Chapter 11

Public Health

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Contents

Introduction

Greenhouse gas emissions have already altered Earth's climate, and substantial global and regional climate changes over at least the next 100 years are virtually guaranteed. This will include continued warming, along with changing patterns of floods, droughts, and other extreme events. The consequences of these climate changes for public health in New York State are likely to be dramatic, particularly for people who are more vulnerable because of age, pre-existing illness, or economic disadvantage.

A range of potential health vulnerabilities related to climate change (Confalonieri et al., 2007; CCSP, 2008) are relevant to New York State, including the following:

- more heat-related deaths
- diverse consequences as a result of more intense rainfall and flooding events
- worsening air quality (due to increasing smog, wildfires, pollens, and molds) and related respiratory health impacts
- changing patterns of vector-borne and other infectious diseases
- risks to water supply, recreational water quality, and food production due to shifting precipitation patterns

The first four of these issues are the focus of this chapter, which presents both public health vulnerabilities and adaptation options available for reducing future climate-related risks. The ClimAID health assessment has been carried out through a combination of research, analysis, and interactions with relevant New York State stakeholders. The broader interdisciplinary, multi-sector ClimAID team also contributed to this sector's work. Case studies highlight the interplay of risks and responses for key health outcomes.

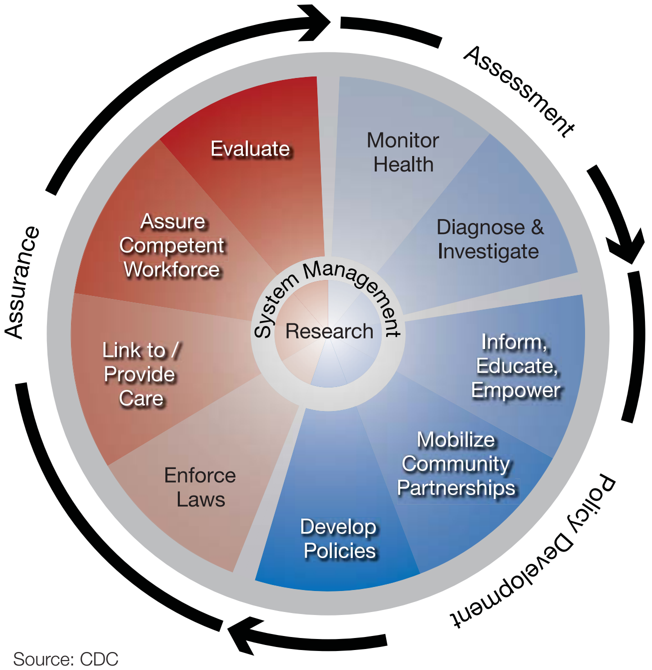
11.1 Sector Description

An overview of the public health system of New York State is essential for understanding potential climate change vulnerabilities as well as opportunities for increased resilience.

11.1.1 New York State Public Health System

The New York State public health infrastructure adheres to the Centers for Disease Control and Prevention's (CDC's) 10 essential public health services and core functions of assessment, policy development, and assurance of services (**Figure 11.1**). A diverse state, with populations spread unevenly over urban and rural service areas, New York is one of 26 states that rely primarily on a county-based system for public health service delivery (NYSPHC, 2003).

Local health departments operate under the authority of either the county legislature or local board of health. The result is a highly decentralized system with a non-uniform provision of core services. For example, local health departments provide environmental health services in 37 out of New York's 62 counties, while the State Department of Health (NYSDOH) provides service to the other areas (PHANYC, 2001). The New York State Public Health Council has identified this decentralization of public health service delivery as a key obstacle to efficient coordination of programming and data resources for climate-health preparedness. The Council has recommended regional, multi-county initiatives, which are proven models for more efficient and equitable distribution of expertise and services (NYSPHC, 2003).



Source: CDC

Figure 11.1 Core functions and 10 essential services of public health

In an effort to improve healthcare provision, in 1996 New York State initiated a data and knowledge communication program linking a wide range of partners, including hospitals, local health departments, nursing homes, diagnostic centers, laboratories, insurance provider networks, and federal agencies. Current communication networks—the Health Alert Network (state and city levels), the Health Provider Network, and the Health Information Network—are viewed as "both very helpful and very underutilized" by the Public Health Association of New York City (PHANYC, 2001). However, as a result of non-standardized data systems, the value of these networks across user groups is often compromised (PHANYC, 2001). These would be appropriate organizations to target for climate-health educational outreach and to evaluate climate-health interventions.

11.1.2 New York City Public Health System

New York City has been at the forefront of public health programming and policy since the founding of the Board of Health in 1866, the first such agency in the United States. More recently, New York City conducted the nation's first regional Health and Nutrition Examination Survey (NYC HANES), modeled after the CDC's National Health and Nutrition Examination Survey, providing policymakers and public health professionals with invaluable population-based health information (NYC DOHMH, 2007).

In 1995, the New York City Department of Health and Mental Hygiene (DOHMH) instituted a system of syndrome-based surveillance to locate potential disease outbreaks through ongoing monitoring of public health service use patterns and analysis for time- and location-related deviations. What started primarily as a means to detect waterborne illnesses that cause diarrhea through tracking influenza-like symptoms has evolved into electronic reporting of diverse health-related data. It now incorporates city emergency departments, pharmacy and over-the-counter medication purchases, employee absenteeism, and ambulance dispatch calls (Heffernan et al., 2004). With 39 city emergency departments participating, the electronic surveillance system covered about 75 percent of annual emergency department visits in its first year of operation alone (Heffernan and Mostashari et al., 2004).

11.1.3 Public Health Funding: Sources and Targets

Local health departments are funded by a combination of federal and state income streams and grants, complemented by fees levied through the local tax base and distributed by the State in proportion to county population. According to the Public Health Association of New York City (PHANYC), in 2001, New York City accounted for 46 percent of State aid, with the next six largest counties (Suffolk, Nassau, Erie, Westchester, Monroe, and Onondaga) receiving an additional 22 percent. Together these most-populous counties, which contain 72 percent of the state's population, accounted for 70 percent of the State aid to local health departments (PHANYC, 2001). In the 2001 fiscal year, the New York City Department of Health and Mental Hygiene budget drew 62 percent of funding from city tax revenues (PHANYC, 2001).

There is growing concern among public health practitioners that the confluence of State budget tightening with increasing needs of emerging chronic illnesses and emergency programming may threaten provision of basic healthcare services—both climate and non-climate related (NYS ACHO, 2008). While post-September 11 federal funding for emergency preparedness programming has benefitted the entire state and many aspects of surveillance and programming, the sufficiency and security of these funds into the future is a matter of serious concern (NYSPHC, 2003). It is also important to note that the federal health care landscape is evolving in significant ways as a result of the recent passage of health care reform legislation.

11.1.4 Emergency Preparedness

Projected changes in frequency and severity of extreme weather events will call upon the emergency preparedness plans within New York State. The New York State Disaster Preparedness Commission, made up of 23 State agencies and the American Red Cross, is responsible for disaster planning as well as communications with all levels of local, state, and federal-related bodies. The attacks of September 11 highlighted both strengths and gaps in New York City's public health infrastructure and underscored the importance of preparedness for the state in general. Immediate responses demonstrated the coordination of multiple health agencies to quickly and effectively react to threats to the public health of the city (Rosenfield, 2002). Transfer of the Office of Emergency Management command center from the World Trade Center (a high-profile, vulnerable location) to its current location in Brooklyn was one of the lessons learned. Most important, the events made clear that investments in preparedness infrastructure benefit the daily operations and effectiveness of the public health system.

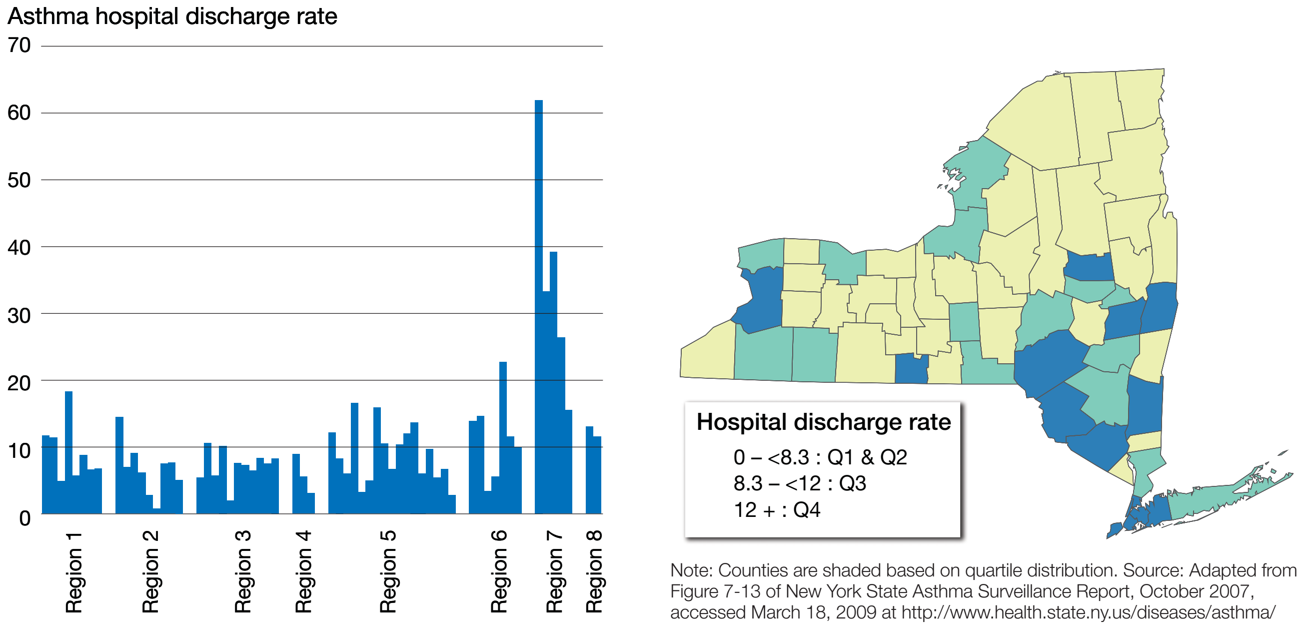
In 2002, Congress designated Centers for Disease Control and Prevention funding for nationwide capacity building and emergency response training initiatives and research through the Academic Centers for Public Health Preparedness program (Rosenfield, 2002). Columbia University in New York City was one of these centers and continues to provide valuable contributions in research and training to public health professionals through its National Center for Disaster Preparedness.

11.1.5 Current Health Status for Climate-sensitive Diseases

People whose health is already compromised by pre-existing disease are likely to be among the most vulnerable to emerging climate impacts. This is likely to be the case for a wide range of disease types. We can also identify a subset of diseases that may be particularly climate sensitive, either because the existing burden of disease is especially high or because climate change could directly impact the incidence or severity of the disease. Here we highlight three broad disease categories—asthma, cardiovascular, and infectious diseases—that are likely to be particularly climate sensitive in New York State. These were selected based on the limited evidence that currently exists on climate change and health. However, we do not mean to imply that these are the only disease categories for which climate change is or will be relevant in New York State. Ongoing research and reassessment will be critical to identify and target emerging health risks.

Asthma

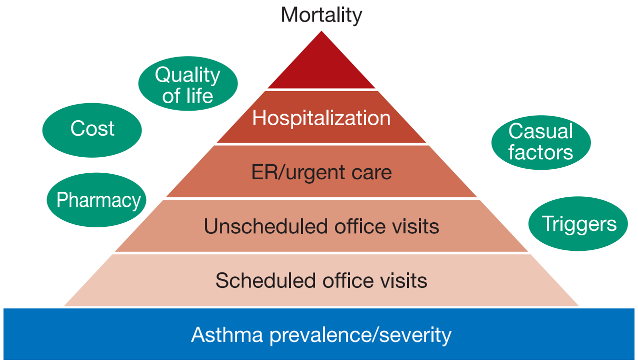
Asthma is potentially a climate-sensitive disease. It is already well established that asthma is exacerbated by certain weather patterns, pollen and mold seasons, and air pollution, and also is affected by indoor allergens like dust mites. Asthma can have allergic (such as pollen) or non-allergic (such as ozone) triggers, with the majority being of the allergic type. Many asthmatics are considered of mixed type, i.e., they are potentially sensitive to both types of triggers.



Note: Counties are shaded based on quartile distribution. Source: Adapted from Figure 7-13 of New York State Asthma Surveillance Report, October 2007, accessed March 18, 2009 at http://www.health.state.ny.us/diseases/asthma/

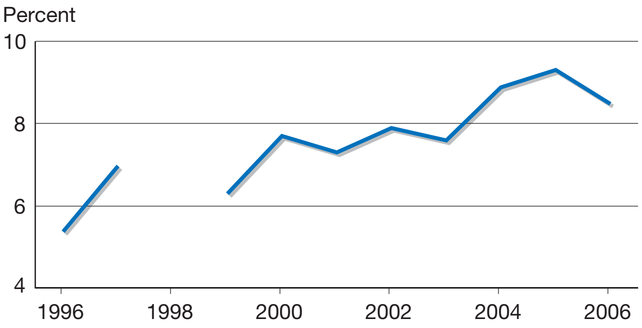
Figure 11.2 Hospital discharge rate for asthma per 10,000 population age 5 to14, 2005–2007 for (left) ClimAID regions (see Chapter 1, "Climate Risks," for definition of regions) and (right) for New York State counties

Childhood asthma is an important current health challenge in many parts of New York State—especially in the five counties that comprise New York City. Asthma events can be severe enough to require hospital admission (see **Figures 11.2** and **11.3**). However, the threshold of severity that triggers a hospital visit and admission likely differs by socioeconomic status. Wealthier individuals with health insurance, under doctor supervision, and with access to controller medications are less likely to have asthma attacks and are less likely to go to the hospital for care than are lower-income individuals lacking these resources.



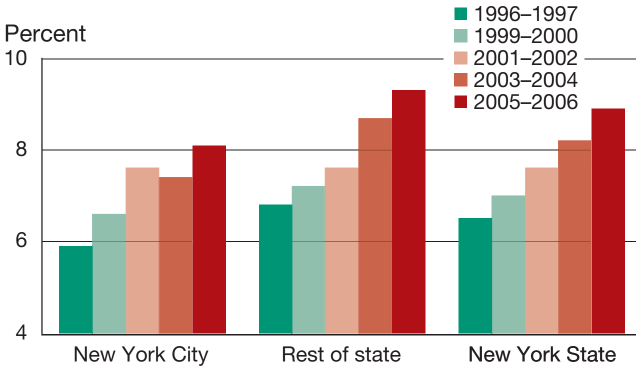
Source: Figure 3-1 of New York State Asthma Surveillance Report, October 2007, accessed March 18, 2009 at http://www.health.state.ny.us/diseases/asthma/

Figure 11.3 Asthma surveillance pyramid



Source: Figure 5-1 of New York State Asthma Surveillance Report, October 2007, accessed March 18, 2009 at http://www.health.state.ny.us/diseases/asthma/

Figure 11.4 Prevalence of current asthma among adults: 1996-2006 in New York State



Source: Figure 5-2 of New York State Asthma Surveillance Report, October 2007, accessed March 18, 2009 at http://www.health.state.ny.us/diseases/ asthma/

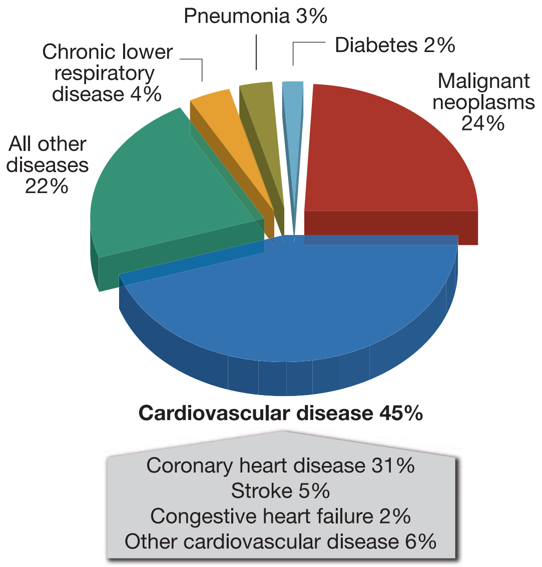
Figure 11.5 Prevalence of current asthma among adults, by region

Figure 11.4 shows that the percentage of New York State adults reporting that they currently have asthma that was diagnosed by a physician (based on survey methods) has trended generally upward between 1996 and 2006. In terms of prevalence as opposed to hospital admissions, New York City shows similar trends to the remainder of New York State (**Figure 11.5**).

Cardiovascular Disease

Cardiovascular disease is the leading cause of death in New York State (**Figure 11.6**). Underlying cardiovascular disease can interfere with a body's ability to regulate temperature in response to heat stress and, thus, can be an important predisposing factor for vulnerability to heat-related deaths. In addition, air pollution is a risk factor for cardiovascular disease (Kheirbek et al., 2011).

Cardiovascular disease is composed of several disease conditions, the most prevalent of which is coronary heart disease. Coronary heart disease, which is the single-greatest killer of New York State residents, occurs



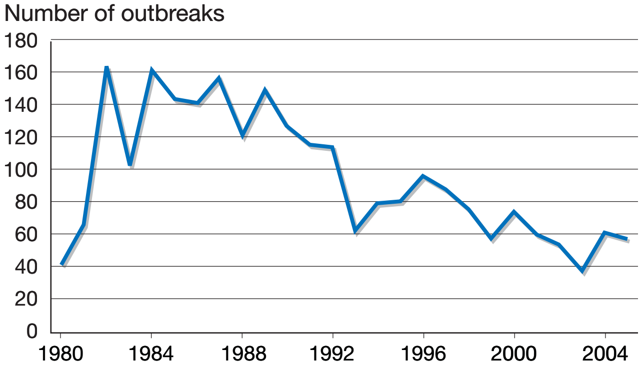
Source: New York State Vital Statistics, 1999

Figure 11.6 New York State causes of death due to thickening and hardening of arteries, resulting in insufficient blood supply and potentially severe damage to heart tissue and other organ systems in the body. Age-adjusted coronary heart disease mortality for persons aged 35 and older in New York State is the highest in the nation, mostly due to coronary heart disease in persons 65 and older. Fortunately, however, there has been a steady reduction in cardiovascular death rates in the state, from the 1979 level of about 600 per 100,000 residents to the 1999 level of less than 400 per 100,000 residents (Fisher et al., 2000).

Infectious Diseases

Infectious diseases were the most important health challenge in New York City during the 1800s and were the prime focus of the New York City Department of Health activities starting in 1866. The advent of antimicrobial drugs in the 1900s strongly reduced the burden of infectious disease. However, the end of last century and the early part of this century have seen the emergence and re-emergence of infectious pathogens in New York State and globally. Climate-sensitive infectious diseases include those spread by contaminated food (**Figure 11.7**) and water as well as those transmitted by insects and other vectors.

New York State has experienced the emergence of several vector-borne diseases in the past few decades. For instance, the state leads the nation in numbers of Lyme disease cases. Between 2002 and 2006, the top two counties in the United States for number of cases, and four of the top 10 counties in Lyme disease incidence rate (cases per 100,000 people) were in New York State. Illness caused by West Nile virus in the state peaked in 2002 at 82 cases, and the state has had the highest numbers of cases on the East Coast since 2005. Both Lyme disease and West Nile virus tend to be most prevalent in the Hudson Valley, Long Island, and New York City areas with dense and growing human populations. The factors responsible for the concentration of Lyme disease and West Nile fever in the southeastern region of the state are not well understood. Similar southeastern concentrations of *Borrelia burgdorferi*-infected blacklegged ticks, as well as of West Nile virus in mosquitoes and wild birds, suggest that ecological conditions, possibly including warmer climate, might be important.



Source: Adapted from Figure 1 of Foodborne Disease Outbreaks in New York State, 2005, NYS DOH, Bureau of Community Environmental Health and Food Protection, January 2005; accessed March 19 2009 at http://www.health.state.ny.us/statistics/diseases/foodborne/outbreaks/2005/ report.htm

Figure 11.7 Reported food-borne disease outbreaks in New York State, 1980–2005

11.1.6 Economic Value

The size of the public health sector is roughly reported in the official State GDP figures issued by the U.S. Bureau of Economic Analysis. The New York State full- and part-time employment in health care and social assistance for 2008 was 1,486,598 (New York State Department of Labor, 2008). The 2008 current dollar state GDP was $1.144 trillion; of this total, more than $82 billion was in the public health sector (U.S. Department of Commerce Bureau of Economic Analysis, 2009). (See also the ClimAID economic analysis in Annex III to the full report.)

11.2 Climate Hazards

Climate factors and measures that are particularly relevant to the health of New Yorkers are highlighted and briefly introduced below. Some of these factors are discussed in more detail in Vulnerabilities and Opportunities (Section 11.3) and in case studies at the end of the chapter.

11.2.1 Temperature

Historical observations over the past 40 years provide clear evidence of increasing average temperatures in New York State. Projected increases in average temperatures in the coming decades will also be associated with increases in other temperature measures, such as the minimum and maximum temperature and the minimum, average, and maximum daily apparent temperature (perceived outdoor temperature, including factors such as wind and humidity, as well as air temperature). Other temperature measures of relevance to public health include the number of days with temperature exceeding 85, 90, and 95°F, all of which are projected to increase. Consequently, heat-related mortality could increase, and persons with heat-sensitive conditions are at particular risk.

As temperature increases, and with potential increases in the frequency of stagnant air events over New York State, conditions favoring high ozone days could increase. Daily maximum 8-hour ozone concentrations and the number of days with 8-hour ozone concentrations above 60–70 parts per billion (ppb) represent useful measures of changing ozone-related risks for respiratory irritation and damage. These risks are particularly relevant for people working or exercising outdoors, including children and those with respiratory disease.

11.2.2 Precipitation

Extreme precipitation and flooding events can have significant direct health impacts due to injury and drowning, and can have a wide range of indirect impacts such as diminished water and food supply and quality, interruption of healthcare service delivery, mental health consequences, and respiratory responses to indoor mold. The most relevant precipitation metrics are not yet known and will likely vary for different health-related outcomes. Research is needed to elucidate the links between precipitation metrics and health in New York State.

11.2.3 Changing Patterns of Monthly Temperatures and Precipitation

Average temperature and precipitation pattern shifts can impact ecosystems (see Chapter 6, "Ecosystems") and can affect vector habitats and prevalence. West Nile virus as well as other diseases carried by mosquitoes, ticks, or other vectors could change their distribution or pattern of occurrence. In addition, allergy triggers such as pollen and molds could change in timing and intensity.

11.3 Vulnerabilities and Opportunities

Climate change vulnerabilities in the public health sector are, to a large extent, ones in which public health and environmental agencies are already engaged. However, climate change places an additional burden on public health agencies that are already burdened by low levels of staffing and funding. Climate-related risk factors include heat events, extreme storms, disruptions of water supply and quality, decreased air quality, changes in timing and intensity of pollen and mold seasons, and alterations in patterns of infectious disease vectors and organisms. Climate-sensitive health vulnerabilities include heat-related mortality (death) and morbidity (illness), respiratory disorders stemming from aeroallergen and/or air pollution exposures, trauma and complex downstream effects related to storm events, and a range of infectious diseases.

In later sections of this chapter, we present case studies to highlight a subset of health vulnerabilities for New York State over coming decades for which adequate information and expertise currently exists to make qualitative or in some cases quantitative assessments. The case studies examine health impacts related to heat, ozone, extreme storms, and West Nile virus. These were chosen as examples based on the current (albeit limited) knowledge base, and should not be viewed as a complete list of future health vulnerabilities for New York State. Evolving science and experience will continue to clarify the picture of health vulnerabilities in coming years. In the present section, our goal is to provide a broad sense of the range of potential health vulnerabilities.

Information on public health vulnerabilities to climate variability and change in New York State is available from a series of assessments carried out over the past decade, including the Metropolitan East Coast Climate Impact Assessment (Rosenzweig and Solecki, 2001), the New York Climate and Health Project (www.globalhealth.columbia.edu/projects/RES0716289.html), and the Northeast Climate Impact Assessment (Frumhoff et al., 2007). Based on an assessment of this and subsequent work, a review of current health challenges in New York State, and on our engagement with stakeholders, several climate-related health vulnerabilities emerged. These include increased risk for all natural-cause mortality associated with more frequent and severe heat waves (Knowlton et al., 2007; Kinney et al., 2008), asthma exacerbations and mortality associated with ozone air pollution (Knowlton et al., 2004), allergy and asthma associated with altered pollen and mold seasons, water- and food-borne diseases, emergence and/or changing distributions of vector-borne diseases, and impacts of extreme storm events, especially coastal storms in the New York City metropolitan area and Long Island.

These vulnerabilities span a range from the relatively direct, data-rich, and well-understood to more complex, multi-factorial systems for which both data and models are currently underdeveloped. Even the direct and relatively well-studied effects of heat waves on mortality among the urban elderly and those with low incomes require further work to assess potential future impacts of climate change against a backdrop of changing economics, energy constraints, demographics, and adaptation responses (Kinney et al., 2008).

Uncertainties pervade any effort to predict either direct or indirect health impacts of climate change. These uncertainties relate to projections of site-specific climate change itself, due to uncertain future pathways of global greenhouse gas emissions and the behavior of the climate system in response. This complicates future projections of climate metrics, including temperature, sea level rise, and the effects of changing temperature and humidity on health outcomes like communicable and vector-borne diseases. Additional uncertainties arise in projecting future health impacts due to potential future pathways of population demographics, economic development, and adaptation measures. These multiple uncertainties increase the importance of building resilience into the public health system to cope with inevitable surprises to come. Vulnerability assessments combined with a full accounting of uncertainties will help in prioritizing climate-health preparedness plans, informing communities on which actions should be taken first, and which information gaps are most critical to fill.

11.3.1 Temperature-Related Mortality

Extreme temperature events have been linked with higher mortality rates and premature death, in particular among vulnerable populations (elderly, young children, or those suffering from cardiovascular or respiratory conditions) (WHO, 2004; Basu and Ostro, 2009). More than 70,000 deaths were associated with the heat wave in Western Europe during the summer of 2003 (Robine et al., 2008). In the United States, mortality rates from higher than normal temperatures have also been documented, with approximately 10,000 deaths during the summer of 1980 (Ross and Lott, 2003). Large metropolitan areas where the heat-island effect is prevalent are particularly affected. It has been estimated that in Chicago, between 600 (Dematte, 1998) and 739 (Klinengberg, 2002) people died during the July 1995 heat wave, and an additional 80 cases were attributed to a second extreme heat episode during the summer of 1999. Similarly, 118 died in Philadelphia during the July 6–14, 1993 heat wave. Moreover, the combined effects of extreme temperature and air pollution have been seen to increase morbidity and mortality cases during heat waves (Cheng, 2005).

There is also emerging evidence for effects of heat on hospital admissions for respiratory and cardiovascular diseases. For example, in a study of summertime hospital admissions in New York City during the period from 1991 to 2004, Lin and colleagues (2009) from the NYSDOH found significant associations between high temperatures and increased risk of both respiratory and cardiovascular admissions. While effects were seen throughout the population, elderly and Hispanic residents appeared to be especially vulnerable.

Those at higher risk for heat-related health effects are among the most vulnerable urban residents: the elderly, those with low incomes, those with limited mobility and social contact, those with pre-existing health conditions and belonging to nonwhite racial/ethnic groups, and those lacking access to public facilities and public transportation or otherwise lacking air conditioning. Children, urban residents, and communities in the northern parts of the state that are not adapted to heat may also be vulnerable subgroups for temperature-related mortality (death) and morbidity (illness). As stated earlier, cardiovascular disease can impair a body's ability to regulate temperature in response to heat stress and thus can be an important predisposing factor for vulnerability to heat-related deaths. Further, persons with cardiovascular disease are often under close medical supervision and care, and thus may be especially vulnerable to disruptions of health care access following extreme storm and flood events. Since physical activity reduces the risk of cardiovascular disease, changing patterns of physical activity due to climate change could impact disease in either positive or negative directions.

As a result of climate change, New York State will experience increased temperatures that could have significant health consequences. Climate change is shifting the overall temperature distribution in the United States such that extreme high temperatures will become hotter. This will change the timing of heat waves and also increase their frequency. Urban areas are especially vulnerable because of the high concentrations of susceptible populations and the influence of the urban heat island effect. Thus, preparing for and preventing heat-related health problems is likely to be of growing importance in urban areas. Health departments, city planners, and emergency response agencies all can benefit from assessments aimed at determining future heat/health vulnerabilities under a changing climate. While the largest changes may lie 50 to 100 years in the future, smaller but still health-relevant changes are likely to occur over time horizons of interest to planners, e.g., 20 to 30 years. However, to be useful, future projections should take account not only of climate change, but also changes in population characteristics, infrastructure, and adaptive measures.

In a relevant recent study, Knowlton et al. (2007) examined potential climate change impacts on heat-related mortality in the New York City metropolitan area. Current and future climates were simulated at a 36-kilometer grid scale over the northeastern U.S. with a global-to-regional climate modeling system. Summer heat-related premature deaths in the 1990s and 2050s were estimated using a range of scenarios and approaches to modeling acclimatization. Acclimatization describes physiological adaptation in the human body that allows for maintenance of normal body temperature range during heat exposure through increased evaporative cooling (sweating), thereby mitigating cardiovascular system stress. Projected regional increases in heat-related premature mortality by the 2050s ranged from 47 to 95 percent, with a mean 70 percent increase as compared to the 1990s. Acclimatization reduced regional increases in summer heat-related premature mortality by about 25 percent. Local impacts varied considerably across the region, with urban counties showing greater numbers of deaths and smaller percentage increases than less urbanized counties. While considerable uncertainty exists in climate forecasts and future health vulnerability, the range of projections developed suggested that by mid-century acclimatization may not completely mitigate the effects of temperature change in the New York metropolitan region, resulting in an overall net increase in heat-related premature mortality.

It is important to note that more people die on average in winter than in summer in New York State and in the United States as a whole. However, winter mortality is heavily influenced by influenza and other viral infections, which are more prevalent during the winter season, likely due to low indoor and outdoor humidity and activity patterns. Temperature per se appears to play a minor role. Thus, it appears unlikely that climate warming will significantly reduce winter mortality in the foreseeable future. To examine this issue further, we present below a new case study of the impacts of daily temperature throughout the year on daily mortality due to all natural causes in New York County (i.e., Manhattan). We first fitted the U-shaped exposure-response function linking temperature with mortality over the full year using an 18-year record of daily observations. The analysis controlled for seasonal and day-of-week cycles in the data. We then used the fitted function to compute future mortality under the alternative climate models and scenarios included in the ClimAID project. While temperature-related mortality was projected to diminish slightly in winter under climate change, increases in warm-season mortality far outweighed this benefit in all cases. Further, we noted that, on a percentage basis, future mortality increases will be most prominent in the spring and fall seasons.

11.3.2 Air Pollution and Aeroallergens

Climate variables such as temperature, humidity, wind speed and direction, and mixing height (the vertical height of mixing in the atmosphere) play important roles in determining patterns of air quality over multiple scales in time and space. These linkages can operate through changes in air pollution emissions, transport, dilution, chemical transformation, and eventual deposition of air pollutants. Policies to improve air quality and human health take meteorologic variables into account in determining when, where, and how to control pollution emissions, usually assuming that weather observed in the past is a good proxy for weather that will occur in the future, when control policies are fully implemented. However, policymakers now face the unprecedented challenge presented by changing climate baselines. Air quality planning is a very important function of the New York State Department of Environmental Conservation, which is charged with the difficult task of developing and implementing strategies to achieve air quality standards despite being downwind of several states that host major emission sources.

There is growing recognition that development of optimal control strategies to control future levels of key health-relevant pollutants like ozone and fine particles ($PM_{2.5}$)* should incorporate assessment of potential future climate conditions and their possible influence on the attainment of air quality objectives. Given the significant health burdens associated with ambient air pollution, this is critical for designing policies that maximize future health protection. Although not regulated as air pollutants, naturally occurring air contaminants of relevance to human health, including smoke from wildfires and airborne pollens and molds, also may be influenced by climate change. Thus there is a range of air contaminants, both anthropogenic and natural, for which climate change impacts are of potential importance.

In spite of the substantial successes achieved since the 1970s in improving air quality, many New Yorkers continue to live in areas that do not meet the health-based National Ambient Air Quality Standards for ozone and $PM_{2.5}$ (www.epa.gov/air/criteria.html). Ozone is formed in the troposphere mainly by reactions that occur in polluted air in the presence of sunlight. The key precursor pollutants for ozone formation are nitrogen oxides (emitted mainly by burning of fuels) and volatile organic compounds (VOCs, emitted both by burning of fuels and evaporation from stored fuels and vegetation). Because ozone formation increases with greater sunlight and higher temperatures, it reaches unhealthy levels primarily during the warm half of the year. Daily peaks occur near midday in urban areas, and in the afternoon or early evening in downwind areas. It has been firmly established that breathing ozone can cause inflammation in the deep lung as well as short-term, reversible decreases in lung function. In addition, epidemiologic studies of people living in polluted areas have suggested that ozone can increase the risk of asthma-related hospital visits and premature mortality (Peel et al., 2005; Peel et al., 2007; Kinney et al., 1991; Levy et al., 2005). Vulnerability to ozone effects on the lungs is greater for people who spend time outdoors during ozone periods, especially those who engage in physical exertion, which results in a higher cumulative dose to the lungs. Thus, children, outdoor laborers, and athletes all may be at greater risk than people who spend more time indoors and who are less active. Asthmatics are also a potentially vulnerable subgroup.

$PM_{2.5}$ is a complex mixture of solid and liquid particles that share the property of being less than 2.5 μm (millionths of a meter) in aerodynamic diameter. Because of its complex nature, $PM_{2.5}$ has complicated origins, including primary particles emitted directly from a variety of sources and secondary particles that form via atmospheric reactions of precursor gases. $PM_{2.5}$ is emitted in large quantities by combustion of fuels by motor vehicles, furnaces and power plants, wildfires, and, in arid regions, windblown dust (Prospero et al., 2003). Because of their small size, $PM_{2.5}$ particles have relatively long atmospheric residence times (on the order of days) and may be carried long distances from their source regions (Prospero et al., 2003; Sapkota et al., 2005). For example, using satellite imagery and ground-based measurements, Sapkota and colleagues tracked a wildfire plume over 621 miles (1,000 km) from northern Quebec, Canada, to the city of Baltimore, Maryland, on the East Coast of the U.S. (Sapkota et al., 2005). Research on health effects in urban areas has demonstrated associations between both short-term and long-term average ambient $PM_{2.5}$ concentrations and a variety of adverse health outcomes, including premature deaths related to heart and lung diseases (Samet et al., 2000; Pope et al., 2002; Schwartz, 1994). In addition, smoke from wildfires has been associated with increased hospital visits for respiratory problems in affected communities (Hoyt and Gerhart, 2004; Johnston et al., 2002; Moore et al., 2006). In a study of acute asthma emergency room visits in NYC, the pollutants most associated were ozone, sulfur dioxide and one-hour $PM_{2.5}$. A more robust health impact was observed for the daily maximum $PM_{2.5}$ concentration than the 24-hour mean, suggesting peak exposure may have larger health impacts (NYSERDA, 2006).

Airborne allergens (aeroallergens) are substances present in the air that, upon inhalation, stimulate an allergic response in sensitized individuals. Aeroallergens can be broadly classified into pollens (e.g., from trees, grasses, and/or weeds), molds (both indoor and outdoor), and a variety of indoor proteins associated with dust mites, animal dander, and cockroaches. Pollens are released by plants at specific times of the year that depend to varying degrees on temperature,

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* PM2.5 is a complex mixture of solid and liquid particles that are less than 2.5 μm (millionths of a meter) in diameter.

sunlight, moisture, and CO_2. Allergy is assessed in humans either by skin prick testing or by a blood test, both of which involve assessing reactions to standard allergen preparations. A nationally representative survey of allergen sensitization spanning the years 1988–1994 found that 40 percent of Americans are sensitized to one or more outdoor allergens, and that prevalence of sensitization had increased compared with data collected in 1976–1980 (Arbes et al., 2005).

Allergic diseases include allergic asthma, hay fever, and atopic dermatitis. More than 50 million Americans suffer from allergic diseases, costing the U.S. healthcare system over $18 billion annually (American Academy of Allergy, Asthma, and Immunology, 2000). For reasons that remain unexplained, the prevalence of allergic diseases has increased markedly over the past three to four decades. Asthma is the major chronic disease of childhood, with almost 4.8 million U.S. residents affected. It is also the principal cause for school absenteeism and hospitalizations among children (O'Connell, 2004). Mold and pollen exposures and home dampness have been associated with exacerbation of allergy and asthma, as has air pollution (Gilmour et al., 2006; IOM, 2000; IOM, 2004; Jaakkola and Jaakkola, 2004).

The influence of climate on air quality is substantial and well established (Jacob, 2005), giving rise to the expectation that changes in climate are likely to alter patterns of air pollution concentrations. Higher temperatures hasten the chemical reactions that lead to ozone and secondary particle formation. Higher temperatures, and perhaps elevated carbon dioxide (CO_2) concentrations, also lead to increased emissions of ozone-relevant VOC precursors by vegetation (Hogrefe et al., 2005).

Weather patterns influence the movement and dispersion of all pollutants in the atmosphere through the action of winds, vertical mixing, and rainfall. Air pollution episodes can occur with atmospheric conditions that limit both vertical and horizontal dispersion. For example, calm winds and cool air aloft limits dispersion of traffic emissions during morning rush hour in winter. Emissions from power plants increase substantially during heat waves, when air conditioning use peaks. Weekday emissions of nitrogen oxides (NOx) from selected power plants in California more than doubled on days when daily maximum temperatures climbed from 75°F to 95°F in July, August, and September of 2004 (Drechsler et al., 2006). Changes in temperature, precipitation, and wind affect windblown dust, as well as the initiation and movement of forest fires.

Finally, the production and distribution of airborne allergens such as pollens and molds are highly influenced by weather phenomena, and also have been shown to be sensitive to atmospheric CO_2 levels (Ziska et al., 2003). The timing of phenologic events such as flowering and pollen release is closely linked with temperature.

Human-induced climate change is likely to alter the distributions over both time and space of the meterologic factors described above. There is little question that air quality will be influenced by these changes. The challenge is to understand these influences better and to quantify the direction and magnitude of resulting air quality and health impacts.

Hogrefe and colleagues were the first to report results of a local-scale analysis of air pollution impacts of future climate changes using an integrated modeling approach (Hogrefe et al., 2004a; Hogrefe et al., 2004b). In this work, a global climate model was used to simulate hourly meteorologic data from the 1990s through the 2080s based on two different greenhouse gas emissions scenarios, one representing high emissions and the other representing moderate emissions. The global climate outputs were downscaled to a 36-kilometer (22-mile) grid over the eastern U.S. using regional climate and air quality models. When future ozone projections were examined, summer-season daily maximum 8-hour concentrations averaged over the modeling domain increased by 2.7, 4.2, and 5.0 ppb in the 2020s, 2050s, and 2080s, respectively, as compared to the 1990s, due to climate change alone. The impact of climate on mean ozone values was similar in magnitude to the influence of rising global background ozone by the 2050s, but climate had a dominant impact on hourly peaks. Climate change shifted the distribution of ozone concentrations toward higher values, with larger relative increases in future decades occurring at higher ozone concentrations.

The finding of larger climate impacts on extreme ozone values was confirmed in a study in Germany (Forkel and Knoche, 2006) that compared ozone in the 2030s and the 1990s using a downscaled integrated modeling system. Daily maximum ozone concentrations increased by 2–6 ppb (6–10 percent) across the study region. However, the number of cases where daily maximum ozone exceeded 90 ppb increased by nearly four-fold, from 99 to 384.

More recently, the influence of climate change on $PM_{2.5}$ and its component species have been examined in the northeastern U.S., including New York State, using an integrated modeling system (Hogrefe et al., 2006). Results showed that $PM_{2.5}$ concentrations increased with climate change, but that the effects differed by component species, with sulfates and primary particulate matter increasing markedly but with organic and nitrated components decreasing, mainly due to transformation of these volatile species from the particulate to the gaseous phase.

The health implications of wildfire smoke have been tragically demonstrated by events in Russia during the summer of 2010. Because the risk of wildfire initiation and spread is enhanced with higher temperatures, decreased soil moisture, and extended periods of drought, it is possible that climate change could increase the impact of wildfires in terms of frequency and area affected (IPCC, 2007a; Westerling et al., 2006). Among the numerous health and economic impacts brought about by these more frequent and larger fires, increases in fine particulate air pollution are a key concern, both in the immediate vicinity of fires as well as in areas downwind of the source regions. Several studies have been published examining trends in wildfire frequency and area burned in Canada and the U.S. Most such studies report upward trends in the latter half of the 20th century that are consistent with changes in relevant climatic variables (Westerling et al., 2006; Gillett et al., 2004; Podur et al., 2002). Interpretation of trends in relation to climate change is complicated by concurrent changes in land cover and in fire surveillance and control. However, similar trends were seen in areas not affected by human interference (Westerling, et al., 2006) or under consistent levels of surveillance over the follow-up period (Podur et al., 2002). Several studies have looked at wildfire risk in relation to climate change (Lemmen and Warren, 2004; Williams et al., 2001; Flannigan et al., 2005; Bergeron et al., 2004).

Aeroallergens that may respond to climate change include outdoor pollens generated by trees, grasses, and weeds, and spores released by outdoor or indoor molds. Historical trends in the onset and duration of pollen seasons have been examined extensively in recent studies, mainly in Europe. Nearly all species and regions analyzed have shown significant advances in seasonal onset that are consistent with warming trends (Root et al., 2003; Beggs, 2004; Beggs and Bambrick, 2005; Clot, 2003; Emberlin et al., 2002; Galan et al., 2005; Rasmussen, 2002; Teranishi et al., 2000; van Vliet et al., 2002; World Health Organization, 2003). There is more limited evidence for longer pollen seasons or increases in seasonal pollen loads for birch (Rasmussen, 2002) and Japanese cedar tree pollen (Teranishi et al., 2000). Grass pollen season severity has been shown to be greater with higher pre-season temperatures and precipitation (Gonzalez et al., 1998). What remains unknown is whether and to what extent recent trends in pollen seasons may be linked with upward trends in allergic diseases (e.g., hay fever, asthma) that have been seen in recent decades.

In addition to earlier onset of the pollen season and possibly enhanced seasonal pollen loads in response to higher temperatures and resulting longer growing seasons, there is evidence that CO_2 rise itself may cause increases in pollen levels. Experimental studies have shown that elevated CO_2 concentrations stimulate greater vigor, pollen production, and allergen potency in ragweed (Ziska et al., 2003; Ziska and Caufield, 2000; Singer et al., 2005). Ragweed is arguably the most important pollen species in the U.S., with up to 75 percent of hay fever sufferers sensitized (American Academy of Allergy, Asthma, and Immunology, 2000). Significant differences in allergenic pollen protein were observed in comparing plants grown under historical CO_2 concentrations of 280 ppm, recent concentrations of 370 ppm, and potential future concentrations of 600 ppm (Singer et al., 2005). Interestingly, significant differences in ragweed productivity were observed in outdoor plots situated in urban, suburban, and rural locales where measurable gradients were observed in both CO_2 concentrations and temperatures. Cities are not only heat islands but also CO_2 islands, and thus to some extent represent proxies for a future warmer, high-CO_2 world (Ziska et al., 2003).

With warming over the longer term, changing patterns of plant habitat and species density are likely, with gradual movement northward of cool-climate species like maple and birch, as well as northern spruce (IPCC, 2007a). Although these shifts are likely to result in altered pollen patterns, to date they have not been assessed quantitatively.

As compared with pollens, molds have been much less studied (Beggs, 2004). This may reflect in part the relative paucity of routine mold monitoring data from which trends might be analyzed, as well as the complex relationships between climate factors, mold growth, and spore release (Katial et al., 1997). One study examining the trends in Alternaria spore counts between 1970 and 1998 in Derby, U.K., observed significant increases in seasonal onset, peak concentrations, and season length. These trends parallel gradual warming observed over that period.

In addition to potential effects on outdoor mold growth and allergen release related to changing climate variables, there is also concern about indoor mold growth in association with rising air moisture and especially after extreme storms, which can cause widespread indoor moisture problems from flooding and leaks in the building envelope. Molds need high levels of surface moisture to become established and flourish (Burge, 2002). In the aftermath of Hurricane Katrina, very substantial mold problems were noted, causing unknown but likely significant impacts on respiratory morbidity (Ratard, 2006). There is growing evidence for increases in both the number and intensity of tropical cyclones in the north Atlantic since 1970, associated with unprecedented warming of sea surface temperatures in that region (IPCC, 2007a; Emanuel, 2005).

Taken as a whole, the emerging evidence from studies looking at historic or potential future impacts of climate change on aeroallergens led Beggs to state (Beggs, 2004):

> [This] suggests that the future aeroallergen characteristics of our environment may change considerably as a result of climate change, with the potential for more pollen (and mold spores), more allergenic pollen, an earlier start to the pollen (and mold spore) season, and changes in pollen distribution.

11.3.3 Infectious Diseases

Infectious diseases that are transmitted by arthropod vectors, such as mosquitoes and ticks, are highly sensitive to climate change. Effects of even small increases in average temperatures can increase rates of population growth and average population densities of mosquitoes and other vectors (Harvell et al., 2002; Epstein, 2005). In addition, both the biting rates of mosquitoes and the replication rates of the parasites and pathogens they transmit increase with increasing temperatures (Harvell et al., 2002). Nevertheless, the degree to which recent and future climate change affects the distribution and intensity of vector-borne diseases remains controversial (Harvell et al., 2002; Ostfeld, 2009). One common criticism of the contention that climate warming will cause vector-borne diseases to spread geographically is that, just as some areas that are below the suitable temperature range will move into this range, others that are currently suitable might become too warm. Evidence to support this contention, however, is scant (Ostfeld, 2009). Moreover, because the overall climate of New York State appears to be well below any detectable upper thresholds for vector-borne disease, it seems that climate warming is more likely to increase, rather than decrease, the burden of vector-borne disease in the state.

In the case of Lyme disease, a climate-based spatial model (Brownstein, et al., 2005) suggested that the conditions under which blacklegged tick populations can be supported will expand northward into Canada as the climate warms. However, this model assumed that ticks currently occupy the entire state of New York and therefore was unable to make predictions relevant to the expansion of Lyme disease within the state. Other models (Ogden et al., 2005) also predict northward expansion of blacklegged ticks into areas currently assumed to be too cold to support them. These models are based on assumed, rather than empirically verified, relationships between temperature and tick demography (Killilea et al., 2008). In contrast, the relationships between specific climatic parameters and cases of West Nile virus illness or mosquito vector demography are better established. Therefore, this chapter focuses on West Nile virus in Case Study D.

11.4 Adaptation Strategies

Climate is often considered a factor that will change the frequency and severity of existing health problems more than create entirely new ones. From this point of view, the challenge is more about integrating specific information about climate-related vulnerabilities into ongoing programs of public health surveillance, prevention, and response than developing new programs to deal with unique challenges. While largely valid, this view misses the mark in one important way, namely that changing climate brings the possibility of entirely new health risks, for example from new infectious diseases or coastal storm events of unprecedented magnitude.

Here we briefly review a range of adaptation options that should be considered in addressing climate-related health risks in New York State.

11.4.1 Key Adaptation Strategies

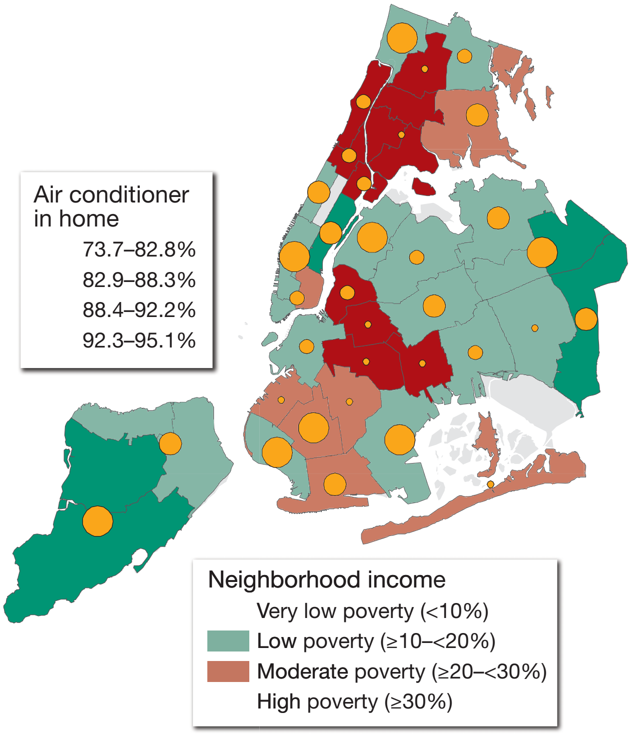
Avoiding or reducing the health impacts of climate change will ultimately depend on public health preparedness. In the sections that follow, a number of adaptations, or preparedness strategies, are discussed.

Heat Adaptation

Heat-related mortality has been recognized as an important public health challenge for many decades. As a result, heat warning and response systems have been implemented in many cities in the United States and Europe, including New York City. These warning systems include collaboration with local meteorologists for forecasting as well as coordination with multiple agencies and community groups. The goal is to maximize dissemination of actionable information for both immediate health protection and provision of additional services during the period of intense heat. Often the additional services include longer hours at community centers for seniors (called cooling centers during the time they are open during a heat wave) as well as reduced fare on public transportation or the implementation of neighborhood buddy systems. In addition, the NYSDOH distributes statewide a fact sheet entitled "Keep Your Cool During Summer Heat" that provides information on what to do before and during a heat event, how to recognize and act on heat-related illness, and who is most vulnerable. The NYSDOH also has worked with the State Environmental Health Collaborative Climate Workgroup to develop several climate indicators. These include indicators for the vulnerable population (elderly and people living in low-income neighborhoods), cardiovascular disease, hospital readmissions for respiratory diseases due to heat, maximum/minimum temperature, and air pollution change due to heat. One important priority with respect to these efforts is to evaluate their effectiveness in reducing morbidity and mortality.

Home air conditioning is a critical factor for prevention of heat-related illness and death (Bouchama et al., 2007). Air conditioning is especially important for elderly, very young, and health-compromised individuals, all of whom have a lower internal capacity to regulate body temperature (CDC, 2009).

Within New York City, approximately 84 percent of housing units had some form of indoor air conditioning in 2003. Air conditioning rates are not uniform across the city, however. Neighborhoods with higher poverty rates, including Central Harlem, Washington Heights, Fordham, the South Bronx, Greenpoint, Williamsburg, Bedford-Stuyvesant, and others, have lower rates of in-home air conditioning than more affluent parts of the city (**Figure 11.8**). These differences suggest that many residents living in lower-income neighborhoods of the city may be more vulnerable to heat-related illness and mortality.



Note: Percentages are age adjusted. Poverty is categorized by the percent of residents in each neighborhood living below the federal poverty level.
Source: NYC Community Health Survey 2007; Bureau of Epidemiology Services, NYC DOHMH; U.S. Census 2000/NYC Department of City Planning

Figure 11.8 Air conditioning distribution and neighborhood-level poverty in New York City

The presence of an air conditioner does not necessarily equate to its effective use during a heat wave. Also, while fans can be helpful at moderate temperatures, Wolfe (2003) points out that their effectiveness diminishes at very high temperatures and humidity.

As noted in the Chapter 8 ("Energy"), energy costs associated with use of air conditioning are a major concern for lower-income households and particularly for lower-income elderly populations (Tonn and Eisenberg, 2007). Even during periods of extreme heat, low-income elderly residents, particularly those living alone, may be reluctant to use their air conditioners due to concerns about energy costs. While age and social isolation were key factors in predicting mortality in the 1995 Chicago heat wave (Semenza et al., 1996), presence of air conditioning in the home did not necessarily have a mitigating effect. Many of the Chicago heat wave's elderly victims had working air conditioners in their apartments, but the machines were not in use at the time of death (Klinenberg, 2003). Thus, to improve the effectiveness of air conditioning as an adaptive measure, it will be important to develop strategies to ensure energy access for low-income, vulnerable individuals, as well as ensure that functional, high-efficiency air conditioners are widely available and in use. Possible measures include monetary support of low-income populations to ensure the use of air-conditioning and programs for peak load and or voltage reduction (Warren and Riedel, 2004). The costs to implement such measures are not well documented.

In addition to these measures, infrastructure investments, particularly in vulnerable urban neighborhoods, could yield substantial health benefits. Urban greening programs, green roofs, and building codes requiring reflective exterior surfaces are among the options that should be considered.

Air Pollution

Implementation strategies addressing ozone and fine particles are well developed in New York State and are described on the New York State Department of Environmental Conservation website (www.dec.ny.gov/chemical/8403.html; see State Implementation Plan). However, integrating climate forecasts into ongoing planning for air quality is a challenge that must be addressed in collaboration with stakeholders at the New York State Department of Environmental Conservation and the U.S. Environmental Protection Agency.

11.4.2 Larger-scale Adaptations

Comparative health-risk assessments of climate change adaptation (and also mitigation) measures, such as the health effects of the combustion byproducts of biofuels and gases of varying ethanol blends, are important. Data gaps, such as the specifics of relationships between certain climate factors and some health outcomes and projections of climate impacts on multiple types of disease and vulnerable subpopulations, and the specific ongoing need for increased environmental monitoring linked to health outcome reporting, are also key to adaptation. Additionally, stakeholders have voiced the importance of public health communication. Alerts regarding known health risks should be tested and tailored to most effectively convey information and needed action to vulnerable communities. Cross-cutting environment and health initiatives that bridge the divide in legislation between ecosystems and human health should also be developed.

11.4.3 Co-benefits and Opportunities

This chapter has focused primarily on potential negative health impacts of a changing climate in New York State. However, it is possible that climate change may bring some positive impacts on health. For example, warmer winters may reduce the burden of some cold-related health effects (e.g., hypothermia among the homeless, snow-related accidents and injuries) and could encourage greater physical activity during extended periods of mild weather. In addition, policies enacted in New York State to reduce greenhouse gas (GHG) emissions by curtailing fossil fuel burning will reduce emissions of other pollutants, and may deliver health benefits as well. Furthermore, unlike climate benefits, these health co-benefits accrue locally in space and time, enhancing their value in economic analyses (Burtraw et al., 2003; Dessus and O'Connor, 2003; Proost and Van Regemorter, 2003; Wang and Smith, 1999; Bloomberg and Aggarwala, 2008). For 20 years at least, researchers have attempted to quantify co-benefits (Ayres and Walter, 1991; Viscusi, 1994). Most studies have found that the magnitude of the ancillary benefits are large, even relative to the large outlays required by GHG mitigation. Most of the literature to date emphasizes co-benefits that accrue from reductions in air pollution, particularly $PM_{2.5}$ and ozone precursors. However, GHG mitigation policies may improve health in other ways, e.g., via increased physical activity, decreased meat consumption, and reduced traffic accidents. For comprehensive reviews see Bell et al. (2008) and Nemet et al. (2010).

11.5 Equity and Environmental Justice Considerations

Climate change is an evolving problem for human health conditioned by unequal access to resources and differential exposure to unhealthy landscapes. The negative impacts of climate change on health may be particularly consequential for people living in poverty or communities segregated by race.

11.5.1 Vulnerability

There are two important pathways for climate-related health inequities. First, lower-income populations and communities of color may be concentrated in areas exposed to more climate-sensitive health risks. For example, compared to higher-income white populations, low-income segregated African-American and Hispanic communities tend to have greater exposure to allergens and smog, and live in homes that are less able to regulate temperature and humidity (Williams and Collins, 2001; Evans and Kantrowitz, 2002). Second, exposure may impose added burdens on pre-existing vulnerabilities of health, living conditions, and socioeconomic position. For example, low-income communities tend to have inferior public infrastructure, higher risk of underlying health conditions such as cardiovascular disease, and less access to quality, affordable health care (Williams and Collins, 2001; Evans and Kantrowitz, 2002). Other indicators of pre-existing vulnerabilities to climate-related health shocks include lower wages or unemployment, lack of insurance, occupational stresses, and poor nutrition.

Higher temperatures will likely increase the duration and intensity of heat waves and associated heat-related health stresses. Heat-related health stresses are felt disproportionately in inner-city urban areas, where a preponderance of heat-trapping surfaces and a scarcity of heat-reducing infrastructure (trees, parks, water) contribute to the urban "heat island" effect (Rosenzweig et al., 2006). The urban heat island effect has been implicated in past heat wave events (Kunkel et al., 1996). Because of residential segregation patterns, these inner-city neighborhoods also tend disproportionately to house low-income communities of color (Williams and Collins, 2001).

Health risks can be intrinsic or extrinsic. Intrinsic heat-related health risks include age, disability, and underlying medical conditions, such as depression or cardiovascular problems (Stafoggia, 2006; Worfolk, 2000). Some of these medical conditions are more prevalent in low-income communities or within communities of color. Extrinsic risks encompass contextual factors such as behavior, quality of housing, community integration, and access to cooling infrastructure and transportation (Kovats and Hajat, 2007; Epstein and Rogers, 2004; Klinenberg, 2003). Some of these risks are also associated with lower-income status, such as the higher probability of residing in heat-trapping buildings and lacking air conditioning (Klinenberg, 2003). All these risks generally interrelate to create unique, magnified vulnerabilities. For example, elderly persons may be medically sensitive to heat stress (intrinsic), while at the same time may lack coping strategies such as access to community support networks (extrinsic) (Worfolk, 2000; Klinenberg, 2003).

Heat-related morbidity also has its own suite of inequities (Lin et al., 2009). Those most likely to die from heat stress are not necessarily those who would suffer the contextual and indirect harms associated with heat morbidity, such as lost wages and productivity and health care expenses.

Air pollution and respiratory health is another area in which environmental justice concerns arise in the context of climate change. African Americans tend to live in urban centers that are more exposed to primary air pollutants. They also are significantly more likely to be hospitalized and die from asthma (Prakash, 2007). Rising temperatures and increasing emissions create conditions for ozone formation and further inequitably distributed health burdens.

Another climate impact is the probability of increased levels of mold and other allergens. This also contributes to respiratory health problems (Beggs, 2004). Dampness of households, a key variable for mold growth, is associated with socioeconomic status (Gold, 1992).

Environmental justice activists have become increasingly concerned about the contribution of mold to the high rates of hospitalization for asthma among African Americans in cities such as New York (NYS Department of Environmental Conservation, 2008). Tackling these high rates of urban asthma or home allergens through health adaptation programs is one way to reduce health disparities.

Securing access to affordable, good quality, nutritious food for lower-income urban communities of color is a priority area for environmental justice advocates in New York State (NYS Department of Environmental Conservation, 2008). Impacts of climate change on local agriculture could make this goal more challenging to achieve.

11.5.2 Adaptation

Some cities, such as New York, have begun developing adaptation programs because of existing health burdens related to heat stress (Rosenzweig et al., 2006). Other more northerly cities in the state may confront new emergent heat stress. They will need to be proactive to avoid any evolving health inequities related to differential coping capacities within their populations.

Since heat danger is frequently mediated by underlying vulnerabilities, one way to build equity into climate change adaptation mechanisms is a broad-based effort to improve health and reduce social isolation among vulnerable populations, including increasing access to health insurance and social support systems, broadening and diversifying economic activities, and improving education. More targeted adaptations include short-term social mechanisms such as warnings and outreach in conjunction with long-term technical design approaches that reduce ambient heat (Bernard and McGeehin, 2004; Rosenzweig et al., 2006). Ensuring equitable implementation of social prevention requires tailoring messages among and within groups. This means confronting language barriers in outreach and warning systems and targeting at-risk groups, such as elderly, disabled, or otherwise isolated persons. For example, the Phoenix heat wave in 2005 took a particular toll on homeless people (Epstein, 2005). Designing a warning for itinerants with tenuous access to information is a challenge for any outreach system. Through the CDC's Climate-Ready States and Cities Initiative, the New York State Department of Health is conducting an assessment that will examine a range of health outcomes related to extreme weather events, as well as waterborne, food-borne, and vector-borne diseases (www.cdc.gov/climatechange/climate_ready.htm).

One way to build social justice into heat adaptive design is to prioritize energy efficiency and retrofits of public housing, such as installing cooling surfaces and insulation. These synergistic approaches are also discussed in Chapter 8, “Energy.” Other strategies that enforce climate-adaptive regulations, such as new building codes, might need to provide support mechanisms, funding incentives, or loans for low-income homeowners and small businesses.

11.6 Conclusions

This ClimAID assessment has identified a set of key existing and future climate risks for public health in New York State. Some health risks arise from increases in the frequency, duration, or intensity of weather events, such as diverse health consequences from more storms and flooding events, and from heat-related mortality and morbidity. Other risks may arise due to gradual shifts in weather patterns, such as changes in vector-borne disease prevalence and distribution, worsening air quality (smog, wildfires, pollen), and related cardiovascular and respiratory health impacts. Similarly, risks to water supply and food production may arise due to increased temperatures and shifting precipitation patterns. While the analyses presented here have been from the perspective of New York State, it is important to note that many of our findings can be generalized to other U.S. locations.

11.6.1 Main Findings on Vulnerability and Opportunities

- Climate will likely change the frequency and severity of existing health problems, while also bringing the possibility of entirely new health risks.
- Impacts of climate change will be particularly significant for people in New York State made more vulnerable because of age, preexisting illness, and/or poverty.
- Illness and death from heat will particularly impact low-income urban residents, the elderly, and those with pre-existing health conditions.

- Climate-related changes in air pollution patterns will be particularly significant for asthmatics and for persons who work, play, or exercise out of doors.

11.6.2 Adaptation Options

Adaptation to climate-related health vulnerabilities in New York State is an evolving process. Aside from heat wave warning and response planning, few climate-specific adaptation strategies yet exist in New York State. Climate impacts and adaptation strategies for the health sector build upon the existing public health system of New York State, which is already engaged to some extent with most of the health domains likely to be relevant to climate change. However, there is the possibility that future climate impacts in the health sector may fall outside of historical experience, presenting new challenges. Of particular concern is that information and capacity for integrating climate change into public health planning remains limited at the local level.

Future adaptations in the health sector should begin by enhancing capacity for climate planning within the existing public health system of New York State, and also by strengthening linkages between health and environmental initiatives.

One key objective is to expand ongoing surveillance of climate-sensitive environmental and health indicators. Surveillance is a central public health function that can inform periodic assessments of emerging risks and anticipated future impacts, and help to guide ongoing adaptation planning.

Another key area of focus should be the development of early warning systems and response plans for a broader range of climate risks, building on the experience with heat systems. Adaptation strategies and messaging should be particularly targeted at, and tailored for, protecting vulnerable populations.

Air quality control efforts will need to increasingly take climate change into account, as well as be integrated with greenhouse gas mitigation strategies, so that maximal health co-benefits are achieved.

A general point worth emphasizing is the importance of integrated health planning across multiple sectors, including environmental quality, parks and recreation, urban planning, food and water supply, and others.

With respect to equity and environmental justice, care is called for in designing both adaptation and mitigation strategies so that disparities can be reduced. Without making this an explicit goal, existing health disparities are likely to be worsened by climate change. People in northern parts of the state may be at particular risk for heat-related health impacts due to lack of adaptation to high temperatures. Mitigation and adaptation actions by New York State should ensure an equitable distribution of costs and benefits.

11.6.3 Knowledge Gaps

Future efforts to address health risks due to climate change will require ongoing, state-based research to inform periodic policy developments. Of particular importance is research to identify cross-sectoral interactions and win-win options for adaptation/mitigation, including extensive health co-benefits assessments.

It is also important to develop and analyze local health impact projections of climate factors and related disease outcomes. Information and capacity building for integrating climate change into public health planning at all levels of government is needed.

Examining the effectiveness of heat warning systems and related adaptive strategies, and translating these strategies to urban areas across the state, should be high priorities.

Enhanced environmental monitoring of climate-related factors linked to health outcome reporting, particularly of airborne allergens and infection vectors, is crucial for improving the knowledge foundation on which decisions are based.

Case Study A. Heat-related Mortality among People Age 65 and Older

As a result of climate change, New York State will experience increased temperatures that could have significant consequences for health, particularly for the most vulnerable members of the population: the elderly, those with low incomes, those with limited mobility and social contact, those with pre-existing health conditions and belonging to nonwhite racial/ethnic groups, and those lacking access to public facilities and transportation or otherwise lacking air conditioning. Urban areas are especially vulnerable because of the high concentrations of susceptible populations and the influence of the urban heat island effect. Thus, preparing for and preventing heat-related health problems is likely to be of growing importance in urban areas.

Projecting Temperature-related Mortality Impacts in New York City under a Changing Climate

Climate change has led to increasing temperatures in urban areas in recent decades, and these changes are likely to accelerate in the coming century. These changes may result in more heat-related mortality but also might alter winter mortality, and the net impact remains uncertain. Our objective was to explore a methodology for projecting future temperature-related mortality impacts over the full year in New York County across a range of climate change models and scenarios. The ClimAID climate team provided temperature projections for the 2020s, 2050s and 2080s over New York County, obtained from five different global climate models (GFDL, GISS, MIROC, CCSM and UKMO) that were run with the Intergovernmental Panel on Climate Change (IPCC) A2 and B1 greenhouse gas emissions scenarios (see Chapter 1, "Climate Risks," for details). Monthly differences between modeled future temperatures and those modeled for the climatological baseline period of 1970–1999 were used to adjust observed daily temperatures for 1970–1999 in Central Park, NY to the future time periods.

The association between maximum temperature and daily mortality in 1982–1999 was modeled using log-linear Poission regression analysis. Seasonal cycles were controlled using a natural spline function with 7 degrees of freedom per year. Day-of-week effects were also controlled. Temperature effects were fit using a natural spline with 2 degrees of freedom, yielding a U-shaped curvilinear relationship (**Figure 11.9**). Percentage changes in mortality in both winter and summer were calculated relative to the minimum point on **Figure 11.9**. This analytical approach is similar to those used extensively in the literature (for example, Curriero, Heiner, et al., 2002; Curriero, 2003; O'Neill, Zanobetti, et al., 2003; Anderson and Bell, 2009). We analyzed mortality in relation to maximum daily temperature observed on the same day as death (i.e., lag zero) for both heat and cold effects. This contrasts with the approach used by Anderson and Bell (2009) in which cold effects were modeled as a 25-day moving average. We avoided this approach because it might lead to confounding by winter season effects, that is, a tendency to mis-attribute seasonal effects to the cold slope. The heat- and cold-related deaths in the 1970s, 2020s, 2050s, and 2080s were estimated by integrating the results from the climate models and the empirical exposure-response relationship, with results shown in **Tables 11.1** and **11.2**, and **Figure 11.10**.

During the baseline period, 1970–1999, we estimated there were on average 604 mean annual temperature-related deaths. Under the A2 scenario, mean annual temperature-related deaths increased to 686 in the 2020s, 782 in the 2050s, and 920 in the 2080s. In the B1 scenario, the mean annual temperature-related deaths were 681 in 2020s, 741 in the 2050s, and 779 in the 2080s. Differences across models and scenarios were minimal early in the century but increased by mid-century (**Figure 11.10**). Warm season impacts on mortality expanded in both number and in annual extent (i.e., earlier in spring and later in fall) as the century progressed (**Table 11.2**). Additional sensitivity analyses using alternative lags of temperature and different reference temperatures are under way. However, these preliminary results suggest that, over a range of models and scenarios of future greenhouse gas

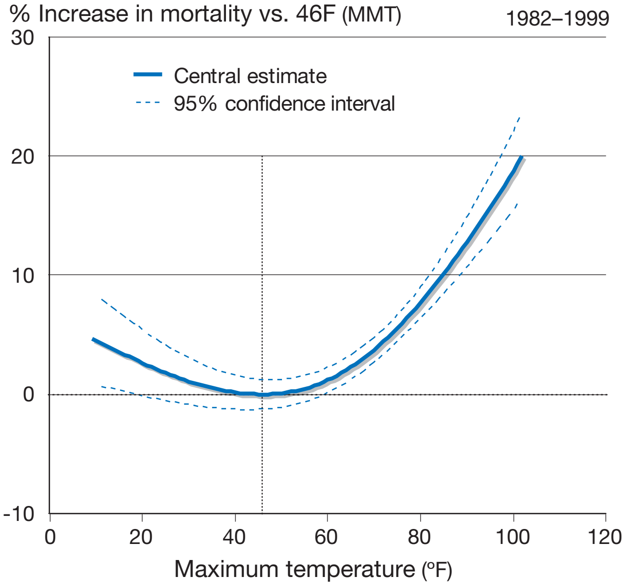


Figure 11.9 Predicted mortality vs. maximum temperature, based on analysis of daily observations from 1982 through 1999

emissions, increases in heat-related mortality could outweigh reductions in cold-related mortality. Further, while the two emissions scenarios produce similar mortality estimates through mid-century, the lower-emission B1 scenario could result in substantially smaller annual mortality impacts by the 2080s.

Economic Impacts of Mortality Due to Heat Waves

As noted above, climate projections can be used in assessing the impact of heat waves on the public health sector and society as well as the effectiveness of potential remedies. Measures to prevent increased mortality during extreme weather events may be

Climate Model	Scenario		Net Temperature Effect		Heat Effect			Cold Effect		
		T_{maxave}(°F)[a]	Deaths[b]	Percent Change[c]	Days Above MMT	Deaths[b]	Percent Change[c]	Days Below MMT	Deaths[b]	Percent Change[c]
Baseline[d]		62.7	604		287	586		78	18	
GFDL	2020s A2	64.4	676	11.92%	294	660	12.63%	72	16	-11.11%
	2020s B1	64.6	674	11.59%	297	659	12.46%	68	15	-16.67%
	2050s A2	66.6	763	26.32%	304	751	28.16%	61	12	-33.33%
	2050s B1	66.0	748	23.84%	299	735	25.43%	66	14	-22.22%
	2080s A2	69.5	902	49.34%	320	894	52.56%	46	8	-55.56%
	2080s B1	66.8	778	28.81%	304	765	30.55%	61	13	-27.78%
GISS	2020s A2	64.4	670	10.93%	295	655	11.77%	70	15	-16.67%
	2020s B1	64.9	679	12.42%	300	666	13.65%	65	13	-27.78%
	2050s A2	66.1	726	20.20%	306	716	22.18%	59	10	-44.44%
	2050s B1	65.2	694	14.90%	299	681	16.21%	65	13	-27.78%
	2080s A2	68.5	818	35.43%	320	812	38.57%	46	7	-61.11%
	2080s B1	65.5	715	18.38%	299	702	19.80%	64	12	-33.33%
MIROC	2020s A2	65.2	697	15.40%	300	685	16.89%	65	13	-27.78%
	2020s B1	65.3	696	15.23%	301	684	16.72%	64	12	-33.33%
	2050s A2	67.8	798	32.12%	314	790	34.81%	52	9	-50.00%
	2050s B1	67.0	765	26.66%	310	755	28.84%	55	10	-44.44%
	2080s A2	71.5	957	58.44%	333	953	62.63%	32	4	-77.78%
	2080s B1	68.3	819	35.60%	317	811	38.40%	47	7	-61.11%
CCSM	2020s A2	65.3	695	15.07%	300	683	16.55%	65	12	-33.33%
	2020s B1	65.6	700	15.89%	302	689	17.58%	62	11	-38.89%
	2050s A2	68.0	807	33.61%	314	798	36.18%	50	9	-50.00%
	2050s B1	66.6	728	20.53%	313	720	22.87%	52	9	-50.00%
	2080s A2	70.6	927	53.48%	326	922	57.34%	39	5	-72.22%
	2080s B1	66.4	735	21.69%	306	725	23.72%	59	10	-44.44%
UKMO	2020s A2	64.6	685	13.41%	294	673	14.85%	71	16	-11.11%
	2020s B1	64.0	658	8.94%	292	643	9.73%	72	15	-16.67%
	2050s A2	67.4	819	35.60%	306	805	37.37%	59	10	-44.44%
	2050s B1	66.5	768	27.15%	302	756	29.01%	63	12	-33.33%
	2080s A2	71.3	997	65.07%	323	991	69.11%	42	6	-66.67%
	2080s B1	68.6	850	40.73%	317	842	43.69%	48	8	-55.56%
Average Across Models	2020s A2	64.4	686	13.6%	297	671	14.5%	68	14	-22.2%
	2020s B1	64.6	681	12.7%	299	668	14.0%	66	13	-27.8%
	2050s A2	66.6	782	29.5%	309	772	31.7%	56	10	-44.4%
	2050s B1	66.0	741	22.7%	305	729	24.4%	60	11	-38.9%
	2080s A2	69.5	920	52.3%	324	914	56.0%	41	6	-66.7%
	2080s B1	66.8	779	29.0%	309	769	31.2%	56	10	-44.4%

[a] Mean daily maximum temperature (MMT) in °F for typical year, from observations for baseline period and from climate models simulations for 2020s, 2050s, 2080s.

[b] Central effect estimate for the net temperature, cold- and heat- related additional deaths in a typical year.

[c] Percentage change in central estimate of additional deaths in a typical year, relative to the baseline.

[d] Baseline refers to 1970-1999 reference period.

Table 11.1 Summary of projected annual mean daily maximum temperature and associated additional deaths in the 1970s versus the 2020s, 2050s, and the 2080s, in the A2 and B1 scenarios for 5 of the 16 global climate models used in ClimAID

Month	Base	A2			B1		
		2020s	2050s	2080s	2020s	2050s	2080s
1	9	8	18	19	8	19	19
2	7	7	16	19	7	17	17
3	10	11	35	52	12	31	38
4	27	35	105	130	34	103	99
5	63	73	206	251	73	198	210
6	99	108	305	354	111	291	305
7	135	151	418	476	148	401	420
8	124	139	394	454	137	369	390
9	79	90	260	297	88	241	257
10	34	42	130	160	41	121	125
11	12	16	48	66	16	45	50
12	6	6	19	24	7	18	19

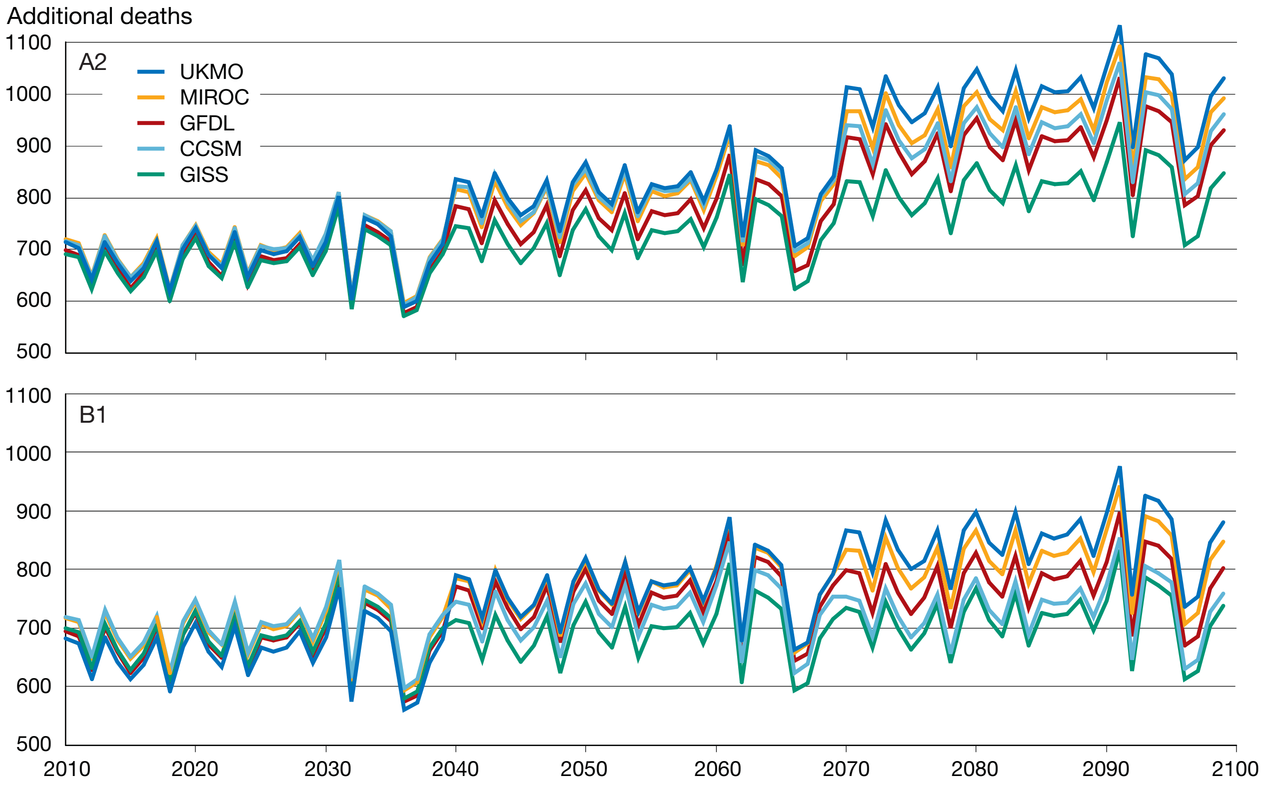
These are 5 of the 16 GCMs used for ClimAID climate projections.

Table 11.2 Average (across five global climate models) projected monthly additional deaths in the 1970s versus the 2020s, 2050s, and 2080s, A2 and B1 scenarios

evaluated in terms of economic net effects. Most public policy decisions requiring economic assessments include estimating the costs of the proposed actions against those ensuing from inaction. The calculus of economic losses from increased mortality includes assigning monetary values to human life as well as estimating costs associated with services rendered before death (e.g., emergency/ ambulance services and/or hospital stay) and/or averting behavior (e.g., purchasing air conditioning units).

Some economics assessments measure mortality as the change in the probability of dying for a specific population due to a change in health status. This does not represent the "crude" mortality rate of the population, measured as the ratio of the total number of deaths divided by the total number of individuals in the population. Instead, some economics methods assume that individuals are able to rank other traded goods against the "value of a statistical life" (VSL) or the "value of a statistical death avoided" (Krupnick, 1996). In this perspective, death and illness are treated as probability rates and individuals as willing to pay to reduce marginal changes in the probability of death or incidence of illness. Thus, people are assumed to be making informed choices about the rate of substitution between small changes in the probability of death or illness, and other traded goods.

Based on such assumptions, various studies have developed coefficients to estimate the value of a statistical life in order to evaluate economic losses ensuing from premature mortality. Two methods may be



These are 5 of the 16 GCMs used for ClimAID climate projections.

Figure 11.10 Annual net additional deaths in the 21st century for five global climate models for A2 (top) and B1 (bottom) emissions scenarios used to identify the VSL in relation to reduced mortality risks. The first is based on surveys that gather information on people's willingness to pay (WTP) to decrease mortality risks. The second one is based on the "revealed preferences" method and applies a "willingness to accept compensation" (WTA) approach to estimate VSLs by using hedonic wages or differential wage rates (Ebi et al., 2004). Hedonic wages are statistically based estimates of the wage rates of different types of jobs based on the characteristics of the jobs. Jobs that are more unpleasant or pose health and safety risks for workers typically pay higher wages than other types of jobs, and hedonic models can be used to estimate the value of these wage differences. In general, the results of both methodologies have been found to be similar (Ebi et al., 2004), with heterogeneity in age and income levels playing a role in explaining variations.

Most studies applying the above methodologies report VSL in dollars per life saved. For example, when evaluating the benefits of policies to reduce pollution, the U.S. Environmental Protection Agency reported VSLs ranging from $2.3M to 11.8M (Smith et al., 2001). Updated estimates provide a central VSL of $7.4 M (in 2006 dollars) (U.S. EPA, 2000, 2004, and 2010). Other recent studies have estimated the value of statistical life averaging $7 million (Viscusi & Hersh, 2008). Another study, which assessed VSL values for Ontario based on wage rates, placed the value of a statistical life as ranging from 0.92M to 4.54M (Krupnick et al., 2000).

Results from surveys assessing WTP to reduce mortality risks are expected, in theory, to reflect the individual characteristics of respondents. These results may be subject to a certain degree of heterogeneity, in particular because of differences in age and income levels of the population sample surveyed. With respect to age, VSLs are seen to increase up to age 50 and then decrease, with older people having the lowest values. For example, a WTP survey of Canadians found that individuals in a 70 to 75 year-old cohort were less willing to pay to reduce mortality risks than cohorts of younger adults (Krupnick et al., 2000). Nevertheless, this study found that the VSL did not decline (per age group) for people whose health is compromised, regardless of the health problem. Another VSL study explored the simultaneous effect that income levels and age have on WTP surveys, within the context of the hedonic wage model (Evans and Schaur, 2010). The authors found that the impact of age on the wage–risk tradeoff varies across the wage distribution. Results are shown in **Table 11.3**.

An alternative approach measures the VSL based on the years of potential life lost (YPLL). This approach has been advanced to consider younger age groups that may lack income streams by assigning heavier weights to premature mortality at younger ages (CDC, 1986). The YPLL approach has also been used to account for differential health status by ethnic background (CDC, 1989).

The economic burden to the health care system must also be taken into account when estimating losses from increased mortality due to heat waves. The elderly, children, and persons with certain medical conditions are at greatest risk for heat-related illness and death. Of particular concern are those individuals affected by cardiovascular disease (CVD), which accounts for more deaths in the United States than any other major cause, with roughly two-thirds related to coronary heart disease (CHD) and stroke (Yazdanyar, 2009). In 2009, costs associated with treating CVD and stroke in the United States were expected to exceed $475 billion, with direct costs, such as services at hospitals or nursing home facilities, professional fees, and medicines, estimated to reach over $313 billion. While not all such

Point in the Real Wage Distribution	Real Hourly Wage	Marginal Impact of Risk	VSL (million $)	Marginal Impact of Risk	VSL (million $)	Marginal Impact of Risk	VSL (million $)
		50-year-old		55-year-old		60-year-old	
10%	6.49	0.07	9.08	0.025	3.24	<0	<0
25%	8.85	0.089	15.75	0.049	8.67	0.009	1.59
50%	13.07	0.251	65.59	0.231	60.36	0.211	55.14
75%	19.49	0.156	60.81	0.141	54.97	0.126	49.12
Mean	15.97	0.046	14.69	0.016	5.11	<0	<0

The VSL estimates are given in 1998 dollars, and have been calculated as: Marginal Impact of Risk*Real Wage*x*y*z, where x=40, y=50, and z=10,000
Source: Evans & Schaur, 2010

Table 11.3 Estimated marginal impacts of risk on the real wage and associated value of statistical life estimates by age and real wage costs are related to extreme heat events, CVD prevalence is likely to be exacerbated during such periods, thus putting additional strain on the public health system and its efforts to reduce CVD incidence. Furthermore, costs are projected to increase in future decades, as the size of the elderly population in the United States is expected to grow (American Heart Association, 2008; Yazdanyar, 2009).

Research conducted in Canada shows that costs associated with elevated mortality due to heat waves and air pollution are of concern. The number of premature deaths linked with hot weather events in Canada has been reported as 121 in Montreal, 120 in Toronto, 41 in Ottawa, and 37 in Windsor, with the value per premature death (based on estimates of lost earning power) estimated as $2.5 million. An additional $7 million a year is being spent by these cities on health care (Cheng et al., 2005).

Mortality cost associated with heat in New York City could be estimated by multiplying the EPA VSL estimate of $7.4 million by the mortality cases identified in the analysis presented above. Such calculation may be adjusted by taking into account findings by Krupnick et al. (2000), if mortality cases for the cohort group of 65 years of age and older are known.

Mortality costs, while significant in terms of lives lost, are only part of the economic costs to society. Table 9.6 in Annex III of the ClimAID report ("An Economic Analysis of Climate Change Impacts and Adaptations in New York State") summarizes the costs associated with major heat waves from 1980 to 2000, which range from $1.3 billion to $48.4 billion, depending on the severity of the event. As this table shows, each major event can accrue considerable costs. It also shows that mortality rates in the central and eastern U.S. are higher (~5,000–10,000 deaths per heat event) than for states that may be better prepared to sustain heat events.

Adaptation Measures

Several cities across the United States and Canada have instituted emergency response plans to address increased mortality rates during extreme heat events. Examples of these response plans include the "Philadelphia Hot Weather-Health Watch/Warning System" (PWWS) set in operation in Philadelphia after the heat wave of 1995 (Ebi et al., 2004) as well as Toronto's "Heat-Health Alert System" (HHAS) (http://www.toronto.ca/health/heatalerts/alertsystem.htm). Given that extreme heat periods are likely to become more prevalent with climate change, other cities are expected to implement similar plans.

The emergency response plans include early warning systems to alert the population about extreme weather events and help the public health sector forecast resource requirements as well as community outreach and other services. For example, Toronto's HHAS includes a team of 900 individuals and community agencies that conduct outreach to vulnerable populations, including delivering water to them. Many cities extend hours of operation at various air-conditioned facilities, or set up cooling centers and arrange transportation to these locations. Air conditioning plays an important role in preventing heat-related mortality. Working air conditioners and participation in group activities have been identified as important preventive measures (CDC, 2003). The evidence from the two Chicago heat waves suggests that mortality risks were larger for individuals with cardiac disease or psychiatric ailments and those living alone. Therefore, outreach to vulnerable populations is seen as an important protective factor (Klinenberg, 2002).

Benefits associated with implementing such systems are seen to outweigh their costs, as documented by a study of the PWWS in Philadelphia (Ebi et al., 2004). While many of the measures taken when issuing a heat warning are reported to be included as part of the city employees' jobs, others require direct costs, such as wages for deploying Heatline (a hotline to provide information and counseling to the public on how to avoid heat stress) and additional Emergency Medical Service (EMS) crews. The study reports that additional wages are calculated at $10,000 per day over a period of three years. Given that during that period the City of Philadelphia issued 21 alerts, costs for the system were estimated at $210,000. The value of 117 lives saved over the same time period was estimated to be $468 million.

Other adaptive measures include monetary support of low-income populations to ensure the use of air conditioning and recommendations for temporary rolling brownouts or blackouts to prevent prolonged blackouts, which have been seen to increase mortality rates during a heat wave (Warren and Riedel, 2004). The costs to implement such measures are not well documented.

Case Study B. Ozone and Health in New York City Metropolitan Area

Knowlton and colleagues examined scenarios for climate impacts on ozone-related and temperature-related mortality in the New York City metropolitan area (Knowlton et al., 2004). Here we summarize the key methods and findings from that work.

The New York Climate and Health Project (NYCHP) was designed to project the relative health impacts of local climate-related changes in temperatures and ground-level ozone concentrations. They compared acute summertime non-accidental mortality during the 1990s to several future decades (2020s, 2050s, and 2080s). They used a four-part methodology to assess region-specific mortality impacts. First, they sought to develop mortality exposure-response functions for temperature and ozone effects on summer mortality, using historical (1990–1999) death, weather, and air quality data for the study area. Next, they developed an integrated modeling system that included modules for global climate, regional climate, and regional air quality. Third, the retrospective epidemiological analysis was combined with the projective integrated climate-air quality model system through application of a health risk assessment, and current versus future mortality was compared to assess potential mortality risks in the metro area in the 21st century. Lastly, a sensitivity analysis examined alternative greenhouse gas (GHG) growth scenarios in order to assess how reduced GHG emissions might reduce potential adverse health impacts of climate change.

Mortality data were obtained from the U.S. National Center for Health Statistics (NCHS) for 1990–1999. Daily death counts within each of the 31 counties for all internal causes (International Classification of Diseases ICD-9 codes 0–799.9 for 1990– 1998 and ICD-10 codes A00–R99 for 1999) were pooled, excluding accidental causes and those among nonresidents, to obtain a set of daily summer regional death count totals.

Air quality data were obtained from the U.S. EPA's Aerometric Information Retrieval System (AIRS) for ozone monitoring stations within the study area. Of 39 reporting stations in the study area with ozone data on any of the 920 summer days from 1990–99 (10 summers x 92 days/summer), those with fewer than 80 percent non-missing days were removed from further analyses. For the 16 remaining stations, there were 13,743 monitor-days with data (93.4 percent) and 977 monitor-days (6.6 percent) for which data was interpolated. None of the 920 study days had region-wide average ozone concentrations based wholly on imputed data.

Daily mean temperature (T_{ave}) and dewpoint temperature (both in °F) data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) data inventory. Stations within the study area with at least 80 percent non-missing T_{ave} data included 16 meteorological stations. Only six airport stations had daily dewpoint data for the years in question, and humidity was not included in the statistical final model.

A statistical model was developed using Poisson regression with log daily death counts as the outcome variable. From b and standard error (SE) estimates the incremental changes in the relative risk of mortality were calculated for T_{ave} and the mean of lag 0 and 1 for maximum 1-hr average ozone.

To estimate future climate, the GISS coupled global ocean/atmosphere model was driven by two different IPCC greenhouse gas scenarios, A2 and B2, with results downscaled to a 36-kilometer grid resolution using the MM5 regional climate model (Lynn et al., 2010). To simulate ozone air quality, the Community Mesoscale Air Quality (CMAQ) model was run at 36-kilometer and took its meteorological conditions from the GISS-MM5 simulations. The simulation periods were June–August, 1993–1997; June–August, 2023–2027; June–August, 2053–2057; and June–August, 2083-2087. Full details are found in Hogrefe et al. (2004a; 2004b). MM5 model simulated temperatures and CMAQ simulated ozone concentrations across the model domain in summers for these four future decades. Gridded temperatures and ozone concentrations were interpolated to county centroid latitude/longitude coordinates using inverse distance weighting from the three nearest station data to individual county centroids, for use in the county-level mortality risk assessments.

The risk assessment evaluated the daily summer ozone-related mortality increase by application of b coefficient estimates from the epidemiological analysis in the formula:

Equation 1: Additional O_3-related mortality = (Population/100,000)* (Daily mortality rate) * [exp((maxO_3 (h)$_{ave(48)}$) * β))-1]

To isolate climate effects in estimates of future mortality risks, they held population constant at the Census 2000 county totals. They also held anthropogenic ozone precursor emissions constant at the 1996 inventory levels and assumed mortality rates would remain constant at county-specific mean 1990s reference rates. To project changes in summer ozone-related mortality relative to the 1990s, the risk assessment was applied to 1-hour maximum ozone concentrations in five 1990s summers from station observations versus from five mid-decade summers from CMAQ simulations (i.e., 1993–1997 versus 2023–2027, etc.) at 36-kilometer horizontal resolution. The mean concentrations from lag days 0 and 1 (i.e., the same and previous days) were calculated so that the corresponding transfer function estimates from the Poisson GAM (generalized additive model) model could be applied in the ozone-mortality regression analysis. The statistical model was run for each decade, using SAS version 9.0 (SAS Institute, 2002) to apply the linear-quadratic-cubic heat and the linear ozone effects.

Mortality for a typical summer in each decade was evaluated and compared to that in a typical 1990s summer. The absolute and relative (percentage) changes in climate-related mortality in the 2050s under the A2 and B2 scenarios are shown in **Table 11.4** for both ozone and temperature. While larger O_3-related mortality was projected for the New York metropolitan region under the B2 scenario assumptions, different patterns across the eastern U.S. exist; domain-wide, O_3 is projected to increase more under the 2050s A2 scenario than under B2.

	1990s	2050s B2 (lower CO_2 emissions)	2050s A2 (higher CO_2 emissions)
Projected summer heat-related mortality	1116	2013 80% increase relative to 1990s	2347 110% increase relative to 1990s
Projected summer O_3-related mortality	1059	1139 7.6% increase relative to 1990s	1108 4.6% increase relative to 1990s

Table 11.4 Projected heat-related and ozone-related mortality impacts during summer in the 2050s, comparing A2 vs. B2 greenhouse gas emission scenarios

Case Study C. Extreme Storm and Precipitation Events

Climate projections of extreme precipitation events, such as hurricanes, indicate increased health risks associated with flooding, storm surges, and severe winter storms. Public health impacts range from direct effects of injury and drowning to longer-term effects on mental health, health service delivery, municipal water infrastructure, respiratory and gastrointestinal tracts, and exposure to toxins. Sea level rise could exacerbate health vulnerabilities of coastal populations, and developed coastal areas may face increased risks of evacuation-related health impacts and stress, including household disruption.

Projected increases in duration and amount of rain as well as extreme wind and snow associated with nor'easter storms present risks of flooding and damage to property and critical infrastructure. The New York City Panel on Climate Change (NPCC) projects that annual precipitation is likely to increase by 0 to 5 percent by the 2020s, 0 to 10 percent by the 2050s and by 5 to 10 percent by the 2080s (NPCC, 2010). Specifically, periods of intense precipitation (defined as either volume per hour or consecutive days of rainfall) are likely to increase into the next century (NPCC, 2010).

Injury and Mortality

Hundreds of injuries and deaths are caused every year by severe storms and precipitation across the United States (Greenough et al., 2001). Flash floods, resulting from intense rain over a short period of time, are of specific concern because they leave little time for warning or evacuation. Drowning accounts for a large majority of deaths during flooding events (Greenough et al., 2001). A review of National Weather Service reports identified inadequate warning systems to be an important mortality risk factor in flooding emergencies (French et al., 1983). Urban areas are particularly vulnerable to flash flooding due to the inability of extensive concrete surfaces to absorb precipitation (Greenough et al., 2001). Additionally, increased volume and duration of snowfall and ice accumulation pose theoretical increased risk of injury, including head trauma and lacerations from falling, vehicular accidents, and hypothermia; however, no studies were found that have quantified these effects.

Mental Health

While mental health effects are difficult to quantify, they have been among the most common and long-lasting post-disaster impacts. Studies following hurricane events over the past 30 years have shown both high prevalence (Norris et al., 1999) and long duration (Logue et al., 1979) of post-traumatic stress disorder among survivors. Depression, substance abuse, and anxiety have also been documented following hurricane and flood disasters (Fried, 2005; Verger, 2003; Weisler, 2006). These mental health conditions are of concern not only for their toll on individuals and families, but also because they can impair recovery efforts and limit resiliency for future events.

Indirect Effects

Indirect health effects are those linked to disturbances in ecological or infrastructure systems upon which we depend, such as impacts to water supply quality and quantity. Effects can be lessened through effective preparedness and mitigation measures. Heavy rainfall events can contaminate water systems by altering runoff patterns and can trigger waterborne disease outbreaks (Auld and Klaassen, 2004). Intense rain events can lead to illness associated with giardia, cryptosporidium, and *E-coli*, among other food-borne and water-borne pathogens. More than half of water-borne disease outbreaks occur after severe precipitation events. An analysis of nearly 50 years of continental U.S. weather records found that 51 percent of waterborne disease outbreaks followed precipitation events that were in the top 10 percent of heaviest rainfall events for the area, and that 68 percent followed events in the top 20 percent (Curriero et al., 2001). Drinking water originating from both surface and groundwater sources becomes vulnerable (Curriero et al., 2001). Such severe precipitation events are likely to be experienced in New York State (see Chapter 1, "Climate Risks") and should be incorporated into risk mitigation planning. In response to these known vulnerabilities and projected challenges of changing precipitation regimes, the New York City Department of Environmental Protection has developed a comprehensive watershed protection plan and water quality monitoring infrastructure (NYCDEP, 2008).

While the hazard of cross contamination of drinking water and sewage infrastructure is not considered a threat to most urban infrastructure, storm system overflow due to heavy precipitation can result in sewage outflow through street-level drains and building basements. System overflows can create opportunities for bacterial infection through exposure to sewage through standing water and green spaces. Chemical toxins from industrial or contaminated sites, including heavy metals and asbestos, can be mobilized during flood and precipitation events (Euripidou, 2004). Residential and recreation areas near brownfields or industrial sites are potential sites for chemical exposures.

Flooding of buildings and standing water have been associated with respiratory problems upon reoccupation of homes that have potentially long-term effects for both residents and remediation workers (Solomon, 2006). As floodwaters recede, molds and fungi can proliferate and release spores that can cause respiratory irritation and allergic reactions when inhaled. Elevated indoor mold levels associated with flooding of buildings and standing water are risk factors for coughing, wheezing, and childhood asthma (Jaakkola et al., 2005; Bornehag et al., 2001). Outdoor molds in high concentrations have also been registered following flood events and are associated with allergies and asthma, with particular risks to children (Solomon, 2006). Safe and timely mold remediation is an important concern for weather-response planning. The New York City Department of Environmental Protection and the Office of Emergency Management already have such plans in place. (See Chapter 5, "Coastal Zones," for a description of permanent and repeated inundation risks related to sea level rise.)

Additionally, extreme events that disable critical infrastructure or interrupt the delivery of health services—even for a brief amount of time—could represent critical risks for certain vulnerable populations. Chronic health conditions, such as asthma, diabetes, and kidney disease, require frequent and timely medical attention, the absence of which could exacerbate health conditions and increase demand for emergency hospital services. Household preparedness and emergency stockpile and distribution networks for critical medications could prove an important component of adaptation planning.

Case Study D. West Nile Virus

In the U.S., more than 25,000 cases of human disease caused by West Nile virus have been reported since its introduction to North America in 1999, and hundreds of thousands of birds have been killed by the infection. The disease-causing pathogen replicates within some species of wild birds and is transmitted among birds and other hosts (including humans) via the bite of infected mosquitoes. Human risk of exposure to West Nile virus is correlated with both the abundance and infection prevalence of mosquitoes carrying the pathogen (Allan et al., 2009). Although the number of infected mosquitoes depends on the infection rate of the hosts upon which they feed, the number of mosquitoes is likely to increase with rising temperatures and a wetter climate. In New York State, the species of mosquitoes that are most likely to carry West Nile virus are those that breed in natural or artificial containers, such as ponds and discarded tires, respectively, including *Culex pipiens*, *Culvex restuans*, and *Aedes albopictus*. While West Nile virus infections in humans and birds have only been reported in a limited part of the state, the prevalence of West Nile virus in mosquitoes is more widespread throughout the state (**Figures 11.11a** and **11.11b**).

In the eastern United States, human incidence of disease caused by West Nile virus at the county level is correlated with above-average total precipitation in the previous year (Landesman et al., 2007). Higher total precipitation likely results in more immature mosquitoes surviving over the winter, which leads to a greater abundance of adults the following year. In Erie County, New York, a higher number of adult mosquitoes in the summer is correlated with cooling degree days base 63 and 65 (degree days above 63 to 65°F) seven to eight weeks earlier, with the product of cooling degree days base 63 and precipitation four weeks earlier, and with rates of evapotranspiration (the loss of water from soil evaporation and plant transpiration) five weeks earlier, although these relationships are complex and nonlinear (Trawinski and MacKay, 2008).

At the national level, higher incident rates of West Nile virus disease are associated with increased weekly maximum temperature, increased weekly average temperature, increased average weekly dew point temperature (the temperature at which water vapor condenses into water), and the occurrence of at least one day of heavy rainfall within a week (Soverow et al., 2009).

Climate change is expected to increase precipitation and summer temperatures in New York. Therefore, in general, risk of human exposure to West Nile virus is expected to increase in the state as the climate becomes warmer and wetter. Quantitative predictions about changes in risk that are specific to regions within the state will require more extensive site-specific data on the relationships between climate variables, the distribution of mosquitoes, the density of their populations and their behavior, and virus replication rates.

Figure 11.11a Numbers of cases of West Nile illness in humans, New York State, 2008

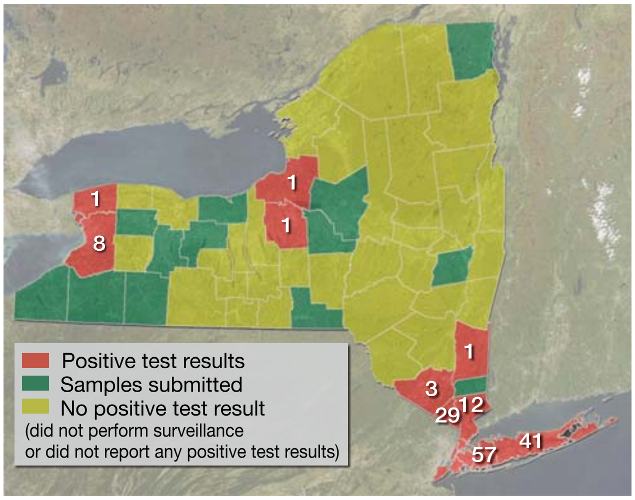


Figure 11.11b Numbers of mosquito samples testing positive for West Nile virus, New York State, 2008

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Appendix A. Stakeholder Interactions

A diverse network of stakeholders and partner organizations has been developed over the course of several assessments carried out by the ClimAID Public Health sector team since the late 1990s. The stakeholders include city, state, and federal governmental agencies in the areas of environment, health, planning, and emergency management; non-governmental environmental organizations; academic institutions with research interests in public health and climate change; environmental justice organizations; clinical health sector organizations; and community-based organizations targeting the elderly, youth, and low-income populations. Stakeholder engagement, involving approximately 100 stakeholders, included direct interviews, informal discussions, attendance at specially convened task forces, and an online survey administered to county health officials across the state.

Stakeholder Concerns

Our first approach involved phone interviews with a subset of key stakeholders at the following agencies and organizations: New York City Department of Health, New York City Mayor's Office of Long Term Planning and Sustainability, a national environmental non-governmental organization, and the New York State Department of Environmental Conservation. The climate-related health issues identified in these interviews included concerns about heat events; vector-borne illnesses such as West Nile virus (the first case in the United States occurred in New York City); other emerging infections; extreme storms (causing health risks from contaminated watersheds as a result of coastal storms, which cause flooding hazards, injury risks, and surface water quality issues that necessitate beach closures); waterborne illness; air pollution such as ground-level ozone, particulate matter and airborne allergens; and population displacement. Additional concerns expressed included the need for a full assessment of potential health effects of adaptation measures such as air pollutants from biofuels.

The stakeholders also identified needs for planning and adaptation. They reported that specific geographic variation of health impacts as well as specific population vulnerability information would be helpful in tailoring community-level adaptation projects and media messaging. Additionally, they reported that health cost-benefit analyses could assist policymakers in choosing between various planning options. Overall, there was strong consensus regarding the need for ongoing environmental and environmental health monitoring and for more data on the effectiveness of different adaptation measures. Evaluation research on the effectiveness of different adaptation measures was also identified as useful, e.g., heat-response plans, including cooling centers, public advisories about heat and the need for hydration, and buddy systems.

Some stakeholders raised concerns that transcended sectors. They questioned if the energy grid can provide continuous output during an extended heat wave and whether there is potential for failure of the power grid. Additional concerns involved energy and air quality feedbacks that could have potential health effects (i.e., power plants may burn dirtier fuels during heat waves to accommodate power demands). Also, as the risk of flooding increases, potential mold problems could increase. Lastly, concerns were raised over the impact of climate change effects on New York City's water supply. This relates to a more general area of interest voiced by our stakeholders: the increased risk of waterborne illness following high precipitation events. The importance of identifying vulnerable communities—by virtue of age, socioeconomic status, or underlying medical conditions, for example—and particular areas statewide that are more likely to be affected was emphasized.

Similar issues were raised in our informal group meetings with physicians, students, and community residents. There is a considerable amount of interest and concern about climate change and its potential health impacts. However, the knowledge base remains limited.

Emerging Adaptations

New York City has been proactive in developing climate-risk information processes for several health-relevant climate risks (NPCC, 2010). Climate-protection levels developed by an advisory group for 2050 and 2080, which include the projected number and severity of heat waves, sea level rise, and extreme rain events, are being used to guide infrastructure policy and codes. Infrastructure is broadly defined to include water, energy, and bridges. Additionally, there are efforts to increase the proportion of the vulnerable population with access to home air conditioning.

Additional adaptation measures that are within the purview of the New York City health and housing codes include beach closing after extreme rain events until water quality meets safety standards and wiring in buildings for energy efficiency and safety.

On the state level, there is a "Climate Smart Community" initiative (see www.dec.ny.gov/energy/50845.html). This initiative encourages municipalities and businesses to jointly form strategies for mitigation while also raising awareness of public health officials for coordinated effort to approach climate change.

Nongovernmental organizations are generating fact sheets and briefing reports on health preparedness for inevitable climate change. The goal is to inform policy discussions and to encourage win-win efforts. There are also efforts to transcend the artificial divide in much legislation between ecosystem and human health. The general perception by these stakeholders was that thinking about climate change and the future risks it poses provides an opportunity to improve our current level of preparedness.

Stakeholders

Natural Resources Defense Council
NYC Department of Health and Mental Hygiene
NYC Office of the Mayor NYS Department of Health
NYS Department of Environmental Conservation
New York State Association of County and City Health Officials (NYSACCHO)
U.S. Environmental Protection Agency Region II
WE ACT for Environmental Justice

Survey of City and County Health Department Directors across New York State

This part of ClimAID stakeholder engagement involved administering an online survey to New York State county health officials. This survey was adapted from the 2007 national survey of city and county health department directors—"Are We Ready?"—which revealed critical gaps between expected climate-related health impacts and local health department capacity to respond. The 2007 national survey results included evidence that 1) the majority of respondents believe that climate change already has and will continue to represent significant health threats in their jurisdiction; 2) a majority perceived lack of knowledge and expertise at all levels; 3) there is minimal incorporation of long-range weather and climate projections; and 4) a majority call for increased funding, staff and training (Maibach et al., 2008).

Climate-related health outcomes were included for specific questions pertaining to perceived current or future threats and adaptation capacity: heat-related illness, hurricanes and floods, droughts, vector-borne infectious disease, water- and food-borne disease, water supply and quality, mental health conditions, and services and infrastructure for populations affected by extreme events. While nearly all departments had some programmatic activity in one of the climate-health categories included, few indicated that they had new programming areas planned. General questions about programming activity levels, knowledge capacity, and resource needs were stratified by climate-related health driver, such as heat waves and disease vectors. Results of the New York State survey are comparable to the national survey and generate meaningful insights into local preparedness infrastructure and needs.

As part of the ClimAID project, city and county health department directors were invited to participate in a statewide replication of this national survey during the winter of 2009–2010. The "Are We Ready?" survey instrument was adapted for online administration and distributed to all department directors. The survey questions are included at the end of this section. A letter of support from the National Association of County and City Health Officials (NACCHO) and the New York State Association of County and the City Health Officials encouraged officials to participate. Responses were anonymous and have no geographic identifiers.

The survey had an overall participation rate of 39 percent. While 57 percent of respondents agreed that climate change would affect their local area in the next 20 years, only 39 percent thought that climate change would cause health problems during that same time period. However, the majority (79 percent) disagreed or strongly disagreed that their local health department had "ample" expertise to assess the impacts of climate change in their jurisdiction. And over 70 percent of respondents reported no use of long-range weather or climate information in their departments' planning.

Among respondents who believed that climate-sensitive health impacts would stay the same or increase over the next 20 years, the following were cited as areas of perceived threat:

- heat waves and heat-related illnesses
- storms, including hurricanes and floods
- droughts, forest fires, or brush fires
- vector-borne infectious diseases
- water- and food-borne diseases
- anxiety, depression, or other mental health conditions
- quality or quantity of freshwater available
- quality of the air, including air pollution
- unsafe or ineffective sewage and septic system operation
- housing for residents displaced by extreme weather events
- healthcare services for people with chronic conditions during service disruptions, such as extreme weather events
- food security
- shoreline damage/loss of shoreline/wetlands/groundwater and saltwater interaction
- severe cold and ice

As permitted by the survey, respondents could choose more than one area of concern regarding the health impacts of climate change. Heat-related health impacts were selected by 30 percent of respondents and storms by 33 percent, vector-borne disease by 56 percent, and air quality changes by 22 percent. Planned and active adaptation programming for these same four areas were reported as heat-related health programs in 33 percent of jurisdictions, storms in 54 percent of jurisdictions, vector-borne disease in 63 percent, and air quality adaptation programming in 25 percent. Of note, these percentages were all less than when respondents simply reported on current program activity in these same four areas. Of those that had a planned or active program in one of these areas, 5 percent deemed the allocated budget insufficient.

Two quotes from survey respondents that speak to the constraints regarding some of these issues:

> "With the current fiscal crisis in our region we are challenged to achieve basic health department mandated functions. We also do not have the

expertise to address this issue nor the funds to expand the programs we currently run."

"The local health department has not traditionally had a primary response role to environmentally related issues although we do support the emergency services department. While we understand that this is a role that public health should have, current fiscal restraints prevent us from being able to address climate change health effects in a suitable manner. Issues with food, water, etc. are covered by New York State Dept. of Health."

Overall, the New York State respondents showed a similar variety of concerns as the national sample though a smaller percentage deemed climate change a current or future threat to the health of residents in their jurisdiction. A non-respondent analysis is currently being explored to address the potential for generalizing these findings.

Survey Questions

Background

1. What is your position at your health department?

2. What is the approximate annual budget for your health department?

3. Approximately how many staff members in full-time equivalents does your health department have?

Climate change

4. People have different ideas about what climate change is. In your own words, what do you think the term "climate change" means?

Knowledge

5a. I am knowledgeable about the potential public health impacts of climate change.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

5b. The other relevant senior managers in my health department are knowledgeable about the potential public health impacts of climate change.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

5c. Many of the other relevant appointed officials in my jurisdiction outside of the public health system—such as environmental, agricultural, forestry and wildlife, energy and transportation officials—are knowledgeable about the potential public health impacts of climate change.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

5d. Many of the relevant elected officials in my jurisdiction are knowledgeable about the potential public health impacts of climate change.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

5e. Many of the business leaders in my jurisdiction are knowledgeable about the potential public health impacts of climate change.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

5f. Many of the leaders of the health care delivery system in my jurisdiction— including the hospitals and medical groups—are knowledgeable about the potential public health impacts of climate change.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

Perception

6a. My jurisdiction has experienced climate change in the past 20 years.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

6b. My jurisdiction will experience climate change in the next 20 years.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

6c. In the next 20 years, it is likely that my jurisdiction will experience one or more serious public health problems as a result of climate change.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

6d. My health department currently has ample expertise to assess the potential public health impacts associated with climate change that could occur in my jurisdiction.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

6e. Preparing to deal with the public health effects of climate change is an important priority for my health department.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

7a. Would you say that preventing or preparing for the public health consequences of climate change is among your health department's top ten current priorities?

○ Yes ○ No ○ Don't know

7b. (If Yes for Q7a) Which number—from one to ten, with one being the highest priority—would you say best characterizes the priority given to climate change currently in your health department?

Programmatic activity

8. Are the following health issues currently areas of programmatic activity for your health department?

a. Heatwaves and heat-related illnesses? ○ Yes ○ No ○ Don't know
b. Storms, including hurricanes and floods? ○ Yes ○ No ○ Don't know
c. Droughts, forest fires or brush fires? ○ Yes ○ No ○ Don't know
d. Vector-borne infectious diseases? ○ Yes ○ No ○ Don't know
e. Water- and food-borne diseases? ○ Yes ○ No ○ Don't know
f. Anxiety, depression or other mental health conditions? ○ Yes ○ No ○ Don't know
g. Quality or quantity of fresh water available to your jurisdiction? ○ Yes ○ No ○ Don't know
h. Quality of the air, including air pollution, in your jurisdiction? ○ Yes ○ No ○ Don't know
i. Unsafe or ineffective sewage and septic system operation? ○ Yes ○ No ○ Don't know
j. Food safety and security? ○ Yes ○ No ○ Don't know
k. Housing for residents displaced by extreme weather events? ○ Yes ○ No ○ Don't know
l. Health care services for people with chronic conditions during service disruptions, such as extreme weather events?
○ Yes ○ No ○ Don't know

9a. Are there other possible health effects associated with climate change in your jurisdiction that I have not mentioned?

○ Yes ○ No ○ Don't know

9b. (If Yes for Q9a) What are those health effects?

9c. (If Yes for Q9a) Is this health issue currently an area of programmatic activity for your department?

○ Yes ○ No ○ Don't know

10a. Does your health department use long-range weather or climate information in planning or implementing any programmatic activities?

○ Yes ○ No ○ Don't know

10b. (If Yes for Q10a) Do you use long-range weather or climate information in your planning or implementation of (each of the health issues a–l listed above)?

○ Yes ○ No ○ Don't know

11. Do you think climate change has already affected (each of the health issues a–l listed above) in your jurisdiction?

○ Yes ○ No ○ Don't know

12. Do you think that over the next 20 years climate change will likely make (each of the health issues a–l listed above) more common or severe, less common or severe, or that the problem will remain the same in your jurisdiction over the next 20 years?

○ More common or severe ○ Less common or severe ○ Remain the same ○ Don't know

13. Which of the potential health impacts of climate change that we have discussed, if any, are of greatest concern to you as a public health official? Feel free to name up to three outcomes.

14. Which of these three is your greatest concern? And which is your second greatest concern?

Adaptation expertise

15a. My health department currently has ample expertise to create an effective climate change adaptation plan.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

15b. My state health department currently has ample expertise to help us create an effective climate change adaptation plan in this jurisdiction.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

15c. The Centers for Disease Control and Prevention currently has ample expertise to help us create an effective climate change adaptation plan in this jurisdiction.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

15d. The health care delivery system in my jurisdiction—including the hospitals and medical groups—has ample expertise to create an effective climate change adaptation plan.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

Adaptation plans

16. Is your health department currently incorporating, planning to incorporate or not planning to incorporate adaptation into your programs for (each of the health issues a–l listed above)?

○ Currently incorporating ○ Planning to incorporate ○ Neither currently nor planning to incorporate ○ Don't know

17. How many staff members—in full-time equivalents—does/will this program have?

18. What is/will be the annual budget for this program?

19. In your opinion, is this an adequate level of funding for the program?

○ Yes ○ No ○ Don't know

The following question only asked if the response to Q16 was "currently":

20. Next year, will the annual budget for this program increase, decrease or remain about the same?

○ Increase ○ Decrease ○ Remain the same ○ Don't know

Mitigation expertise

21a. My health department currently has ample expertise to create an effective climate change mitigation plan.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

21b. My state's health department currently has ample expertise to help us create an effective climate change mitigation plan in this jurisdiction.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

21c. The Centers for Disease Control and Prevention currently has ample expertise to help us create an effective climate change mitigation plan in this jurisdiction.

○ Strongly disagree ○ Disagree ○ Agree ○ Strongly agree ○ Don't know

Mitigation plans

22. Does your department currently have, plan to have, or not have nor plan to have programs focused on the following activities?

a. Mitigating climate change by reducing greenhouse gas emissions from the health department?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

b. Helping residents of your jurisdiction reduce their greenhouse gas emissions?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

c. Reducing fossil fuel use or conserving energy in the operation of the health department?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

d. Helping residents of your jurisdiction reduce their fossil fuel use or conserve energy?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

e. Encouraging or helping people to use active transportation such as walking or cycling?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

f. Encouraging or helping people to use mass transportation?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

g. Encouraging or helping people to change the way they purchase foods such as buying locally grown foods, organic foods or plant-based foods?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

h. Educating the public about climate change and its potential impact on health?

○ Currently have ○ Plan to have ○ Neither currently nor plan to have ○ Don't know

23a. Are there other activities associated with climate change mitigation in your jurisdiction that I have not mentioned?

○ Yes ○ No ○ Don't know

23b. (If Yes for Q23a) What are those activities?

23c. (If Yes for Q23a) Is this a current, future or not an area of programmatic activity for your department?

○ Yes ○ No ○ Don't know

The following questions only asked if the response to Q22 was "currently" or "planning":

24. How many staff members—in full-time equivalents—does/will this program have?

25. What is/will be the annual budget for this program?

26. In your opinion, is this an adequate level of funding for the program?

○ Yes ○ No ○ Don't know

The following question was only asked if the response to Q22 was "currently":

27. Next year, will the annual budget for this program increase, decrease or remain about the same?

○ Increase ○ Decrease ○ Remain the same ○ Don't know

Regulatory role

28. Does your health department have any regulatory responsibility for the following functions?

a. Water supply and quality?	○ Yes	○ No	○ Don't know
b. Air quality?	○ Yes	○ No	○ Don't know
c. Food safety and security?	○ Yes	○ No	○ Don't know
d. Sewage or septic systems?	○ Yes	○ No	○ Don't know
e. Health care services?	○ Yes	○ No	○ Don't know
f. Mental health services?	○ Yes	○ No	○ Don't know
g. Housing code?	○ Yes	○ No	○ Don't know

Resources

29a. Are there resources that your department does not currently have that, if made available, would significantly improve its ability to deal with climate change as a public health issue?

○ Yes ○ No ○ Don't know

29b. (If Yes for Q29a) What are those resources?

○ Additional Staff ○ Staff Training ○ Equipment ○ Budget/Money/Funding ○ Other

Respondents were asked to describe their answers in further detail:

a. How many additional staff and what would they do?

b. What kind of training?

c. What kind of equipment?

d. How much money and what would you use it for?

Conclusion

Is there anything else that will help us understand the public health response to climate change in your jurisdiction?

Appendix B. Technical Information on Heat Wave Cost

Year	Event Type	Region Affected	Sector(s) Most Affected	Total Costs / Damage Costs (billion $)	Deaths
2000	Severe drought & persistent heat	South-central & southeastern states	agriculture and related industries	$4.2	140
1998	Severe drought & persistent heat	TX / OK eastward to the Carolinas	agriculture and ranching	$6.6–9.9	200
1993	Heat wave/drought	Southeast US	agriculture	$1.3	16
1988	Heat wave/drought	Central & Eastern US	agriculture & related industries	$6.6	5000–10,000
1986	Heat wave/drought	Southeast US	agriculture & related industries	$1.8–2.6	100
1980	Heat wave/drought	Central & Eastern US	unspecified	$48.4	10,000

Source: Ross and Lott, 2003

Table 11.5 Costs for major heat waves in the United States

Appendix C. Annotated Heat-Mortality, Wildfires, and Air Pollution Methods References

Anderson, B. G. and M. L. Bell. 2009. "Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States." *Epidemiology* 20(2):205–213.

Background:

Many studies have linked weather to mortality; however, the role of such critical factors as regional variation, susceptible populations, and acclimatization remain unresolved.

Methods:

They applied time-series models to 107 U.S. communities allowing a nonlinear relationship between temperature and mortality by using a 14-year dataset. Second-stage analysis was used to relate cold, heat, and heat-wave effect estimates to community-specific variables. They considered exposure timeframe, susceptibility, age, cause of death, and confounding effects of pollutants. Heat waves were modeled with varying intensity and duration.

Results:

Heat-related mortality was most associated with a shorter lag (average of same day and previous day), with an overall increase of 3.0 percent (95 percent posterior interval: 2.4 percent–3.6 percent) in mortality risk comparing the 99th and 90th percentile temperatures for the community. Cold-related mortality was most associated with a longer lag (average of current day up to 25 days previous), with a 4.2 percent (3.2 percent–5.3 percent) increase in risk comparing the first and 10th percentile temperatures for the community. Mortality risk increased with the intensity or duration of heat waves. Spatial heterogeneity in effects indicates that weather-mortality relationships from one community may not be applicable in another. Larger spatial heterogeneity for absolute temperature estimates (comparing risk at specific temperatures) than for relative temperature estimates (comparing risk at community-specific temperature percentiles) provides evidence for acclimatization. They identified susceptibility based on age, socioeconomic conditions, urbanicity, and central air conditioning.

Conclusions:

Acclimatization, individual susceptibility, and community characteristics all affect heat-related effects on mortality.

Hoyt, K. S. and A. E. Gerhart. 2004. "The San Diego County wildfires: perspectives of healthcare providers [corrected]." *Disaster Management and Response* 2(2):46–52.

The wildfires of October 2003 burned a total of 10 percent of the county of San Diego, California. Poor air quality contributed to an increased number of patients seeking emergency services, including healthcare providers affected by smoke and ash in hospital ventilation systems. Two large hospitals with special patient populations were threatened by rapidly approaching fires and had to plan for total evacuations in a very short time frame. A number of medical professionals were forced to prioritize responding to the hospital's call for increased staff during the disaster and the need to evacuate their own homes.

Johnston, F. H., A. M. Kavanagh, et al. 2002. "Exposure to bushfire smoke and asthma: an ecological study." *Medical Journal of Australia* 176(11):535–538.

Objective:

To examine the relationship between the mean daily concentration of respirable particles arising from bushfire smoke and hospital presentations for asthma.

Design and Setting

An ecological study conducted in Darwin (Northern Territory, Australia) from 1 April–31 October 2000, a period characterised by minimal rainfall and almost continuous bushfire activity in the proximate bushland. The exposure variable was the mean atmospheric concentration of particles of 10 microns or less in aerodynamic diameter (PM_{10}) per cubic metre per 24-hour period.

Outcome Measure:

The daily number of presentations for asthma to the Emergency Department of Royal Darwin Hospital.

Results:

There was a significant increase in asthma presentations with each $10 \mu g/m^3$ increase in PM_{10} concentration, even after adjusting for weekly rates of influenza and for weekend or weekday (adjusted rate ratio, 1.20; 95 percent confidence interval (CI), 1.09–1.34; $P < 0.001$). The strongest effect was seen on days when the PM_{10} was above $40 \mu g/m^3$ (adjusted rate ratio, 2.39; 95 percent confidence interval (CI), 1.46–3.90), compared with days when PM_{10} levels were less than $10 \mu g/m^3$.

Conclusions:

Airborne particulates from bushfires should be considered as injurious to human health as those from other sources. Thus, the control of smoke pollution from bushfires in urban areas presents an additional challenge for managers of fireprone landscapes.

Kinney, P. L. and H. Ozkaynak. 1991. "Associations of daily mortality and air pollution in Los Angeles County." *Environmental Research* 54(2):99–120.

They report results of a multiple regression analysis examining associations between aggregate daily mortality counts and environmental variables in Los Angeles County, California for the period 1970 to 1979.

Methods:

Mortality variable included total deaths not due to accidents and violence (M), deaths due to cardiovascular causes (CV), and deaths due to respiratory causes (Resp). The environmental variables included five pollutants averaged over Los Angeles County: total oxidants (Ox), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and KM (a measure of particulate optical reflectance). Also included were three metereological variables measured at the Los Angeles International Airport: temperature (Temp), relative humidity (RH), and extinction coefficient (B_{ext}), the latter estimated from noontime visual range. To reduce the possibility of spurious correlations arising from the shared seasonal cycles of mortality and environmental variables, seasonal cycles were removed from the data by applying a high-pass filter. Cross-correlation functions were examined to determine the lag structure of the data prior to specifying and fitting the multiple regression models relating mortality and the environmental variables.

Results:

The results demonstrated significant associations of M (or CV) with Ox at lag 1, temperature, and NO_2, CO, or KM. Each of the latter three variables was strongly associated with daily mortality but all were also highly correlated with one another in the high-frequency band, making it impossible to uniquely estimate their separate relationships to mortality

Conclusions:

The results of this study show that small but significant associations exist in Los Angeles County between daily mortality and three separate environmental factors: temperature, primary motor vehicle-related pollutants (e.g., CO, KM, NO_2), and photochemical oxidants.

Levy, J. I., S. M. Chemerynski, et al. 2005. "Ozone exposure and mortality: an empiric Bayes metaregression analysis." *Epidemiology* 16(4): 458–468.

Background:

Results from time-series epidemiologic studies evaluating the relationship between ambient ozone concentrations and premature mortality vary in their conclusions about the magnitude of this relationship, if any, making it difficult to estimate public health benefits of air pollution control measures. Authors conducted an empiric Bayes metaregression to estimate the ozone effect on mortality, and to assess whether this effect varies as a function of hypothesized confounders or effect modifiers.

Methods:

They gathered 71 time-series studies relating ozone to all-cause mortality, and they selected 48 estimates from 28 studies for the metaregression. Metaregression covariates included the relationship between ozone concentrations and concentrations of other air pollutants, proxies for personal exposure-ambient concentration relationships, and the statistical methods used in the studies. For the metaregression, they applied a hierarchical linear model with known level-1 variances.

Results:

They estimated a grand mean of a 0.21 percent increase (95 percent confidence interval = 0.16–0.26 percent) in mortality per 10-$\mu g/m^3$ increase of 1-hour maximum ozone (0.41 percent increase per 10 ppb) without controlling for other air pollutants. In the metaregression, air-conditioning prevalence and lag time were the strongest predictors of between-study variability. Air pollution covariates yielded inconsistent findings in regression models, although correlation analyses indicated a potential influence of summertime $PM_{2.5}$.

Conclusions:

These findings, coupled with a greater relative risk of ozone in the summer versus the winter, demonstrate that geographic and seasonal heterogeneity in ozone relative risk should be anticipated, but that the observed relationship between ozone and mortality should be considered for future regulatory impact analyses.

O'Neill, M. S., A. Zanobetti, et al. 2003. "Modifiers of the temperature and mortality association in seven US cities." *American Journal of Epidemiology.* 157(12):1074–1082.

This paper examines effect modification of heat- and cold-related mortality in seven U.S. cities in 1986–1993.

Methods:

City-specific Poisson regression analyses of daily noninjury mortality were fit with predictors of mean daily apparent temperature (a construct reflecting physiologic effects of temperature and humidity), time, barometric pressure, day of the week, and particulate matter less than 10 micro m in aerodynamic diameter. Percentage change in mortality was calculated at 29°C apparent temperature (lag 0) and at -5°C (mean of lags 1, 2, and 3) relative to 15°C. Separate models were fit to death counts stratified by age, race, gender, education, and place of death. Effect estimates were combined across cities, treating city as a random effect.

Results:

Deaths among Blacks compared with Whites, deaths among the less educated, and deaths outside a hospital were more strongly associated with hot and cold temperatures, but gender made no difference. Stronger cold associations were found for those less than age 65 years, but heat effects did not vary by age. The strongest effect modifier was place of death for heat, with out-of-hospital effects more than five times greater than in-hospital deaths, supporting the biologic plausibility of the associations.

Conclusions:

Place of death, race, and educational attainment indicate vulnerability to temperature-related mortality, reflecting inequities in health impacts related to climate change.

Peel, J. L., K. B. Metzger, et al. 2007. "Ambient air pollution and cardiovascular emergency department visits in potentially sensitive groups." *American Journal of Epidemiology* 165(6):625-633.

Limited evidence suggests that persons with conditions such as diabetes, hypertension, congestive heart failure, and respiratory conditions may be at increased risk of adverse cardiovascular morbidity and mortality associated with ambient air pollution.

Methods:

The authors collected data on over four million emergency department visits from 31 hospitals in Atlanta, Georgia, between January 1993 and August 2000. Visits for cardiovascular disease were examined in relation to levels of ambient pollutants by use of a case-crossover framework. Heterogeneity of risk was examined for several comorbid conditions.

Results:

The results included evidence of stronger associations of dysrhythmia and congestive heart failure visits with comorbid hypertension in relation to increased air pollution levels compared with visits without comorbid hypertension; similar evidence of effect modification by diabetes and chronic obstructive pulmonary disease (COPD) was observed for dysrhythmia and peripheral and cerebrovascular disease visits, respectively. Evidence of effect modification by comorbid hypertension and diabetes was observed in relation to particulate matter less than 10 microm in aerodynamic diameter, nitrogen dioxide, and carbon monoxide, while evidence of effect modification by comorbid COPD was also observed in response to ozone levels.

Conclusions:

These findings provide further evidence of increased susceptibility to adverse cardiovascular events associated with ambient air pollution among persons with hypertension, diabetes, and COPD.

Peel, J. L., P. E. Tolbert, et al. 2005. "Ambient air pollution and respiratory emergency department visits." *Epidemiology* 16(2):164-174.

Background:

A number of emergency department studies have corroborated findings from mortality and hospital admission studies regarding an association of ambient air pollution and respiratory outcomes. More refined assessment has been limited by study size and available air quality data.

Methods:

Measurements of five pollutants (particulate matter [PM_{10}], ozone, nitrogen dioxide [NO_2], carbon monoxide [CO], and sulfur dioxide [SO_2]) were available for the entire study period (1 January 1993 to 31 August 2000); detailed measurements of particulate matter were available for 25 months. Authors obtained data on four million emergency department visits from 31 hospitals in Atlanta. Visits for asthma, chronic obstructive pulmonary disease, upper respiratory infection (URI), and pneumonia were assessed in relation to air pollutants using Poisson generalized estimating equations.

Results:

In single-pollutant models examining three-day moving averages of pollutants (lags 0, 1, and 2): standard deviation increases of ozone, NO_2, CO, and PM_{10} were associated with 1–3 percent increases in URI visits; a 2 μg/m increase of $PM_{2.5}$ organic carbon was associated with a 3 percent increase in pneumonia visits; and standard deviation increases of NO_2 and CO were associated with 2–3 percent increases in chronic obstructive pulmonary disease visits. Positive associations persisted beyond three days for several of the outcomes, and over a week for asthma.

Conclusions:

The results of this study contribute to the evidence of an association of several correlated gaseous and particulate pollutants, including ozone, NO_2, CO, PM, and organic carbon, with specific respiratory conditions.

Westerling, A. L., H. G. Hidalgo, et al. 2006. “Warming and earlier spring increase western U.S. forest wildfire activity.” *Science* 313(5789): 940–943.

Background:

Western United States forest wildfire activity is widely thought to have increased in recent decades, yet neither the extent of recent changes nor the degree to which climate may be driving regional changes in wildfires has been systematically documented. Much of the public and scientific discussion of changes in western United States wildfires has focused instead on the effects of 19th- and 20th-century land-use history.

Methods:

They compiled a comprehensive database of large wildfires in western United States forests since 1970 and compared it with hydroclimatic and land-surface data.

Results:

Here, the authors show that large wildfire activity increased suddenly and markedly in the mid-1980s, with higher large-wildfire frequency, longer wildfire durations, and longer wildfire seasons. The greatest increases occurred in mid-elevation, Northern Rockies forests, where land-use histories have relatively little effect on fire risks and are strongly associated with increased spring and summer temperatures and an earlier spring snowmelt.