6 — Human Health and Welfare

SUBCOMMITTEE CHAIRS:	Ann Lowery	Department of Environmental Protection
	Michael Celona	Department of Public Health

ADVISORY COMMITTEE PARTICIPANTS:

Eugene Benson	Alternatives for Community and Environment
Roseann Bongiovanni	Chelsea Greenspace and Recreation Committee
Andrew Cavanaugh	University of Massachusetts–Amherst
Paul Epstein	School of Medicine, Harvard University
Timothy Griffin	Tufts University
Arthur Marin	Northeast States for Coordinated Air Use Management

OTHER CONTRIBUTORS:

Ruth Alfasso	Department of Public Health
Kathleen Baskin	Executive Office of Energy and Environmental Affairs
Leon Bethune	Boston Public Health Commission
Sean Bowen	Department of Agricultural Resources
Brian Brodeur	Department of Environmental Protection
Catherine Brown	Department of Public Health
Suzanne Condon	Department of Public Health
Janet Curtis	Department of Energy Resources
Yvette DePeiza	Department of Environmental Protection
Neenah Estrella-Luna	Suffolk University
Yana Garcia	Alternatives for Community and Environment
Russell Gaulin	Department of Environmental Protection
John Graham	Northeast States for Coordinated Air Use Management
John Grieb	Department of Public Health
Michael Hutcheson	Department of Environmental Protection
Christian Jacqz	MassGIS
Peter Judge	Massachusetts Emergency Management Agency
Gerard Kennedy	Department of Agricultural Resources
Sharon Lee	Department of Public Health
Richard Lerner	Department of Public Health
Jennifer Mieth	Department of Fire Services
Madelyn Morris	Department of Environmental Protection
Joe Pelczarski	Office of Coastal Zone Management
Vandana Rao	Executive Office of Energy and Environmental Affairs
Timothee Rodrique	Department of Fire Services
Margaret Round	Department of Public Health
Paul Schumacker	Boston Public Health Commission
Marina Spitkovskaya	Alternatives for Community and Environment
Jeffrey Trask	Massachusetts Emergency Management Agency
Gregor Trinkaus-Randall	Board of Library Commissioners
Elizabeth Wade	Board of Library Commissioners
Carol Rowan West	Department of Environmental Protection
Hotze Wijnja	Department of Agricultural Resources

INTERNS: Craig Altemose, Celine Clabaut, Cassandra Snow, Kira Sargent

6 Human Health and Welfare

Introduction

Changes in climate will undoubtedly affect human health and welfare in Massachusetts—both directly via extreme heat events and indirectly through increases in vector-borne diseases. Climate change will affect the quality of the air we breathe, the shelter we rely on, the quality and quantity of the water we consume, the food we grow and transport, and the nature and level of demands for health care services.

Some residents will be more susceptible to the effects of climate change, and adaptive change will be more difficult for them. Whether by virtue of economic status, social capacity and resources, health, age, or geography, adaptation efforts should include planning to meet the unique needs and conditions of the state's most vulnerable populations—including those with limited resources to take protective and adaptive measures and to recover after losses, and those coping with existing chronic illnesses that could be aggravated by the expected climatic changes. Children, the elderly, the disabled, and low-income groups, in particular, should be considered in any adaptive plan. A focus on vulnerable populations requires an understanding of community or population characteristics, conditions that could contribute to a disproportionate risk, and obstacles to resiliency. (Note that in this chapter, strategies that are especially applicable to vulnerable populations are denoted by "VP".)

The maintenance, support, and improvement of existing public health and health care infrastructure are critical to the overall preparedness for the effects of climate change. To support and promote a strong, healthy, and resilient population, and responsive local health systems, adaptation efforts for human health should build on conventional and existing medical and public health standards, using a variety of approaches. These approaches may include using health surveillance systems to track disease occurrence and identifying locations and population groups at greatest risk for specific health threats. These efforts may also include assessing infrastructure capacity and emergency response preparedness, developing preparedness and response plans, and creating treatment plans to reduce health risks. Effective adaptation and mitigation strategies should seek to reduce exposure and increase resilience. These efforts can be executed at scales ranging from large-scale regional initiatives to delivery of personalized health services. This chapter examines topics within the following categories outlined in Table 6.

General Overview of Vulnerabilities

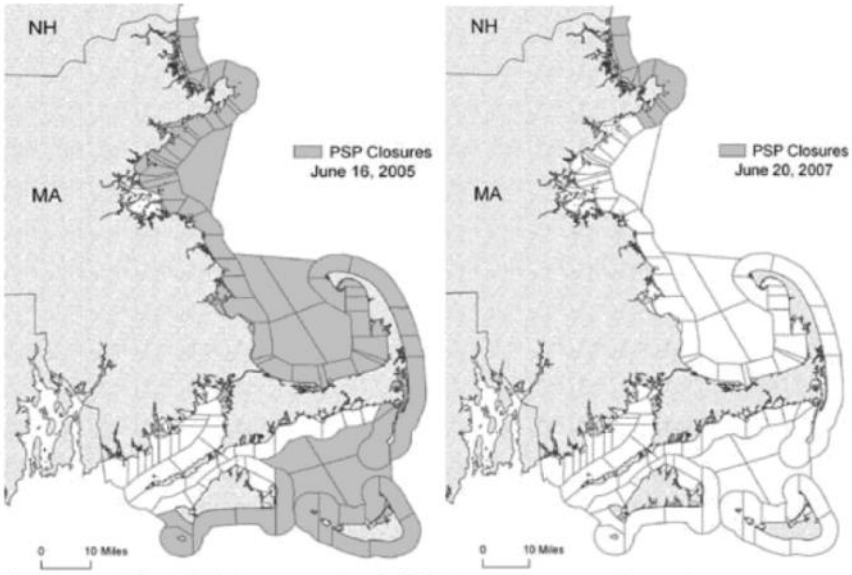
Vulnerabilities of each of the above categories are closely interconnected. As an example, an increase in precipitation will lead to increased runoff of nutrients and chemicals into water bodies, potentially compromising surface water quality and possibly affecting drinking water quality. Water laden with nutrients promotes the emergence of algal blooms, which release into the air and water toxins harmful to humans and animals, and which can contaminate shellfish stocks.

In general, climate change impacts on human health may include:

- higher temperatures contributing to complications or exacerbation of conditions

CATEGORY	TOPICS
Public Health	Public health infrastructure, vector-borne diseases, heat stress, allergens, respiratory and cardiovascular diseases, extreme and anomalous weather events
Air Quality	Ambient and indoor air quality
Water Quality/Sanitation	Drinking water, algae blooms, wastewater, water-borne diseases
Agriculture and Food Systems	Crops and livestock, water demand, pesticide use, new or invasive pests, food transmitted illnesses, security and safety
Vulnerable Populations	Food security, pesticides, allergens, air and water quality, vector-borne diseases, recovering from extreme weather events

Table 6. ***Public Health topics examined in this chapter***



A record Red Tide event in 2005 led to extensive closures throughout state waters (left) while 2007 saw shorter closures confined mainly to the North Shore (right).

among those with respiratory illnesses and cardiovascular disease;

- increased ozone and particulate matter production, coupled with higher temperatures, which result in poor air quality, and increased risk to those with existing respiratory diseases;
- increased plant pollen production and more allergenic pollen content, which may aggravate and exacerbate allergies, asthma and other respiratory illnesses;
- changes in disease patterns and a possible increase of vector-borne diseases (including Lyme disease, Eastern Equine Encephalitis and West Nile virus) as ticks and mosquitoes adapt to changing conditions;
- increased potential for water-borne disease outbreaks during and after flooding events;
- degraded surface water quality from sediments, pathogens, nutrients, and pesticides in stormwater and agricultural runoff;
- shifts in shellfish pathogens, with possible increasing contamination and closed shellfish beds;
- extreme weather events such as ice storms, heat waves, and more powerful storms that disrupt power and sanitary services, health care services, and access to safe and nutritious food, and which cause damage to homes and property; and
- increased mental and physical health burdens from the need to cope with more extreme weather, disaster response, and uncertainty.

Advancing Adaptation and Mitigation from a Public Health Perspective

While some greenhouse gas reduction (climate mitigation) measures will improve public health and welfare (such as reducing carbon emissions from cars), others may have significant adverse health and environmental consequences (such as potential increased national reliance on nuclear power without nuclear waste management improvements or proper consideration of potentially harmful public health consequences resulting from climate change impacts to nuclear reactors, particularly those sited along the coast). Likewise, adaptation strategies, such as increased use of air conditioning, may contribute to further climate change. A life cycle analysis that examines the health, environmental, and economic costs of proposed technologies and practices is a useful method for projecting potential co-benefits and potential costs of implementing them (Epstein et al., 2008).

The following are complementary mitigation and adaptation strategies that have multiple public health and environmental benefits.

- A Healthy Cities Initiative: Promote green buildings, rooftop gardens, walking paths, biking lanes, tree-lined streets, open space, access to locally grown healthy food, flood control systems that mimic natural processes, low impact development techniques, motor vehicle transit / congestion control, smart growth, and improved clean public transport. These strategies will reduce the heat island effect, decrease vehicular miles traveled, promote exercise, save money, support local agriculture and healthy nutritious diets, create jobs, and advance climate-stabilizing technologies. The State's June 2009 landmark transportation reform legislation created "The Healthy Transportation Compact" which supports this strategy. The compact involves the transportation, public health, and environmental agencies "work[ing] cooperatively to adopt best practices to increase efficiency to achieve positive health outcomes through the coordination of land use, transportation and public health policy" (www.massdot.state.ma.us, click on Healthy Transportation Compact link).
- Alternative fuel vehicles: Hybrid and electric vehicles can minimize fossil fuel combustion, reduce emissions of particulates (such as black carbon), ozone precursors, and CO_2, which will

The Chicago Heat Waves of 1995 and 1999

Heat waves are responsible for approximately ten times as many fatalities per year as hurricanes, rainstorms, lightning, floods, and tornadoes combined. Lessons learned in other parts of the country can help guide Massachusetts' response to heat waves.

In the summer of 1995, the city of Chicago experienced a heat wave that killed 739 residents. The temperatures reached a peak of 106°F (41°C) during the day, while night time lows were still in the high 70s and low 80s. Temperatures stayed in the 90s and 100s for over a week. As air-conditioner usage soared, area utilities could not cope with the record-breaking energy demand and 49,000 households lost electricity—leaving them even more vulnerable to the overbearing heat. Fatalities were highest among those who lived alone, had little access to transportation, did not leave the house on a daily basis, and lacked an air conditioner.

In 1999, when Chicago was hit by another heat wave, it was better prepared with a more responsive municipal effort. Chicago officials responded faster to the weather, alerting the press and the public, providing free transportation to rapidly opened cooling centers around the city, and checking in on elderly people through phones and in-person visits by police officers. Fatalities attributed to the heat wave numbered 110 that year.

Today the city is taking additional steps to prepare it for a warmer summer—water and heat trapping alleyways are being replaced by permeable materials, heat hot-spots are being targeted for pavement removal, plants are being added to roofs, and trees that are more resistant to higher temperatures are being planted citywide.

ultimately decrease unhealthy emissions, and benefit urban areas in particular.

- Improving the electricity grid infrastructure: A more efficient distribution grid can reduce air emissions from existing power plants, which in turn can mitigate expected increases in ground level ozone and particulate matter that result from higher ambient air temperatures.

The rest of this chapter covers key aspects of public health and offers no regret, short-term, and long-term adaptation strategies for each sub-category in response to potential climate change impacts. The following narrative outlines strategies that will continue to be reviewed and considered for implementation.

Public Health Infrastructure

Massachusetts has a comprehensive and sophisticated public health infrastructure with a variety of resources—material and human, local and statewide, governmental and private—that support disease prevention, surveillance, and management.

At the municipal level, boards of health are responsible for public health issues and enforcing public health regulations. Local and state public health officials share enforcement responsibility for state sanitary and housing codes. In addition, several regional boards or health department associations (e.g., Franklin Regional Council of Government, Nashoba Valley Association of Boards of Health) exist to provide additional services to member communities. There are 15 regional health coalitions in place to strengthen public health preparedness and capacity.

At the state level, the Massachusetts Department of Public Health (DPH) provides services to residents, enforces regulations, and operates several hospitals and a state public health laboratory. DPH provides technical assistance to local boards of health, and manages a range of programs focused on disease surveillance, communicable disease control, and environmental health.

The public and private health care system provides acute and chronic care to residents through hospitals, community health centers, nursing homes, and private practice offices. These entities are the primary sources of data for disease tracking and surveillance. The public and private health care system employs over 100,000 professionals at more than 125 hospitals and rehabilitation facilities, 600 clinics and community health centers, 500 nursing homes and hospices, 65 psychiatric and mental health facilities, 300 Emergency Medical Services units, 35 Medical Reserve Corps, and 5 Veterans Affairs Hospitals. A large number of medical care facilities are located near the coastline around the Greater Boston area where the population concentration is highest.

Vulnerabilities

The effects of climate change will potentially stress each component of the public health infrastructure. Public and private health care systems will need to respond to increased occurrences and demand for

treatment of acute and chronic diseases and ailments such as heat stress, exacerbation of pre-existing asthma, new diseases, mental health effects such as anxiety resulting from displacement under emergency circumstances, and physical trauma from flooding.

DPH Assists Communities Understand and Plan for Climate Change

The Massachusetts Department of Public Health (DPH) is one of five entities (four states and one city) to be awarded a $345,000 three-year cooperative agreement under the Centers for Disease Control and Prevention (CDC) Climate Change Ready States and Cities Initiative to conduct needs and capacity assessments and to help create plans for cities and towns to address the human health consequences of climate change. Under this program, DPH will work primarily with Massachusetts local health officials, but will also coordinate such efforts with the Massachusetts Climate Change Adaptation Advisory Committee. The project proposal uses information developed in this chapter and references many of the goals and strategies presented in this chapter. This important award will allow the DPH to assist Massachusetts communities with understanding and planning for the potential health effects associated with climate change.

Boards of health will need to respond to increasing burdens in the areas of housing, sanitation, disease, and other public health issues arising from sea level rise, higher summer temperatures, and extreme weather events. Other impacts will result from the potential interruption of transportation and energy generation and transmission critical to providing health care, and interruption of services at hospitals and health care centers.

The greatest vulnerability to the local health infrastructure is likely to be the lack of resources. Boards of health have broad responsibilities and face difficulties in enforcing a wide variety of existing public health regulations and responding to local, small-scale emergencies. Public health goals, and the extent to which they are met by boards of health, vary greatly depending on staff resources and experience, access to testing and tools, and the community's overall capacity for emergency response. In the event of an increased number of emergencies, state or regional boards and other entities may need to divert resources—sometimes all available resources—to the emergencies at the expense of executing core public health programs.

Vulnerabilities in the private health care system include ongoing challenges in the capacity to handle an increasing number of patients with chronic illnesses, such as asthma, and surges of patients after climatic events. The possibility of migration into Massachusetts from other states and countries, so called "climate refugees," could add to the demand for emergency response and public health services.

Facilities and supporting infrastructure near the coastline and in floodplains are particularly vulnerable to rising sea level and increased flooding. Hospitals are an energy-intensive commercial sector, and are consequently vulnerable to power disruptions from weather events, as well as to increasingly higher energy costs.

Potential Strategies

Existing public health infrastructure may be able to meet the challenges expected from climatic changes. Still, planning at all levels of health infrastructure could begin to evaluate and identify climate-related vulnerabilities in order to adjust priorities and plan for improving our response capabilities.

The current public health infrastructure could undergo a system-wide climate change needs assessment. Planning documents already contain much of the information needed for such an assessment, although they do not organize the information to assist adaptation planning. Changes in the current local public health program model, such as enhancing regionalization efforts to address non-emergency situations, can allow for more efficient mutual aid and increased coverage across the state. The need for enhanced capacity in core public health activities could be met by a regional system that supports the critical skills necessary to prevent disease and injury in communities.

The public and private healthcare system may need to plan for physically modifying or relocating vulnerable health care facilities located along the coastline or in floodplains. In addition, a more detailed evaluation of current provider capacity to meet the needs of more patients suffering from climate change-related ailments is needed.

Short-Term Strategies

1. State, regional, and local public health officials may begin to incorporate climate vulnerabilities into existing plans.
2. State, regional, and local public health officials could begin to conduct public health climate change planning to identify the most vulnerable facilities and response capacity from the state to the facility level.
3. Consider promoting an education campaign targeted to vulnerable populations, which could include support for a network of notification procedures for vulnerable communities, cooling

Operation Helping Hands

"Operation Helping Hands," the Massachusetts response to assisting evacuees from Hurricane Katrina, was a broad and comprehensive program to coordinate the efforts of federal, state and non-profit organizations to assist approximately 250 Katrina area evacuees who were transported to Massachusetts within a few days of the event.

The Massachusetts Department of Public Health (DPH) is the primary support agency responsible for coordination of "state public health, mental health, medical, and health care resources during activation of the State Emergency Operations Center". The response included:

- administration and management tasks, such as making sure evacuees had identification;
- medical assistance, including acute care, management of prescription medications, and assistance in obtaining replacement eyewear;
- mental health evaluation and care for both existing chronic illness and post-traumatic stress;
- public health measures such as assuring access to applicable vaccinations and the collection and sharing of standardized information with other responding states; and
- social support, such as assisting with food, clothing and housing; assistance regarding pets; school registration, and assistance with finding other family members and developing plans for the future.

Approximately 60 staff and volunteers were coordinated as a part of this effort, along with about 100 National Guardsmen. Additional efforts were required to assure that volunteers had proper credentials.

Many lessons were learned from this experience in Massachusetts, including the need for immediate structured, yet flexible, responses to emergencies, and the usefulness of the Massachusetts Medical Society, the regional Center for Public Health Preparedness and the Medical Reserve Corps. Having access to a fallow military base for immediate housing and other

centers (gathering places for people to get relief during heat waves), and "check on your neighbor" programs (VP).

4. Consider assessing the capacity of providers to address anticipated increased patient volumes and changing health demands, including capacity to address heat waves and anomalous winter weather events.
5. Seek to implement the DPH asthma action plan to improve the ability to adequately treat chronic asthma with effective care plans.
6. Promote participation in energy efficiency programs for the health care sector such as the U. S. Department of Energy's Hospital Energy Alliance and Energy Smart Hospitals and the U. S. Environmental Protection Agency's Energy Star for Healthcare.

Long-Term Strategies

1. Facilitate and enhance regionalization efforts among local boards of health.
2. Encourage distributed sources of energy generation (such as community-scale solar and wind power) to increase preparedness and resiliency of the network of health care providers, and to decrease emissions.
3. Promote workforce development to train public health staff to respond to climate change-related health threats.
4. Identify facilities and strategize how to modify or relocate vulnerable health care facilities away from the coastline, improve flood control protection, or stabilize facilities in flood prone areas.
5. Support efforts to reduce greenhouse gas emissions, which in turn, would reduce long-term health effects of climate change.

Vector-Borne Diseases

Vector-borne diseases are transmitted by carriers such as insects and arthropods. In Massachusetts, Lyme disease, babesiosis, human granulocytic anaplasmosis, tularemia, and Rocky Mountain spotted fever are spread by ticks. West Nile virus and Eastern Equine Encephalitis virus are spread by mosquitoes. Several of these diseases can cause serious illness or even death. Others could become established in Massachusetts as a result of changing climatic patterns.

Warming Temperature and Vector-Borne Diseases

Eastern equine encephalitis is Massachusetts' most severe vector-borne disease. With the general trend of warmer temperatures leading to higher mosquito numbers and greater activity, the possibility of more human disease will apply to all mosquito-borne diseases, including West Nile virus and St. Louis encephalitis virus. A similar trend is probable with tick-borne diseases as well, resulting in the prospect of more human cases of Lyme disease, babesiosis (a malaria-like parasitic disease), and anaplasmosis (a bacteria which infects white blood cells).

Vector life cycles, particularly of the mosquito, are dependent on temperature and moisture, making impacts from climate change likely. Populations particularly vulnerable to vector-borne diseases include people who are elderly, very young, un- or under-insured, outdoor laborers (i.e., farm and construction workers), those geographically isolated from health care services, and those with low levels of education, low-income, or compromised immune systems.

Existing Resources

Health care providers and veterinarians are required to report the occurrence of certain vector-borne diseases (e.g., West Nile virus, Eastern Equine Encephalitis, and Lyme disease) to the appropriate state agencies. Mosquito control districts assist with mosquito surveillance and control, while DPH conducts mosquito surveillance and virus testing on mosquito, animal, and human samples. DPH also routinely tests samples to detect the emergence of new mosquito-borne diseases. Limited tick and tick-borne pathogen surveillance occurs through academic institutions and cooperative extensions. The environmental control of ticks occurs mainly through individual use of fee-for-service pesticide application companies. DPH records and analyzes data collected on human cases of some vector-borne diseases. In addition, DPH creates educational materials for the public to encourage personal prevention practices, and for health care providers to promote prompt recognition of certain vector-borne diseases and appropriate treatment.

Vulnerabilities

With climate change, the general public will likely be subject to greater exposure to disease vectors and related pesticide application. The likely effects of predicted climate change are prolonged transmission seasons for all vector-borne diseases, extending the risk of transmission outside of the traditional late spring through early fall timeframe. In addition, mosquito populations are likely to increase as rising temperatures shorten reproductive cycles and result in more generations per season. There will be a greater demand for monitoring, treatment, and health services. Increased suspected human cases may tax laboratory resources and potentially limit their capacities to perform other work needed to detect the emergence of new pathogens.

Although warming temperatures will not increase the speed at which tick vectors reproduce, warmer winters may decrease tick mortality and would likely support an abundant tick population. Unless populations of preferred tick host species such as white-tail deer and small rodents diminish, an increased risk of transmission to humans can be expected. Substantial increases in the number of the more serious tick-borne diseases, such as human granulocytic anaplasmosis, babesiosis, and Rocky Mountain spotted fever, could result in rising use of medical resources. In addition, babesiosis could pose a threat to blood supply since many carriers who could be potential blood donors are asymptomatic, and most blood recipients are immuno-suppressed and more vulnerable to developing severe diseases. Because surveillance of tick populations and pathogens is not as systematic or centralized as surveillance of mosquitoes, detection of new tick species and/or identification of emerging pathogens spread by ticks could be delayed.

Potential Strategies

Short-Term Strategies

1. Continue requiring reporting of human cases and positive laboratory results of vector-borne diseases including diseases that are not currently endemic to Massachusetts.
2. Work to improve capacity to respond to vector-borne diseases, streamline and automate reporting mechanisms, and stockpile supplies for prevention (e.g., insect repellent, repellent impregnated work clothing).
3. Continue to develop and enhance electronic reporting procedures for laboratories.
4. Maintain mosquito surveillance at multiple sites throughout Massachusetts.
5. Continue testing to identify other, currently non-endemic, viral agents.
6. Educate the public, particularly high-risk groups, about personal prevention practices, and encourage their adoption.
7. Educate the public about mosquito breeding habitats and opportunities to eliminate them (such as reducing areas of standing water).

Long-Term Strategies

1. Consider developing a systematic tick surveillance program statewide to monitor vector densities and infection rates.
2. Evaluate the benefits of implementing a web-based disease reporting procedure for health care providers.
3. Evaluate and support service providers in expanding institutional capacity to meet the needs associated with climate change induced increases in vector-borne diseases.
4. Consider using community-based groups and trade organizations to do outreach and education about risks and prevention, and to connect individuals and families to appropriate services (VP).

5. Examine developing occupational health and safety regulations to protect outdoor workers (VP).
6. Facilitate monitoring of current non-endemic diseases for trends (VP).
7. Develop strategies for large-scale use of integrated pest management control to reduce pesticide use (VP).
8. Improve capacities to conduct vector and human surveillance in order to identify high-risk groups and places to better target outreach, education, and prevention efforts (VP).

Ambient Air Quality

Climate change alters local weather patterns, such as temperature and wind speed, which, in turn, affect the distribution of air pollution. Anthropogenic sources of air pollution promote climate change through the emission of CO_2, volatile organic compounds and oxides of nitrogen. Volatile organic compounds, oxides of nitrogen and sunlight combine to form ozone and smog, which are harmful to public health, ecology, and public welfare. Byproducts of combustion, such as, ozone and fine particulate matter, contribute to air pollution and associated respiratory and cardiovascular disease.

Massachusetts Environmental Public Health Tracking Network

The Massachusetts Department of Public Health (DPH) recently launched a web-based Massachusetts Environmental Public Health Tracking network, which contains data on ambient air quality, hospitalizations due to asthma and myocardial infarction, and pediatric asthma for all Massachusetts communities. Using information from this tracking network, federal, state, and local public health agencies, the medical community and advocacy groups will be better prepared to develop and evaluate effective public health actions to prevent or control these diseases.

Principal public health concerns are allergy symptoms related to increased allergen production, and increased respiratory and cardiovascular disease related to worsening air pollution and higher temperatures. Particularly vulnerable populations include the elderly; the very young; low-income groups; immigrants; the homeless; un- or underinsured people; residents with increased exposure to ambient asthmagens; residents of older or substandard housing; people who are geographically isolated from health care services; people with certain pre-existing conditions, especially asthma or lung dysfunction or compromised immune systems; and outdoor laborers such as farm and construction workers.

Existing Resources

The Massachusetts Department of Environmental Protection (DEP) is responsible for monitoring outdoor air quality and developing regulatory programs to reduce emissions of pollutants that adversely affect public health, welfare, and the environment. DEP provides data on criteria pollutants (sulfur dioxide, ozone, carbon monoxide, nitrogen dioxide, lead, particulate matter ≤10 microns and ≤ 2.5 microns), controls many other pollutants emitted from facilities (e.g., power plants, incinerators, vehicles), and administers the Massachusetts regulatory portion of the Regional Greenhouse Gas Initiative. The DPH Bureau of Environmental Health evaluates environmental and health data to determine the likelihood of health effects associated with environmental factors.

Vulnerabilities

Warming conditions may increase ground-level ozone and particulate matter levels, allergens, and extreme heat events which, in turn, can exacerbate existing cardiovascular and respiratory conditions and other health effects. Meteorological changes can impact local and regional pollution distribution, with a number of modeling studies (Tagaris et al., 2007; Murazaki and Hess, 2006) predicting accumulation and concentration of pollutants (e.g., ozone) in the Northeast. An increase in ambient temperature is likely to stimulate earlier flowering, increased growth and prolonged pollen production in plants, which can increase and prolong asthma and allergy incidents. Also, the potency/strength of pollen can increase as a result of higher temperatures and carbon dioxide levels. The increases in allergenicity of plant materials can lead to more severe respiratory responses. In addition, synergistic effects can be expected from entrainment of respirable-sized particles that attach to pollen are delivered deep into the lungs and contribute to, or worsen lung dysfunction. Increased plant growth correlates to increases in decomposition—suggesting heightened fungal abundance. Such increases may result in greater amounts of airborne spores which are linked with exacerbation of asthma.

Individuals with pre-existing respiratory and cardiovascular conditions will be the most susceptible to decreased air quality, especially those who do not have access to quality health care. People who work outdoors most of the day will be disproportionately impacted. The heat island effect in urban areas will exacerbate air quality deterioration and disproportionately impact lower-income individuals who do not have ready access to air

conditioning or health care, as well as people who work outside in urban environments. An increase in pollen production and its allergenicity will impact individuals statewide. The increasing need for health care will likely stress the existing health care and public health infrastructure if certain adaptation strategies are not implemented.

Potential Strategies

Training of and coordination between physicians, other health practitioners, local health officials, and other components of the health care industry will help mitigate health impacts resulting from decreased air quality through improved primary health care for affected populations. Determining how each health and environmental agency manages adaptation and data tracking as a whole will assist in coordinating care. Some of this work may be integrated into existing programs or centralized through agency coordination. In order to understand local impacts of climate change risks, it is important to identify sensitive populations, develop targeted preparedness and response plans, and develop the capability to conduct health impact assessments that evaluate health outcome data and relevant air quality indicators associated with climate change.

To minimize future air quality impacts, more aggressive emissions controls (both in the U.S. and elsewhere) will be needed to make progress toward reducing emissions of particulates and key ozone precursors (especially NO_x so that ozone concentrations are below health-based standards). The primary strategy for responding to health impacts from climate change is preventing the occurrence of illness and injury by reducing risk factors, early detection and treatment of disease, and effective preparedness and emergency response plans. To accomplish the goal of preventing illness and injury due to climate change, more specific efforts could include:

Short-Term Strategies

1. Achieve and maintain air quality standards. Attain air quality standards for ozone; continue to attain current federal particulate matter standards. Continue to control direct particulate emissions and precursors of particulates such as sulfur and oxides of nitrogen and other asthmagens.
2. Enhance clean energy generation programs. Control emissions from sources such as industrial and wood burning facilities and diesel engines.
3. Build on the existing public health practice of surveillance and health outcome tracking in order to identify and monitor health impacts related to climate change.
4. Promote telecommuting to avoid exposure during air quality alerts.
5. Promote heat island effect reduction strategies: cool roofs, green roofs, green spaces, and designs that minimize heat magnification.
6. Encourage opportunities for public transit use, walking, and bicycling, and evaluate expanding facilities that promote these transportation options.
7. Seek to increase use and installation of green infrastructure such as trees and other vegetative cover, with preference for hypoallergenic species.
8. Create mechanisms to provide technical advice and communicate the health-related aspects of climate change, including risks and risk reduction. Disseminate air quality ratings to the public, decision makers, local health departments, and healthcare providers, and ensure that the information is accessible to all residents (i.e., translated from English to relevant native languages and distributed broadly in affected communities).
9. Enhance scientific understanding of the relationship between climate change, air quality, and health outcomes by conducting health impact assessments at the state and local levels.
10. Use existing DPH and census data to identify and physically locate vulnerable populations (VP).
11. Expand capacity for modeling and forecasting health effects using standardized health impact assessment methods to incorporate climate change.

Long-Term Strategies

1. Explore and develop multi-pollutant strategies to reduce greenhouse gas emissions, criteria air pollutant emissions, and air toxics emissions.
2. Continue monitoring and meeting regional haze requirements by decreasing haze-forming pollutant emissions, with a goal of restoring natural visibility conditions in our state and national parks and wilderness areas.
3. Encourage and invest in expansion of scientific and technological research to identify novel means to reduce air pollution.
4. Facilitate improved access to health insurance and medical care, medical support equipment and medications (VP).
5. Support expansion of strategic planning efforts to assist both health-related service providers and health care recipients in meeting anticipated needs associated with climate change impacts.
6. Prioritize planting of hypoallergenic trees in communities with high rates of asthma and lung dysfunction (VP).

7. Consider providing technical and financial support to companies to reduce their ambient air emissions (specifically ozone precursors and particulate matter) (VP).
8. Examine the feasibility of reducing or removing subsidies for activities and projects that result in reduced ambient air quality (VP).

Indoor Air Quality

Climate change impacts on both outdoor air quality and the built environment have the potential to negatively impact indoor air quality. If there are increasing numbers of "bad air days" due to poor outdoor air quality, people may spend more time indoors. Buildings as shelter are the first line of defense against a sub-optimal outdoor environment, but they can also be severely impacted by the effects of climate change. Increased temperature and precipitation, as well as extreme weather events, can degrade the building envelope, allowing moisture and pest penetration, mold growth, and off-gassing from building materials in the indoor environment. The natural solution is dilution with outdoor air. However, when ambient air quality is poor, using it to dilute indoor pollutants may not be recommended. Strategies are needed to decrease exposure to indoor air pollutants, particularly during poor air quality days.

Existing Resources

To understand the effects of climate change on indoor air quality, a number of indicator data can be used, including environmental data sets, building history, weather/meteorology, and floodplain forecasts. As discussed in the previous section, DEP is responsible for monitoring outdoor air quality and developing regulatory programs to reduce the emission of pollutants that impact human and environmental health and welfare. The Massachusetts School Building Authority and the Division of Capital Asset Management are beginning to examine the age and needs of existing government-owned buildings, so that the highest priority risks and building needs of the most vulnerable properties can be identified and addressed. Further, the DPH Indoor Air Quality program has conducted assessments of hundreds of schools and other public buildings in Massachusetts, generating data to further identify vulnerable areas. There is a need for similar examination by private property owners. Where flood damage may be severe, building modification or even relocation may need to be considered. Both forecasting and floodplain information are important for identifying geographic risks related to climate change, pinpointing buildings most at risk, and predicting the extent of damage that may occur.

Vulnerabilities

Flooding can have severe impacts on buildings, properties and their occupants. When water penetrates a structure, it can compromise its integrity, promote mold growth, and cause aggravated health responses in compromised populations (asthmatics and those with pre-existing respiratory conditions). Mold can induce irritant symptoms, particularly among those with pre-existing respiratory conditions who may experience more aggravated effects (i.e. asthma attacks). Responding to water damage issues can be very costly and especially burdensome for those without health or homeowners insurance, and financial considerations add to the stress or trauma of adequately responding.

Saturated soils can cause damage to building structures (i.e., cracking, collapse) and buried components can provide further points for moisture penetration. If water-damaged porous materials such as gypsum wallboard are not dried within 24 to 48 hours, the damaged materials should be removed and replaced. Appropriate containment practices should be used during remediation to prevent exposure. Those with pre-existing conditions, such as asthma, or who are immuno-compromised may be displaced during the remediation process. This displacement can cause short- and medium-term stress and trauma.

Conversely, prolonged periods of water shortage (i.e., droughts) can cause soils to dry out and settle. This can damage building foundations and create pathways for later moisture penetration. Droughts are associated with increases in airborne particulates, particularly if there are wildfires. Increased dust loads can cause irritant symptoms, and exacerbate conditions of those with pre-existing respiratory conditions.

Increased temperature (with high humidity levels) can directly degrade building components, promoting indoor condensation and mold growth (cracks in roofs allow more water entry, for example). Increases in temperature/UV index can also result in off-gassing from building materials. Overall increases in temperature can magnify the effects of the urban heat island effect and accelerate building deterioration.

There may not be enough cooling center capacity to manage the expected increases in heat stress and illness, particularly in urban areas. Heat stress can be a trigger for respiratory, cardiovascular, and cerebrovascular episodes, such as heart attacks and strokes. An increase in temperature is often coupled with an increase in ambient ozone levels, which is a respiratory irritant. This can also cause increased indoor ozone levels (from penetration through open windows or increased ventilation rates) which can result in the production of more toxic compounds as ozone interacts with household products.

An extended growing season could result in increased numbers of pests including flies, mosquitoes, and cockroaches. Window screens are required by the state sanitary code to be used in homes to prevent pest intrusion through open windows. With increased degradation rates in homes, breaches in the building envelope can also allow pests to enter. In turn, this may result in increased exposure to toxic compounds as a result of increased use of pesticides.

Potential Strategies

Strategies for emissions reductions are particularly important in this area. Improvements in building materials can help prevent off-gassing, improve energy efficiency and recovery, improve air filtration, and make buildings mold resistant. Buildings are also high energy users, with energy expended in producing building components, building construction, and operating costs. Reducing the embedded energy and operational costs related to buildings can reduce adverse impacts and air pollution from energy generation.

Information such as building surveys and histories can help building owners anticipate water damage, and meteorological data and associated indexes can help building owners anticipate and prepare for heat-related incidents. Building renovations, efficiency improvements to buildings, and the energy supply network provide an opportunity to improve capacity to manage extreme heat events.

Short-Term Strategies

1. Educate property owners about existing and future floodplains to encourage implementation of methods to reduce damage.
2. Seek to increase cooling center capacity, particularly in urban areas.
3. Encourage or mandate use of reflective paints and materials, and white roofs to decrease heat stress on buildings.
4. Consider targeted surveying of buildings (residential, commercial and public) to identify structural needs and vulnerabilities.
5. Promote installation of drainage improvements, insulation, and vapor barriers or retarders, and provide instruction on appropriate drying and salvage efforts.
6. Compile a database of areas expected to experience localized street flooding throughout the state and share this information with interested parties.
7. Consider enhancing construction standards for buildings to be resilient to climatic impacts, including flood, and hurricane resistance.
8. Improve overall drainage around buildings and on thruways. Consider installing building drainage that infiltrates stormwater into the ground or storage for use during droughts.
9. Promote the increased use and installation of natural systems for control of stormwater and flooding.
10. Expand use of porous pavement to improve drainage on roadways and prevent run-off into buildings or into ground surrounding buildings with basements or crawlspaces.

Long-Term Strategies

1. Continue to support research and development in heating, ventilation, and air-conditioning and the clean energy fields to ensure that reduced energy consumption and improved indoor air quality are achieved.
2. Continue to support research and development of building components that resist microbial growth, reduce emissions of volatile organic compounds, and have low environmental impact.
3. Encourage the planting of shade trees, use reflective, light colored paints and use alternate cooling practices (i.e. more ceiling fans, green roofs, and urban open space and garden areas) to reduce the impacts of heat stress on buildings and the general population.
4. Seek to implement the Governor's Zero Net Energy Buildings Task Force recommendations.
5. Continue using the State Sanitary Code (105 CMR 410.000: Minimum Standards of Fitness for Human Habitation, State Sanitary Code, Chapter II) to protect tenants, and require property owners take action to remediate water-damaged building materials, including mold contaminated materials. Resources to assist the DPH and local boards of health to enhance this activity should be considered (VP).
6. Continue to have the DPH Indoor Air Quality Program provide technical service to building/ home owners and local boards of health concerning remediation of water damage in

buildings.

7. Initiate and implement efforts to educate health care providers regarding health risks related to mold exposure and encourage health care providers to contact appropriate persons (e.g., local or state health department) to investigate potential exposures (VP).
8. Evaluate opportunities to provide technical and financial support to property owners to remediate mold (VP).

Water Quality

Different patterns of precipitation, drought, flooding, and extreme events will all have an impact on the quality of water and its use for drinking, food processing, recreation, commercial and industrial production, and energy generation.

Vulnerabilities

Sea level rise, higher storm surges, and more extreme precipitation patterns can affect the quality and quantity of water supplies. Saltwater intrusion in coastal water supplies could affect drinking water quality and lead to increased corrosion of pipes and related infrastructure. Extreme precipitation patterns may also result in higher and faster streamflows which, in turn, can lead to over-bank flooding, stream channel erosion and sedimentation, and impacts to surface water bodies (see Chapter 5 on impacts to infrastructure, and Chapter 4 on impacts to natural resources). Surface and groundwater may become contaminated as extreme precipitation and floods release toxic material, nutrients, and pathogenic microorganisms and parasites from land surfaces. Flooding can cause sewage systems to fail and overflow, increasing hazards from sewage-related pathogens and toxic materials. High turbidity levels in ground or surface waters contribute to an increase in disinfection by-products with a greater potential for bacterial regrowth within drinking water distribution systems. Increased precipitation and water levels may provide breeding grounds and harborage for pests, resulting in an increased potential for water-borne diseases.

Increased nutrient enrichment of salt and freshwater systems from increased runoff can lead to an increase in algae blooms and shellfish pathogens. These issues carry high societal costs, which potentially include the loss of drinking water supplies; increased water treatment costs; increased frequency of water-borne disease incidents, food recalls, and shellfish bed closings; and decreases in trade, tourism, and allied industries.

Finally, periods of reduced rainfall resulting in drought could reduce stream flows, snow pack, aquifer recharge, contaminant dilution, and dissolved oxygen. Intense droughts may also put more pressure on local water supplies and agricultural irrigation needs. Populations vulnerable to the effects of drought include people with heightened sensitivity to water quality (the elderly, some low-income groups with higher exposure to poor water quality, and people with compromised immune systems), households dependent on private wells, and individuals and families lacking access to clean water recreational resources. Large and small businesses that rely on large amounts of water (such as power plants, manufacturing facilities, laundries and farms) are also particularly vulnerable.

Potential Strategies

Short-Term Strategies

1. Continue to monitor water quality reports, toxicology reports, epidemiologic reports, and the impacts of storms and hurricanes on water-borne diseases.
2. Create a forum for gathering information on exposures and diseases related to extreme weather events and flooding, and the potential impact of climate change on morbidity and mortality.
3. Educate the public about ecologically-sound landscaping practices, which reduce reliance on chemical fertilizers that can enrich freshwater systems with ecosystem-disrupting nutrients.
4. Work with communities and provide local authorities with information about the impacts of weather on water supply and increased inland and coastal flooding.
5. Seek to redirect and reduce flooding through improved stormwater management techniques including reducing impervious surfaces and using best management practices, and potentially relocating problematic pollutant sources from flood plains.
6. Identify water and sewer facilities susceptible to saltwater intrusion and coastal inundation.
7. Evaluate and prioritize implementation of improved controls of agricultural, urban, and stormwater runoff to prevent ocean and freshwater contamination, as well as enrichment of nutrients in aquatic areas that offer ideal growth medium for harmful algal blooms.
8. Assess and plan for impacts on regulatory and incident response resources. This will require an expansion of the emergency response workforce at all levels to enforce regulations, address water shortages, provide pest control measures, and respond to disease outbreaks.

9. Support local mutual aid collaboration to develop contingency plans to respond to water supplies impacted by climate change.

Long-Term Strategies

1. Consider re-evaluating standards for the design and maintenance of septic systems and implement changes as necessary to offset climate change related impacts.
2. Conduct outreach and education on water conservation practices, and reducing the use of pesticides and fertilizers.
3. Identify means to improve and implement water management, including improving and enforcing water quality protections.
4. Seek to implement and enforce legal and design standards to reduce agricultural, urban, and stormwater runoff.

Agriculture and Food Systems

The primary impacts of climate change, including increased air temperature, more frequent and severe drought, and more high-intensity precipitation events, could directly influence the productivity and resilience of agricultural systems in Massachusetts. Plant and animal species used in agriculture respond to these factors individually and interactively; plants respond directly to the principal cause of climate change i.e., increased atmospheric CO_2 concentration. There are a number of secondary impacts as well such as changes in crop species (including opportunities for new crops or varieties and loss of existing crops); increasing pressure from existing plant and animal pests that respond to temperature; and emergence of new or invasive pests as warmer climate ranges shift northward. There are additional impacts on agriculture and the food system that will be realized principally as public health and welfare effects, rather than direct agricultural effects.

Vulnerabilities

While there is some potential for benefit to certain crops (mostly cool-season crops) from the direct effects of increased carbon dioxide (CO_2 fertilization) and from a longer growing season, the negative impacts of higher temperatures and more erratic and severe weather far outweigh any benefits. The ability to produce food is susceptible to increased pest pressure from insects, diseases, and weeds that is likely to result from higher annual temperatures. New and organic farmers, who may be less experienced, have fewer options in terms of agricultural chemicals, have potentially less access to capital for infrastructure improvements, and are vulnerable to increased pest and disease pressure.

Many farms, particularly those with less access to working capital for infrastructure improvements, are vulnerable to erosion from an increase in heavy rains, and to crop loss from longer and more frequent droughts. An increase in heat stress days (maximum temperature of more than 90°F) will have a strong negative impact on farming and livestock, especially milk production in dairy cows. Increased use of pesticides against increased plant pests and diseases will potentially create risks to pesticide applicators, farm workers, the public, the environment, immigrants, low-income residents, pregnant women, young children, and those who rely on subsistence fishing. Warming trends have been linked to increases in marine and freshwater algal blooms, as well as seafood-borne toxins. Uncooked seafood, particularly shellfish, may pose new health threats through increases in infectious or toxic organisms.

Also, extreme weather events may contribute to movement of toxins into different environments from run-off, which may then affect food supply. Ocean acidification through CO_2 settling may impact seafood supplies with adverse effects on organisms' abilities to form shells, and could result in ecosystem ripple effects. With respect to outdoor recreational activities provided by agriculture, impacts on crops such as apples, berries, and maple syrup may reduce the opportunities for certain popular and emblematic New England outdoor activities such as apple and berry picking and maple sugaring.

Populations vulnerable to climate change impacts on food systems include the elderly, low-income communities, immigrants, people who rely on subsistence fishing, those living in areas with limited or no access to affordable nutritious food ("food deserts"), and people with low health status, particularly those with illnesses most severely impacted by diet (i.e., diabetes, heart disease, and cerebrovascular disease).

Potential Strategies

Local agriculture has been expanding in Massachusetts for the last few years, keeping pace with a growing awareness of the benefits and importance of locally grown food. Beyond the issues of food quality and a desire to preserve the infrastructure necessary to ensure food security, agriculture plays a role in the state's cultural heritage and helps to preserve dwindling open spaces. Farmers face enormous challenges in adapting to the changes that are likely to result from climate change. Resources that could mitigate these

challenges include ongoing programs to monitor food supply and pest/disease outbreaks, an existing inventory of land suitable for agricultural use, public communication on food safety and food security issues, and a regulatory system for registration and use of pesticides.

Short-Term Strategies

1. Continue to monitor food supplies for potential disease outbreaks.
2. Consider providing funding and personnel to monitor for new insects, weeds, and pathogens that are likely to expand their ranges into Massachusetts.
3. Revisit integrated pest management thresholds and strategies in light of changing pest population dynamics.
4. Encourage adoption of best practices to control runoff of pesticides, nutrients, or fertilizers, and soil, which contribute to poor water quality.
5. Consider providing low- or no-cost loans for infrastructure adaptations such as irrigation, drainage, and livestock facilities.
6. Expand educational efforts for pesticide risk management, crop adaptation and management, and conservation practices.
7. Increase efforts to monitor the use and occurrence of pesticides in the environment.
8. Continue to track food-borne illnesses to determine if new patterns or agents are emerging.
9. Provide technical assistance and outreach in partnership with existing federal programs (such as U.S. Department of Agriculture's Natural Resources Conservation Service) that deliver programs at the state or county level.

Long-Term Strategies

1. Facilitate research on crop adaptation and diversity.
2. Seek to identify and understand specific impacts of climate change on food supplies, food quality, and disease transmission to develop appropriate policies and regulations.
3. Consider increasing food subsidies for lower income residents, and modify eligibility requirements to ensure access to healthy food (VP).
4. Evaluate the benefits of modifying development/ zoning priorities to increase access to places to purchase fresh food (VP).
5. Investigate providing technical and financial support to assist small farms to bring produce to new markets, particularly in urban areas. This may include support for participation in community-supported agriculture by low-income families (VP).
6. Promote and provide/increase technical and financial support for small-scale farming (VP).
7. Evaluate the opportunity to provide disaster assistance or insurance for small farms for crop losses (VP).
8. Strive to improve and enforce water quality protections for water bodies that are used for subsistence fishing (VP).
9. Examine providing technical and financial support to farmers for transitioning to new crops and infrastructure (VP).
10. Increase and improve support for and enforcement of federal and state OSHA and workplace safety laws relating to pesticide/ herbicide exposure prevention (VP).
11. Conduct outreach and education targeting vulnerable population groups and their employers about health and safety precautions (VP).
12. Study potential improvements to state health and safety laws relating to pesticide/herbicide exposure prevention (VP).

 The symbol signifies adaptation strategies that are also climate change mitigation actions.

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