrastructure will also be vulnerable to damage from extreme heat and flooding caused by precipitation.
- **The Eastern Inland Region** has a considerable amount of rail infrastructure (including commuter lines and the subway that provides connections to the Boston area) that is vulnerable to extreme temperature, which could cause track buckling. Rail infrastructure in the region is also vulnerable to other extreme weather that results in flooding, erosion, downed lines and trees, and debris, as well as other events that would disrupt rail service or damage the infrastructure. The region's electric transmission and utility distribution infrastructure is also likely to be vulnerable to extreme temperature, flooding from precipitation, and coastal flooding.
- **The Boston Harbor Region** has rail and transit infrastructure (including commuter and freight rail lines, rail rapid transit, air travel, and subway and trolley lines) that is vulnerable to hazards including extreme heat, coastal flooding, and storms. Urban tree cover in the region will also be vulnerable to extreme heat, invasive species, and drought. The region also includes areas of fill, resulting in an increased risk of damage from earthquakes due to liquefaction.
- **North and South Shores Region** infrastructure will be most vulnerable to hazards from coastal flooding, hurricanes and tropical cyclones, and other extreme weather events. Electric transmission and utility distribution infrastructure will be very vulnerable to these hazards, as will coastal buildings and ports.
- **Cape, Islands, and South Coast Region** electric transmission and utility distribution infrastructure will be very vulnerable from many hazards, including extreme temperature, flooding from precipitation, coastal flooding, and wildfire. Clean water supply (e.g., public water supply, wells) will also be at risk due to flooding from precipitation, extreme temperatures, and drought.

- **Critical facilities.** Many healthcare facilities, correctional facilities, and shelters are in areas of increased risk, including from extreme temperatures and coastal flooding. Additionally, some critical facilities—such as the Massachusetts Information Technology Center, multiple State Police barracks and county prisons, and the

Massachusetts Department of Transportation (MassDOT) Highway Operations Center—are in soft clay soils and are thus likely to be more vulnerable to earthquakes.

- **Roads and transportation infrastructure.** Roads and transportation infrastructure throughout the Commonwealth are vulnerable to a variety of hazards, including flooding, wildfire, hurricanes, extreme heat, coastal erosion, extreme storm events, and sea level rise, with many of these vulnerabilities increasing due to climate change. For instance, low-lying roads that are most at risk from coastal erosion include Cranberry Highway in Cape Cod (located within 50 feet of shoreline that could erode from 2 to 8 feet, which could place the highway at risk of damage) and North End Boulevard in Salisbury, which is located on shoreline that could erode 5 or more feet. Additionally, the Central Artery tunnels, which provide a critical regional transportation link and are an important transportation corridor for the Boston metropolitan area, are at increased risk from coastal flooding.
- **Electric and utility infrastructure.** Both the aboveground and belowground electric transmission and utility distribution infrastructure located along coastal shorelines, rivers, and streams are vulnerable to increasing flood risk due to sea level rise, and the increased intensity of coastal and inland storm events. They are also at risk from other hazards such as extreme heat, extreme storms, and droughts, which can significantly change demand for heating, cooling, and energy—in addition to resulting in damage to this infrastructure during hazard events. Damaged water storage and treatment infrastructure facilities and pipelines can put water supply provisioning at risk due to exposure to contaminants or saline groundwater, or loss of pressure and volume.

Table 6-2. Hazards and Infrastructure Vulnerabilities

Hazard	Vulnerabilities to Infrastructure
Earthquake	• Certain areas of Boston are vulnerable to liquefaction. • Towns with higher proportions of older buildings that pre-date building codes will be more vulnerable to earthquake damage (e.g., buildings with unreinforced masonry). • Other infrastructure that is particularly vulnerable due to its extensive aboveground and belowground facilities include energy facilities, hospitals, and community health centers in areas susceptible to liquefaction; bridges; underground subway and highway tunnels; and water and wastewater utilities. • Many critical facilities are in soft clay soils, which are likely to be more vulnerable to earthquakes. Example facilities include the Massachusetts Information Technology Center, multiple State Police barracks and county prisons, the MassDOT Highway Operations Center, and multiple pump houses and stations.
Hurricanes and tropical cyclones	• Low-lying and linear infrastructure and utility networks are extremely vulnerable, especially buried sewer lines, wastewater treatment plants, stormwater systems, power and communication infrastructure and services, and roads, bridges, trails, and air and marine travel.

Hazard	Vulnerabilities to Infrastructure
	• Suffolk County has the highest number of exposed critical facilities, followed by Plymouth and Barnstable counties. • Barnstable County has the most road mileage that could be exposed to hurricane storm surge inundation. • Stormwater and sewage systems, particularly those that are inadequate or aging, could be vulnerable to heavy rainfall, resulting in combined sewer overflows or release of contaminants.
Invasive species	• State-owned recreation areas or facilities that rely on healthy ecosystems for services (e.g., outdoor recreation, recreational fishing) could be vulnerable to impacts by invasive species. • The agricultural sector is vulnerable to increased invasive species due to drought, as well as changing temperatures and growing seasons. • Physical maritime assets could be disrupted and damaged by invasive species. • Water storage facilities may be impacted by invasive aquatic species. These species may lead to reduced water quality, which could impact drinking water supplies and the cost of water treatment.
Coastal erosion	• Infrastructure near the shoreline, including transportation systems, housing, businesses, recreational areas, and shoreline protection structures (e.g., seawalls, revetements, armoring), will be vulnerable to coastal erosion. For instance, in Newburyport's Reservation Terrace community, many homes have already experienced damage and destruction due to coastal erosion. • Other types of infrastructure that are vulnerable to coastal erosion include energy infrastructure on the coastline; coastal roadways, bridges, and airports; and water infrastructure (e.g., pipes for septic systems, drinking water, stormwater, and wastewater). • Specific roads that are most at risk include Cranberry Highway in Cape Cod (located within 50 feet of shoreline that could erode from 2 to 8 feet and cause damage to the highway) and North End Boulevard in Salisbury, which is located on shoreline that could erode 5 feet or more. East Chop Drive in Oaks Bluff on Martha's Vineyard has also experienced closures due to erosion. • Many open space and natural areas are also at risk of erosion, such as Plum Island State Reserve, the Parker River National Wildlife Refuge, and Coskata-Coatue Wildlife Refuge.
Groundwater rise	• Below- or at-grade buildings, building foundations, and utilities (e.g., pipes, belowground electrical assets, water infrastructure) are vulnerable to flooding, unstable soils, groundwater rise, and saltwater intrusion along coastal areas. • Coastal roads will experience repeated damage from rising groundwater. • Agricultural lands may be vulnerable to changes in drainage and flooding due to groundwater rise.

Hazard	Vulnerabilities to Infrastructure
Extreme temperature	• High-value crops that rely on specific temperature regimes—such as apples, cranberries, and maple syrup—will be vulnerable to temperature increases, as will dairy and cattle production and crops such as sweet corn. • Extreme cold could lead to energy supply concerns and utility failures during times of extreme need, and periods of both hot and cold weather can stress energy infrastructure (e.g., brownouts caused by hot weather). • Twenty-nine percent of critical facilities are in high land-surface temperature (LST) areas. Among critical facilities in high LST areas, the largest proportion is residential buildings, followed by corrections facilities and energy facilities. • Many hospitals throughout the Commonwealth are in regions with high LST, including Worcester State Hospital, the University of Massachusetts Chan Medical Center, Taunton State Hospital, Soldiers Home in Holyoke and Chelsea, Newton Pavilion, and the Massachusetts Mental Health Center. • Shelters in Amherst, Lowell, Quincy, and Worcester and correctional facilities in Billerica, Boston, Bourne, Bridgewater, Chelsea, Chicopee, Framingham, Gardner, Greenfield, Lancaster, Ludlow, New Bedford, Norfolk, Northampton, Pittsfield, Plymouth, Shirley, West Boylston, and Worcester are also in high-LST regions.
Tornado	• State-owned, municipal, and residential buildings constructed prior to current building codes may be more vulnerable to tornado-related damages. • Middlesex, Worcester, and Hampshire Counties have the highest numbers of critical facilities located in zones with high tornado hazard. • Other types of infrastructure that could be vulnerable to tornadoes include forestry and agricultural crops, livestock, equipment, and infrastructure; power lines and poles; public safety facilities and equipment; roads, bridges, and rail systems; and water infrastructure such as storage tanks and hydrants.
Wildfire	• Infrastructure located in the wildland-urban interface and intermix area will be vulnerable to wildfire. • Building types most prominent in moderate wildfire hazard zones are water resources facilities, residential buildings, and energy facilities. • Norfolk, Middlesex, and Plymouth counties have the most critical facilities located in moderate wildfire hazard zones. • Other types of vulnerable infrastructure include forestry and agriculture industry infrastructure, energy distribution and transmission lines in wildfire risk zones, and roads, bridges and rail systems that may become blocked due to fire and debris.
Drought	• Agricultural land and infrastructure will be particularly vulnerable to drought. Franklin, Plymouth, and Hampshire Counties have the highest acreage of agricultural land in the Commonwealth. • Energy production plants that rely on water for cooling will be uniquely vulnerable to drought, as could hydropower plants.

Hazard	Vulnerabilities to Infrastructure
	• Groundwater sources and smaller surface water supplies will also be vulnerable to drought due to reduced rates of replenishment.
Coastal flooding	• The Boston Harbor region is particularly vulnerable to coastal flooding due to projected sea level rise and its existing development footprint. • Other infrastructure that is vulnerable to coastal flooding includes ports and marinas throughout the Commonwealth, coastal rapid rail transit (e.g., trolley and subway systems), and solar energy production resources that lie within the existing or potential future Federal Emergency Management Agency 100-year coastal flood plain. • Based on available MassGIS data, at least four healthcare facilities (including nonacute care hospitals and community health centers) are most at risk to a 100-year flood event. • Critical facilities including the Suffolk Sheriff's Department in Chelsea and the Department of State Police Special Operations Marine Division in Boston are also in zones that are most at risk of exposure from a 100-year flood event. If these facilities have been retrofitted to withstand this exposure—such as elevating them, removing all sensitive equipment and workspaces from belowground or at-grade spaces, or designing and having a plan to deploy temporary flood measures—then they will have reduced their risk from direct exposure. However, the function will be disrupted during a flood event and access to and from the buildings will likely be compromised, as well as power, water, and other services, which would impede the services these facilities can provide to the community. • Many state-operated coastal roads are likely to be at risk from coastal flooding. One significant asset at risk is the Central Artery tunnels, which provide a critical regional transportation link and are an important transportation corridor for the Boston metropolitan area.
Flooding from precipitation	• Both residential and state-owned properties are vulnerable to riverine flooding, with the Eastern Inland and Greater Connecticut River Valley regions likely to experience the largest annual increases in damage to residential structures by 2090. • Solar energy production infrastructure may be vulnerable to riverine flooding, as 26% of current solar production is located within a Federal Emergency Management Agency 100-year floodplain. • Other infrastructure that is vulnerable to riverine flooding includes aging culverts and bridges, due to potential flood impacts such as bridge scour, overtopping, culvert blowout, and road embankment destabilization. • The Greater Connecticut River Valley and Central regions are most likely to experience the highest projected annual economic impacts from dam overtopping and breaching.
Landslide and mudflows	• Infrastructure (e.g., farmlands and soils, crops and critical equipment, energy transmission lines, transportation infrastructure) in areas with steep slopes or exposure to extreme precipitation, wildfire, drought, or flood is likely to be most vulnerable to landslides or mudslides.

Hazard	Vulnerabilities to Infrastructure
	• Highly vulnerable infrastructure includes mountain roads, coastal roads, and transportation infrastructure and utilities adjacent to such roads.
Tsunami	• Hospitals, elder care facilities, prisons, animal care facilities, and elementary schools and preschools are most vulnerable during a tsunami as they require special levels of care and coordination. • Plymouth, Suffolk, and Barnstable counties have the highest numbers of critical facilities vulnerable to tsunami exposure. • Other infrastructure that could be vulnerable includes cropland and livestock (which could be devastated by flooding), aboveground utilities like power lines and radio/cellular communication towers, power generation facilities, state-owned police facilities and fire departments, roads and bridges, and water and wastewater treatment plants located in tsunami inundation zones.
Severe winter storms	• Worcester County contains the highest number of critical facilities in areas likely to experience the most days with 5 inches or more of snow. • Coastal buildings and ports are vulnerable to storm surge and high winds from nor'easters, which will be exacerbated by sea level rise and coastal erosion. • Other types of infrastructure that are vulnerable include low-lying agricultural areas that could be impacted by flooding, power lines and other aboveground energy infrastructure, public safety buildings (e.g., police, fire, and medical facilities), roadways, public transit, and water and wastewater treatment plants.
Other severe weather	• Buildings that are particularly vulnerable include residential structures, wood and masonry buildings, and high-rise buildings. • Forestry species and agricultural crops, equipment, and infrastructure may be directly damaged by high winds. • Other infrastructure that may be vulnerable includes power and aboveground communication lines, utility infrastructure (e.g., power lines, gas lines, electrical systems, communications), public safety facilities and equipment, and water infrastructure, including water supply, stormwater, dams, and wastewater systems. • Roads, bridges, cargo and passenger rail, and transit may be vulnerable to disruptions from falling trees, landslides, downed power and communication lines, flooding, or debris.

6.1.1.2 Specific Impacts to Agency Functions and Services

Beyond the general details regarding how past hazard events resulted in disruption of functions, agencies also described past and potential consequences of damage and disruption to agency functions. Agencies provided specific examples of concerning impacts to their services, such as:

- **Communications service impacts** such as disruption of emergency services and infrastructure, as well as information technology (IT) and security services.

- **Community service impacts** such as potential limited access to job placement and employment benefit services, interruption of community health screening, cessation of community outreach and information events, impacts to mosquito control operations, and damage and destruction to residential facilities that would impact the ability of these facilities to provide community services.
- **Critical service impacts** such as limited ability to conduct facilities inspections, interruptions in child protection visits, disruption to medical service provision, and interrupted emergency services coordination.
- **Hazardous material and contaminated land services impacts,** including disruptions to site cleanup activities and potential inability to access and repair damage to hazardous material facilities.
- **Port and maritime service impacts,** such as disruptions to the fish and seafood supply chain, processing operations, and seafood transportation, as well as supply chain interruption and limited distribution of other goods imported and exported through ports.
- **Recreational, open space, natural area, and working land service impacts,** including temporary loss of recreational fishing and boating access, impacts to habitat in natural areas that could limit access for recreational users, and loss of protected open space that could negatively affect species living in these areas. (See box above.)
- **Transportation and mobility service impacts** such as lack of access to emergency routes, disrupted transportation due to damage to roads and bridges, and disruption of transportation services (e.g., trains, boats, buses).
- **Utilities and infrastructure service impacts,** including disruption of gas, electric, water, stormwater, and wastewater services due to facility damage.

Spotlight: Impacts from Loss to Services

The Division of Ecological Restoration (DER) is responsible for leading projects that help restore and protect rivers, wetlands, and watersheds in Massachusetts. Loss of DER operations—which may occur from hazards such as flooding, drought, and storms—could result in delay or total cessation of restoration projects. Work stoppage could lead to loss of funds and difficulty remobilizing the project team once activities can resume. If DER operations cease, DER and partners would not be able to move forward on restoration projects and would not have the funds to support local businesses. Additionally, loss of DER operations may result in the delay of permitting a project and may increase the cost of permitting due to the delay. Recovery from these impacts may be a matter of days, weeks, or months depending on the severity of impact to DER operations.

The survey also asked agencies to indicate specific types of critical services that would be impacted following loss of an agency's operations, as well as how long it would take for the resource to be impacted and the time it would take to recover following impacts. Over half of the agencies that responded to the survey indicated that public health and safety

services would be impacted due to a loss of operations, with impacts felt immediately and recovery times ranging from days to months. Table 6-3 summarizes responses to these questions and the various ways critical services will be impacted by hazard events.

Table 6-3. Agency Responsibilities and Description (N = 85)

Types of Services Impacted	% of Agencies with Impacts	Examples of Length of Time to Experience Impacts and Recover
Education	28%	• Immediate impacts on educational programs and training and systems that impact education (e.g., housing, transit). • Recovery time could be as quick as few hours but could also take days to months and even result in permanent changes.
Food support and security	27%	• Could experience both immediate and delayed impacts to food (e.g., dairy and milk supply), services, and programs (e.g., food provided through shelters or public housing, food stamp program). • Response times would vary depending on disaster and severity, as well as ability to coordinate within and among agencies.
Goods movement	16%	• Some immediate impacts due to loss of power and internet, but operations could be restored as soon as these services resume. • Potential for immediate impacts due to loss of transportation infrastructure, with highly variable recovery times based on event severity.
Health services	33%	• Potential immediate impacts to services due to impacted facilities and need to transport residents to alternative sites. • Potential immediate impacts to programming (e.g., mental health services, background checks for volunteers and employees, veteran care, pharmacy and medical benefits) with potential recovery of a few days or longer depending on severity.
Local businesses	34%	• Potential immediate or short-term impacts on contractors, employment agencies, and employers, as well as potential impacts to work and projects performed by businesses and contractors. • Recovery could take weeks to months depending on the severity of the event.
Natural resource management and protection	19%	• Potential for immediate impacts, including loss of infrastructure and natural resources and inability to perform project work. • Recovery time varies highly based on the event.

Types of Services Impacted	% of Agencies with Impacts	Examples of Length of Time to Experience Impacts and Recover
Permits	27%	• Potential inability to or delay in issuing permits for projects and potential impacts to permitting, though impacts may be mitigated through online permitting systems.
Public health and safety	49%	• While there could be potential minor disruptions to 9-1-1 data centers, calls would still be answered, and disruptions would be minimal due to backup data centers and systems. Recovery, reinstallation, and reconfiguration of equipment could take years. • Potential for impacts within days to weeks if there are disruptions to mosquito control operations. Time to recover would be contingent on severity of the event and the number of mosquito control districts impacted. • Potential immediate impacts to housing, emergency shelters, or utilities, with variable recovery times.
Recreational opportunities	25%	• Immediate impacts to and curtailment of recreational activities until the event had been resolved. • Could take months to recover depending on impacts to natural areas and associated infrastructure.
Regulatory programs	27%	• Potential immediate impacts to services that cannot be performed remotely, such as in-person site visits, inspections, and licensing, with some ability to continue regulatory functions (e.g., review, hearings) online depending on power and internet. • Recovery time would likely depend on severity of the event, potentially varying from multiple days to weeks.
Transit and transportation	26%	• Immediate curtailment of transit or transportation activities until event resolution. • Potential loss of transportation networks if construction on maintenance projects is delayed (and roads remain closed for longer than anticipated), and elevated risks of flood damage and loss of life if aging infrastructure fails during a storm or flooding event. • While agencies (e.g., MassDOT) would take immediate steps to implement temporary solutions, full recovery from impacts could take days, weeks, or months depending on the severity of the impact to operations.
Youth services	19%	• Potential immediate impacts to infrastructure that supports youth services (e.g., family housing, emergency shelters) depending on the event. • Resolution would depend on the severity of the issue, but could take at least two weeks or be permanent, depending on location and event severity.

6.1.2 Social Vulnerability

6.1.2.1 Populations at Risk

Within the Commonwealth, many populations are more at risk from hazards due to a variety of factors, such as geographic location, resources available, and socioeconomic characteristics. Chapter 5 (Risk Assessment) outlines potential vulnerabilities of each hazard to the human sector, and the MA Climate Assessment details the most urgent impacts of hazards to the human sector. Understanding which characteristics make communities more vulnerable to specific hazards—as well as potential disproportionate impacts that may occur—can help the Commonwealth design actions to best mitigate vulnerabilities and reduce risk to human communities.

In the survey, agencies described their primary concerns regarding impacts to populations from hazard events. Table 6-4 lists examples of populations of concern and disproportionate impacts according to the categories of assets and functions for which agencies are responsible. Responses regarding impacted populations varied greatly, from concerns about impacts to the public (e.g., disruption of critical and transportation services) to more specific impacts for certain populations such as veterans, people with disabilities, and people dependent on public transportation.

Table 6-4. Populations of Concern and Disproportionate Impacts

Asset and Function Category	Example Populations of Concern	Examples of Disproportionate Impacts of Concern
Communication	• Residents, business, and municipalities. • Municipal, campus, hospital, and environmental police and deputy sheriffs.	• Delays in court date proceedings and filings. • Extended response times. • Impacts to communities reliant on public transportation from disruptions related to offline services.
Community	• Building occupants. • People with disabilities. • Job seekers. • Mosquito Control District member municipalities.	• Loss of in-home or facility support and services for at-risk adults. • Impacts to those in agricultural sector from hazards.
Critical	• Veterans. • People with disabilities. • At-risk youth. • General public (e.g., hospital patients, school children).	• Food insecurity impacts due to crop damage. • Environmental justice and other priority population families and children. • Employees in at-risk facilities.

Asset and Function Category	Example Populations of Concern	Examples of Disproportionate Impacts of Concern
Hazardous material sites and contaminated lands	• Adjacent neighborhoods and communities affected by environmental injustices. • Farmers.	• Neighborhoods adjacent to cleanup sites (particularly environmental justice communities). • Delays in staff services to farmers.
Ports and maritime	• Adjacent neighborhoods and communities affected by environmental injustices. • Seafood-consuming public. • Public dependent on imported goods. • Traveling public and employees.	• Loss of business. • Supply chain disruptions and associated local and regional economic losses. • Potential impacts felt throughout all communities, particularly coastal communities.
Recreation, open space, natural areas, and working lands	• General public (e.g., hikers, park users, recreational fishers, and others). • Visitors. • Landowners that manage open space and restoration projects.	• Potential impacts felt throughout all communities. • Open space users with disrupted access to natural areas.
Transportation and mobility	• Communities reliant on public transportation. • Motorists. • Emergency service providers. • Traveling public and employees.	• Potential impacts felt throughout all communities. • Environmental justice populations dependent on disrupted transportation services. • Coastal communities impacted by damage to roads from flooding and erosion.
Utilities and infrastructure	• Motorists and emergency services in hazard vicinity. • Utility service users.	• Environmental justice populations with disrupted utility services. • Potential impacts felt throughout all communities.
Other	• Insurance customers. • Injured workers.	• Limited access to hearing rooms and disrupted support from agencies. • Delays in proceedings or document filing.

The survey also asked agency respondents to detail how disruptions to their services from unplanned hazard impacts would result in consequences to directly impacted populations, public health and safety, climate-vulnerable populations, and associated costs due to damage, disruption, and loss. Table 6-5 summarizes these responses. Understanding the

social consequences of hazard-related disruptions, damage, and loss can help state agencies consider types of populations and areas for focusing adaptation efforts, and these consequences were used to help determine actions and strategies highlighted in Chapter 7 (State Strategy, Actions, and Implementation Plan) of the MA SHMCAP.

Table 6-5. Populations Impacted and Social Consequences of Hazard-Related Disruptions, Damage, and Loss

Category	Examples of Populations Impacted and Consequences
Populations affected	• Incarcerated people, their visitors, and staff. • Workers, businesses, and public agencies. • Recreational boaters and fishermen, anglers, hunters, students, nature enthusiasts. • Construction contractors. • Veterans.
Public health and safety impacts	• Reduced oversight of workplace safety and health. • Loss of life and severe injury. • Delayed response by emergency and essential personnel. • Air quality impacts from reduced public transit use.
Disproportionate impacts	• Disproportionate impacts to elderly and youth populations. • Populations affected by environmental injustices are likely to be disproportionally affected, particularly if they rely on public transit that is disrupted. • Inability for veterans and families with disabilities to receive assistance. • Subsistence fishers are vulnerable to the effects of prolonged fishing closures.
Economic impacts	• Costs associated with infrastructure for remote work (e.g., laptops, monitors, docking stations, software licenses). • Undefined loss of revenue from missed hunting and fishing license sales. • Loss of work hours. • Repair and recovery costs.

6.1.2.2 Environmental Justice and Other Priority Populations

Overall, while the provided examples mentioned various populations that could be impacted, many respondents cited potential disproportionate impacts to environmental justice and other priority populations. The Commonwealth characterizes environmental justice populations as those that meet one or more of the following criteria:

1. The annual median income is 65 percent or less of the statewide annual median household income.
2. Minorities make up 40 percent or more of the population.
3. At least 25 percent of households identify as speaking English less than “very well.”

4. Minorities make up 25 percent or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150 percent of the statewide annual median household income.

Beyond environmental justice populations, other priority populations include people or communities who are disproportionately impacted by climate change due to life circumstances that systematically increase their exposure to climate hazards or make it harder to respond. In addition to factors that contribute to environmental justice status (i.e., income, race, and language), other factors like physical ability, access to transportation, health, and age can indicate whether someone or their community will be disproportionately affected by climate change. This disproportionate impact is driven by underlying contributors such as racial discrimination, economic disparities, or accessibility barriers that create vulnerability. The term priority populations acknowledges that the needs of people with these experiences and expertise must take precedence when developing resilience solutions to reduce vulnerability to climate change.

Within the Commonwealth, environmental justice populations are distributed throughout all counties (Figure 6-1, Table 6-6). Suffolk County has the highest percentage of residents that are considered part of an MA Environmental Justice community, followed by Hampden and Middlesex. Actions to reduce hazard vulnerability—especially within these counties, but also throughout the Commonwealth—will need to consider how to respond to the needs of these populations.

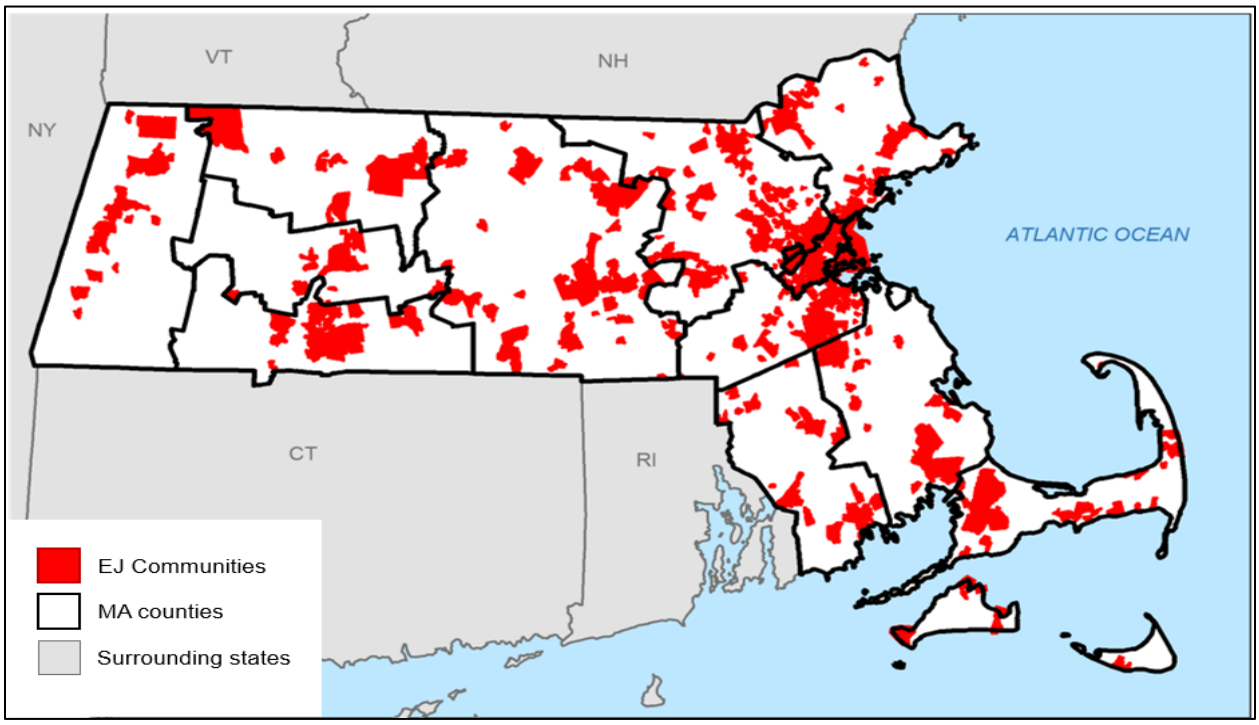


Figure 6-1. MA Environmental Justice populations.

Table 6-6. Percentage of Counties with Environmental Justice Populations

County	County Population	Percent of County in Environmental Justice Population
Barnstable	214,445	20%
Berkshire	127,975	41%
Bristol	561,037	40%
Dukes	17,312	25%
Essex	783,676	43%
Franklin	77,602	30%
Hampden	**467,871**	**58%**
Hampshire	162,778	37%
Middlesex	**160,0842**	**44%**
Nantucket	11,168	8%
Norfolk	700,437	38%
Plymouth	515,303	26%
Suffolk	**796,605**	**80%**
Worcester	824,772	42%

Note: Counties with the top three highest percentages of environmental justice populations are in bold.

A particular category of environmental justice and other priority populations likely to be at risk from impacts of hazards to state agency assets, functions, and services are those that depend on state agencies for shelter, transportation needs, or other critical social services. For instance, agencies that provide services or shelter to environmental justice and other priority populations—such as the elderly, very young, incarcerated, housing or transportation cost-burdened individuals, renters, people without a car, or people with animals—will need to have clear plans in place to ensure they can shelter in place or safely evacuate and relocate, if necessary. Only 15 percent of agencies that responded to the survey indicated they provide shelter or services to these populations; however, those that responded provided many examples of the plans they have in place in case of hazard impacts to ensure the well-being of these populations. Respondents highlighted plans and actions such as:

- Collaborative, multi-agency crisis plans to provide shelter to individuals.
- Facility-specific procedures and policies for shelter-in-place or evacuation and relocation depending on event severity.
- Emergency preparedness guidelines for local housing authorities.
- Plans for transferring shelter residents, if shelters are compromised due to weather or other emergencies, to facilities that are not at risk.
- Contingency plans for using public health hospitals as shelters or cooling and warming centers for those experiencing homelessness and those most dependent on home health services.
- Detailed Continuity of Operations Plans (COOPs) that are continually updated and include contingencies such as processes for relocation, alternate facility operations, leadership and delegation of authority, and virtual coverage of essential functions.

Spotlight: Loss of Services to Youth

The Department of Youth Services serves many youths that are socially vulnerable. Services include food provided through kitchens in its facilities, social services like site and home visits, shelter, and more. Disruption of operations due to hazard impacts would require the department to find alternate means for food and other services and could impact its service continuum and the outcomes and effectiveness of its programming.

The MA Climate Assessment analyzed impacts to the human sector related to people's health, welfare, and safety. It found that the three most urgent impacts to the human sector were health and cognitive effects from extreme heat, health effects from degraded air quality, and emergency services response delays and evacuation disruptions. There are a variety of populations most vulnerable to these urgent impacts. Overall, these results reflect the findings of the survey and the increased vulnerability of environmental justice and other priority populations. Specifically:

- **The linguistically isolated** are highly vulnerable to extreme heat and are 28 percent more likely to experience mortality related to extreme heat.
- **Black and African American individuals** are at higher risk of health effects from degraded air quality, as they are 40 percent more likely to live in areas with the highest projected asthma incidences and highest projected increase in childhood asthma diagnoses.
- **All classifications of environmental justice Census block groups** are likely to experience greater impacts to disruptions to emergency service response delays and evacuations than non–environmental justice populations across the Commonwealth.

6.1.3 Environmental Vulnerability

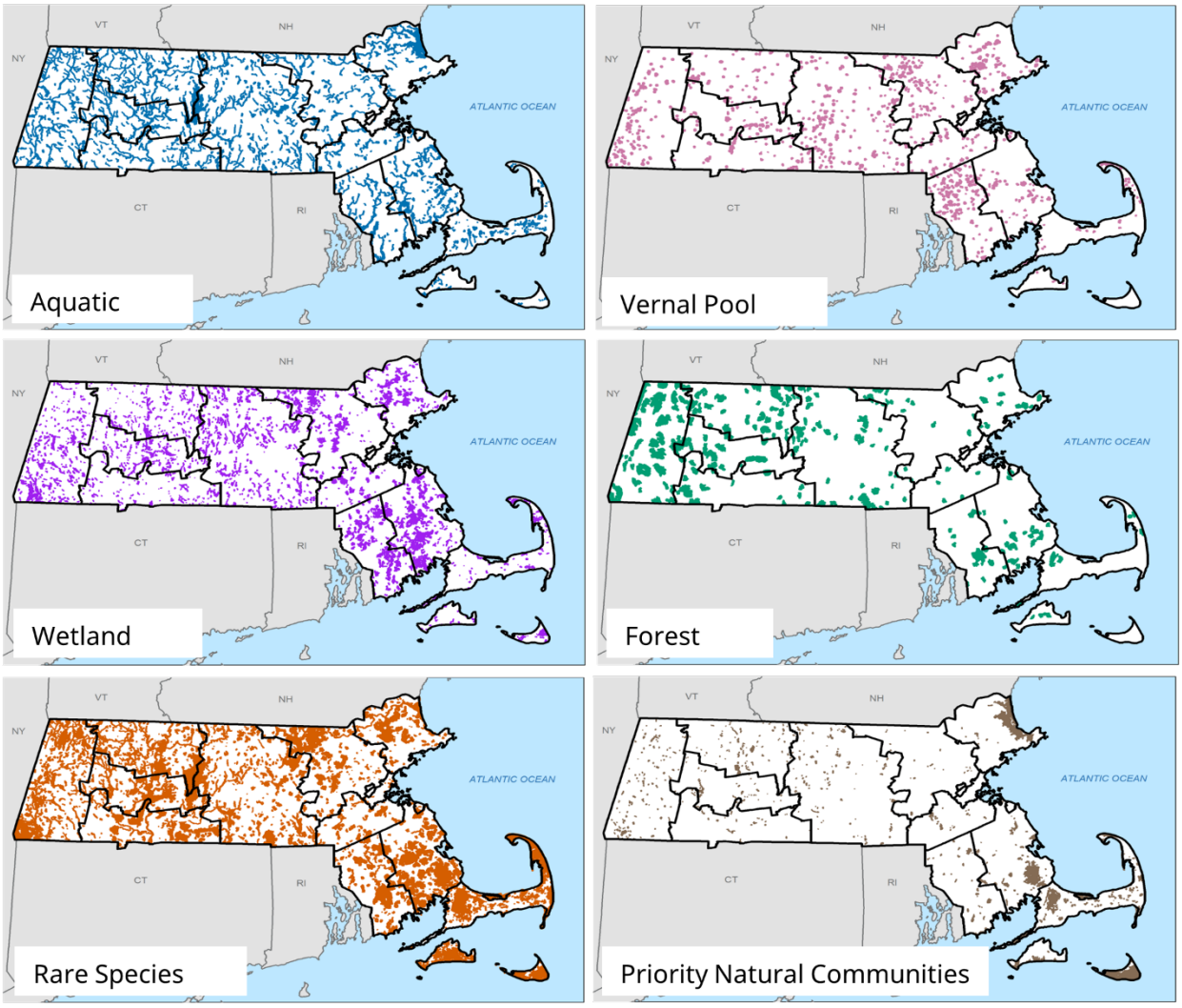
6.1.3.1 Core Habitats in the Commonwealth

The Commonwealth has a rich diversity of natural ecosystems, including forests, wetlands, rivers, grasslands, and coastline. Besides sustaining important habitat for plants and animals, they also provide many important ecosystem services, such as carbon storage, water filtration, and flood risk reduction. Understanding the system scale vulnerability of these ecosystems to natural hazards is a key consideration for determining the resilience of the Commonwealth as a whole. BioMap, a tool used for biodiversity conservation in Massachusetts, identifies core habitats, which are areas that are critical for the long-term persistence of rare species, exemplary natural communities, and resilient ecosystems across the Commonwealth (MassWildlife & The Nature Conservancy, 2022). These core habitats consist of 1.52 million acres, of which about 49 percent are protected. These habitats are described in Table 6-7 and mapped in Figure 6-2.

Table 6-7. Descriptions of BioMap Core Habitat

Core Habitat	Description
Aquatic core	Intact aquatic habitats (i.e., rivers, streams, lakes, and ponds) supporting a diversity of aquatic species and important physical and ecological processes.
Vernal pool core	Clusters of ecologically significant pools and intact surrounding upland habitat to ensure connectivity between pools.
Wetland core	The most intact, least disturbed wetlands within resilient, less developed landscapes, with fewer stressors such as pollution.
Forest core	The most intact forests of Massachusetts, least impacted by development and essential for animals and plants dependent on remote habitat.
Rare species core	Areas critical to the long-term conservation of our most vulnerable species and their habitats.
Priority natural communities	Assemblages of plant and animal species with limited distribution and the best examples of common assemblages.

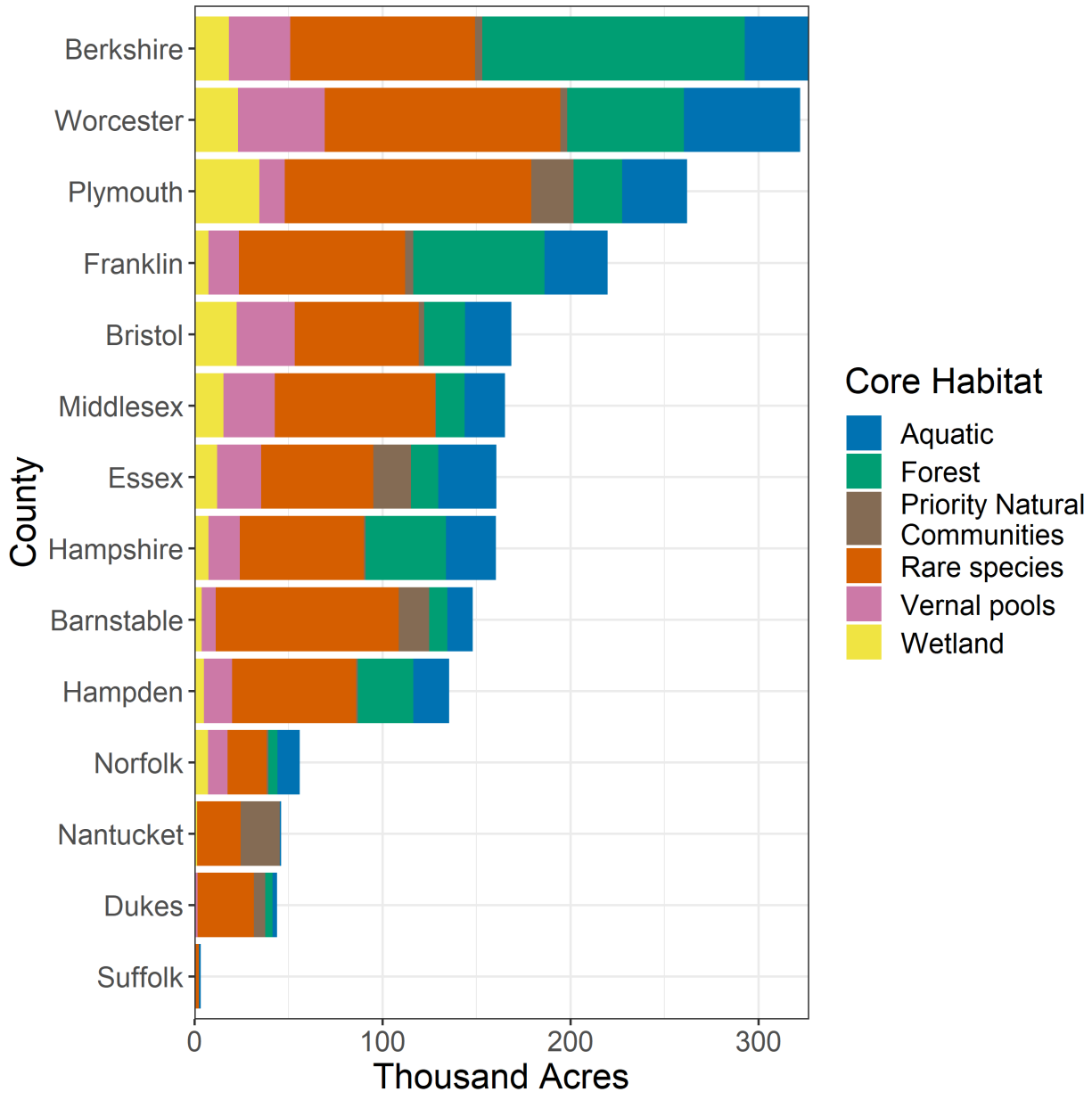
Source: MassWildlife & The Nature Conservancy (2022).



Source: MassWildlife & The Nature Conservancy (2022).

Figure 6-2. BioMap core habitats.

These core habitats are of high importance for conservation efforts, as they are key areas for safeguarding the Commonwealth's biodiversity. Figure 6-3 shows that Berkshire, Plymouth, and Worcester counties have high percentages of almost all core habitats. This is an important consideration for conservation planning and for identifying potential habitats that may be most vulnerable to hazards. For instance, about 32 percent of forest core habitat in the Commonwealth is in Berkshire County, which also is at a relatively higher risk for landslides and currently has medium wildfire hazard potential.



Source: MassWildlife & The Nature Conservancy (2022).

Figure 6-3. Acres and percent of each BioMap core type in each county.

6.1.3.2 Vulnerability of Natural Areas

As part of the state agency vulnerability assessment survey, Massachusetts state agencies were asked whether their agency manages, provides, or protects habitat for threatened or endangered species. Of the 83 total respondents, only 12 percent said their agency did manage these habitats. (However, note that these agencies, such as the Department of Conservation and Recreation, Department of Fisheries and Wildlife, and Department of

Ecological Restoration, are responsible for managing a large percentage of these state-owned lands.) Most of these respondents also said that the habitat they managed was scarce in their region. Two habitat types that were specifically mentioned included butterfly wildflower habitat and eelgrass. Respondents also agreed that most of the habitats they managed were relatively unique to their regions and could not be established in other areas if they were to be damaged by natural hazards. A few of the reasons habitats would be difficult to establish elsewhere include:

- Impacts to existing species
- Funding
- Permitting
- Time required for planning and implementing long-lasting and effective restoration projects
- Staff capacity
- Scarcity of suitable habitats for species to be established in

As endangered or threatened habitat may not easily be established in other areas, there are a variety of species and ecosystem benefits that are vulnerable and could be lost if the threatened habitat was destroyed or altered. Sensitive species with limited abundances and distributions are the most likely to be lost, which can lead to a loss of ecosystem services and natural heritage. Some specific habitats and species that respondents identified as threatened are listed below, many of which are part of BioMap's aquatic or wetland cores:

- Salt marsh habitat and the unique plants and animals that inhabit them (e.g., salt marsh sparrow)
- Eels and river herring
- Coldwater fisheries habitat and other rare fish and shellfish species
- Unique or rare types of freshwater plant communities such as Atlantic white cedar bogs
- Important habitat for several commercially and recreationally managed finfish and shellfish species
- Eelgrass

An example of a critical natural area that is vulnerable to multiple hazards is The Great Marsh, which spans the northeastern region of the Commonwealth. The marsh is considered one of the most important coastal ecosystems in northeastern North America and has been designated a Critical Natural Landscape, Long Term Ecological Research Network site, Important Bird Area of Global Significance, Western Hemisphere Shorebird Reserve Network site, and an Area of Critical Environmental Concern (Schottland et al., 2017). Additionally, communities surrounding the marsh rely on it to buffer storm

damages, reduce coastal erosion, and dampen flooding. However, sea level rise, coastal erosion, hurricanes, or winter storms threaten to damage or destroy areas of this critical marsh habitat. Large areas of the marsh may become inundated with just 1 foot of sea level rise, and future storms on top of this can further inundate or erode habitat (Schottland et al., 2017). As detailed Chapter 5 (Risk Assessment), Section 5-5 (Coastal Flooding), the greatest statewide loss of high and low marsh habitat is predicted to occur between the years 2070 and 2100, with 98 percent of today's combined high and low marsh habitats transitioning to tidal flat by 2100.

Table 6-8 summarizes environmental risks detailed for each hazard. One common concern in the aftermath of many hazards is the total disruption or destruction of a habitat. This can completely eradicate important biodiversity hotspots and lead to increased vulnerability or total loss of already endangered or threatened species. Additionally, large disturbances can create conditions favorable for the spread of invasive species, which can outcompete native communities, displacing many native species and causing widespread economic and environmental damage. Contamination from debris and pollutants can also occur after a variety of hazards and may seriously degrade ecosystems or kill off species in the area. As pollutants can remain long after a hazard, taking steps to preemptively plan for and reduce potential debris creation is important.

Table 6-8. Potential Environmental Impacts from Each Hazard Type

Hazard	Impacts and Vulnerabilities to Natural Areas
Earthquake	• Disturbance and displacement of the physical foundation of an ecosystem can disrupt the balance of species and leave the area more vulnerable to the spread of invasive species. • Damage to gas and fuel pipes may cause explosions or leaks, which can discharge hazardous materials into the local environment or watershed if rivers are contaminated. • Fires caused by earthquakes can cause extensive damage to ecosystems.
Hurricanes and tropical cyclones	• Flooding and wind can damage trees and other vegetation. • Coastal storm surge often results in significant damage to tidal estuaries and can alter the salinity of these systems. • Priority natural communities, coastal adaptation areas, and tern foraging habitats have some of the highest portions of their habitats exposed to hurricane-related storm surge.
Invasive species	• Reduced diversity of native plants and animals. • Degradation of water quality. • Degradation of wildlife habitat. • Local and complete extinction of rare and endangered species.
Coastal erosion	• Potential damage to or loss of area for salt marshes, mudflats, beaches, coastal banks, and uplands that support native species and provide for inland migration.

Hazard	Impacts and Vulnerabilities to Natural Areas
	• Loss or change of wetland and salt marsh shoreline functions, including habitat for native species, filtering pollutants, retaining and trapping sediment, and shoreline buffers. • Loss of biodiversity, natural and cultural resources, and disruption to networks and systems of habitat along the Massachusetts coast.
Groundwater rise	• Saltwater intrusion and inundation of aquifers, wetlands, and ecosystems unable to adapt to new conditions. • Mobilization of contaminants into habitats, vegetation, and wetlands. • Coastal plain ponds, freshwater wetlands, and fish hatcheries are likely to be at risk of saltwater intrusion that will result from groundwater rise, which could alter their function and allow for persistence and proliferation of invasive species. • Areas with higher exposure to polluted water, such as locations near septic systems and overburdened sewer systems or contaminated sites, are at higher risk of exposure to contaminated water.
Extreme temperature	• Warming of freshwater, coastal wetland, and marine ecosystems are the most urgent impacts (as identified by the 2022 Climate Change Assessment) to the natural environment in Massachusetts. • Warming temperatures threaten freshwater ecosystems through increased growth of aquatic plants and algae, as well as shifting habitats. • Warming temperatures increase the risk of algal blooms, including cyanobacteria (a harmful variety of algae). • High temperatures and evapotranspiration rates could lead to habitat loss and wetlands drying out at least seasonally. • As the climate warms, species will shift north and to higher elevations away from their historical ranges, leading to the loss of species that play key ecosystem roles, or the range expansion of invasive species that previously did not extend into these habitats. • Shifting habitat from temperature changes may result in a geographic mismatch between the location of conserved land and the location of critical habitats and species the conserved land was designed to protect. • Changes in timing of flowering, growth, and reproduction of native plants may result in impacts to the health and viability of insects, birds, and other wildlife. • Forests stressed from rising temperatures may have reduced capacity to provide ecosystem services like carbon storage and water filtration. Trees, soil, streams, and rivers work as a system, and damage to any component due to drought or heat

Hazard	Impacts and Vulnerabilities to Natural Areas
	results in damage to the whole system. Rising temperatures result in degraded soils, damaged trees, habitat shifts, and the movement of water out of the environment. They also result in forests emitting carbon rather than storing it. These factors lead to increased wildfire risk, which leads to carbon emissions and air quality impacts.
Tornado	• Damage and disruption to native species and habitats can occur if a tornado event uproots and transports vegetation and habitat. • As felled trees decompose, the increased dry matter may increase the threat of wildfire in vegetated areas. • The loss of root systems from vegetation removal increases the potential for soil erosion. • Disturbances created by blowdown events may also impact the biodiversity and composition of forest ecosystems. • Invasive plant species are often able to quickly capitalize on the resources (e.g., sunlight) available in disturbed and damaged ecosystems.
Wildfire	• Frequent wildfires can eradicate native plant species and encourage the growth of both highly flammable and fire-resistant invasive species. • If invasive species establish themselves after a wildfire, they can outcompete the native species, which can lead to a decrease in overall biodiversity of a site or ecosystem and threaten or cause extinction of these species over time, as well as increasing the cost of managing these non-native species. • Wildfires and the ash they generate can distort the flow of nutrients through an ecosystem, reducing the biodiversity that the ecosystem can support.
Drought	• Loss of fish and wildlife habitat, including reduction of stream flows to downstream rivers, estuarine habitats, reservoirs, lakes, and ponds. • Animal mortality due to lack of water resources. • Decreased plant growth and productivity. • Increased wildfires. • Greater insect outbreaks. • Increased local species extinctions. • Changes in the timing, magnitude, and strength of mixing (i.e., stratification) in coastal waters due to changes in freshwater inputs and increased temperatures. • Increased potential for hypoxia (i.e., low oxygen) events. • Direct and indirect effects on goods and services provided by habitats, such as timber, carbon sequestration, recreation, and water quality.

Hazard	Impacts and Vulnerabilities to Natural Areas
	• Limited fish migration or breeding due to dry streambeds or fish mortality caused by dry streambeds. • Wind and water erosion of soils. • Pests and diseases may have a greater impact in a drier world, as they will begin feeding and breeding earlier in the year.
Coastal flooding	• If coastal ecosystems (e.g., tidal flats, salt marshes) are not able to build elevation to keep pace with sea level rise, or if they migrate landward or into other wetlands, then existing habitat (e.g., salt marshes) could experience transitions to mudflat habitat. • Total inundation can also lead to the complete loss of tidal wetland, mudflats, and other intertidal habitats as they become open water habitats and the species that rely on them can no longer survive if they need upland refugia. • Conversion of salt marshes to other wetland types, including tidal flats, could result in a loss or change of critical ecosystem services such as carbon sequestration, recreation, cultural value, and storm protection, as well as nursery, feeding, and nesting areas for fish and wildlife.
Flooding from precipitation	• Intense precipitation events scour and erode stream channels. • Increased runoff from impervious surfaces increases nutrient and contaminant concentrations in freshwater bodies. • Increased freshwater flow could affect coastal environments by changing the chemistry of the system, which could lead to biodiversity loss, an increase in invasive species, and other ecosystem impairments.
Landslide and mudflows	• Following a landslide, soil and organic materials may enter streams, reducing the potability of the water and the quality of the aquatic habitat. • Mass movements of sediment may result in the stripping of forests, which in turn degrades the habitat quality of those forests. • Nearby flora may struggle to re-establish following a significant landslide because of a lack of topsoil. • Landslides and mudflows can lead to increased susceptibility of natural areas and habitat to invasive species due to disturbed surfaces.
Tsunami	• The inundation of typically dry areas can reshape the topography of an area, both by scouring existing sediment and by depositing sediment from other locations. • A tsunami can uproot trees and other plants in its path, causing habitat loss.

Hazard	Impacts and Vulnerabilities to Natural Areas
	• A tsunami can cause animal mortality due to drowning, and marine animal mortality as a result of chemicals or contaminants swept into the ocean. • Chemicals and contaminants, as well as saltwater, can remain in aquifers or can percolate into groundwater supplies after a tsunami recedes, causing extensive and prolonged environmental devastation.
Severe winter storms	• More intense winds and precipitation will increase tree mortality, which can increase soil erosion rates, impact the water quality of aquatic ecosystems, and alter the forest landscape. • Flooding from storms can alter soil nutrient pathways, reducing the productivity of forest ecosystems. • Nor'easters can reduce growth rates in coastal forests for about three years after a storm. • The flooding that can occur when snow and ice melt can also cause extensive environmental impacts. • Severe storms can cause direct damage to species and ecosystems, habitat destruction, and damage from the distribution of contaminants and hazardous materials throughout the environment. • Changes in snowmelt can lower spring river flows of aquatic ecosystems and impact the health and abundance of freshwater fish. • While coastal storms can be an important driver of available sediments for salt marsh systems, the associated severe winds, flooding, and impaired water quality can also damage and erode salt marshes and other wetlands, reducing their ability to provide coastal protection in subsequent storms. When storms occur with historic intensities and frequencies, they can result in much needed sediments that restore and build marshes. However, storms occurring at increased intensities and frequencies in altered or urbanized habitats may not result in the same historic benefits of storms feeding natural systems.
Other severe weather	• Severe weather events result in significant damage to forests, with downed trees, defoliated forest canopies, and structural changes within an ecosystem that destabilize food webs. • Direct damage to plant species includes uprooting or destroying trees and an increased threat of wildfire in areas with tree debris. • High winds erode soils, which damages both the ecosystem from which soil is removed as well as the system on which the sediment is ultimately deposited.

Hazard	Impacts and Vulnerabilities to Natural Areas
	• Extreme precipitation events often cause soil erosion and the growth of excess fungus or bacteria. • Lightning tends to strike free-standing, tall structures, such as trees, which results in tree damage and fires. The intense heat from lightning vaporizes the water inside a tree, creating steam that can blow apart the tree in a small explosion. • If lightning strikes a vegetated area experiencing dry conditions or a dead tree, it can start a wildfire. This risk occurs even when accompanied by rain, as the dry air below a storm front can cause rain to evaporate quickly as it falls.

6.1.4 Actions Taken to Reduce Vulnerabilities

6.1.4.1 State Agency Actions

To address the vulnerabilities described throughout this chapter—as well as all hazards described in detail in Chapter 5 (Risk Assessment)—agencies have taken and are continuing to refine an array of actions. Survey respondents were asked to describe the major updates, improvements, repairs, or replacements and relocations since 2018 that agencies have made to reduce vulnerabilities. Responses provided by agencies included the following:

- **Enhanced remote work capabilities** through actions such as providing staff with laptops to facilitate remote work and allowing for hybrid office work and telework options.
- **Updated IT systems** through actions such as transferring physical files to cloud storage systems and creating new networks and systems for staff and clients.
- **Relocation of office and equipment,** including moving or expanding services to new buildings.
- **Updated or repaired critical physical assets,** such as replacing, repairing, and updating critical infrastructure (e.g., sewage system updates, police facility renovations, agency office modernization, roof replacements) and equipment (e.g., power plant boilers, emergency generators, fire alarms, energy and heating, ventilation, and air conditioning systems) and restoring natural physical assets.
- **Revised policies to procedures,** including updated plans, policies, and protocols that reflect climate change and hazard mitigation considerations.
- **Strengthened staff capacity** to respond to hazard events through training staff (e.g., on topics such as climate change, adaptation, and response), hiring of new staff skilled in emergency management, and cross-training staff to ensure continuity of work and services if some staff are unable to work due to hazards.

For agencies responsible for managing critical assets and services, survey respondents described many examples of actions that their agencies have taken to provide alternate access to critical physical assets or redundancies in services in the event of damage or disruption due to a hazardous event. For instance, respondents stated that they have equipment to maintain or restore **access to critical roads, emergency lifelines, and community facilities**. Respondents also provided examples of actions they had taken to ensure the resilience of critical physical infrastructure, such as replacing boilers, changing the siting of emergency generators and main electrical services to be above projected sea level rise, and establishing new office buildings. To reduce vulnerability of critical facility and transportation infrastructure, Massachusetts Port Authority completed a risk assessment, hardened critical facilities, and developed a Floodproofing Design Guide, as well as Logan Airport and Maritime Flood Operations Plans.

In relation to access routes and roads, other respondents noted that there are multiple means of egress and emergency routes available that are included in their COOP and other emergency management plans that can help direct their operations in the event of hazard impacts. Agencies that provide **services to transit-dependent communities** also described redundancies in their services that they are working to formalize within their strategic and operating plans, such as the potential for bus service if other transit (e.g., rail) is disrupted, as well as virtual tools available to help facilitate communication and provision of services (e.g., remote hearings, email communications to reschedule visits) to transit-dependent communities.

Agencies that provide **power services** have taken many actions to ensure redundancy of services, such as emergency backup generators and power services on site and remotely, relocation plans, institution of solar power and battery backup energy systems, and transfer of critical IT infrastructure to multiple, more resilient third-party facilities. Agencies indicated that most employees are regularly trained and updated on these plans and procedures and that plans (e.g., COOPs) are updated annually.

In the survey, agencies responsible for nonphysical assets and functions described many ways their agencies have included goals and objectives to reduce risks and provide for climate adaptation through their plans, policies, mission, and partnerships, including:

- **Expanding telework and hybrid** work policies for staff.
- **Using cloud data storage** to provide backups of critical data and create IT redundancies.
- **Establishing or strengthening partnerships** with other agencies to assist in planning, emergency response, supplementary staff capacity for partner agencies with similar staff capabilities, and hazard mitigation strategies.
- **Encouraging outreach and education** within and between state agencies to raise awareness of climate hazards and potential mitigation and adaptation options (e.g.,

through establishing the RMAT in 2019 and the RMAT Climate Resilience Design and Standards Tool).

- **Incorporating targeted mitigation, adaptation, and risk reduction strategies** into agency plans, including plans for agencies such as the Office of Preparedness and Emergency Management, DER, MassDOT, Department of Energy Resources, and Department of Fish and Wildlife. Plans with these considerations that agencies cited included COOPs, architectural plans, restoration and habitat management guidelines, design standards, and strategic and capital plans.

In addition to the actions described within the survey, as detailed in the Chapter 4 (State Capability and Adaptive Capacity Analysis), agencies have been working on actions identified in the 2018 MA SHMCAP and tracked through the SHMCAP Action Tracker. Over 60 percent of actions are complete or in progress, close to 30 percent are in development, and only about 10 percent have either been deferred or not started. (See the Chapter 4 [State Capability and Adaptive Capacity Analysis] for more detail on action status.) Actions completed since 2018 mostly focus on strengthening understanding of climate hazards and building state agency capacity to respond to hazard events. However, a few of the actions have directly helped the Commonwealth reduce vulnerability. Highlights include:

- The Executive Office of Energy and Environmental Affairs worked with staff across many agencies to review and update design standards to consider climate change projections. The new Climate Resilience Design Standards provide recommendations for design criteria and implementation that will help ensure new agency facilities, roads, parkways, and other infrastructure are less vulnerable to climate impacts.
- The Division of Fisheries and Wildlife (MassWildlife) successfully removed two dams (Welsh Pond Dam and Putnam Pond Dam) that provide significant recreational benefits. These projects are reducing vulnerability and improving resilience of the agency's resources by improving the hydraulic capacity of the roadway stream crossings and reducing solar heating of Singletary Brook.
- The Department of Conservation and Recreation (DCR) developed an updated State Forest Action Plan to incorporate strategies to deal with future conditions presented by a warming planet. The plan is reducing vulnerabilities to forest systems by outlining strategies to reduce risks, address climate threats, and ensure the continued vitality of forest ecosystems.
    - DCR's Office of Water Resources has begun working with other state and federal agencies to develop a statewide floodplain management plan. This plan will be coordinated across all levels of stakeholders: federal partners, state agencies, local governments, academia, nonprofit organizations such as river and watershed alliances, flood-vulnerable populations, and others.
- The Executive Office of Technology Services and Security (EOTSS) migrated the EOTSS Human Resources Compensation Management System and Massachusetts Management Accounting and Reporting System to the cloud, removing the need to

maintain and protect on-premise servers for these systems. Following the migration of these systems, EOTSS was able to decommission physical servers, thus reducing the Commonwealth's hardware footprint and the vulnerabilities of these systems to climate hazards.

6.1.4.2 Gaps in Actions Taken

The Commonwealth's agencies have made progress in addressing hazard and climate vulnerabilities and designing and implementing plans to reduce risk. However, there are still gaps in relation to actions taken, as well as the capabilities and capacity of state agencies to undertake mitigation actions. The MA Climate Assessment reviewed adaptation gaps in relation to each of the most urgent impacts per sector. Additionally, Chapter 4 (State Capability and Adaptive Capacity Analysis) outlined the key challenges state agencies face to effectively address hazard mitigation and climate adaptation. To help identify the types of actions needed to address hazards and vulnerabilities—in addition to categorizing actions that are already occurring—Massachusetts identified a series of sectors adapted from the MA Climate Assessment that it used to group the priority impacts and additional vulnerabilities. These sectors include environmental health, human health, infrastructure, buildings, natural and working lands, government services, and statewide cultural assets. (See the MA Climate Assessment for more information on the most urgent impacts and Chapter 7 of this MA SHMCAP [State Strategy, Actions, and Implementation Plan] for more details on the action and strategy categories.)

Based on a comparison of gaps and challenges to vulnerabilities identified by the MA Climate Assessment, Chapter 5 (Risk Assessment), and Chapter 4 (State Capability and Adaptive Capacity Analysis), major gaps in relation to actions, capabilities, and capacity organized by the identified subsectors include:

- **Environmental health (with linkages to natural and working lands).** Given the number of natural areas within the Commonwealth, a relatively small number of agencies are responsible for managing a large amount of land. The natural environment and health of natural lands is critical to hazard and climate resilience efforts, as these lands provide important climate protection and buffering services. Mitigation actions will need to consider how to best promote coordination among these agencies and ensure sufficient staff capacity to protect and restore these valuable areas in the event of hazards, as well as identifying ways to ensure continued stewardship in a changing climate.
- **Government services.** In the survey, agencies described how they have or are beginning to take actions to train staff and create redundancies and increase staff capacity. Many agencies, however, still lack adequate staff capacity and availability to address hazard mitigation and climate adaptation due to limited financial resources to support additional staff, hiring challenges, and general staffing shortages. Ongoing limited staff capacity will make it challenging for agencies to create redundancies among staff and ensure that all staff have the skills needed to address potential

hazard events and associated impacts. In relation to services that government agencies can provide, Chapter 4 (State Capability and Adaptive Capacity Analysis) also found a need for more data and information about climate-specific impacts, adaptation, and risk. Similarly, the MA Climate Assessment emphasized the need for robust and reliable data and information to inform new modelling and model development, which could help identify and prioritize which planning activities are most critical for ecosystem adaptation. The survey also highlighted that agencies are lacking data in relation to projected vulnerabilities and recovery times following disruptions. These findings illustrate the need for agencies to gain increased access to climate-specific data and technical capacity (e.g., through educational institutions, offices, and staffing organizations) that can help them develop plans based on the best available and most up-to-date climate information.

- **Human health.** A recurring theme throughout the vulnerability assessment component of the survey was the potential for disproportionate impacts to environmental justice and other priority populations. This theme is also highlighted extensively throughout the MA Climate Assessment. These populations are highly vulnerable and have limited resources to reduce risk. While state agencies are currently thinking about the vulnerabilities of these populations and how to address them, as they move forward with developing specific mitigation actions, they will need to engage communities and consider carefully how to reflect the needs and vulnerabilities of these populations within state agency plans and mitigation actions.
- **Infrastructure and buildings.** Currently, a gap exists related to direct actions to strengthen the resilience of physical assets. Throughout the survey, agencies highlighted many concerns related to potential damage and disruptions to physical assets and the associated services these assets and agencies provide. The MA Climate Assessment also emphasized the need for direct adaptation actions to address potential impacts to physical infrastructure and highlighted these actions as an adaptation gap in relation to many of the urgent impacts. Upgrading, remediating, and replacing physical infrastructure is costly. Chapter 4 (State Capability and Adaptive Capacity Analysis) found that agencies have limited capital and operating budgets to address hazard mitigation and climate adaptation, and they need more coordination and funding to implement these types of efforts.
- **Natural and working lands.** The MA Climate Assessment found that, for many hazards, nature-based solutions are good options to strengthen resilience. Many nature-based solutions may require new and traditional technical knowledge and skills—which, according to Chapter 4 (State Capability and Adaptive Capacity Analysis), can be challenging for many agencies. Additionally, projects to strengthen resilience and increase ecosystem protection—such as coastal wetland restoration and strategic land acquisition and conservation—are costly and need considerable technical expertise and knowledge, financial capacity, and coordination to implement. Even when implemented, as highlighted in the survey, these types of projects can still be at

risk from climate impacts and require careful plans to ensure their continuation following a hazard event.

6.1.5 Conclusions

The Commonwealth is at risk from a variety of hazards that have and will continue to impact the physical assets, nonphysical assets, and functions of its state agencies and the communities and environments they serve. Potential vulnerabilities are wide ranging and include risk of damages to physical infrastructure and associated services, losses of network and database function and administrative services, disruptions to the ability of agencies to provide critical services to vulnerable populations, and further loss of critical natural resources that will result in greater risks to Massachusetts. State agencies have taken many actions—as described throughout this chapter and in Chapter 4 (State Capability and Adaptive Capacity Analysis)—to reduce vulnerabilities and develop clear plans to guide operations in the event of a disaster. However, given uncertainties in relation to the timing, magnitude, and consequences of hazards, determining strategies to reduce vulnerabilities will continue to be challenging for state agencies. In addition to the findings highlighted in the previous section related to gaps, there are a few additional factors state agencies could consider in working to reduce their vulnerabilities to hazard and climate risks, as outlined below. These recommendations are overarching across the sectors described in the previous section, and the Commonwealth used these to help consider the detailed actions described in Chapter 7 (State Strategy, Actions, and Implementation Plan). Recommendations include the following:

- **Identify strategies to promote enhanced interagency collaboration.** It will be critical for state agencies to work together to address geographic and issue area risks, in addition to ensuring that risks to infrastructure, the environment, and governance are addressed jointly. By coordinating efforts, state agencies can better leverage funding, physical improvements, and opportunities to increase resilience, which will help the Commonwealth develop integrated adaptation strategies. Strengthened state agency coordination will also help agencies leverage resources and address many of the most urgent impacts identified through the MA Climate Assessment, including an increased demand for state and municipal government services, increased costs of responding to climate migration, and reduction in state and municipal revenues.
- **Regularly assess vulnerabilities.** The survey agencies responded to as part of the MA SHMCAP process helped each agency consider its vulnerabilities to hazards and climate change and outline actions they have taken to reduce risks. Updating vulnerability assessments at regular intervals (e.g., annually, biennially) and tracking the actions taken to reduce risks would allow agencies to communicate progress and identify areas that need further work.
- **Consider clear strategies to address social vulnerabilities.** Survey results highlighted the potential disproportionate impacts of risks to environmental justice and other priority populations and how these populations are likely to experience

greater impacts due to damage and disruptions to physical assets and agency services. Similarly, the MA Climate Assessment noted a range of urgent impacts for communities, including health and cognitive effects from extreme heat, health effects from degraded air quality, and the potential for delayed emergency services and disrupted evacuations. Agencies have developed many plans to address continuation of services to populations throughout the Commonwealth, with a focus on environmental justice and other priority populations. However, agencies need to assess the sustainability of these plans and resources available to implement them. Agencies also need to advance projects to reduce risk and increase hazard and climate resilience in socially vulnerable communities. Additionally, strong interagency coordination is likely necessary to ensure limited impacts of services and functions.

- **Determine adaptation actions to strengthen resilience of ecosystems, particularly in aquatic areas.** In discussing vulnerabilities of endangered and threatened habitat and species, survey respondents highlighted vulnerabilities of species and habitat that are part of BioMap's aquatic or wetland cores. These ecosystems and species are at risk from a variety of hazards. The MA Climate Assessment highlighted the many potential impacts to the natural environment sector, with the most urgent impacts encompassing degradation to freshwater, marine, coastal, and forest ecosystems and habitats—all of which will occur from a range of natural hazards. Agencies are already implementing many projects to protect and restore these ecosystems and should consider coordinating with other agencies responsible for land use and infrastructure, as well as private landowners and researchers, to develop and evaluate cost-effective strategies to reduce vulnerabilities of these systems.
- **Evaluate efficacy of actions taken to reduce vulnerabilities.** As described in Chapter 4 (State Capability and Adaptive Capacity Analysis), state agencies should build on the MA SHMCAP Action Tracker to include metrics that track progress. Agencies should also work to ensure they are not only tracking which actions they have implemented, but also evaluating the effectiveness of these actions in terms of reducing risks and vulnerabilities.

If agencies in the Commonwealth continue to assess their vulnerabilities and work together to design and implement strategies to reduce risk and vulnerability, the Commonwealth will be able to build its resilience to hazards and associated consequences. While the exact nature of hazard impacts is difficult to predict, by better understanding their vulnerabilities, state agencies can develop adaptation plans that can help prepare them to respond to climate impacts, as well as mitigate impacts to their assets and the individuals that they serve throughout the Commonwealth.

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